Appendix 1

1-A: Santa Barbara Countywide Integrated Regional Water Management Plan (2007)

1-B: South Coast Recycled Water Development Plan, RMC, 2013

1-C: Santa Maria Valley Groundwater Assessment, GEI, 2013

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Appendix 1-A: Santa Barbara Countywide Integrated Regional Water Management Plan (2007)

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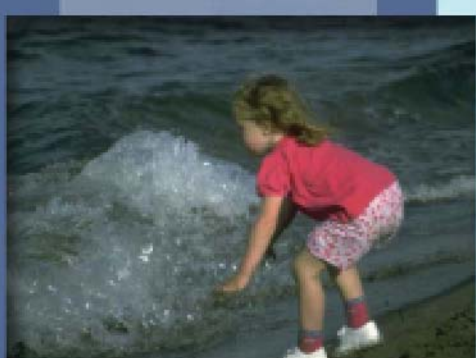

Santa Barbara Countywide Integrated Regional Water Management Plan

MAY 2007

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WWW.COUNTYOFSB.ORG/PWD/WATER/IRWMP.HTM
FOR FURTHER INFORMATION, CONTACT THE SANTA BARBARA COUNTY WATER AGENCY AT
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Cooperating Partners for the Santa Barbara Countywide IRWMP

Cachuma Conservation and Release Board
Cachuma Operation and Maintenance Board
Carpinteria Sanitary District
Carpinteria Valley Water District
Casmalia Community Services District
Central Coast Water Authority
City of Buellton
City of Carpinteria
City of Guadalupe
City of Lompoc
City of Santa Barbara
City of Santa Maria
City of Solvang
Cuyama Community Services District
Golden State Water Company
Goleta Sanitary District
Goleta Water District
Goleta West Sanitary District
La Cumbre Mutual Water Company
Los Alamos Community Services District
Mission Hills Community Services District
Montecito Sanitary District
Montecito Water District
Santa Barbara County
Santa Maria Valley Water Conservation District
Santa Ynez River Water Conservation District
Santa Ynez River Water Conservation District Improvement District No. 1
Summerland Sanitary District
Vandenberg Village Community Services District

Acknowledgements

Santa Barbara Countywide Integrated Regional Water Management Plan

The Santa Barbara Countywide IRWMP is a result of the combined efforts of many agencies, organizations, and individuals. The Cooperating Partners spent numerous hours developing the information that is included in the Plan, as well reviewing its contents. The following individuals prepared or reviewed sections of the IRWMP:

Cooperating Partners

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- William Brennan, Central Coast Water Authority
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- Jeff Dameron, La Cumbre Mutual Water Company
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Contents

Appendices

Acronyms

AF	acre-feet
AFY	acre-feet per year
ASR	Aquifer Storage and Recovery
CCA	Critical Coastal Area
CEQA	California Environmental Quality Act
DAC	disadvantaged community
DAU	designated analysis unit
DWR	State of California Department of Water Resources
ERP	Emergency Response Plan
FISH	Tri-Counties Funding for Improved Salmonid Habitat
GIS	geographic information system
gpd	gallons per day
IRWMP	Integrated Regional Water Management Plan
μg/L	micrograms per liter
MCL	maximum contaminant level
mg/L	milligrams per liter
mgd	million gallons per day
MS4	municipal separate storm sewer systems
MTBE	methyl tertiary butyl ether
NEPA	National Environmental Policy Act of 1969
NPDES	National Pollutant Discharge Elimination System
Reclamation	U.S. Bureau of Reclamation
RWEP	Regional Water Efficiency Program
RWQCB	Regional Water Quality Control Board
SBCWA	Santa Barbara County Water Agency
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
TMDL	Total Maximum Daily Load
TSS	total suspended solids
UCSB	University of California, Santa Barbara
USGS	U.S. Geological Survey
UWMP	Urban Water Management Plan

Executive Summary

Development of the IRWMP

Purpose of the IRWMP

The Santa Barbara Countywide Integrated Regional Water Management Plan (IRWMP) increases coordination among agencies and districts responsible for water resources, along with nongovernmental organizations and the public. It facilitates optimal management of water resources, a key challenge facing Santa Barbara County.

Funding Opportunities

The IRWMP provides the foundation for grant applications needed to augment limited local financial resources. Proposition 50, passed by voters in 2002, authorized $500 million for integrated regional water management projects. In November 2006, Proposition 84 was passed, providing an additional $1 billion in funding for integrated regional water management. Proposition 1E was also passed at that time, authorizing the state to sell $4.09 billion in bonds to rebuild and repair California's most vulnerable flood control structures. *An IRWMP is a prerequisite for seeking funds from all of these programs.*

Cooperating Partners

In Santa Barbara County, a range of local agencies, special districts, private companies, and regional joint powers authorities are responsible for managing water and wastewater. All but one of these entities came together in a collaborative process to prepare this IRWMP, as indicated by the following list of "Cooperating Partners":

Cachuma Conservation and Release Board
Cachuma Operation and Maintenance Board
Carpinteria Sanitary District
Carpinteria Valley Water District
Casmalia Community Services District
Central Coast Water Authority
City of Buellton
City of Carpinteria
City of Guadalupe
City of Lompoc
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Montecito Sanitary District
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Santa Barbara County
Santa Maria Valley Water Conservation District
Santa Ynez River Water Conservation District
Santa Ynez River Water Conservation District Improvement District No. 1
Summerland Sanitary District
Vandenberg Village Community Services District

Public Participation

In conformance with the Brown Act, public stakeholders participated in development of the IRWMP and influenced decisions by attending stakeholder workshops and Cooperating Partner meetings. Public stakeholders represent the general public, agricultural and business interests, disadvantaged communities (DACs), environmental groups, academic institutions, and the media. Four sets of public workshops were held between October 2006 and April 2007 to advise the public of progress on the IRWMP and obtain input at strategic points in its development; each set of workshops was held in both a South Coast and a North County location, for a total of eight workshops. A public review period was held from mid-March through April 27th in order to obtain comments on the Draft IRWMP. These comments were considered in the completion of the Final IRWMP. In addition, the County of Santa Barbara established a Web site to facilitate IRWMP communications with all stakeholders in the region (www.countyofsb.org/pwd/water/irwmp.htm).

Water Resources: Description and History

Regional Description

The planning region for this IRWMP encompasses all of Santa Barbara County. The large land area north of the Santa Ynez Mountains is primarily drained by streams that comprise only a few large watersheds for three relatively long waterways: the Santa Ynez River, San Antonio Creek, and the Santa Maria River, which is formed by the Cuyama and Sisquoc rivers. In contrast, the land area south of the Santa Ynez Mountains is composed of approximately 50 short, steep watersheds. Segments of some of these waterways, along with some coastal areas, have been identified by the State Water Resources Control Board (SWRCB) as being “impaired” for particular contaminants.

Given the county’s low annual rainfall and the fact that nearly all rivers and creeks are dry in summer, many areas have historically been dependent on groundwater from four basins along the South Coast and seven basins in the north. Groundwater quality varies considerably between basins.

The county also contains areas of notable freshwater habitat, coastal salt marshes and sloughs, marine protected areas, critical coastal areas and coastal dunes, and areas with sensitive aquatic species.

In spite of low average annual rainfall, Santa Barbara County experiences periods of high intensity rains, which can cause flooding in virtually any watershed. At the other extreme, drought periods of several years or more occur with some regularity.

History of Water Development in Santa Barbara County

Santa Barbara County has a long water development history. Some of that history has been contentious, especially regarding the diversion of Santa Ynez River water to South Coast communities beginning in the early 1900s. Ultimately, through various court decisions, state permit conditions, operation agreements, and settlement agreements, the long contentious arguments over Santa Ynez River water now seem largely settled, providing for both diversions of water to the South Coast and releases for certain downstream needs. In the

South Coast, disagreements also arose over rights to groundwater in the Goleta area, but these were resolved through the 1989 Wright Settlement Agreement.

The history of water management in the Santa Maria watershed has focused primarily on groundwater and on reducing the risk of occasional flooding of the Santa Maria River. In the late 1950s, construction of Twitchell Dam and Reservoir greatly helped to protect against floods, as well as to provide water for recharge of groundwater. However, in 1997, the Santa Maria Valley Water Conservation District filed suit to adjudicate water rights in the Santa Maria Valley Groundwater Basin. Since 2001, the adjudication has proceeded through various court orders, a "partial statement of decision," and a settlement agreement. Although the court has approved an agreement among those parties who have signed it, not all parties to the adjudication have agreed to it. The court's final judgment is pending.

Although water management issues in the Santa Maria area seem far removed from water issues of the Santa Ynez Valley and South Coast, they are now linked through the arrival of imported water from the State Water Project. Since 1997, the Central Coast Water Authority has been delivering State Water Project water to Santa Maria, Guadalupe, Orcutt, Vandenberg Air Force Base, Buellton, Solvang, and Santa Ynez; and then to Lake Cachuma, where State Water Project water is available to the Central Coast Water Authority's member units on the South Coast (Carpinteria, Montecito Water District, Santa Barbara, La Cumbre Mutual Water Company, Goleta Water District, Raytheon Research Center, and the Morehart Land Company). The Central Coast Water Authority's extensive water distribution system now links most of the communities within Santa Barbara County, and is therefore a key component of the overall countywide "system" for managing water distribution, which includes the various agreements for managing Lake Cachuma and the Santa Ynez River, as well as the groundwater adjudications and conjunctive use decisions made by local water managers.

History of Wastewater Management

Efforts to manage wastewater within the county have been underway for more than a century, but have been less visible and less contentious. As communities have grown, septic systems historically have been replaced by sewers, but at first, coastal communities simply discharged the collected and untreated wastewater directly into the ocean. Wastewater treatment plants, providing at least a basic level of treatment, began to be built in South Coast communities in the mid-1900s. These plants have been upgraded a number of times to meet increasingly strict federal standards and state permit requirements.

In the northern part of the county, the City of Santa Maria has treated and disposed of wastewater since 1910. After a major study in 1977 and subsequent plant expansion, the treated effluent was applied to percolation ponds and irrigated lands. Lompoc completed its fourth wastewater treatment plant, the Lompoc Regional Wastewater Reclamation Plant in 1977, with discharge to the Santa Ynez River. It serves Lompoc, Vandenberg Village Community Service District, and Vandenberg Air Force Base.

In some unincorporated areas of the county, wastewater services are currently provided by four community services districts formed between 1956 and 1983. Three of these districts provide both water and wastewater services.

Existing Infrastructure and Management

Water resources management requires extensive physical infrastructure. Through shared water supplies and connected infrastructure, water resources can be managed as an interconnected system within the county boundaries, although no one entity is vested with overarching countywide responsibility.

Water Supply and Distribution

Major infrastructure for water supply in Santa Barbara County includes four major reservoirs. The three surface storage reservoirs on the Santa Ynez River (Cachuma, Gibraltar, and Jameson) provide water to South Coast communities through an extensive system of pipes, conduits, and tunnels. Twitchell Reservoir, on the Santa Maria River, provides for both flood control and groundwater recharge. Other smaller reservoirs are located in cities and districts.

With the advent of State Water Project water in the 1990s, the Central Coast Water Authority constructed a 42-mile extension of the State Water Project pipeline, which ends at Lake Cachuma, as well as pumping stations and related facilities. The Water Authority operates the Polonio Pass Water Treatment Plant and all of the State Water Project Coastal Branch facilities downstream of that plant.

Because communities rely on different types of water supplies, a variety of facilities and processes are in place to treat water before it is provided to customers. Additionally, the City of Santa Barbara owns a desalination plant to be used as an emergency water supply. The plant is currently decommissioned but could be brought into operation within 6 to 12 months if needed.

Water purveyors and the County Water Agency also support a cloud seeding program as a weather modification activity. This program is only conducted in the upper Santa Ynez and Twitchell Reservoir watersheds.

Wastewater Treatment

Wastewater service providers must address increasingly strict discharge limits for wastewater treatment plants under federal requirements and SWRCB's "General Waste Discharge Requirement for Sanitary Sewer Systems." Within the county, there are 14 principal wastewater treatment plants. One of these plants provides only a primary level of treatment; ten provide secondary treatment; and three plants provide tertiary treatment, which is the highest level of treatment. Some wastewater service providers produce treated water that is directly reused in the community (for example, for irrigating landscaped areas). Such recycled water must meet water quality standards before it can be reused. Wastewater service providers may also produce treated water that flows into ponds where the water percolates into the ground to recharge aquifers.

Flood Control

Infrastructure for flood control is most evident with the Santa Maria River levee, which protects residential, commercial, and agricultural areas in and around the city. Various levels of flood control are also offered by the dams that form the reservoirs noted above.

Finally, there are many other less-visible flood control structures countywide, including approximately 42 miles of closed conduits; 22 miles of lined channels; 50 miles of improved earth channels; 34 retarding and recharge basins; and 31debris basins.

Water Resources Management Framework

All projects included in the IRWMP are expected to be consistent with current general plans and land use plans. Any IRWMP project that will be included in a future Proposition 50 grant application will have to be formally evaluated for consistency with the relevant plans prior to submittal to the state as part of a grant request.

Both the IRWMP and the individual projects are consistent with the Urban Water Management Plans (UWMPs), which are required in California for all water purveyors with 3,000 or more customers. Several cities and districts in the region also have adopted or are preparing groundwater management plans, or have adjudicated basins. Unlike UWMPs, development of groundwater management plans is entirely voluntary.

Storm Water Management Plans (SWMPs) are required under federal and state law for local municipalities. Santa Barbara County government is responsible for implementing the SWMP program in unincorporated urbanized areas of the South Coast, Santa Ynez Valley, and Santa Maria Valley. The cities of Carpinteria, Santa Barbara, Goleta, Solvang, Buellton, Lompoc, and Santa Maria have their own SWMPs. The IRWMP includes projects that will help implement some SWMPs.

Water monitoring (for water supply and/or water quality) is occurring through a network of programs at different levels of government, through nonprofits, and though public-private cooperation.

Water conservation programs are implemented at both a local level by individual water purveyors and as a Regional Water Efficiency Program (RWEP) coordinated by the Santa Barbara County Water Agency. Through water efficiency programs, additional water supplies become available for use, reducing pressures on other water sources. The RWEP's scope includes school education; public information; commercial, industrial, and institutional; landscapes and outdoor; and residential/indoor.

Key Elements of the IRWMP

Objectives

Objectives and regional priorities were established to address regional needs. The Cooperating Partners adopted six objectives. Four of these are required by the state: water supply, groundwater management, ecosystem restoration, and water quality. The four mandatory objectives were augmented to reflect regional needs for emergency preparedness and infrastructure efficiency and reliability.

Strategic Approach

In order to attain the IRWMP objectives, the Cooperating Partners adopted a strategic approach with a straightforward, linear path relating place-specific problems to regional objectives, priorities, and strategies in order to identify appropriate projects. In this way, a list of substantial issues that challenge agencies and special districts in one or more parts of the region is narrowed to specific projects to address key problems.

Key Issues

The Santa Barbara County region faces both regionwide and watershed-specific water issues and problems. The regionwide issues are consistent with the State of California Department of Water Resources (DWR)'s California Water Plan Update 2005, which emphasized two "initiatives" for ensuring reliable water supplies: implementing integrated regional water management and improving areawide water management systems. These key issues reflect short-term (5 years) and long-term (5 to 20 years) regional priorities.

On a watershed-specific basis, water issues evident in one location may be similar or even identical to issues in another area, but **the most pressing water-related problems vary considerably from watershed to watershed** within the region. Nevertheless, the Cooperating Partners noted the following key water issues and actual or potential problems (which are not listed in order of priority):

- The need to replace, rehabilitate, or upgrade **aging infrastructure** serving the general population and especially DACs
- Risk of illness from **inadequate drinking water and pollution from wastewater,** especially in DACs
- Water supply reliability, stemming from multiple factors, including the variable **reliability of State Water Project water**, the **loss of storage capacity** in the four major reservoirs, and the need for water supplies to serve a **growing population**
- The need to operate and maintain water and wastewater systems in a manner that **minimizes impacts to sensitive habitats and species** and complies with federal, state, and local regulatory requirements
- **Overdrafted groundwater** basins in North County
- **Water quality impairments** in both groundwater and surface water bodies, including pollution of creeks and ocean water, especially from sediment runoff
- Potential harm to people and property from **flooding**
- The need for **emergency planning** to address potential impacts to water and wastewater facilities from floods, earthquakes, and fires, as well as planning for (and responding to) periodic droughts

In the short-term, for the purpose of seeking integrated regional water management funding from the state, the Cooperating Partners have determined that Proposition 50 grant requests should focus on two overarching needs: (1) more efficient water use in the northern and central portions of the county through improved water and wastewater treatment to meet standards; and to allow effluent reuse and improved quality of surface discharges and returns to groundwater; and (2) increased reliability and efficiency through conjunctive use and system flexibility in the southern portion of the county.

Regional Priorities: Short-term (5 years)

These priorities focus on the need for "new" projects/initiatives. They do not focus on the substantial existing efforts being made to meet ongoing public needs and protect the local environment. The short-term and long-term priorities described below are not listed in order of importance.

- Protect public safety by reducing the potential for flooding in strategic areas through infrastructure improvements such as levee reinforcement, channel modifications, floodplain restoration, and increasing reservoir storage capacity.
- Increase water supply reliability by developing new water sources; maximizing the efficient use of existing sources, including recycled water used for landscaping, irrigation, industrial and commercial purposes, desalinated water, conservation, and groundwater treatment; and strategically restoring or replacing water infrastructure.
- Strategically restore and replace infrastructure to improve wastewater quality, limit the potential for adverse impacts to water quality and sensitive environmental areas, increase wastewater management efficiency, and meet regulatory requirements.
- Ensure the adequacy of water and wastewater facilities in DACs (Guadalupe, Cuyama, and Casmalia).
- Improve surface and ocean water quality and reduce beach closures by replacing septic systems with sanitary sewers, ensuring the integrity of wastewater collection systems near the ocean and surface water bodies, improving the quality of urban runoff, reducing runoff that enters the ocean and surface waters, and developing education programs to increase awareness of measures to improve water quality.
- Further define sources of groundwater contamination, and develop strategies to prevent contamination and improve quality in areas with known contamination.
- Protect, restore, and enhance ecological processes in aquatic areas through water quality improvements; public education; restoration efforts, including removal of invasive species; and improved steelhead passage on strategic creeks.
- Ensure the adequacy of water supplies during droughts and emergencies such as fires, floods, and earthquakes through strategic replacement and rehabilitation of critical infrastructure.
- Develop programs and policies to increase groundwater recharge or decrease groundwater use, especially in overdrafted groundwater basins.
- Encourage cooperation in beginning to develop groundwater banking programs.

Regional Priorities: Long-term (5 to 20 years)

The preceding short-term priorities will continue to be important in the more distant future, as well; thus, there is overlap between short-term and long-term priorities.

- Provide adequate water and wastewater services to meet projected growth.
- Implement regional and/or interagency conjunctive use and groundwater banking programs where supported by water cases and landowners.
- Promote programs, policies, and infrastructures to increase water supply sustainability through artificial recharge of local groundwater basins.
- Maximize storage capacity of existing surface reservoirs.
- Optimize the use of seawater desalination to increase water supply reliability and offset groundwater use.
- Expand distribution systems to provide recycled water to new users.
- Expand voluntary water conservation programs for residential, commercial, industrial, and agricultural uses.
- Continue interagency coordination to develop opportunities to further integrate the management of water and wastewater projects and programs.
- Continue to coordinate with adjacent counties to develop strategies and programs that improve the management of regional water resources.

Water Management Strategies

The state's IRWMP Guidelines identify 20 water management strategies as potential methods to meet objectives. These strategies were considered by the Cooperating Partners and were part of the evaluation process, as were the resource management strategies identified in the DWR's California Water Plan Update 2005. Many of the strategies in the IRWMP have multiple benefits, and many are already being implemented through local plans and programs. The three "foundational actions" outlined in the California Water Plan (i.e., using water efficiently, protecting water quality, and supporting environmental stewardship) are evident in our priorities and strategies.

Project Solicitation and Prioritization

In determining which projects to include in the IRWMP, the Cooperating Partners evaluated potential projects using the following criteria:

1. Readiness to proceed:
    a. California Environmental Quality Act (CEQA) process has been initiated or completed.
    b. Costs have been adequately estimated.
    c. Schedule, including project timeframe and milestones, has been prepared.
2. One or more regional objectives are addressed.

3. One or more water management strategies are utilized.
4. One or more regional priorities are addressed.
5. One or more statewide priorities are addressed.
6. The project is likely consistent with applicable general plan.
7. The project will not cause long-term significant adverse impacts, including long-term adverse impacts to agriculture.
8. The project serves a DAC.

The highest scoring projects were grouped as Tier I projects, with all other projects being Tier II. This preliminary sorting of projects into two tiers does not presume that any project is more likely, or less likely, to be included in a future application for a Proposition 50 grant. The complete IRWMP contains brief project descriptions for the Tier I projects. Appendices to the IRWMP include a complete listing of all projects, as well as information on how each project was evaluated relative to regional objectives, regional priorities, water management strategies, and statewide priorities.

Compliance with Statewide Priorities

As required by the state's Proposition 50 Guidelines, the IRWMP addresses the state's 11 water-related priorities, which cover a broad range of water supply and water quality issues. DWR and SWRCB also put a heavy emphasis on *integration* through the following program preferences, each of which is discussed in the IRWMP:

- Integration through use of multiple water management strategies
- Integration through multiple projects using the same water strategy; Integration resulting from projects with multiple benefits
- Integration with other projects not in the IRWMP
- Integration with other management plans and programs
- Geographic integration of multiple projects in a single location
- System integration, when new projects complete or complement existing ones
- Integration through interagency cooperation

In addition to these program preferences, the IRWMP has already served as a catalyst for discussions between the Cooperating Partners and other stakeholders regarding ways to increase integrated water resource management planning within Santa Barbara County.

Plan and Project Implementation

The Cooperating Partners will evaluate projects and plan performance, and will use adaptive management strategies to modify the current list of projects and overall plan as needed. The Cooperating Partners will conduct a biennial review and produce a 5-year report summarizing progress made in achieving IRWMP goals, including the tracking of funded and unfunded projects. Likewise, IRWMP objectives, priorities, water management strategies, and project lists will be evaluated during the biennial review and modified appropriately.

Management of data is an integral component of the IRWMP process. Information from the IRWMP will be available to stakeholders through the use of a Web site, which will be supported by the Santa Barbara County Water Agency. Other venues for information sharing will include project progress meetings, agency coordination meetings, public workshops, e-mail subscription lists, and e-mail newsletters. These forums will serve to continue to facilitate the ongoing data sharing between stakeholders.

Santa Barbara County will maintain existing data and will make it available to the public on the Santa Barbara County Water Agency Web site located at: http://www.countyofsb.org/pwd/water/index.htm. This site will also provide the forum for sharing of reports, public meeting dates, agendas, meeting minutes, and annual reports.

1

1 Introduction

1.1 Background and Purpose of the Santa Barbara Countywide Integrated Regional Water Management Plan

The effective management of water resources is one of the key challenges facing Santa Barbara County. Water resource planning within the county must address multiple factors, including limited local water supplies, variability of imported supplies, water quality issues, population changes and impacts from development, increasing regulatory requirements, aging infrastructure, the need to protect sensitive species and habitats, the loss of capacity in key reservoirs, existing and changing climatic conditions, and ongoing threats from droughts, floods, fires, and earthquakes.

Water resource managers in the Santa Barbara County region have a long history of working cooperatively to resolve multiple issues related to water and wastewater, including ensuring the adequacy of supplies and services, protecting and improving surface and groundwater quality, and protecting and enhancing ecosystems. Together they have planned and implemented significant water resources projects; developed integrated supplies and delivery systems; managed resources to meet the needs of urban users, agriculture, and ecosystems; and developed adaptive management strategies to respond to changing circumstances. Nonetheless, challenges remain, and the Santa Barbara Countywide Integrated Regional Water Management Plan (IRWMP) is intended to increase the level of coordination among all the agencies and districts responsible for water resources planning, nongovernmental organizations, and interested members of the public to facilitate the optimal management of water resources within the county over the next 20 years. The IRWMP also provides the foundation for grant applications needed to augment limited local financial resources.

The planning framework established by the IRWMP will be modified as needed to respond to changing conditions, including regulatory requirements, and will increase flexibility and efficiency by integrating multiple aspects of water resources management, such as water quality, local and imported water supplies, watershed protection, wastewater treatment and recycling, and protection of local ecosystems.

1.1.1 Consistency with State of California Planning Efforts

The IRWMP will allow regional needs to be met in a manner that is consistent with state of California planning efforts, including the California Department of Water Resources (DWR) Bulletin 160 (California Water Plan Update 2005), the State Water Resources Control Board (SWRCB) Strategic Plan, Watershed Management Initiative, basin planning process, and the Central Coast Regional Water Quality Control Board’s (RWQCB) draft “Vision, Goals, and

Objectives." The Santa Barbara Countywide IRWMP will help implement these planning efforts by developing an appropriate mix of resource management strategies and projects based on water management objectives and priorities that are specific to Santa Barbara County.

California Water Plan Update 2005

The California Water Plan Update 2005, a roadmap for meeting the state's water demands through the year 2030, indicates that to attain reliable water supplies, water management must pursue two initiatives that incorporate the following actions:

- Promote and practice integrated regional water management
  - Foster regional partnerships
  - Develop integrated regional water management plans
  - Diversify regional water portfolios
- Maintain and improve statewide water management systems, which are the backbone of water management in California
  - Improve aging facilities
  - Improve flood management
  - Implement the CALFED program and sustain the Sacramento-San Joaquin Delta (which will help ensure that State Water Project water flows to Santa Barbara County)

The California Water Plan Update 2005 further indicates that California water management must be based on the following three foundational actions in order to achieve sustainable water uses and reliable water supplies.

- Use water efficiently
  - Increase levels of urban and agricultural water use efficiency
  - Increase recycled municipal water, and expand its uses
  - Change the way water facilities are operated to improve their operation and efficiency
  - Facilitate environmentally, economically, and socially sound transfers to avoid regional shortages
  - Reduce and eliminate groundwater overdraft
- Protect water quality
  - Protect surface waters and aquifers from contamination
  - Explore new treatment technologies for drinking water and groundwater remediation
  - Match water quality to its intended uses
  - Improve management of urban and agricultural runoff

  - Improve watershed management
- Support environmental stewardship
  - Integrate ecosystem restoration with water planning and land use planning
  - Restore and maintain the structure and function of aquatic ecosystems
  - Minimize the alteration of ecosystems through water management actions
  - Improve watershed management
  - Protect public trust resources
  - Integrate flood management with water supply management

SWRCB Strategic Plan

In 2001, the SWRCB and RWQCBs developed a Strategic Plan that highlights new priorities to be addressed, along with specific objectives, key strategies, and strategic projects to be implemented. It identifies nonpoint source pollution from urban and agricultural runoff and other sources as the most significant water quality challenge facing California today; and the plan emphasizes the importance of (1) developing and implementing Total Maximum Daily Loads (TMDLs); (2) reducing storm water pollution; (3) addressing groundwater pollution; (4) permitting point source discharges; (5) increasing compliance assurance and enforcement; and (6) monitoring and assessing water quality (SWRCB and RWQCB, 2001). The SWRCB and RWQCBs have recently begun a process to revise the Strategic Plan.

SWRCB Watershed Management Initiative

The SWRCB and RWQCBs developed the Watershed Management Initiative to meet the goal of providing water resource protection, enhancement, and restoration, while balancing economic and environmental impacts. Potential water quality issues include impacts from agriculture, TMDLs, urban runoff, point source regulatory programs, basin planning, monitoring, and cleanup. Three targeted watersheds are located in Santa Barbara County, and the corresponding state agency concerns are (Central Coast RWQCB, 2002):

- Santa Maria River – Priority concerns include nitrate contamination of groundwater, sedimentation build up in Twitchell Reservoir, and habitat loss.
- Santa Ynez River – Priority concerns include effects of water rights decisions, erosion, sedimentation, flood control, and habitat loss (especially for steelhead); water quality impacts from urban development are another concern.
- South Coast – Priority concerns include creek and near shore water quality and beach closures.

Water Quality Control Plan for the Central Coastal Basin (Basin Plan)

The Central Coast RWQCB developed the Basin Plan in 1994 to show how the quality of the surface- and groundwaters in the Central Coast Region (which includes Santa Barbara County) should be managed to provide the highest water quality reasonably possible. The Basin Plan lists the various water uses in the region, describes the water quality that must be maintained to allow those uses, and describes the programs, projects, and other actions that are necessary to achieve the standards established in the plan. The Regional Board implements the Basin Plan by issuing and enforcing waste discharge requirements to individuals, communities, or businesses whose waste discharges can affect water quality. These requirements can be either (1) State Waste Discharge Requirements for discharges to land, or (2) federally delegated National Pollutant Discharge Elimination System (NPDES) permits for discharges to surface water. The Regional Board also establishes prohibitions on types and locations of discharges through the Basin Plan. The Basin Plan is also implemented by encouraging water users to improve the quality of their water supplies, particularly where discharged wastewater is likely to be reused.

Central Coast RWQCB "Vision, Goals, and Objectives"

The Regional Board (2006) is in the process of developing measurable goals for its region. The proposed goals currently include:

- By 2025, 80 percent of the Aquatic Habitat is healthy, and the remaining 20 percent exhibits positive trends in key parameters.
- By 2025, 80 percent of lands within any watershed will be managed to maintain healthy watershed functions, and the remaining 20 percent will exhibit positive trends in key watershed parameters.
- By 2025, 80 percent of the groundwater will be clean, and the remaining 20 percent will exhibit positive trends in key parameters.

The staff is currently working on organizational objectives.

1.1.2 Related Legislation

Integrated regional planning is facilitated in California by the passage of several legislative acts. The IRWMP is intended to be a dynamic document and will be updated as needed to meet the requirements of changing legislative standards.

Proposition 50, the "Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002," amended the California Water Code to authorize the Legislature to appropriate $500 million for integrated regional water management projects. The purpose of the integrated regional water management grant program is to "encourage integrated regional strategies for management of water resources and to provide funding, through competitive grants, for projects that protect communities from drought, protect and improve water quality, and improve local water security by reducing dependence on imported water." This IRWMP meets all requirements established by Proposition 50, Chapter 8, as specified in the November 2004 Integrated Regional Water Management Grant Program Guidelines prepared by DWR and SWRCB, who jointly administer the program. The guidelines specify that an adopted IRWMP is a prerequisite to obtaining project implementation grant funding through Proposition 50.

In November 2006, voters passed Proposition 84, the "California Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act of 2006." This act includes $1 billion in funding for integrated regional water management, including

$52 million for the Central Coast hydrologic region[1], of which Santa Barbara is a part. These funds will provide grants on a regional level to increase water supply, reduce demand, and protect water quality.

Proposition 1E, the "Disaster Preparedness and Flood Prevention Bond Act" also was passed in 2006. This act authorizes the state to sell $4.09 billion in bonds to rebuild and repair California's most vulnerable flood control structures to protect homes and prevent loss of life from flood-related disasters, including levee failures, flash floods, and mudslides; the sale of bonds also is intended to protect California's drinking water supply system by rebuilding delta levees that are vulnerable to earthquakes and storms.

The IRWMP may serve as the basis for obtaining grant funding from these sources to facilitate the implementation of certain projects, and it may be used to obtain funding from other sources as well, such as the federal Clean Water Act Section 319 Nonpoint Source Implementation Program and the U.S. Bureau of Reclamation's (Reclamation) Title XVI Program.

1.2 Group Responsible for Developing the IRWMP

The IRWMP has been prepared by a broadly based group, referred to as the "Cooperating Partners," comprising all but one of the entities responsible for managing water and wastewater in Santa Barbara County. The Cooperating Partners include the following 29 water districts, sanitary districts, community service districts, water conservation districts, private water companies, cities (large, medium, and small), Santa Barbara County, and joint powers agencies.

Cachuma Conservation and Release Board
Cachuma Operation and Maintenance Board
Carpinteria Sanitary District
Carpinteria Valley Water District
Casmalia Community Services District
Central Coast Water Authority
City of Buellton
City of Carpinteria
City of Guadalupe
City of Lompoc
City of Santa Barbara
City of Santa Maria
City of Solvang
Cuyama Community Services District
Golden State Water Company
Goleta Sanitary District
Goleta Water District
Goleta West Sanitary District
La Cumbre Mutual Water Company
Los Alamos Community Services District
Mission Hills Community Services District
Montecito Sanitary District
Montecito Water District
Santa Barbara County
Santa Maria Valley Water Conservation District
Santa Ynez River Water Conservation District
Santa Ynez River Water Conservation District Improvement District No. 1
Summerland Sanitary District
Vandenberg Village Community Services District

[1] This region corresponds with the area under the jurisdiction of the Central Coast Regional Water Quality Control Board, comprising all of Santa Barbara, Santa Cruz, San Benito, Monterey, San Luis Obispo, Monterey, and Santa Cruz counties, as well as the southern one-third of Santa Clara County and small portions of San Mateo, Kern, and Ventura counties.

Many of the Cooperating Partners have worked together since 2002 to develop the regional objectives, strategies, and priorities in the IRWMP, as well as projects to meet regional water needs.

Additionally, as described in detail in Section 4, a broad range of stakeholders participated in the development of the IRWMP, including agricultural, environmental, and academic interests, as well as members of the general public.

1.3 Governance Structure

For the purposes of developing the IRWMP, a Memorandum of Understanding was created and signed by the Cooperating Partners. During the Implementation Grant process, the Cooperating Partners and interested stakeholders will consider a variety of governance models that will lead to establishment of a long-term governance structure. A number of grant application and grant implementation tasks will be conducted as part of this ongoing process. Those tasks are listed at the end of this section.

Agreement will be reached on the steps to be taken to identify a long-term governance structure that will work best for the region. Those steps could include the following: (1) identify the objectives for the long-term governance structure; (2) set a schedule for the process; (3) find examples of governance structures that have led to successful implementation of major projects both within Santa Barbara County (Section 3.3 refers to the many successful interagency planning and integrated management agreements in place within the County) and around the country; (4) lay out the options for governance structures that exist within current state and local legislation; (5) make recommendations for legislation that may be required to enable implementation of governance structures; and (6) develop briefings and workshops to lead to agreement upon and implementation of a permanent governance structure. Examples of governance structures will include a narrative discussion of what has worked, either here in California or elsewhere, along with an appendix of legislation that enables such entities in this state. In addition, sample agreements, which can be a starting point for discussion among departments and agencies, will be included. The County of Santa Barbara will assume a leadership role in the coordination of this task.

Viable governance models should meet the following minimum needs: promote partnerships within the region; facilitate ongoing stakeholder involvement and decision-making; serve as a planning body charged with periodically updating the IRWMP; oversee IRWMP projects and manage data collection and data coordination with state systems.

There are a number of models that could meet the needs of the region. Models to be considered include:

- Memorandums of Understanding/Cooperative Agreements
- Commissions
- Joint Powers Authority

1.3.1 Memorandums of Understanding/Cooperative Agreements

At the simplest level, Memorandums of Understanding and Cooperative Agreements are contracts between and among organizations that specify how work will be performed. They can be of indefinite length and general as to the nature performed or specific to projects. Typical language includes the purpose of the agreement and provisions for financing, indemnification, settlement of disputes, and length and termination of the agreement. They require only the signatures of the authorized representatives of the organizations; although depending on the organization, the agreements may have to go to the governing boards for approval.

1.3.2 Commissions

Commissions exist at every level of government and are often created for purposes of advice and oversight. Commissions can issue plans, award or receive funds, and enter into contracts.

A local example of a commission is the Santa Monica Bay Restoration Commission, formerly the Santa Monica Bay Restoration Project. According to the California Public Resources Code, “It is the intent of the Legislature that the Santa Monica Bay Restoration Commission be a non-regulatory, locally based state government entity that will monitor, assess, coordinate and advise all state programs, and oversee funding that affects the beneficial uses, restoration, and enhancement of Santa Monica Bay and its watershed.” The governance structure of the Commission is delineated through a Memorandum of Understanding among the Secretaries for Environmental Protection, Resources Agency, and Chair of the Commission. The Memorandum of Understanding further prescribes the membership by federal, state, and local public agency officials and employees, as well as representatives of other stakeholder interests.

The enabling legislation allows the Commission to request and receive federal, state, local, and private funds, award and administer grants, and enter into and carry out joint powers authority agreements. A separate account was established in the state treasury for receipt and expenditure of funds.

1.3.3 Joint Powers Authority

Joint Powers Authorities are separate public entities created when two or more public agencies come together for a particular mission or purpose. In the pooling of powers, the new entity may have greater power than the parties to the agreement alone. For example, the ability to issue bonds may come from one agency, while eminent domain may come from another. The Joint Powers Authority may be able to act more quickly and efficiently in the hiring and management of staff, making land acquisitions, or carrying out projects.

Section 6500 et seq. of the California Government Code allows for the formation of joint powers authorities. As stated, “If authorized by their legislative or other governing bodies, two or more public agencies by agreement may jointly exercise any power common to the contracting parties, even though one or more of the contracting agencies may be located outside this state. The agreements shall state the purpose of the agreement or the power to be exercised. They shall provide for the method by which the purpose will be accomplished or the manner in which the power will be exercised.”

1.3.4 Future Proposition 50 Tasks

Potential future Proposition 50 Grant Application tasks for the Cooperating Partners include:

1. Develop a new Memorandum of Understanding among Cooperating Partners for a Proposition 50 grant application and implementation process covering items such as schedule, process, funding, and key roles.
2. Develop a grant application by:
    a. Managing a process for project evaluation and selection;
    b. Preparing application and related materials, per state requirements; and
    c. Coordinating Partners' and public review and revisions.
3. Submit single application on behalf of Partners with selected projects.
4. Negotiate with state, respond to comments, and revise application.

Potential Proposition 50 Grant Implementation tasks for the Cooperating Partners include:

1. Carry out fiduciary tasks such as tracking expenditures, compiling Cooperating Partners' invoices, preparing billing for submittal to state, and keeping appropriate records.
2. Carry out grant management tasks such as, tracking project status, compiling data, and preparing reports to state on performance and results.
3. Submit invoices, progress reports, and data to state.
4. Manage contracts and subcontracts with Cooperating Partners and consultants.

2

2 Region Description

The IRWMP encompasses all of Santa Barbara County (Figure 2-1). The county is an appropriate region for integrated planning for a number of reasons:

- Different subregions within the county share water supplies and infrastructure, and water is managed as an interconnected system within the county boundaries (refer to Section 3).
- Water and wastewater management entities must address issues and challenges that are specific to the region and that would benefit from an integrated management approach (refer to Sections 2 and 3).
- From an institutional perspective, many of the Cooperating Partners have a long history of working together to resolve water issues, and a framework already exists for addressing key issues related to water resource management (refer to Section 3). The IRWMP builds on this framework, expanding existing programs and identifying further opportunities for integration.
- The county is largely geographically separate from neighboring counties. Santa Barbara County abuts Kern County only along its sparsely populated northeast corner. The portions of the Rincon Creek watershed shared by Ventura County and the Cuyama River watershed shared by Ventura and San Luis Obispo counties have very low population densities, are subordinate in size, and have no shared water infrastructure. The Santa Maria Groundwater Basin, shared with San Luis Obispo County, is the subject of nearly complete adjudication (refer to Section 3); the court has imposed a mandatory management structure, and thus, any integrated management must accommodate the court's directives.

2.1 Overview

Santa Barbara County is located approximately 100 miles northwest of Los Angeles and 300 miles south of San Francisco. The county occupies approximately 2,739 square miles. Bordered on the west and south by the Pacific Ocean, the county has 110 miles of coastline. Four of the Channel Islands—Santa Cruz, Santa Rosa, San Miguel, and Santa Barbara—are in Santa Barbara County. These islands are not addressed in this IRWMP, because they are largely owned and managed by the federal government as a national park and marine sanctuary. The county has a population of approximately 421,656 (State of California, 2007a), which is projected to increase to 562,700 by 2030 and to 605,600 by 2040 (SBCWA, 2003). The county is highly diverse in terms of climate, topography, economic activities, recreational opportunities, and social/economic structure. Additionally, there are five major ecological zones and numerous subareas ranging from arid high desert regions in the interior; mountains and foothills; and coastal plains.

About 65 percent of the terrain of Santa Barbara County is hilly or mountainous, and most of the remaining 35 percent is composed of valleys and plains. The steep Santa Ynez Mountains bound the coastal plain on the north; farther north, the San Rafael Mountains rise to the highest elevations in the county; and the Sierra Madre Mountains occupy the northeast portion of the county. Approximately one-third of the land area within the county is located within the Los Padres National Forest, which includes two wilderness areas, the San Rafael Wilderness and the Dick Smith Wilderness. The national forest includes portions of watersheds that provide an important water source for coastal populations, as well as important habitat for several threatened, endangered, proposed, candidate, and sensitive species.

Most of the county population lives in the coastal valleys and in the cities of Santa Barbara and Santa Maria. Other population centers on the South Coast include the cities of Goleta and Carpinteria, along with unincorporated areas such as Isla Vista, Hope Ranch, Mission Canyon, Montecito, and Summerland. The cities of Solvang and Buellton, the unincorporated communities of Los Olivos, Ballard, and Santa Ynez, and the Chumash Indian Santa Ynez Reservation are located in the Santa Ynez Valley, north of the Santa Ynez Mountains. The City of Lompoc, the unincorporated communities of Vandenberg Village and Mission Hills, Vandenberg Air Force Base, and the Lompoc Federal Correctional Complex are in the Lompoc Valley, where the Santa Ynez River flows out to the sea. Los Alamos is the only community in the San Antonio watershed. The cities of Santa Maria and Guadalupe, and the unincorporated towns of Orcutt, Casmalia, Betteravia, Garey, and Sisquoc are located in the northern portion of the county. The City of Santa Maria is the largest city in Santa Barbara County. Northeast of the San Rafael mountains is the dry and sparsely populated Cuyama Valley, where the community of Cuyama is located.

Major land use categories are shown in Figure 2-2, along with a breakdown of land ownership and the amount of land dedicated to generalized land uses. The federal government is the largest land owner in the county; the United States Forest Service and Air Force have jurisdiction over nearly 46 percent of the land area. Los Padres National Forest and Vandenberg Air Force Base comprise approximately 748,000 acres combined. The national forest provides a scenic backdrop to many communities within both north and south Santa Barbara County and is managed for multiple purposes, including recreation, oil development, and grazing. Vandenberg Air Force Base is headquarters for the 30th Space Wing, which manages Department of Defense space and missile testing and places satellites into polar orbit from the West Coast.

The state of California owns approximately 1 percent of county lands, or 18,000 acres. Most of this land comprises the University of California at Santa Barbara (UCSB), near the City of Goleta; the Sedgwick Reserve, which is operated by the University as part of its Natural Reserve System and located east of Los Olivos in the Santa Ynez Valley; La Purisima Mission State Park, located near Lompoc; and several state parks located along the coast, within the city of Santa Barbara, and in the Santa Ynez Mountains. Less than 1 percent of the county is owned by the county or other local agencies, and the remainder is privately owned.

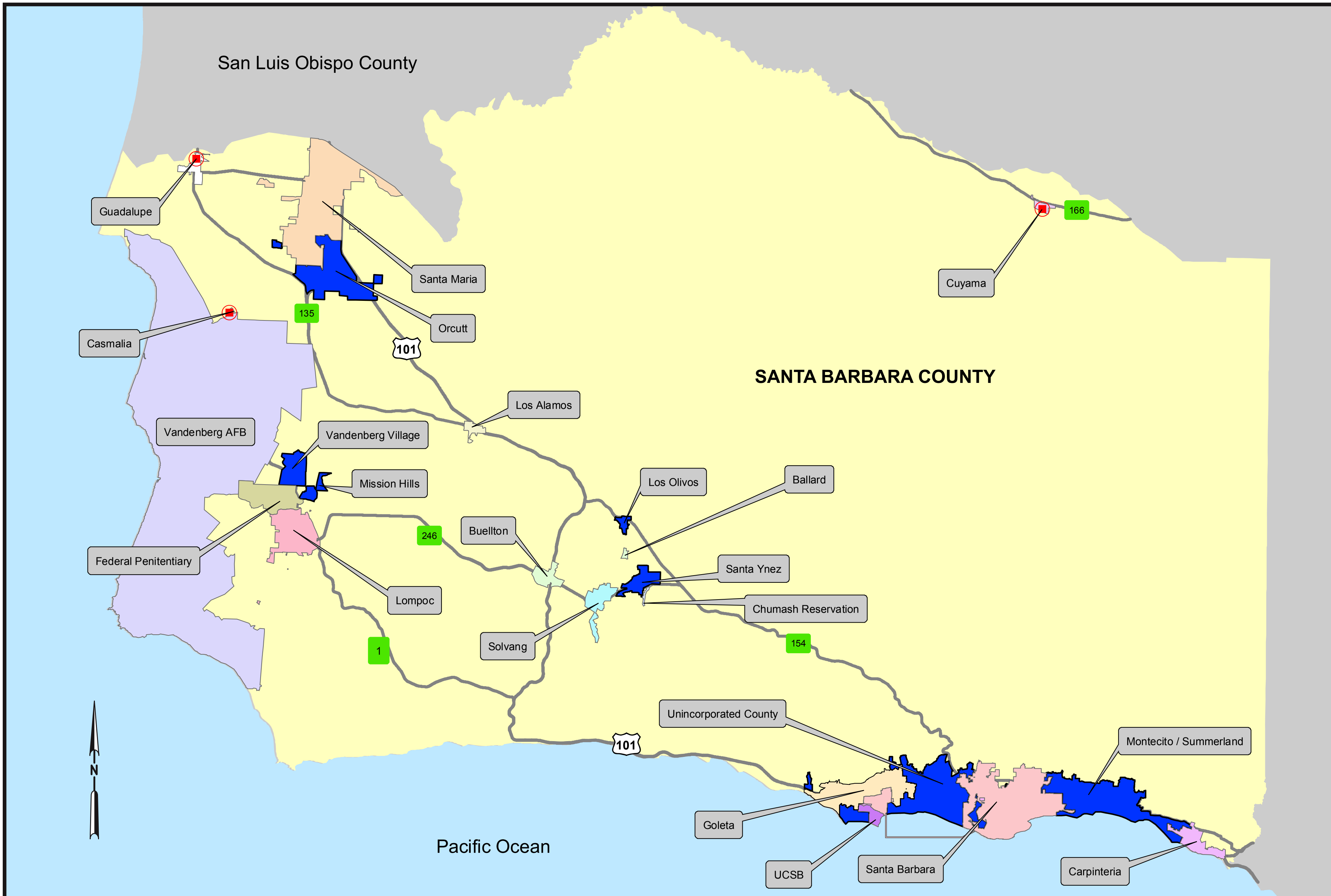

FIGURE 2-1
IRWMP REGIONAL MAP
SANTA BARBARA IRWMP

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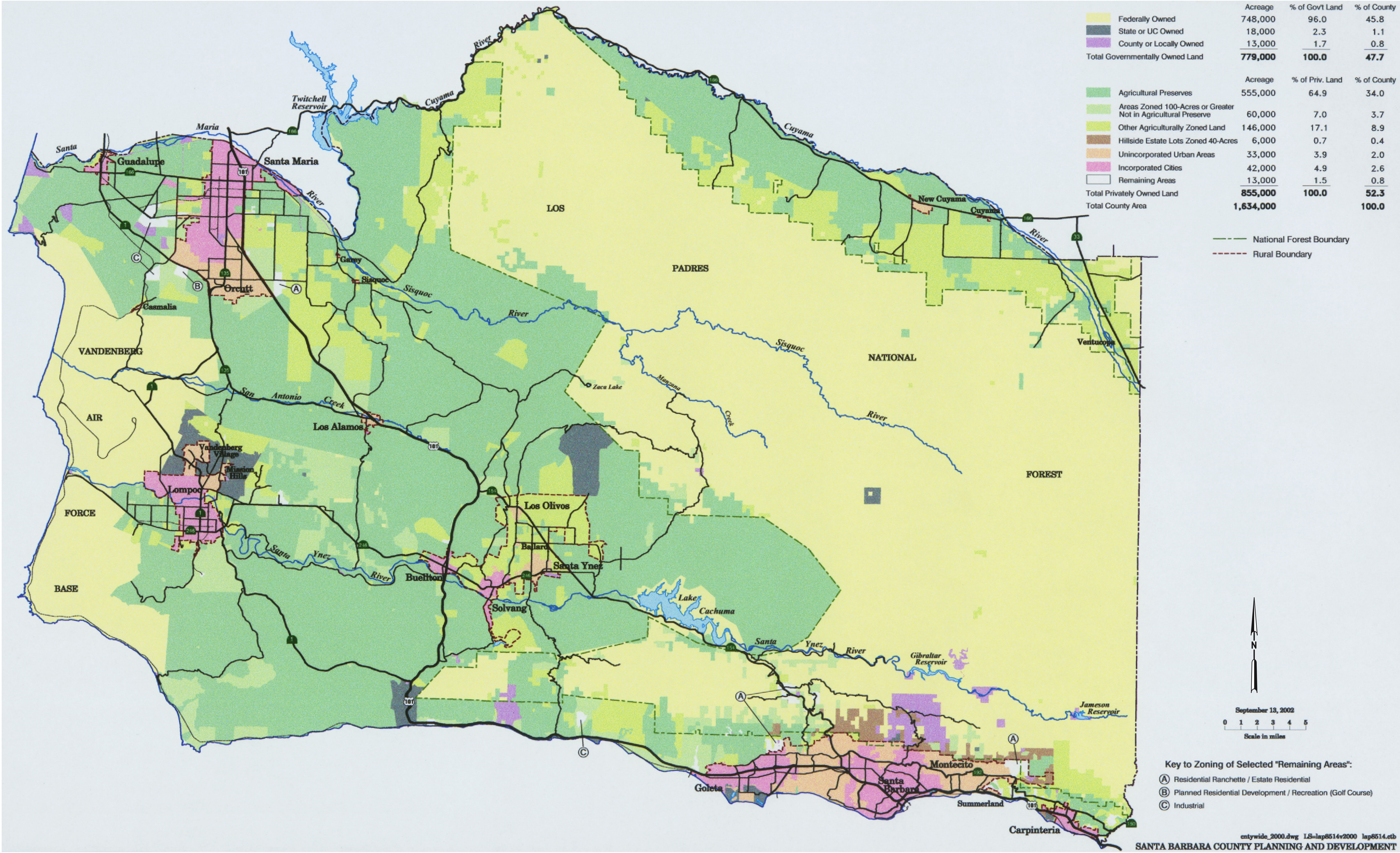

FIGURE 2-2
SANTA BARBARA COUNTY LAND STATUS
SANTA BARBARA IRWMP

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Thirty-four percent of the county (555,000 acres) is in agricultural preserves, and an additional 13 percent (206,000 acres) is zoned for 100-acre or greater lot size, or is in other agriculturally zoned land. Less than 3 percent of the county is within incorporated cities, 2 percent is within unincorporated urban areas, and less than 1 percent is zoned for hillside estate lots of 40 acres or more.

2.2 Climate

Santa Barbara County has a Mediterranean climate with several microclimatic regions. Summers are warm and dry; the winters are cool and often wet. Annual precipitation typically ranges from 7 to 9 inches near Cuyama to a maximum of about 36 inches at the uppermost elevations of the San Rafael Mountains. Average rainfall throughout the county is approximately 15 to 18 inches per year. The county topography has a unique physical orientation compared to the rest of California with a series of east-west transverse mountain ranges. This topography causes an orographic effect when a storm approaches from the Pacific Ocean. Storms from the south can cause heavy precipitation on south-facing slopes, while storms from the north or west can concentrate precipitation on west or north-facing slopes. Annual average rainfall at the highest elevation is twice that of the lowest elevation. Most precipitation occurs between November and March with the exception of some far inland mountain areas that may receive sporadic late summer thundershowers. Moist air from the Pacific Ocean moderates temperatures in the coastal areas; lower winter minimums and higher summer maximums prevail in the inland valleys.

Santa Barbara County weather is mainly controlled by the Pacific high pressure system. In the dry season, from about May through September, the Pacific high pressure system usually occupies the area northeast of Hawaii. During the winter months, it is weaker and positioned further south. At times, the persistence of the Pacific high pressure system at a latitude farther north than normal keeps the Pacific storm track farther to the north. This “blocking high” results in either no precipitation for part or all of California, or, at most, only light amounts of rainfall. This climatological scenario is the reason for most of California’s droughts, including those occurring in 1976 to 1977 and 1986 to 1991.

2.3 Economic Conditions and Trends in the Region

Santa Barbara County is economically diverse with pronounced differences between the north and the south. Agricultural activities and oil development traditionally have been the dominant economic forces north of the Santa Ynez Mountains; although in recent years, tourism has increased, oil leases have been decommissioned, and more white-collar workers have been moving in to the area because of the high housing prices in the south. Agriculture continues to be the county’s major producing industry, despite reductions in the amount of farmland.

The South Coast’s economy is largely based on tourism, software or other high-tech pursuits, and education-related activities; although the area continues to support oil development offshore, and agricultural activities continue to occur in the Goleta and Carpinteria valleys, particularly in the foothills. The South Coast has experienced slow economic growth in recent years, while the North County has undergone considerable economic growth. This is due in large part to the extremely high cost of housing in the South Coast, where the median price of a single family home exceeds $1 million. As a result, the North County is undergoing significant population growth, which in turn, is driving construction and service industry growth in the area. Economists predict that the North County region will be the main driving force in the economy for the foreseeable future because of relatively affordable housing, available work force, and a perceived business-friendly environment (UCSB, 2006).

2.4 Santa Barbara's Social and Cultural Makeup

Santa Barbara County is socially and culturally diverse. The county is predominantly composed of White/Caucasians (approximately 56 percent) and Hispanics (approximately 34 percent), with Asians and African Americans comprising most of the remaining population (State of California, 2007c). The county includes three Disadvantaged Communities (DAC)—Cuyama, the City of Guadalupe, and Casmalia—all of which are located in North County[1]. All three communities are fairly isolated from other populated areas within the county, especially Cuyama and Casmalia. These communities face financial hardships and serious health risks related to the condition of their respective water supply systems and potential threats to the quality of their drinking water, as described in greater detail in Section 6.

Due in part to the high cost of housing, the population in the South County is becoming increasingly stratified. The number of middle class residents is decreasing, leaving a concentration of younger and poorer residents, as well as older and wealthier retirees. School enrollments have been declining in the South County because working families can not afford housing and choose to move to less expensive areas. The North County, on the other hand, is experiencing an influx of younger families because housing is more affordable. North County school enrollments are on the rise (UCSB, 2006).

Santa Barbara residents appreciate its mild climate, scenic beauty, beaches, mountains, recreational resources, and cultural opportunities. Those qualities that make the county a desirable destination for tourists also make it an appealing place to live. The county is home to a long-standing environmental movement, stemming in part from the large oil spill that affected 35 miles of coastline in 1969. Environmental activists are, however, sometimes at odds with other interests regarding the most appropriate way to manage Santa Barbara County resources.

2.5 Major Watersheds and Rivers

The county contains four principal watersheds (Table 2-1): Santa Maria, which includes the Cuyama and Sisquoc watersheds; San Antonio Creek; Santa Ynez; and South Coast, which is composed of approximately 50 short, steep watersheds (Figures 2-3 and 2-4). The headwaters of the principal watersheds are generally undeveloped, and the middle and

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[1] DACs were identified by reviewing median household income (MHI) data from the 2000 US Census for all zip codes within Santa Barbara County and identifying those that were 80 percent or less of the statewide MHI based on the 2000 Census ($37,994). MHIs are as follows: Guadalupe, $30,864; Casmalia, $37,574; and New Cuyama, $36,500. In comparison, the MHI for all Santa Barbara County zip codes is $49,027.

lower sections are often developed with urban or agricultural uses. The four major rivers draining these watersheds are the Santa Maria, Sisquoc, Cuyama, and Santa Ynez. Rainfall is variable, and streamflow is flashy. Streamflow is generated directly from rainfall with little base flow contribution from headwaters. Most rivers and the lower reaches of streams are dry in the summer.

TABLE 2-1
Santa Barbara County Watersheds

Watershed	Square Miles
Santa Maria (including Cuyama and Sisquoc watersheds)	1,845
San Antonio Creek	165
Santa Ynez River	900
South Coast (composed of numerous smaller watersheds)	416

2.5.1 Santa Maria Watershed

The Santa Maria Watershed (Figure 2-5) is drained by the Santa Maria River, which is formed by the confluence of the Cuyama and Sisquoc rivers at Fugler Point, 20 miles inland from the coast. Elevations range from sea level to 6,828 feet at Big Pine Mountain, which is at the headwaters of the Sisquoc River. The Santa Maria River Valley covers the 260-square-mile watershed area downstream of the Cuyama-Sisquoc River confluence. Much of the valley consists of a broad alluvial area known as the Santa Maria Plain. The Cuyama River drains a 1,140-square-mile watershed area that includes southeastern San Luis Obispo County, northeastern Santa Barbara County, and relatively small portions of Ventura and Kern counties. Major tributaries to the Cuyama River are Huasna River and Alamos Creek. Most of the river and its tributaries have intermittent flows, although some reaches of the river have surface water most of the year. Some of the major tributaries also have perennial flows in some reaches. Since 1959, flow in the Cuyama River has been regulated by Twitchell Reservoir, which retards a portion of intercepted storm flow for later release. The Sisquoc River receives runoff from a watershed area of approximately 470 square miles. The watershed of the Sisquoc River is defined by the northwestward-trending Sierra Madre Mountains on the north and the westward trending San Rafael Mountains on the south. Most of the Sisquoc River drainage lies within the boundaries of the Los Padres National Forest. The Sisquoc River is designated as a Wild and Scenic River. Except for wilderness areas in the National Forest, all of the land is used for some form of agriculture. Other industries of significance include oil and gravel mining, recreation, light manufacturing, and research and development mostly related to the aerospace business (CARCD, 2002).

2.5.2 San Antonio Creek Watershed

The drainage system of the San Antonio Creek Watershed starts at a point approximately 10 miles east of Los Alamos. It traverses generally to the west through Los Alamos and Vandenberg Air Force Base to the ocean. The basin is rather confined, averaging about 8 miles in width. The lower reaches throughout Vandenberg Air Force Base have a perennial flow, in part because of irrigation tailwater, but primarily because of a geologic rift at Barca Slough, which causes an upwelling. The principal crops grown are vegetables in the flat areas, and winegrapes in the transitional uplands. All are irrigated from groundwater resources (CARCD, 2002).

2.5.3 Santa Ynez River Basin

The Santa Ynez River originates in the San Rafael Mountains in the Los Padres National Forest near the eastern border of the county. A small portion of the Santa Ynez River watershed lies in Ventura County. The river flows westerly about 90 miles to the ocean, passing through Jameson Lake, Gibraltar Reservoir, and Lake Cachuma. The Santa Ynez River basin is the largest drainage system that is wholly located in Santa Barbara County. The 621,577 acres that it drains is about 40 percent of the mainland part of the county. It is the primary source of water for about two-thirds of the Santa Barbara County residents, including the heavily populated south coastal region around Santa Barbara. Three dams have been constructed on the river to store and divert water to the South County. These are described in detail in Sections 3 and 4. None of the reservoirs on the Santa Ynez River has a prescriptive requirement for a flood control storage area. All of the water diversions from the dams are by tunnels cut through the Santa Ynez Mountains to terminal reservoirs near urban areas.

Approximately 260,000 acres in the watershed are public land, 215,000 of which is within the Las Padres National Forest. The remaining public lands are, for the most part, on Vandenberg Air Force Base. In the Santa Ynez Valley there is an extensive thoroughbred racehorse industry. Crops grown in this area include wine grapes and irrigated forage crops for the horses. Most of the relatively flat lands between Buellton and Lompoc are used for growing a variety of irrigated crops including flowers, vegetables, wine grapes, beans, and walnuts. Most of the irrigated land is located in Lompoc Valley west of Lompoc. That area is similar to Santa Maria Valley in that the marine influences allow year round crop production. All irrigation water is pumped from underground resources. Almost all of the upland areas are used as range to raise beef cattle. Other important industries are oil production, diatomaceous earth mining, and human resources support for Vandenberg Air Force Base (CARCD, 2002).

FIGURE 2-3
WATERSHEDS OF SANTA BARBARA COUNTY
SANTA BARBARA IRWMP

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FIGURE 2-4
COASTAL WATERSHEDS IN SOUTHERN SANTA BARBARA COUNTY
SANTA BARBARA IRWMP

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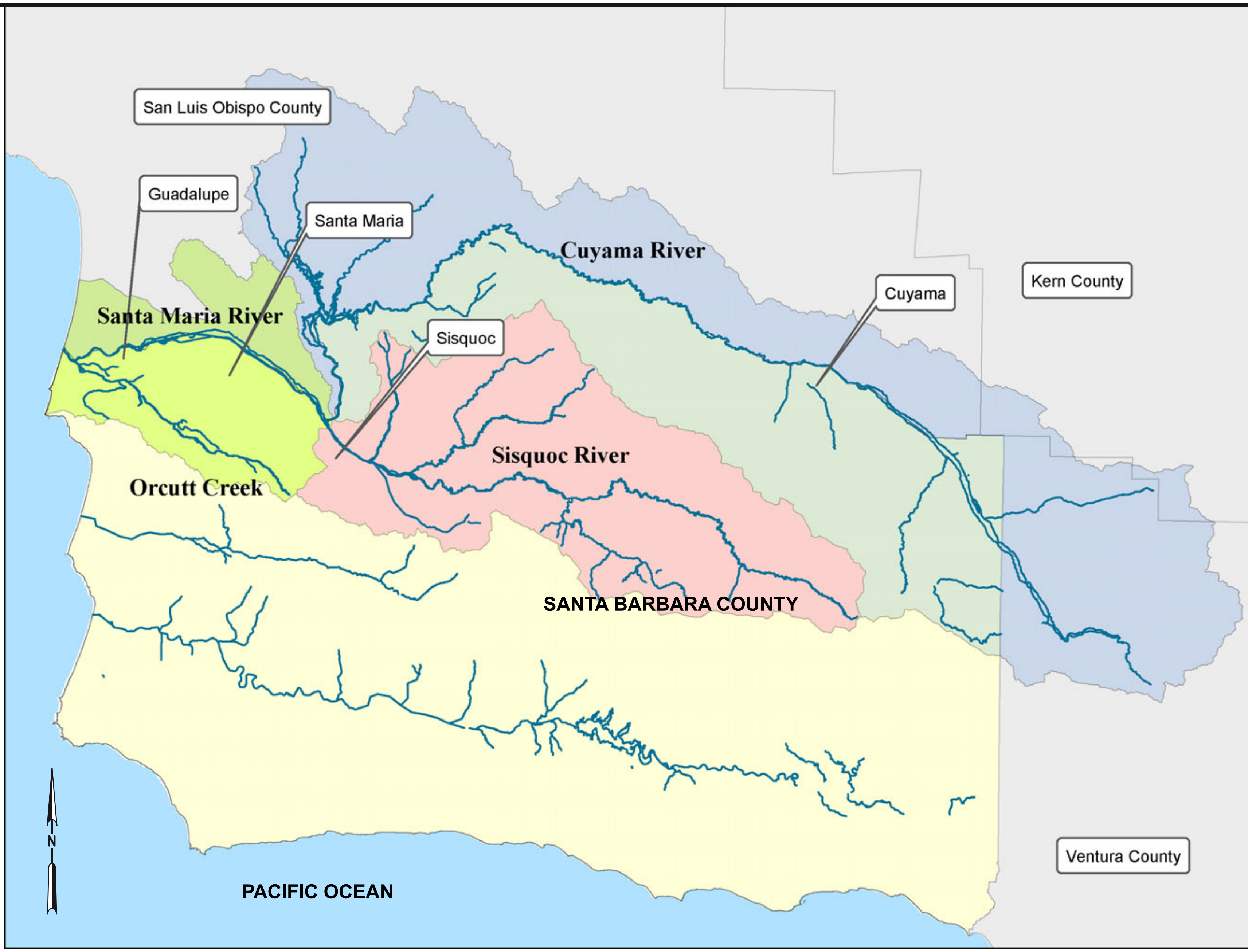

FIGURE 2-5
SANTA MARIA WATERSHED
SANTA BARBARA IRWMP

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2.5.4 South Coast Watersheds

The south coastal region generally includes all of the southerly drainages from Point Concepcion to the Ventura County line. Its approximately 50 watersheds range from 162 acres to 30,572 acres, with an average size of 3,209 acres. This area is heavily influenced by the ocean because of the southerly aspect, and the ocean current which is usually about 10 degrees higher than the current north of Point Concepcion during the winter months. This south to north current is from South American waters as opposed to the north to south Humboldt Current north of Point Concepcion. The currents merge near the point and then trend seaward. The topography is precipitous, rising abruptly from sea level to about 4,300 feet. Annual rainfall varies from about 16 inches on the coast to about 30 inches at the summits. Virtually all the subtropical fruit (principally avocados) and about 75 percent of the nursery and hot-house products of the county are raised in the South Coast, most of which are in the vicinity of the urban complex between Goleta and Carpinteria. Irrigation water is provided from a variety of sources, including pumped groundwater; diversions from Cachuma, Gibraltar, and Juncal Dams; and to a lesser degree from on-farm surface entrapments. The southeastern part is heavily urbanized, and includes the contiguous communities of Goleta, Santa Barbara, Montecito, Summerland, and Carpinteria. Other than agriculture, important industries include tourism, electronic products manufacturing, city and county government, and University of California, Santa Barbara (CARCD, 2002).

2.6 Groundwater Basins

Santa Barbara County groundwater basins are shown in Figure 2-6; their sizes and land uses served are summarized in Table 2-2.

TABLE 2-2
Santa Barbara County Groundwater Basins

Basin	Size (Acres)	Land Use Summary
North County Groundwater Basins		
Santa Maria	110,000 with 80,000 within Santa Barbara County	Two cities; extensive unincorporated urban area (Santa Barbara County); extensive irrigated agriculture; petroleum
San Antonio Creek	70,400	One town; extensive agriculture; some petroleum; Vandenberg Air Force Base
Cuyama	441,600 with 81,280 within Santa Barbara County	Extensive agriculture; some petroleum; very low population density
Santa Ynez River Groundwater Basins		
Santa Ynez Uplands	83,200	Three towns, one city and other medium-density residential; varied high-value agriculture
Buellton Uplands	16,400	Agriculture; one city
Lompoc[a]	48,600	One city, 2 areas of unincorporated urban development; Vandenberg Air Force Base; varied agriculture; petroleum; Federal Penitentiary Complex
Santa Ynez River Riparian Basins	12,000 (3 subunits)	Two cities; 7,300 acres of irrigated cropland
South Coast Groundwater Basins		
Carpinteria	6,700	One city; unincorporated urban development; orchards, irrigated crops, and greenhouses
Montecito	4,300	Primarily low-density residential use; unincorporated
Santa Barbara	4,500	Primarily residential, industrial and commercial
Foothill	3,000	Primarily residential and commercial
Goleta North/Central	5,700	Primarily residential, industrial, and commercial
Goleta West	3,500	Primarily residential, industrial, and commercial
More Ranch	502	Primarily open space; limited residential/agriculture
Ellwood to Gaviota Coastal Basins	67,200	Agriculture, primarily orchards and grazing; limited municipal/industrial
Gaviota to Pt. Conception Coastal Basins	23,040	Agriculture, primarily grazing

Sources: Santa Barbara County, 2000; Santa Barbara County, 2003

[a]Consists of three hydrologically connected subbasins: Lompoc Plain, Lompoc Terrace, and Lompoc Upland

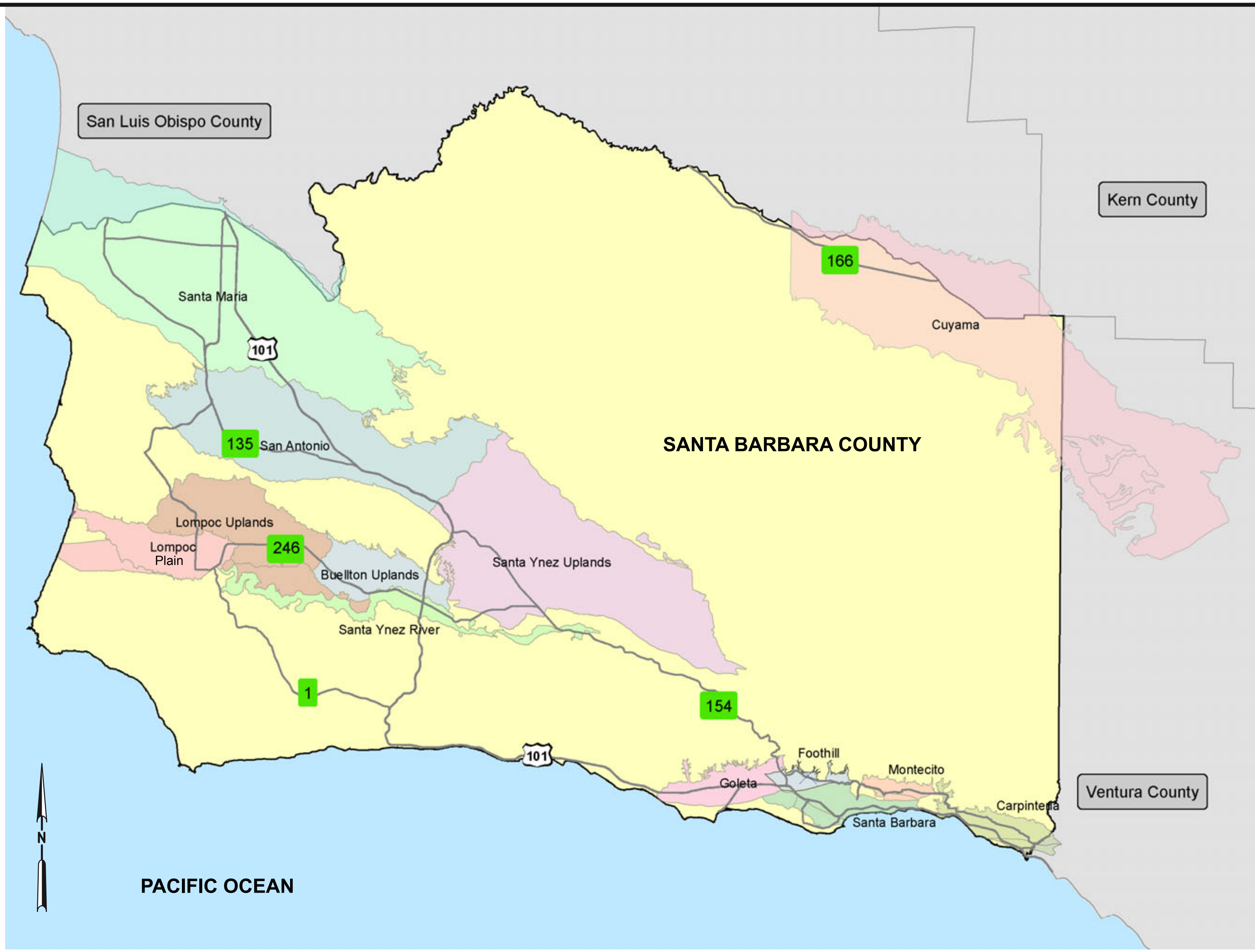

FIGURE 2-6
GROUNDWATER BASINS OF SANTA BARBARA COUNTY
SANTA BARBARA IRWMP

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The following conclusions regarding groundwater basins are taken from the 2005 Santa Barbara County Groundwater Report (Santa Barbara County, 2006). References to overdraft pertain to safe yield and not perennial yield. Safe yield is defined in the 2005 report as the maximum amount of water which can be withdrawn from a basin (or aquifer) on an average annual basis without inducing a long-term progressive drop in water level. Perennial yield is defined as the amount of water that can be withdrawn from a basin (or aquifer) on an average annual basis without inducing economic or water quality consequences.

The 2005 Santa Barbara County Groundwater Report (Santa Barbara County, 2006) summarizes the status of groundwater basins as follows:

- The Cuyama Groundwater Basin is in a state of overdraft of approximately 28,525 acre-feet per year (AFY) based on a 1992 study. Water levels have fallen significantly, but no regional economic or water quality problem has yet been documented.
- In the recent litigation, *Santa Maria Valley Water Conservation District versus the City of Santa Maria et al.,* the court ruled that, based on a preponderance of evidence, the Santa Maria Groundwater Basin is not currently in a state of overdraft. Management of this groundwater basin will be subject to the adjudication, which is expected to be completed in 2007. (Refer to Section 3 for additional discussion).
- The San Antonio Groundwater Basin is in a state of overdraft of approximately 9,540 AFY based on a 2003 study. Water levels have fallen significantly, but no regional economic or groundwater quality problem has yet materialized.
- The Lompoc Plain Groundwater Basin is in equilibrium under the State Water Resources Control Board (SWRCB) Decision WR 89-18 and management by the Santa Ynez River Water Conservation District, because natural recharge is augmented with periodic water releases that are made from Cachuma Reservoir to maintain groundwater levels in the basin.
- The Lompoc Uplands Groundwater Basin has apparently reached equilibrium since, over time, water levels have been lowered to approach the elevation of the Lompoc Plain and Santa Ynez River, which now regulate the water levels in the Uplands Basin.
- The Santa Rita subarea of the Lompoc Basin is in a state of overdraft of approximately 800 AFY based on a 2001 study. However, water levels in some parts of this area have declined significantly in the past few years, and thus, in the future some economic effects may be realized as the balance between energy costs and commodity prices fluctuate.
- The Buellton Uplands Basin is in a state of surplus of approximately 800 AFY based on a 1995 study.
- The condition of the Santa Ynez Uplands Groundwater Basin has varied over time, and a 2001 study reported the basin as being in a state of overdraft of approximately 2,028 AFY at that time. The decline in water levels in this basin appears to have bottomed out in the 1987 to 1991 drought, however, and the basin may currently be in equilibrium. Under current extraction practices, part of the basin is used conjunctively

with local and imported surface water supplies. No regional economic or water quality impacts associated with pumping have materialized.

- The South Coast Basins are in equilibrium through management by local water districts and the Wright Suit Settlement[2]. The City of Santa Barbara practices conjunctive use of groundwater resources in the Foothill Basin and Storage Unit No. 1 of the Santa Barbara Groundwater Basin. Relatively minor amounts of pumping occur during average and wet years. More pumping is used during droughts to replace supplies lost to diminished surface water. Between pumping by the City and various private pumpers, the basins are in long term balance.

2.7 Ecological Processes and Environmental Resources

Santa Barbara County is located at a point of transition between the Southern California and Northern California ecozones and is characterized by rare plant assemblages. The county has a range of climatic zones, ranging from Mediterranean climate (South Coast) to Alpine (Big Pine Mountain) to high desert (Cuyama area), resulting in considerable ecological diversity. Over 1,400 plant and animal species are found in the county. Of these, 54 are federally or state-listed threatened or endangered species (22 plant and 32 animal species), and another 60 species are considered rare or of special concern (including proposed endangered, threatened, candidate, and sensitive species).

2.7.1 Aquatic Sensitive Species

The listed species found in Santa Barbara County include five aquatic/stream dependent species (tidewater goby [*Eucycloglobius newberryi*], tiger salamander [*Ambystoma californiense*], red-legged frog [*Rana aurora draytonii*], arroyo toad [*Bufo californicus*], and southern California steelhead trout [*Oncorhynchus mykiss*]). The county's watersheds provide critical habitat for the anadromous steelhead trout, which are found primarily in the Santa Ynez River and its tributaries and the South Coast creeks, including Mission Creek. Steelhead populations have declined due to human activity impacts, such as loss of native vegetation, influx of aggressive exotic species, increased creek/stream scouring, streamflow and groundwater diversion, increases in impervious surfaces and runoff, and degraded water quality because of thermal pollution and potential nutrient, sediment, and other polluted runoff from urban development. Dams, culverts, concrete channels, low-flow crossings, or other structures have created fish passage barriers to important upstream habitat. The southwestern pond turtle (*Clemmys marmorata pallida*), a California Species of Special Concern, also is found in the county.

[2] The 1989 Wright Suit Settlement served to adjudicate the water resources of Goleta North/Central Basin and assigned quantities of the basin's safe yield to various parties, including the Goleta Water District and the La Cumbre Mutual Water Company. The judgment also ordered the Goleta Water District to bring the North/Central Basin into a state of hydrologic balance by 1998. The district has achieved compliance with this order through the importation of State Water Project water and the development of other supplemental supplies. These supplemental supplies have offset the court mandated reduction in pumpage from the basin. Given that the basin has been adjudicated and pumpage is controlled by the court, overdraft is not foreseeable in the North-Central Basin.

2.7.2 Freshwater Habitats

Zaca Lake, located in the San Rafael Mountains north of Lake Cachuma, is the only natural lake in Santa Barbara County. It is less than 1 mile in circumference and tends to become anaerobic seasonally; therefore, the waters do not support a large or diversified biota.

Lake Los Carneros is located on the grounds of Stow House in Goleta and is not a natural body of water; it does, however, support a large and stable ecological community. It is surrounded by typical aquatic vegetation and supports diverse bird species.

Lake Cachuma is the largest reservoir in the county. It attracts numerous migratory birds and has a rookery of great blue herons. The endangered southern bald eagle (*Haliaeetus leucocephalus*) may be observed at the lake. The lake supports large populations of large mouth and small mouth bass, crappie, bluegill, redear, sunfish, channel catfish, and rainbow trout.

The county's four major rivers (Santa Ynez, Santa Maria, Cuyama, and Sisquoc) and its many creeks and streams are characterized by riparian vegetation along their banks. This habitat can also occur along arroyos, barrancas, and other types of drainages throughout the county. Riparian vegetation supports a great diversity of aquatic and terrestrial wildlife species. Streams and pools provide habitat for aquatic and semiaquatic species such as Pacific chorus frog, western toad, Pacific treefrog, and the introduced bullfrog. Common reptiles include the ensatina, western fence lizard, common kingsnake, gopher snake, and common garter snake. Riparian vegetation is also used by small mammals for cover, movement corridors, and foraging. Small populations of the southwestern willow flycatcher (*Empidonax trailii extimus*), least Bell's vireo (*Vireo bellii pusillus*), federally and state-listed species, are present in the riparian areas along the Santa Ynez River, portions of which are designated as critical habitat for these species.

A number of invasive weeds are present in the county's riparian areas, including arundo, tamarisk, Pampas grass, myoporum, cape ivy, and castor bean. Such weeds are detrimental to habitat and water conservation, and they increase the risk of flooding and erosion in riparian systems. South Coast creeks discharge to the Santa Barbara Channel, and impaired creek water quality affects the water quality of the ocean in the vicinity of public beaches. Common to all urban south coastal watersheds, the natural function of local creeks has been affected over time by human activities and land alteration, which ultimately has altered natural hydrologic and geomorphologic processes, degraded water quality, and diminished native biological communities.

2.7.3 Sloughs/Coastal Salt Marshes

Several salt marshes occur in the county and provide habitat for a number of estuarine invertebrates and fish, migratory birds, and rare and endangered animal species, such as Belding's Savannah sparrow (*Passerculus sanwichensis beldingi*), California brown pelican (*Pelicanus occidentalis californicus*), western snowy plover (*Charadrius alexandrinas*), light-footed clapper rail (*Rallus longirostris levipes*), and tidewater goby; and plant species such as salt marsh bird's beak (*Cordylanthus maritimus*).

Carpinteria Salt Marsh

Carpinteria Salt Marsh is a 230-acre estuary adjacent to the City of Carpinteria and is owned by the City of Carpinteria, the University of California (as part of its Natural Reserve System), and the Land Trust for Santa Barbara County. The marsh was one of the original California Critical Coastal Areas identified in 1995 as an impaired estuary. It is also a 303(d) listed waterbody (for nutrients, organic enrichment, low dissolved oxygen, and priority organics). Nurseries, greenhouses, orchards, row crops, and residential areas may contribute to nutrients in the watershed. Sedimentation is likely coming from construction, storm drains, and agriculture. The marsh and its tributaries (Santa Monica Creek, Franklin Creek, and Arroyo Paredon) contain levels of nitrates that exceed Basin Plan objectives for municipal and domestic supply. Flood control, sediment management, and ecosystem enhancement measures recently have been implemented.

Goleta Slough

Goleta Slough is located near UCSB and includes portions of the Santa Barbara Airport, which is under the jurisdiction of the City of Santa Barbara. Large volumes of sediment and debris contained in runoff from the mountains have entered the Goleta Slough ecosystem and profoundly affected the ecosystem by raising ground surface elevations and affecting patterns of flooding and the development of wetland versus upland habitats. High inputs of sediment and debris, funneled into relatively narrow areas as a result of creek channelization and development of the Goleta Valley, have diminished the capacity of creek channels to convey floodwaters through developed areas, which require regular maintenance by the Santa Barbara County Flood Control District. Goleta Slough is a 303(d) impaired water body for pathogens, and priority organics and is considered a Critical Coastal Area (CCA). The slough is managed by the Santa Barbara Airport and the Goleta Slough Management Committee, which is composed of a variety of federal, state, and local agencies, organizations, and individuals, through the Goleta Slough Ecosystem Management Plan. The importance of the slough is recognized and reflected in its designation as an Environmentally Sensitive Habitat in the Local Coastal Plans of both the City and County of Santa Barbara.

Greater Devereux Slough

The Greater Devereux Slough ecosystem is located on the West Campus of UCSB, and a large portion of the area is a designated Environmentally Sensitive Habitat. The upland drainage areas, commonly referred to as Santa Barbara Shores and Ellwood, are important because they are home to one of the largest monarch butterfly overwintering sites on the West Coast. As a part of the University of California’s Natural Reserve System, the area is reserved for habitat and wildlife preservation, public education, and academic research. The slough is not listed on the 303(d) list, but sediment loading is reducing the total size of the slough. Continued residential development in the watershed may increase contamination of runoff entering the slough, and exotic plant species are displacing native plants and altering the habitats. The Santa Barbara Audubon Society began a new habitat restoration project on the north shore of Devereux Slough in September 2002 intended to restore a 1.42-acre portion of Devereux Slough seasonal wetland and upland margin, improve foraging habitat for the state-listed Belding's Savannah sparrow and two species of marsh-dependent butterflies, pygmy blue and wandering skipper.

Surf/Ocean Beach Park

The Surf area, including Ocean Beach Park, is located about 13 miles west of Lompoc at the mouth of the Santa Ynez River. The area contains a salt marsh, a small freshwater marsh, and dune habitat. Access to certain parts of the beach is restricted at times because the western snowy plover nests there. Like the other marshes, this area is a stopover for birds using the Pacific Flyway, and it contains habitat suitable for a number of sensitive species, including Belding's Savannah sparrow and the black rail. Endangered plant species, such as salt marsh bird's beak also may be found here. The Santa Ynez River Lagoon also is found here and generally forms when flows decrease after the winter runoff period when the mouth of the river fills with sand deposited by both the river and by the strong longitudinal drift of sand from north to south along the shoreline. Low summer flows generally are unable to keep the outlet open, although inflow from the Lompoc treatment facility and wave action can breach this barrier (COMB and USBR, 2004). The lagoon represents a unique habitat characterized by saltwater/freshwater mixing.

2.7.4 Coastal Dunes

This community occurs in several places along the coast, including on the southwestern edge of the University of California, Santa Barbara, campus (Devereux Dunes), at Vandenberg Air Force Base, north of Point Sal, between Point Sal and Purisima Point, south of Purisima point, and around Surf. Of particular note is the Guadalupe-Nipomo Dunes Complex, located near the mouth of the Santa Maria River. The Dunes Complex is a National Natural Landmark comprising 18 miles and more than 22,000 acres of one of the largest coastal dune ecosystems on earth. The Dunes Complex is located in a transition zone between Northern and Southern California plant and animal communities, resulting in a high degree of habitat diversity, a large number native plants and animals, and susceptibility to disturbing delicate ecosystem balances. With more than 1,000 known species of birds, plants and animals and some of the highest dunes on the West Coast, it is a place of rare beauty and significance. Established in 2000 and encompassing 2,533 acres, the Guadalupe-Nipomo National Wildlife Refuge is located in the heart of the Dune Complex. The habitat includes coastal dune scrub, dune swales, wetlands, fore and active dune areas and coastal strand. Sensitive species found in the refuge include the western snowy plover, California red-legged frog, California least tern and over 16 species of rare plants. The Oso Flaco Lake Natural Area, a California State Park, also is located within the Dune Complex.

2.7.5 Areas of Special Biological Significance

The SWRCB designates Areas of Special Biological Significance (ASBS) throughout the State of California, defined as "a nonterrestrial marine or estuarine area designated to protect marine species or biological communities from an undesirable alteration in natural water quality, including, but not limited to, areas of special biological significance that have been designated by the SWRCB through its water quality control planning process (PRC Section 36700[f]). In these areas, non-point source pollution is to be controlled as much as possible, and point source and thermal discharges are generally not permitted. The only ASBS within Santa Barbara County is the Channel Islands National Marine Sanctuary, which is managed by the National Park Service out to 6 miles from shore.

2.7.6 Marine Protected Areas

California Assembly Bill (AB 993) the Marine Life Protection Act was passed into law on October 10, 1999. A ''marine protected area'' is a named, discrete geographic marine or estuarine area seaward of the high tide line or the mouth of a coastal river, including any area of intertidal or subtidal terrain, together with its overlying water and associated flora and fauna that has been designated by law, administrative action, or voter initiative to protect or conserve marine life and habitat. Marine protected areas include marine life reserves and other areas that allow for specified commercial and recreational activities, including fishing for certain species but not others, fishing with certain practices but not others, and kelp harvesting, provided that these activities are consistent with the objectives of the area and the goals and guidelines of the law. Marine protected areas are primarily intended to protect or conserve marine life and habitat, and are therefore a subset of marine managed areas, which are broader groups of named, discrete geographic areas along the coast that protect, conserve, or otherwise manage a variety of resources and uses, including living marine resources, cultural and historical resources, and recreational opportunities. A number of marine protected areas are present within Santa Barbara County, primarily at the Channel Islands, although the Goleta Slough has this designation, as do the Refugio State Marine Conservation Area and Vandenberg State Marine Reserve.

2.8 Water Quality

Water quality is a concern because of its potential effect on human health, enterprise, aquatic organisms, and ecosystem conditions. Quality is determined by factors such as native condition of groundwater and surface water, sources of contamination (natural and human induced), and extent of seawater intrusion.

2.8.1 Critical Coastal Areas (CCA)

The CCA Program is part of the state's Nonpoint Source Pollution Plan and a nonregulatory planning tool to coordinate the efforts of multiple agencies and stakeholders, and direct resources to CCAs. The program’s goal is to ensure that effective nonpoint source pollution management measures are implemented to protect or restore coastal water quality in CCAs. CCAs in Santa Barbara County include the Santa Ynez River, Goleta Slough, and Carpinteria Marsh. Criteria for identifying CCAs reflect the dual goals of improving degraded water quality and providing extra protection from non-point source pollution to marine areas with recognized high resource value. The CCA program relies on existing designations of degraded water quality (i.e., the Clean Water Act 303(d) list of impaired and threatened water bodies), and marine or estuarine areas with high resource value (i.e., California Marine Managed Areas, including State Water Quality Protection Areas, and equivalent areas specified in the San Francisco Bay Plan).

2.8.2 Section 303(d) Impaired Water Bodies

Water quality is assessed by comparing measured levels of contaminants to standards that have been established for each beneficial use. The state of California has established “beneficial uses” for all surface water bodies within its jurisdiction. Water quality standards have been established for each beneficial use. The standards are the basis for identifying which water bodies are “impaired,” or restricted in their beneficial uses. These impaired water bodies are formally identified under Section 303(d) of the Clean Water Act, which requires states, territories, and authorized tribes to develop a list of water quality limited segments. The list of these water bodies and their pollutants of concern is the basis for setting priorities for the improvement of water quality. The county contains a number of water bodies that are listed as impaired under Section 303(d). The current list, shown in Appendix A, was approved by the SWRCB on October 25, 2006 (Resolution No. 2006 – 0079); the water segments and their impairments are listed in Table 2-3. Sources of pollution include both urban and agricultural uses, as well as natural sources. The waters on the list do not meet water quality standards, even after point sources of pollution have installed the minimum required levels of pollution control technology. The law requires that priority rankings be established for the development of action plans, called Total Maximum Daily Loads (TMDLs), to improve the water quality for waters on the list.

2.8.3 Groundwater Quality

The importation of State Water Project water, with lower salt content than the local sources, provides for higher quality "return flows," and thus, helps the basin water quality. In the Santa Maria basin, in addition to improvements provided by the recharge operations of Twitchell Reservoir and state water importation, the Laguna County Sanitation District helps improve water quality in the basin by utilizing a reverse osmosis process to remove and a deep injection well to dispose of approximately 8,000 pounds per day of salts, which would otherwise accumulate in the basin system. In the Santa Ynez River watershed, under the Cachuma Project Settlement Agreement, State Water Project water is mixed with water rights releases from Bradbury Dam to lower the salt content of flows downstream. Since 1997, discharge of State Water Project water has tended to lower the total dissolved solids (TDS) of groundwater in the vicinity of these sources.

Increases in TDS have been recorded in many basins in the county. Efforts to increase recharge and improve irrigation efficiency have been implemented to address this problem.

Several areas in the county (Santa Barbara and near Santa Maria) have experienced signs of seawater intrusion. As of yet, these initial signs of intrusion do not pose a threat to drinking water supplies.

The county contains a number of non-sewered, fairly densely populated areas that remain on septic tanks, requiring integrated action by the Local Agency Formation Commission, cities, and special districts to provide for extensions of sewer systems to serve these areas or other measures to address potential groundwater contamination. State maximum contaminant levels (MCLs) for nitrates already have been exceeded in some areas, and methyl tertiary butyl ether (MTBE) and chlorinated solvents pose problems for some wells. Additionally, the recently constructed Chumash wastewater treatment plant in the Santa Ynez Valley is a new source of wastewater discharge into Sanja de Cota Creek, which is a tributary to the Santa Ynez River. As would occur with any wastewater treatment plant upstream of potable water wells, there is a potential risk of contamination of the potable wells in the Santa Ynez River alluvium. Because of the federal nexus, the U.S. Environmental Protection Agency has regulatory jurisdiction over this discharge. A water quality control plan is being developed to determine potential sources of contamination, designate beneficial uses, and assign water quality objectives.

The following describes groundwater quality in the major basins (Santa Barbara County, 2000; Santa Barbara County, 2005).

Carpinteria Groundwater Basin

Water quality has been monitored sporadically over most of the 20th century. Since the initial U.S. Geological Survey (USGS) study, TDS concentrations within the basin have increased, with recent concentrations ranging from 436 to 980 milligrams per liter (mg/L). Groundwater analyses conducted in 1985 revealed nitrate levels below the state MCL of 45 mg/L for public water systems.

Montecito Groundwater Basin

Water quality in the basin is generally suitable for agricultural and domestic use. Some wells near fault zones or coastal areas yield groundwater with elevated levels of TDS and other constituents. Studies indicate that seawater intrusion is not a significant problem in the basin. It is thought that deeper aquifers of the basin are protected from seawater intrusion by an impermeable offshore fault. However, some encroachment of seawater might occur in shallower aquifers during periods of heavy pumping such as during the early 1960s.

Santa Barbara Groundwater Basin

TDS concentrations within the two basins range from about 400 mg/L to about 1,000 mg/L. Isolated wells have exhibited much higher TDS concentrations. Seawater intrusion occurred in some areas of the south basin (Storage Unit No. 1) where heavy pumping from municipal wells caused groundwater levels to drop as much as 100 feet in the late 1970s. More recently, samples taken from coastal wells have confirmed the presence of seawater intrusion with chloride concentrations greater than 1,000 mg/L. Groundwater pumping within the Santa Barbara Groundwater Basin has been drastically reduced since 1991. Effective pumping practices, together with groundwater injection programs, have restored the previously existing gradient thereby reversing the trend of seawater intrusion.

Foothill Groundwater Basin

TDS concentrations range from 610 to 1,000 mg/L in seven wells sampled in the basin. Chloride concentrations in this basin are relatively low (44 to 130 mg/L) in the seven wells. An eighth well was sampled in the USGS study from which poor quality water (TDS 1,900 mg/L, chloride 360 mg/L) was recovered. This well, however, is known to produce water from bedrock aquifers below the sediments that comprise the Foothill Basin.

TABLE 2-3
List Of Water Quality Limited Segments in Santa Barbara County

Segment Name	Pollutant/Stressor
Alamo Creek	Fecal Coliform
Arroyo Burro Creek	Pathogens
Arroyo Paredon	Boron; Nitrate as Nitrate (NO3); Toxicity
Bell Creek	Nitrate as Nitrate (NO3)
Bradley Canyon Creek	Ammonia (Unionized); Fecal Coliform; Nitrate as Nitrate (NO3)
Bradley Channel	Fecal Coliform; Nitrate as Nitrate (NO3)
Canada de Gaviota	Boron
Carneros Creek	Ammonia (Unionized)
Carpinteria Creek	Pathogens
Carpinteria Marsh (El Estero Marsh)	Nutrients; Organic Enrichment/Low Dissolved Oxygen; Priority Organics
Casmalia Canyon Creek	Sedimentation/Siltation
Cuyama River	Boron
Franklin Creek	Nitrate as Nitrate (NO3)
Glen Annie Canyon	Nitrate as Nitrate (NO3)
Goleta Slough/Estuary	Pathogens; Priority Organics
Main Street Canal	Ammonia (Unionized); Nitrate
Mission Creek	Pathogens; Unknown Toxicity
Orcutt Creek	Ammonia (Unionized); Boron; Chlorpyrifos; DDT; Dieldrin; Fecal Coliform; Nitrate
Rincon Creek	Boron; Toxicity
San Antonio Creek (San Antonio Watershed, Rancho del las Flores Bridge at Hwy 135 to downstream at Railroad Bridge)	Ammonia as Nitrogen; Boron; Nitrogen; Nitrate
Santa Maria River	Ammonia (Unionized); Chlorpyrifos; DDT; Dieldrin; Endrin; Fecal Coliform; Nitrate
Santa Ynez River (below City of Lompoc to Ocean)	Nitrate as Nitrate (NO3); Salinity/TDS/Chlorides; Sedimentation/Siltation
Santa Ynez River (Cachuma Lake to below City of Lompoc)	Salinity/TDS/Chlorides; Sedimentation/Siltation
Shuman Canyon Creek	Sedimentation/Siltation
Pacific Ocean at Arroyo Burro Beach	Total Coliform
Pacific Ocean at Carpinteria State Beach (Carpinteria Creek mouth)	Fecal Coliform; Total Coliform
Pacific Ocean at East Beach (mouth of Mission Creek)	Fecal Coliform; Total Coliform

TABLE 2-3
List Of Water Quality Limited Segments in Santa Barbara County

Segment Name	Pollutant/Stressor
Pacific Ocean at East Beach (mouth of Sycamore Creek)	Total Coliform
Pacific Ocean at Gaviota Beach (mouth of Canada de la Gaviota Creek)	Total Coliform
Pacific Ocean at Hammonds Beach	Fecal Coliform
Pacific Ocean at Hope Ranch Beach	Fecal Coliform
Pacific Ocean at Jalama Beach	Fecal Coliform; Total Coliform
Pacific Ocean at Ocean Beach	Fecal Coliform; Total Coliform
Pacific Ocean at Point Rincon (mouth of Rincon Creek)	Fecal Coliform; Total Coliform
Pacific Ocean at Refugio Beach	Total Coliform

Note: Adopted by Resolution of the SWRCB on October 25, 2006

Goleta Groundwater Basin

The USGS compiled water quality data for these basins in the early 1940s. Groundwater analyses completed at that time indicated that chloride concentrations throughout most of the North-Central and West basins were less than the Department of Health Services secondary standard of 250 mg/L. TDS ranged from about 170 mg/L to 1,400 mg/L in the North-Central Basin, and was approximately 800 mg/L in the West Subbasin. More recent studies yielded similar TDS ranges as the USGS study with the exception of high concentrations in some wells of the West Basin. The recent study yielded no evidence of seawater intrusion. In addition, seawater intrusion is not likely to have occurred at any time due to the rock formations and the More Ranch Fault along the coast that act as barriers to groundwater migration. Near-surface low permeability sediments cause the southern portion of the North-Central and West basins to be under confined conditions and provide a barrier to contamination from potential surface sources of water quality degradation such as agricultural return flow or infiltration of brackish water in the overlying Goleta Slough. High TDS perched water is present in shallow aquifers above the confining layers. This water is not in general use. Water quality in the North-Central Basin is sufficient for many agricultural uses but might require treatment for domestic uses. Water in the West Basin requires treatment for domestic use and can be used for irrigation of a limited variety of crops. The Goleta Water District has extracted water from a bedrock well on a test basis. The well pumped water from the fractures in consolidated bedrock in the foothills north of the basin and was of very poor quality. The District has no plans to utilize water from this source.

Santa Ynez Uplands

Water quality within the basin is generally adequate for most agricultural and domestic purposes. Studies completed in 1970 indicate TDS concentrations ranging from 400 to 700 mg/L. Although recent water quality data are limited, samples analyzed by the USGS in 1992 exhibited a TDS concentration of 507 mg/L.

Buellton Uplands Groundwater Basin

Current water quality data for the basin is limited. However, data from late 1950s and early 1960s indicate TDS concentrations between 300 and 700 mg/L for several wells within the basin.

Lompoc Groundwater Basin

Water quality in the shallow zone of the Lompoc Plain tends to be poorest near the coast and in heavily irrigated areas of the subbasin. TDS concentrations of up to 8,000 mg/L near the coast were measured in the late 1980s. The poor quality water in this area is attributed to upwelling of poor quality connate waters, reduction in fresh water recharge from the Santa Ynez River beginning in the early 1960s, agricultural return flows, and downward leakage of seawater from an overlying estuary in the western portion of the basin. The presence of elevated boron and nitrates (constituents common in seawater and agricultural return flow, respectively) supports this conclusion. In the middle zone, water samples taken from below agricultural areas of the northeastern plain contained TDS concentrations averaging over 2,000 mg/L. However, some middle zone groundwater from the western plain exhibited TDS levels below 700 mg/L. Areas of recharge, adjacent to the Santa Ynez River, contained TDS concentrations of less than 1,000 mg/L in the eastern plain. It is believed that leakage from the shallow zone is responsible for elevated TDS levels in the middle zone in the northeastern plain. Groundwater from the main zone exhibited TDS concentrations as high as 4,500 mg/L near the coast. It is thought that contamination of the main zone (mainly near the coast) is due to percolation of seawater through estuary lands and upward migration of poor quality connate waters from the underlying rock. Groundwater of the Lompoc Terrace and Lompoc Upland Subbasin is generally of better quality than that of the Lompoc Plain, averaging less than 700 mg/L TDS. Some of the natural seepage from these subbasins is of excellent quality. Groundwater users and public agencies within the basin are working to clarify and resolve water quality concerns.

San Antonio Groundwater Basin

Water quality studies conducted by the USGS in the late 1970s indicated an average TDS concentration within the basin of 710 mg/L, with concentrations generally increasing westward. The cause of the westward water quality degradation is thought to be the accumulation of lower quality water from agricultural return flow and the dissolution of soluble minerals. The highest TDS concentration (3,780 mg/L) was found in the extreme western end; the lowest concentration (263 mg/L) was found at the extreme eastern end. Analyses compiled for samples taken between 1958 and 1978 indicate that groundwater quality remained fairly stable during that period. Analyses of water sampled in 1993 for several wells show only slight increases in TDS since the previous study. There is evidence that poor quality connate waters exist within fracture zones of the bedrock and that this water might be induced into overlying strata through excessive pumping. There is no evidence of seawater intrusion in the basin, nor is the basin considered susceptible to seawater intrusion due to the consolidated rock that separates the basin from the ocean.

Santa Maria Valley Groundwater Basin

Water quality data indicates that TDS concentrations generally increase from east to west, with the most significant degradation occurring in the western part of the basin. TDS concentrations for shallower wells also tend to increase southward, away from the recharge area of the Santa Maria River. TDS concentrations east of Guadalupe have increased to over 3,000 mg/L in 1975 from less than 1,000 mg/L in the 1930s. In addition, TDS levels have increased significantly in Orcutt wells since the 1930s, but have remained relatively stable since 1987. The importation and domestic use of State Water Project water now results in better quality discharge water from the treatment facilities. A recent study conducted by the SWRCB indicates that the basin is subject to nitrate contamination, particularly in the vicinity of the City of Santa Maria and in Guadalupe. The study shows that nitrate concentrations have increased from less than 30 mg/L in the 1950s to over 100 mg/L in the 1990s in some parts of the basin. Coastal monitoring wells are measured biannually for any indication of seawater intrusion, although there has been no evidence that it has occurred. The concern of seawater intrusion is based on evidence that the Careaga Sand crops out on the ocean floor several miles west and there are no known barriers to prevent intrusion. Although it is likely that the seawater-freshwater interface has migrated toward land during the 20th century, the slope of groundwater has remained positive toward the ocean in the western-most part of the basin.

The Central Coast Regional Water Quality Control Board (RWQCB) has begun initial reports on bacteria and nitrates in the Santa Maria River Basin. Based on these reports, they have served notice of the intention to initiate a process to establish TMDLs for these two pollutants of concern. Part of the TMDL process focuses on identification of pollution sources.

Cuyama Groundwater Basin

Agricultural water use began in 1938 and has since progressively increased. The constant cycling and evaporation of irrigation water has resulted in decreasing water quality. Groundwater within the basin makes up 100 percent of the water supply for Cuyama Valley agriculture, petroleum operations, businesses and homes. Agriculture accounts for over 95 percent of the water use within the valley.

2.8.4 Surface Water Quality

Urban Water Quality

Various entities in the IRWMP planning region are focusing their efforts on poor surface water quality in creeks, rivers, and oceans due to polluted storm water and urban runoff discharges. Runoff pollutants can include pesticides, fertilizers, green waste, animal waste, human waste, petroleum hydrocarbons (gasoline, motor oil), trash, and other constituents.

Section 402 of the Clean Water Act established the National Pollutant Discharge Elimination System (NPDES) to regulate the discharge of waste from a point source to a receiving water body. Phase II of the NPDES program, enacted in 1999, requires preparation of Storm Water Management Plans (SWMP) to manage discharge of urban runoff to receiving waters (refer to Section 3 for a discussion of regional SWMPs. These plans summarize the management plans and strategies to maintain compliance in all applicable discharge and effluent prohibitions, including control measures such as public education and outreach on storm water impacts, public involvement/participation, illicit discharge detection and elimination, construction site storm water runoff control, post-construction storm water management in new development or redevelopment, and pollution prevention/"good housekeeping."

There are a number of potential urban storm water constituents of concern that the NPDES Phase II Storm Water Management Program aims to control on a national level and that are found in low levels in many areas throughout the county. (Water bodies that are sufficiently polluted to warrant clean up are listed in Table 2-3). These urban pollutants may include sediment, nutrients, bacteria and viruses, oil and grease, metals, organic compounds, pesticides, and gross pollutants such as trash. Storm water and incidental urban runoff are two of the primary carriers of pollutants that enter the county storm drain systems and creeks. Non-storm urban runoff from commercial and residential areas, streets and parking lots, city and commercial facilities, and building construction sites, among others, can all contribute as non-point sources of water pollution.

2.8.5 Ocean Water Quality

Ocean water quality is of concern in Santa Barbara County, as it is in many places along the California coast. Scientific evidence has linked storm water runoff with high levels of indicator bacteria in creeks and ocean water. Exposure to indicator bacteria correlates with an increased health risk to humans, requiring beach warnings. Sources of these indicator bacteria may include human and domestic and wild animal excrement, decomposing plant matter, and septic and sanitary sewer overflow. Investigations of the City of Santa Barbara sewer system, for example, have indicated that local sewer pipe leaks likely occur in some areas of the city, contributing untreated wastewater to the shallow groundwater zone that can eventually make its way to creeks and to the beaches. In addition, damaged and broken sewer lines may also allow inflow of percolating rainwater into the city sewer system, overwhelming the capacity of the Estero treatment plant to effectively treat sewage during large storm events and resulting in discharge of only partially treated wastewater (City of Santa Barbara Creeks Restoration/Water Quality Improvement Division, 2005).

Table 2-4 summarizes the exceedance percentages (the number of samples exceeding one or more standards/total number of samples taken from the site) for the beaches monitored by the Santa Barbara County Environmental Health Services Department from 1998 to 2006.

2.8.6 Agricultural Water Quality

Agricultural sources may contribute to water quality impairments through irrigation return flow, flows from tile drains, and storm water runoff. These discharges can affect water quality by transporting pollutants including pesticides, sediment, nutrients, salts (including selenium and boron), pathogens, and heavy metals from cultivated fields into surface waters. Some surface water bodies are classified as impaired, at least in part, because of pollutants from agricultural sources.

To control and assess the effects of these discharges, the Central Coast RWQCB has adopted a comprehensive conditional waiver, using proactive solutions to control agricultural discharges, including an extensive public outreach and education approach, resulting in the enrollment of 400,000 acres in the program (State of California, 2007b). All farmers are expected to complete 15 hours of farm water quality education within 3 years of adoption of the waiver, develop farm water quality management plans that address, at a minimum, irrigation management, nutrient management, pesticide management and erosion control, and begin implementing management practices identified in their plans. Those who have completed the above requirements by the deadline qualify for a waiver with reduced reporting requirements.

2.8.7 Drinking Water Quality

Imported water from the State Water Project is of high quality, ranging from 222 to 510 mg/L TDS. In parts of the North County, State Water Project water is blended with other lower quality water, which results in a higher overall quality of the water distributed to customers. For the South Coast water purveyors, State Water Project water is conveyed through Lake Cachuma, where it mixes with local surface water. The water is then directed to local water treatment plants, after which it is distributed to customers. According to the U.S. Geological Survey figures for 1998 (Agajanian et al., 1998) the TDS for the rivers in Santa Barbara County range from 518 mg/L to 1,130 mg/L. Water treatment facilities are discussed in Section 4, and specific drinking water quality issues, including those facing DACs are addressed in Section 8.

TABLE 2-4
Percentage Exceedances for Indicator Bacteria (1998 to 2006)*

Beaches	**Exceedance Percentage**								
	1998	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Arroyo Burro	44	33	36	27	21	17	13	26	46
Butterfly Beach	-	-	11	10	7	12	4	6	12
Carpinteria City Beach	7	10	4	13	9	4	2	10	8
Carpinteria State Beach	36	37	13	31	9	6	4	18	16
East Beach at Mission Creek	55	27	19	39	28	15	25	38	40
East Beach at Sycamore Creek	24	20	20	17	25	13	10	12	16
El Capitan State Beach	15	5	11	9	7	6	2	8	8
Gaviota State Beach	17	13	31	30	4	12	10	4	14
Goleta Beach	13	11	19	27	12	13	6	18	10
Guadalupe Dunes State Beach	3	2	4	12	12	2	4	2	4
Hammond's Beach	15	18	23	20	12	10	6	14	10
Haskell's Beach	-	-	-	21	4	13	6	16	16
Hope Ranch Beach	37	18	30	16	8	10	6	8	18
Jalama Beach	42	36	31	22	6	10	6	22	12
Leadbetter Beach	25	11	16	28	11	12	6	14	16
Ocean/Surf Beach	27	25	11	12	4	2	6	8	4
Refugio State Beach	28	24	32	25	22	6	4	18	18
Rincon at Bates Beach	54	27	17	7	2	2	0	6	4
Sands at Coal Oil Point	12	6	7	12	4	4	4	4	2
Summerland Beach	-	-	-	-	-	-	-	-	9
Average Percentage	30	22	21	23	12	9	6	14	14

Source: County of Santa Barbara Public Health Department, 2007.

*Based on AB 411 year-round sampling data.

2.9 Water Demand

Current agricultural and urban demands are discussed below, as are projected demands.

2.9.1 Agricultural Demand

Agricultural development increased dramatically after World War II due to advances in refrigerated-transport technology, which allowed crops grown in the county to be transported by train in refrigerated rail cars for sale in distant locations. Agricultural water use now accounts for approximately 75 percent of all water demand in the county;

calculating an exact amount would require accounting for the fact that some of the water used for agricultural returns as groundwater recharge. Most agricultural water supplies are obtained from private groundwater wells, although some water purveyors provide agricultural water, as well. Table 2-5 summarizes the amount of water currently provided to agricultural users by source. In recent years, improvements in agricultural technology have allowed increases in crop yield and intensification of agricultural development on an acre-by-acre basis. In some cases, water demand per acre has increased to allow for double and triple cropping and for higher water-using (and income-producing) crops, such as strawberries, to be grown. Irrigation technologies have also improved, reducing the amount of water used by some crops. These improvements include drip irrigation, seedling propagation in controlled greenhouse environments, laser leveling of fields, and use of tailwater recovery systems in furrow-irrigated fields.

TABLE 2-5
Estimated Agricultural Water Demand

Source	Demand (AFY)
Carpinteria Valley Water District	1,840[a]
Goleta Water District	2537[b]
La Cumbre Mutual Water Company	103[c]
Montecito Water District	550[d]
Santa Ynez River Water Conservation District Improvement District No. 1	2,404[e]
Private Wells, Cuyama Valley	15,300[c]
Private Wells, San Antonio Valley	17,020[c]
Private Wells, Santa Maria Valley	117,852[c]
Private Wells, Santa Ynez Valley	59,980[c]
TOTAL	**218,115**

Sources:
[a]Carpinteria Valley Water District, 2005b, Table 12
[b]Goleta Water District, 2005a, Table 16
[c]Santa Barbara County Water Agency, 2000
[d]Montecito Water District, 2005, Table 5D
[e]Santa Ynez River Water Conservation District **Improvement District No. 1, 2006**

2.9.2 Urban Demand

Urban water use accounts for approximately 25 percent of all water demand in Santa Barbara County. Current supplies provided by each water purveyor are shown in Table 2-6.

Per capita water use is shown in Table 2-7. Variances in water usage are due in part to the amount of industry and subregional climate, as well as variation in lot sizes and soil types.

TABLE 2-6
Urban Water Use Summary for Santa Barbara County

Water Purveyor	Typical Demand (AFY)
Carpinteria Valley Water District	2,122[a]
City of Buellton	806[b]
City of Guadalupe	574[b]
City of Lompoc	5,212[c]
City of Santa Barbara	12,960[d]
City of Santa Maria	13,243[e]
City of Solvang	1,277[b]
Cuyama Community Services District	166[b]
Golden State Water Company (Orcutt)	7,394[b]
Goleta Water District	11,781[f]
La Cumbre Mutual Water Company	1,258[b]
Los Alamos Community Services District	238[b]
Mission Hills Community Services District	540[b]
Montecito Water District	5,655[g]
Santa Ynez River Water Conservation District Improvement District No. 1	2,405[h]
Vandenberg Air Force Base	4,500[b]
Vandenberg Village Community Services District	1,311[f]
TOTAL	**71,239**

Sources:
[a]Carpinteria Valley Water District, 2005b, Table 12
[b]Santa Barbara County Water Agency, 2000
[c]City of Lompoc, 2005, Table 15
[d]City of Santa Barbara, 2005, Figure 7
[e]City of Santa Maria, 2005, Table 4-2
[f]Goleta Water District, 2005a, Table 16
[g]Montecito Water District, 2005, Table 5D
[h]Santa Ynez River Water Conservation District Improvement District No. 1, 2006, Table 6; service area includes the Santa Ynez Reservation
[i]Santa Barbara County Water Agency, 2007

TABLE 2-7
Municipal and Industrial Water Use: Per Capita in 2006

Agency	Per-Capita Water Use (Gallons/Person/ Day)
City of Buellton	281
Carpinteria Valley Water District	102
Casmalia Community Services District	52
Cuyama Community Services District	183
Golden State Water Company	178[a]
Goleta Water District	108
City of Guadalupe	116
La Cumbre Mutual Water District	295
City of Lompoc	104
Los Alamos Community Services District	195
Mission Hills Community Services District	189
Montecito Water District	345
City of Santa Barbara	121
City of Santa Maria	123
Santa Ynez River Water Conservation District Improvement District No. 1	273
City of Solvang	227
Vandenberg Village Community Services District	202

Source: Santa Barbara County Water Agency, unpublished data

[a]Source: Santa Barbara County Water Agency, 2007

2.9.3 Projected Water Demand and Supply

By 2040, the Santa Barbara County population is expected to increase by almost 52 percent over 2000 levels (from about 399,000 to 606,000) (Santa Barbara County, 2003). Total water demand for this same 40-year period is projected to increase by only 9 percent, from 314,000 AFY to 345,000 AFY (Santa Barbara County, 2003). Agricultural water demand, which accounts for about 75 percent of total demand, is expected to remain nearly the same. At present, with careful and strategic planning, water supplies are sufficient to meet demand countywide during normal water years, but water purveyors will need to develop an additional 10,800 AFY by 2030; this number is projected to increase to 12,400 AFY by 2040, or they will have to rely on mining groundwater in certain areas in order to meet future demand (Santa Barbara County, 2003).

Only one of the five Designated Analysis Units (DAU) in Santa Barbara County (as defined by State of California Department of Water Resources [DWR]), DAU 75 South Coast, has a water supply that meets the current demand in normal rainfall years. The other basins have existing shortfalls in water supply that will increase in the future (Santa Barbara County, 2003).

- DAU 71 Santa Maria—The current 4,200 AFY water supply shortfall will increase to 7,700 AFY by 2040, although water conservation efforts are expected to continue.
- DAU 73 San Antonio—The current 3,900 AFY shortfall will decrease slightly to 3,800 AFY by 2040, primarily due to limited population growth and increased conservation.
- DAU 74 Santa Ynez—Although this DAU has a slight overall current water supply deficit of only 300 AFY, the water supply shortfall is expected to reach 1,600 AFY by 2040.
- DAU 75 South Coast—The DAU as a whole has sufficient water supplies through the year 2040 on a normal year basis. However, periodic severe droughts reduce supplies by as much as 25 percent, requiring water purveyors to reserve available water supply during normal years for later drought use to partially offset shortages.
- DAU 76 Cuyama Valley—This DAU is already experiencing a water supply shortfall of about 7,900 AFY of its total average water demand of 20,700 AFY. This water shortfall is expected to decline slightly to about 6,600 AFY in 2040; however, significant new water supplies will be required to balance average annual water supply and demand.

2.10 Natural Hazards Requiring Emergency Planning

Water resources planning in Santa Barbara County must consider the potential for service disruptions due to natural hazards such as earthquakes, fires, and floods, which can damage water and wastewater infrastructure. Additionally, the area experiences periodic droughts, which requires planning for periodic shortages.

2.10.1 Severe Storms and Flooding

Santa Barbara County experiences periods of high intensity rainfall, which cause flooding and landslides. For example, widespread problems resulted from the December 2004/ January 2005 storms including facilities damage, road and railroad closures, mudslides, flooding, power outages, fallen trees, and beach erosion. Some areas, such as the eastern end of Santa Maria, experience chronic flooding in modest storm events because existing floodwater conveyances are not adequate to meet the increased runoff due to both agricultural and urban growth. The Cuyama Valley agricultural area in the proximity of the Cuyama River is another region that is highly susceptible to flooding because the river banks are low (less than 4 feet) and highly erodable, so the natural ability to contain the river is limited. In the city of Santa Barbara, Mission Creek and Sycamore Creek are prone to flooding when significant rainfall occurs. Periodic flooding also occurs on the Santa Ynez River, particularly in the City of Lompoc and on agricultural fields west of Lompoc, associated with the limited ability to maintain channel capacity because of sensitive habitat considerations.

2.10.2 Earthquakes

The county, like the rest of California, is seismically active and has experienced multiple large-scale (magnitude 6.0 or greater) earthquakes over the last two centuries. The December 21, 1812, earthquake was estimated to be magnitude 7.2 (Harp, 1980). Much of Santa Barbara was damaged by the magnitude 6.3 earthquake of June 29, 1925. Another strong earthquake of magnitude 6.0, which also caused damage in Santa Barbara, occurred June 30, 1941. The county contains numerous active and potentially active faults and is also susceptible to ground shaking from regional faults, such as the San Andreas Fault, which is located approximately 7 miles from the northeast corner of the county. Earthquakes present the potential to damage water storage facilities and levees, cause landslides, and disrupt water supply and treatment capabilities in the region for weeks or possibly months.

2.10.3 Fire

During the summer and early fall, much of Santa Barbara County is at risk from wildfires stemming from a combination of dry, windy conditions and woodlands, brushlands, chaparral, and grasslands that burn readily. The county contains a number of high fire hazard areas, particularly in undeveloped and mountainous locations, although fires may occur in urban areas, as well. Fires pose a number of challenges to water resources planners, because adequate water must be supplied at correct pressure to meet fire department requirements, particularly during major incidents, and portions of the county have deficient fire flows. Fires also can result in erosion and runoff from burned areas, which can affect surface water quality and increase sedimentation of local creeks, and reservoirs.

2.10.4 Drought

Historical records show that local drought periods of several years or more are cyclical. Tree ring studies covering time periods of several centuries reveal apparent droughts lasting as long as 16 years or more. The most recent drought occurred from 1986 until 1991 and included some of the driest years on record. Evidence from tree ring analysis indicates that severe droughts occurred as far back as 1544. Droughts in Santa Barbara County have lasted an average of 5 years with a maximum of 9 years. Local water purveyors implement water conservation programs to extend local surface water and conserve groundwater. They also import supplemental water supplies to cope with drought.

3

3 History of Water and Wastewater Management

This section provides an overview of the history of key water and wastewater milestones, as well as integrated regional water management efforts.

3.1 Key Water Management Milestones

Santa Barbara County has a long water development history, dating back to the founding of the Santa Barbara, La Purisima, and Santa Inés missions between 1786 and 1804. Extensive water supply systems, including aqueducts, cisterns, and gravity-fed fountains, were developed to serve the earliest non-native settlements. As the county's population increased, water supplies and treatment and delivery systems were expanded to meet the growing needs in a manner that was accounted for by the County's limited water supply. This section focuses on the development of the major regional water infrastructure, which led to the agreements and management practices that are in place today, as well as the importation of water from the State Water Project.

3.1.1 South Coast, Santa Ynez Valley, and Lompoc Valley

The history of Santa Ynez River water use is a contentious one, and issues raised by water rights holders downstream of the three Santa Ynez River dams have been addressed over the years by litigation, decisions by the State Water Resources Control Board (SWRCB), and by agreements reached between the parties involved. As described below, years of dissent culminated in the Cachuma Project Settlement Agreement, which uses the Bradbury Dam and the Santa Ynez Extension of the State Water Project to integrate surface and groundwater management strategies including surface storage, conjunctive use, groundwater recharge, groundwater quality improvement, flood protection, and habitat improvements. Existing infrastructure is managed cooperatively, creatively, and efficiently to maximize the use and improve the reliability of available water resources, as well as to provide environmental enhancements.

Early Need for Water in the South Coast

The Santa Barbara Mission was founded in 1786 and supported surrounding ranching and fruit-growing efforts. When water supplies became limited due to higher concentrations of people in more populated areas, plans were made to construct the South Coast's first large dam and reservoir, which was completed in 1807. After incorporation as a city in 1850, the population of Santa Barbara expanded, and the city continued to experience the pressures of limited water supplies. A report written in 1889 by the City Engineer concluded that the only feasible long-term source of water for Santa Barbara would have to come from the Santa Ynez River. He recommended land purchases for two possible dam and reservoir sites on the Santa Ynez River, but the city's initial bond proposal was defeated. Droughts in 1894 and from 1898 through 1900 re-emphasized the report's conclusions. While the Cold Spring

Tunnel (constructed in 1896) initially provided essentially a horizontal well producing approximately 290 acre-feet of water per year (AFY), its yield steadily decreased to about 100 AFY, and attention again turned to potential dam and reservoir sites on the Santa Ynez River.

Mission Tunnel

A 1905 report by the United States Geological Survey recommended the construction of a tunnel (the Mission Tunnel) from the Santa Ynez River to the coast side of the mountains, in conjunction with building a dam and reservoir at the Gibraltar site on the river (SBCWA, 2000). The main obstacle to this plan was that the tunnel would have to pass through lands held by the Santa Barbara Water Company, a private firm that owned extensive tracts of land encompassing all practicable reservoir sites on the headwaters of the Santa Ynez River. The City negotiated a contract with the Santa Barbara Water Company to allow construction of the tunnel in exchange for maintenance of flows in Mission Creek. The 3.7-mile-long Mission Tunnel was completed in 1912, the same year that the City purchased the holdings of the Santa Barbara Water Company. Mission Tunnel was designed to intercept groundwater flow and to later convey water from Gibraltar Reservoir to the City of Santa Barbara. Infiltration into Mission Tunnel varies with rainfall, but averages approximately 1,100 AFY.

Gibraltar Dam and Reservoir

The presence of major reservoirs in Santa Barbara County began in 1920 with the completion of Gibraltar Dam and Reservoir on the Santa Ynez River. By 1945, sedimentation had reduced storage in Gibraltar Reservoir from 14,500 acre-feet (AF) to approximately 7,800 AF. In 1948, the dam was raised 23 feet, and storage capacity was restored to approximately the original volume.

Juncal Dam, Jameson Lake, and Doulton Tunnel

The Montecito Water District completed construction of Juncal Dam and Jameson Lake in 1930. Water is diverted from the Santa Ynez River to the Montecito area through the Doulton Tunnel. Construction of Doulton Tunnel began in 1924 and initially penetrated only the first mile of the Santa Ynez Mountains due to substantial groundwater inflow. The tunnel was finally completed in 1928.

Gin Chow Judgment and Upper Santa Ynez River Operations Agreement

The storage and diversion of Santa Ynez River water by the City of Santa Barbara and Montecito Water District at Gibraltar and Juncal dams, respectively, was challenged in court by downstream interests in 1928. Gin Chow, a Lompoc farmer and local prophet, and over 30 others filed suit against Santa Barbara and Montecito, claiming that they were unlawfully diverting water from the Santa Ynez River. In 1933, the California Supreme Court upheld the rights of Santa Barbara and Montecito, setting limits on their ability to store and divert water, and decreeing that the City must release up to 616 AF of water per year from Gibraltar Reservoir for downstream water rights.

In the 1980s, when the City of Santa Barbara initiated a seismic retrofit project at Gibraltar Dam, concern by downstream interests that this could lead to a second enlargement of the dam (see "Gibraltar" above) led to the "Upper Santa Ynez River Operations Agreement." This Agreement provides for diversions of water to the City of Santa Barbara (including a pass-through provision to protect against loss of capacity) and for downstream releases consistent with the Gin Chow judgment.

Cachuma Project

The Cachuma Project had its beginnings in 1939 when a study referred to as the Hill Report was submitted to the County Board of Supervisors recommending further development of the Santa Ynez River. This resulted in the formation of the Santa Ynez River Water Conservation District by people who felt that the interests of the residents of the Santa Ynez River watershed were not being adequately protected by individual water users, as evidenced by the Gin Chow litigation. The District called for a more extensive study by an impartial government agency. The County contracted with the U.S. Geological Survey (USGS) in 1940 to obtain basic data and with the U.S. Bureau of Reclamation (Reclamation) in 1941 to prepare a countywide water resources development plan. The Cachuma Project, among others, was recommended by Reclamation in 1944.

The Santa Barbara County Water Agency was formed in 1945 to act as a go-between, contracting with both the federal government and local water purveyors (the Cachuma Member Units). The Cachuma Member Units were to be the City of Santa Barbara, Montecito, Carpinteria, Goleta, and Summerland County Water Districts, and the Santa Ynez River Water Conservation District. The Cachuma Project was approved by these entities in 1947 and by the Secretary of the Interior in 1948. Contract negotiations resulted in a master contract, and Member Unit contracts were approved by all parties except for the Santa Ynez River Water Conservation District, which withheld approval pending the negotiation of a separate agreement with Reclamation to protect downstream water rights. The so-called "Live Stream Agreement" was subsequently agreed to, allowing elections to occur in 1949. The elections were successful, federal funding was ultimately forthcoming, and the Cachuma Project facilities were completed by 1956.

The Cachuma Project consists of the Bradbury Dam, which impounds Lake Cachuma; the Tecolote Tunnel, which diverts 90 percent of the Project's yield to the South Coast; and the South Coast Conduit conveyance facilities, which consists of a pipeline and four regulating reservoirs to transport water from Goleta to Carpinteria along the South Coast. In 1957, the Cachuma Operation and Maintenance Board, then consisting of the South Coast Member Units and the Santa Ynez River Water Conservation District, was formed to operate and maintain Tecolote Tunnel and the South Coast Conduit system. Today, the South Coast Member Units consist of the City of Santa Barbara and the Goleta, Montecito, and Carpinteria Valley Water Districts. These entities serve both urban and agricultural users, and in 1973, they formed the Cachuma Conservation Release Board to represent their Cachuma Project water rights interests.

In 1963, the Santa Ynez River Water Conservation District formed Improvement District No. 1 to serve 10 percent of the Cachuma Project yield to urban and agricultural users in the more urbanized areas of the Santa Ynez Valley. In 1968, a separate Improvement District No. 1 Board of Trustees was established, and in 1993, the Santa Ynez River Water Conservation District assigned its interests in the Cachuma Project to Improvement

District No. 1. Today, Improvement District No. 1 and the four South Coast entities comprise the Cachuma Member Units.

Because, under federal law, Reclamation is required to comply with state water rights law, Reclamation filed application with the State Water Rights Board (precursor to the SWRCB) to appropriate Santa Ynez River water in 1946. Hearings did not occur until 1957, a year after the project was in operation. After a contested hearing in 1958, the State Water Rights Board issued the Cachuma Permits subject to the rights of downstream water users. The Board retained continuing jurisdiction for 15 years to ensure that the prescribed releases were adequate.

After prolonged and sometimes contentious negotiations between the South Coast Member Units (now represented by the Cachuma Conservation Release Board) and the Santa Ynez River Water Conservation District, the latter and Reclamation reached agreement on a stipulated modification of the 1958 permit conditions, with the concurrence of the Cachuma Conservation Release Board. These modifications resulted in establishing the Above and Below Narrows Accounts, and the credit water in these accounts is stored in Cachuma Reservoir. The credit water is released for the benefit of downstream water users for the area above the Lompoc Narrows and the Lompoc Plain. The SWRCB adopted these concepts in WR Order 73-37 in 1973. It again retained jurisdiction for 15 years.

Prior to 1989, negotiations between the parties led to agreement on stipulated modifications to WR 73-37. Experience indicated that adjustments were needed because the Lompoc Valley was not receiving the recharge water to which it was entitled. These modifications were adopted by the SWRCB in WR 89-18 in 1989. The Board extended its jurisdiction for another 5 years (1994), which was subsequently extended to 2000.

An SWRCB hearing in 2000 was adjourned and reconvened in 2003. In 2002, the Santa Ynez River Water Conservation District and other downstream interests settled many long outstanding issues with the South Coast interests in the Cachuma Project Settlement Agreement. Although operative for the most part, portions of that Agreement, which are under the jurisdiction of the SWRCB, are pending a Decision of the Board.

Lower Santa Ynez River Fish Management Plan and the Cachuma Project Biological Opinion

During the Cachuma Project authorization process before Congress in the 1940s, the U.S. Fish and Wildlife Service and others suggested that instream flow should be considered for fish and wildlife needs; however, the Division of Water Resources recommended to the Secretary of the Interior that no water from Lake Cachuma be dedicated to the protection of fish because of the limited water supply available to provide for present and future needs of people. The U.S. Congress relied on this recommendation in its funding appropriation; Reclamation and the Member Units relied on it in the construction of the Cachuma Project; and the SWRCB relied on it to issue the Cachuma Project water rights permits. The permits eventually were challenged by fisheries interests, and in 1990, the SWRCB held hearings on fisheries and other issues relating to the Santa Ynez River system.

As a result of the 1990 hearings, beginning in 1993, Reclamation and the Member Units formed a working group seeking consensus on fisheries issues and began to make water releases from Lake Cachuma to maintain fish habitat and to carry out various studies downstream of Bradbury Dam. The releases were made mandatory by the SWRCB in 1994. Additional studies led to the development of the Cachuma Project Biological Opinion issued by the National Marine Fisheries Service and the Lower Santa Ynez River Fish Management Plan issued by the Santa Ynez River Technical Advisory Committee (to comply with SWRCB Order WR 94-5) in 2000. These two documents contain essentially the same operations, which include enhanced habitat flows, passage flows, and various other actions to benefit the steelhead fishery.

Cachuma Project Settlement Agreement

The 2002 "Cachuma Project Settlement Agreement" resolves various differences between the South Coast Member Units and downstream interests pertaining to the operation of the Cachuma Project that existed for over 50 years. It provides the vehicle to manage Cachuma releases conjunctively downstream of the dam. The background and provisions of the Cachuma Project Settlement Agreement are summarized below.

- The parties support WR 89-18 and agree that releases pursuant to WR 89-18, as modified by the Agreement, will protect downstream water rights holders and will improve quality of water released for downstream uses. The parties agree to mutually support the National Marine Fisheries Service Biological Opinion and the Fish Management Plan for the Cachuma Project to address public trust (steelhead) issues. The parties further agree that WR 89-18 releases will operate conjunctively with fish water releases required to meet target flows in the Biological Opinion.
- In order to lower the salt (total dissolved solids) content of water rights releases for the lower Santa Ynez River downstream of Bradbury Dam, the parties agree to comingle State Water Project water with water from Cachuma in the outlet works of Bradbury Dam by maximizing deliveries of State Water Project water (consistent with the Biological Opinion) when water rights releases are made.
- Santa Ynez River flooding issues are addressed in the Agreement through winter storm operations of Bradbury Dam, including precautionary drawdowns and temporary surcharging, in order to reduce peak flows and provide some measure of flood control. Project water supply is protected by achieving a full reservoir following the peak flow events.
- The parties have requested the SWRCB to incorporate into WR 89-18 a provision involving conjunctive operation of the Below Narrows Account (water stored in Lake Cachuma) with the Lompoc Groundwater Basin. More water would be available for the Lompoc (Below Narrows) area in most years, although some Below Narrows Account water stored in Cachuma Reservoir would be made available to Cachuma contractors during shortage years.

Most of the provisions of the Cachuma Project Settlement Agreement were implemented in 2002. Some others are pending before the SWRCB. Approval of the remaining provisions and full implementation of the Agreement would provide the basis for further water management planning by individual water purveyors downstream of the dams in accordance with the objectives, water management strategies, and regional priorities in the IRWMP.

Wright Suit Settlement

The 1989 Wright Suit Settlement served to adjudicate the water resources of Goleta North/ Central Basin and assigned quantities of the basin's safe yield to various parties, including the Goleta Water District and the La Cumbre Mutual Water Company. The judgment also ordered the Goleta Water District to bring the North/Central Basin into a state of hydrologic balance by 1998. The district has achieved compliance with this order through the importation of State Water Project water and the development of other supplemental supplies. These supplemental supplies have offset the court mandated reduction in pumpage from the basin. Given that the basin has been adjudicated and pumpage is controlled by the Court, overdraft is not foreseeable in the North/Central Basin.

3.1.2 Santa Maria Valley

Santa Maria Project

Prior to the construction of Twitchell Reservoir, large portions of the Santa Maria Valley were subject to periodic flooding. In an effort to provide relief from flooding disasters, the Santa Maria Valley Water Conservation District, the Santa Barbara County Water Agency, and Reclamation evaluated a number of potential dam sites on the Santa Maria River in the 1940s and 1950s. In the late 1950s, Reclamation constructed the Twitchell Dam as part of the Santa Maria Project. The dam was intended to provide water for beneficial uses within the District that otherwise would rely on the groundwater supplies underlying the Santa Maria Valley, as well as to protect urbanized and agricultural areas from flood damage. The project provides recharge to the groundwater basin underlying the Santa Maria Valley and provides for flood protection. Twitchell Reservoir is operated and maintained by the Santa Maria Valley Water Conservation District. Twitchell Reservoir is important to both the water supply and the flood protection of the Santa Maria Valley. The reservoir supplies about 20,000 AF of recharge to the Santa Maria Groundwater Basin annually.

Santa Maria Groundwater Adjudication

In 1997, the Santa Maria Valley Water Conservation District filed a lawsuit to adjudicate water rights in the Santa Maria Valley Groundwater Basin (*Santa Maria Valley Water Conservation District vs. City of Santa Maria, et al.*, commonly known as the "Santa Maria Groundwater Adjudication." The court divided the trial of the case into phases. In January 2001, the Court issued the Phase 1 Order, which established the Outermost Boundaries of the Basin. In December 2001, the Court issued the Phase 2 Order, which established the area constituting the Basin for purposes of the adjudication. In May 2004, the Court issued a Partial Statement of Decision on Phase 3 issue regarding the hydrologic conditions in the Basin. As part of its Phase 3 Partial Statement of Decision, the court reserved jurisdiction over remaining water rights issues and management of the Basin.

Subsequent to the Phase 3 trial, the majority of the parties to the lawsuit, including the original plaintiff, the Santa Maria Valley Water Conservation District, negotiated a Settlement Agreement ("Stipulation") that set forth terms and conditions for a physical solution concerning the overall management of Basin water resources, including rights to use groundwater, State Water Project water and associated return flows, the developed groundwater yield resulting from the operation of Twitchell and Lopez reservoirs (located in San Luis Obispo County), use of Basin storage space, and the ongoing monitoring and management of these resources, consistent with common law water rights priorities and Article X, Section 2 of the California Constitution. The majority of the parties actively participating in the litigation have signed the stipulation.

The Stipulation also subdivides the Basin into three Management Areas: the Northern Cities Management Area, Nipomo Mesa Management Area, and the Santa Maria Valley Management Area. The delineation of these areas was based on historical development and use of Basin water resources, as further delineated in the Stipulation and the court record. As noted above, the Stipulation provides the City of Santa Maria certain rights to water in the Basin. These rights include: a recognition of the City's highest historical use of groundwater from the Basin; the right to recapture a preset portion of the return flows from the City's use of State Water Project in the Basin; and a 14,300 AFY share of the developed groundwater yield resulting from Twitchell Reservoir operations. In addition, the City may access additional supplies through the transfer of Twitchell Yield. Also, return flows from State Water Project water are assignable in whole or part, subject to accounting. The Stipulation also establishes certain preset water shortage response measures in anticipation of reduced availability of groundwater.

Although the court has approved the Stipulation as between those who have signed it, not all parties to the adjudication have agreed to it. Phase 4 proceeded to trial in early 2006 as between the public water suppliers, including the City, and a small number of landowners who opposed the Stipulation. The Phase 4 tentative decision issued by the Court stated that the City and Golden State Water Company met the burden of showing a prescriptive right during various time periods prior to the time the Twitchell Project began recharging the Basin. Phase 5 occurred in July of 2006. The scope of the Phase 5 trial was to allow the remaining landowners to show that they had engaged in self-help during the applicable prescriptive periods and to determine whether, and in what form, the Court should impose a physical solution on the parties' collective future use of the Basin. The Phase 5 tentative decision reaffirms the prescriptive rights obtained by the City and Golden State Water Company, states that those rights are correlative to the rights of the overlying landowners, and provides that the City and Golden State Water Company are entitled to those specific quantities of water in the Basin, the same as any overlying landowner, so long as there is a surplus of water in the Basin. The tentative decision also states that the physical solution contained in the Stipulation will be incorporated into the Court's final judgment and will be binding on all parties to the litigation. Further, the Phase 5 tentative decision provides that the Court will retain jurisdiction to enforce the judgment and to implement the physical solution as necessary. The Phase 5 tentative decision further confirms the ability of the Santa Maria Valley Water Conservation District to allocate Twitchell Yield in the manner provided in the Stipulation. The Court will hold a hearing on the Phases 4 and 5 tentative decisions in January 2007. It is anticipated that a final judgment and physical solution will be entered in early 2007.

The Santa Maria Groundwater Adjudication will determine the manner by which Twitchell Reservoir and the groundwater basin are managed; any projects included in the IRWMP that could affect the Santa Maria Valley Groundwater Basin or Twitchell Reservoir will need to be consistent with the terms of the adjudication.

3.1.3 State Water Project

The increasing population of Santa Barbara (mainly in the county's South Coast), as well as problems associated with rapid siltation of reservoirs, which led to diminished storage capacities, required the development of additional water supplies, including State Water Project water. In 1963, the Santa Barbara County Flood Control and Water Conservation District contracted with the State of California Department of Water Resources (DWR) to deliver State Water Project water to Santa Barbara County. At that time, the County began payments to DWR to retain a share of the State Water Project yield ("Table A Amount[1]") for 57,700 AFY, but funds were not allocated to construct the necessary local facilities to deliver water within the county. In 1981, the original contract was amended to reduce the County's State Water Table A Amount to 45,486 AFY. In 1994, this amount was further modified by the project participants of the Central Coast Water Authority to include 39,078 AFY of Table A Amount; 3,908 AFY of drought buffer; and 2,500 AFY of a special drought buffer for the Goleta Water District.

In 1991, after 4 years of extremely dry conditions, voters in several service areas in Santa Barbara County voted to import State Water Project water. This included the communities of Carpinteria, Summerland, Montecito, Santa Barbara, Hope Ranch, Goleta, Buellton, Solvang, Santa Ynez, Orcutt, and Guadalupe. The Santa Maria City Council and Vandenberg Air Force Base also decided to participate in the State Water Project. The communities of Lompoc, Vandenberg Village, and Mission Hills voted not to participate in the State Water Project. Beginning in 1997, the Central Coast Water Authority began to deliver State Water Project water to Lake Cachuma, where it is mixed with Cachuma Project water and delivered through Tecolote Tunnel to the contractors on the South Coast. South Coast Member Units also receive Cachuma water that was exchanged for State Water Project water with Santa Ynez River Water Conservation District Improvement District No. 1. The Santa Ynez Pipeline, which delivered water to Improvement District No. 1 from Lake Cachuma, was owned by the District until 1996, when it was sold to the Central Coast Water Authority in anticipation of State Water Project deliveries.

3.2 History of Wastewater Management

Efforts to manage wastewater within the county have been underway for more than a century. This section describes the history of the larger wastewater providers in order to give an overview of how systems have evolved over time in responding to population growth and regulatory requirements.

1 "Table A" is a term used in SWP Water Supply Contracts. The "Table A Amount" is the annual maximum amount of water to which an SWP Contractor has a contract right to request delivery, and is specified in Table A of each Contractor's Water Supply Contract. (Prior to the Settlement Agreement arising out of a legal challenge to the Monterey Amendment to the State Water Project contracts, the Table A Amount was referred to as "entitlement.") The amount of water actually available for delivery in any year may be an amount less than the Contractor's Table A Amount due to a number of factors, including hydrologic conditions.

3.2.1 South Coast

City of Santa Barbara

The City of Santa Barbara's first sewers were installed in the 1870s. In 1925, the City constructed a "screening plant" and ocean discharge outfall. The City's growing population and increasing environmental awareness led to the construction of the first treatment plant in 1951. The El Estero Treatment Plant as it exists today was built to comply with the 1972 Federal Water Pollution Control Act. The City continues to update and upgrade the treatment facility each year. Investment in the treatment plant ensures it remains a state-of-the-art, modern facility.

Carpinteria Sanitary District

The Carpinteria Sanitary District was formed in 1928. During the 1930s and 1940s, wastewater was collected and discharged to the ocean without the benefit of treatment. It was during this period that the bulk of the sewer system serving the downtown area was constructed. The District's first wastewater treatment plant, designed to treat 500,000 gallons per day (gpd), was completed and put into operation in 1951. Treated effluent was discharged directly into the Pacific Ocean via an 18-inch outfall pipe that ran along the eastern bank of Carpinteria Creek. As the community grew, so did the sewer collection system and the treatment plant. In 1961, the treatment plant was expanded and upgraded to a capacity of 2.0 million gallons per day (mgd) which included a new, longer outfall pipe, primary clarification, trickling filters, final clarification, and anaerobic sludge digestion. This facility served the community for over 30 years. In 1993, the District completed another major upgrade to its wastewater treatment plant that involved replacement of the majority of the process infrastructure. The current treatment plant includes preliminary screening and grit removal, primary clarification, extended aeration biological treatment, final clarification, chemical disinfection, aerobic digestion, and odor control systems.

Goleta Sanitary District

The Goleta Sanitary District was formed in 1942 to serve the rural agricultural area called Goleta. Only 1,500 people lived within the District. In those years, sewage wastes were disposed of through individual cesspools and septic tanks. With the ending of World War II, the fledgling District applied to the Navy Department to connect its sewer lines to the Marine Air Base, located on the site of today's Municipal Airport. Plans were drawn to build a sewer system and treatment plant. In 1988, Goleta Sanitary District enlarged and improved its treatment system to meet the discharge requirements of a 301(h) National Pollutant Discharge Elimination System (NPDES) permit, whereby primary and secondary effluent is blended, disinfected, and discharged into the Pacific Ocean. The Goleta Sanitary District owns and operates the treatment facility and serves under contract four public agencies: Goleta West Sanitary District, City of Santa Barbara Municipal Airport, University of California at Santa Barbara (UCSB), and certain facilities of Santa Barbara County. In 1991, in cooperation with the Goleta Water District, a water reclamation facility was constructed. The reclaimed water produced at the sanitary district is distributed throughout the community and used as landscape irrigation. The Goleta Sanitary District is required to upgrade its treatment facilities to achieve full secondary effluent treatment by 2014.

Goleta West Sanitary District

The Goleta West Sanitary District was formed as the Isla Vista Sanitary District in 1954 to serve the needs of the growing area of Isla Vista. The organization established a five member Board of Directors and hired a General Manager. The District changed its name to Goleta West Sanitary District in January 1990 to reflect the areawide aspects of the District's service area. In the late 1950s, over 5 miles of sewer lines were installed in the Isla Vista area using assessment bonds. The balance of the system, force main, pump station, and trunk sewers, was financed by issuing general obligation bonds. Through a joint use agreement the District connected to the Goleta Sanitary District treatment plant for treatment and disposal. The District owned only 5 percent of the plant capacity in the 1950s, but has expanded its ownership to over 40 percent to meet District needs.

3.2.2 North County

City of Santa Maria

The City of Santa Maria has treated and disposed of wastewater at the present site off of Black Road since 1910. The original facilities were expanded in several phases beginning in the mid-1930s through 1962. The 1962 expansion resulted in a capacity to handle 5 mgd of wastewater. During peak months of 1975, flows to the treatment plant reached its capacity of 5 mgd. An expansion to treat present and future flow was needed. Also, much of the original plant was 40 years old and had reached its useful life. The City completed a study in 1977 evaluating alternative means of increasing wastewater treatment and disposal capacity. The recommended plan consisted of expanding the existing plant with similar types of processes and equipment. Many of the existing structures were to be rehabilitated and incorporated into the treatment scheme to reduce construction costs. The treated effluent was to be applied to percolation ponds and irrigated pasture. This land application achieves additional treatment at a low cost. Construction of the recommended expansion began early in 1980 and was completed by mid-1982.

Laguna County Sanitation District

Laguna County Sanitation District was formed by the Santa Barbara County Board of Supervisors on December 29, 1958, pursuant to the provision of the County Sanitation District Act (Health & Safety Code Section 5700 et seq.). At that time Lompoc and Santa Maria were experiencing tremendous growth as a result of activities at Camp Cook (renamed Vandenberg Air Force Base in 1958). Housing development occurred in the areas south of the Santa Maria Public Airport District. Septic systems were proposed initially, but the soil was found to be incompatible. The original plant had a capacity of 1.6 mgd. Effluent was recycled for use in growing sugar beets that were processed at the Union Sugar (later Holly Sugar) processing plant constructed in 1898. The district absorbed the Orcutt Sanitary District (formed in 1926) in 1961, as well as two county collection system districts in 1975. The wastewater treatment plant capacity was increased to 2.4 mgd in 1975, to 3.2 mgd in 1987, and to 3.7 mgd in 2003. The most recent upgrade modified the plant to Class IV due to full tertiary treatment using membranes including reverse osmosis for the portion of flow containing high salt levels from water softener discharge.

Santa Ynez Community Services District

The Santa Ynez Community Services District provides wastewater collection for urban uses in the Santa Ynez Township and was formed in 1971. The District owns 0.29 mgd capacity in the City of Solvang 1.5-mgd wastewater treatment plant, and the main trunk line carries an average of 175,000 gpd to Solvang's treatment plant.

The Chumash Indians have a contract for 88,000 gpd of the District's capacity and constructed a wastewater treatment plant with a capacity of 200,000 gpd that was brought online in May 2004. This plant serves the Chumash Casino, hotel, administration buildings, and approximately 350 residents on the reservation. Treatment includes head works, extended aeration, filtration, and ultraviolet disinfection prior to discharge to Zanja de Cota Creek. The discharge meets California Title 22, tertiary 2.2 standards. Some of this tertiary water is being utilized in the irrigation throughout the reservation and for water to flush the toilets. The Santa Ynez Community Services District is under contract to maintain the Chumash wastewater plant and collection system.

Los Alamos Community Services District

The Los Alamos Community Services District was formed on October 29, 1956. Phase I of the Los Alamos Wastewater Collection and Treatment Plant was built in 1988, and Phase II was completed in 1994, increasing the capacity of the treatment facilities to allow a maximum discharge of 176,000 gpd, averaged over each month. In 2005, the Central Coast RWQCB established new waste discharge requirements for the Phase III expansion, allowing the District to discharge a maximum of 225,000 gpd, averaged over each month and to allow for build out of the town as defined in the Community Plan. Phase III was completed in 2006.

City of Lompoc

The City of Lompoc owns the Lompoc Regional Wastewater Treatment Plant. In 1974, the City of Lompoc entered into long-term agreements with Vandenberg Air Force Base and Park Water Company (a private water company that served Vandenberg Village) to construct the Lompoc Regional Wastewater Reclamation Plant. This plant, built in 1975 to 1977, utilizes secondary treatment technology and is the City of Lompoc's fourth plant in its 87-year commitment to protect the environment. The plant has a design capacity of just over 5 mgd and an instantaneous wet weather flow of 16 mgd. The City of Lompoc, Vandenberg Village Community Services District, and Vandenberg Air Force Base contribute flows to the plant. Vandenberg Village Community Services District has contractual rights to 0.89 mgd of the plant capacity. Vandenberg Air Force Base is a contract customer for wastewater treatment. The base's contract is not to exceed an average of 1.3 mgd during the dry weather flow and not to exceed 3.4 mgd for the wet-weather flow. The treatment process incorporates systems to reduce oxygen-demanding organics by at least 85 percent. This keeps the water discharged to the Santa Ynez River from creating a nuisance. Ammonia (nitrogen), which is toxic to fish, is converted to nontoxic nitrate (nitrification). Methane gas is a by-product of the natural digestion of wastewater solids; this gas is burned in internal combustion engines to provide the energy for nitrification and biosolids stabilization. Anaerobically digested, stabilized biosolids are utilized as a soil amendment. Each year, 1.5 billion gallons of water and 1,000 dry weight tons of biosolids are made safe for return to the environment. The plant will be upgraded in 2007 through 2010 to improve reliability, meet more stringent discharge requirements, and increase treatment level from secondary to tertiary.

Mission Hills Community Services District

Mission Hills Community Services District was formed in 1979 and provides water and wastewater services through 1,200 service connections to the community of Mission Hills. The District operates a primary wastewater treatment plant.

Vandenberg Village Community Services District

Vandenberg Village Community Services District was established in 1983 and provides water and wastewater services though 2,400 service connections to the community of Vandenberg Village. The District acquired wastewater infrastructure and a 17.8 percent capacity right in the Lompoc Regional Wastewater Reclamation Plant from Park Water Company.

3.3 History of Integrated Regional Water Resource Management

Countywide integrated water resource planning has occurred over the past several decades through interagency planning, development of shared water supplies, joint management of resources and operational systems for multiple purposes, and interagency adaptive management responses to changing circumstances.

3.3.1 Interagency Planning and Integrated Water Supply Development

Significant water resources projects have been developed within the Santa Barbara County region. Each new project in the last half century has been characterized by close cooperation among the communities in need and their local agencies. These projects include:

- Cachuma Project (five Cachuma Member Units, Cachuma Operation and Maintenance Board, Cachuma Conservation Release Board, Reclamation, and the Santa Barbara County Water Agency)
- Twitchell Project (Reclamation, Santa Maria Valley Water Conservation District, and Santa Barbara County Water Agency)
- State Water Project (12 local agencies, four private parties, Santa Barbara County Flood Control District, Central Coast Water Authority, and DWR)
- Goleta Valley water recycling project (Goleta Water District and Goleta Sanitary District)
- City of Santa Barbara desalination project (City of Santa Barbara, Goleta Water District, Montecito Water District)
- Interconnections between South County water districts (Goleta Water District, City of Santa Barbara, Montecito Water District, Carpinteria Valley Water District)

- Interconnections between Central County water districts (City of Solvang, Santa Ynez River Water Conservation District Improvement District No. 1)
- Interconnections between North County water districts (City of Santa Maria, Golden State Water Company)

In each case, local agencies evaluated their service area needs, identified opportunities for addressing those needs and, with community support and cross-agency integration and coordination, successfully implemented the above projects.

3.3.2 Integrated Management of Resources and Operational Systems

Several noteworthy examples of integrated management of water resources and operational systems exist in Santa Barbara County. The delivery of Cachuma water to the South Coast area is provided through close cooperation with Reclamation and an interagency agreement that established the Cachuma Operation and Maintenance Board, which operates a key distribution system. The South Coast Conduit's functionality and flexibility are essential to meeting both the day-to-day needs and future demand of the South Coast. The nature and operation of the South Coast Conduit allows the South Coast Cachuma Member Units to integrate their various sources of water allowing conjunctive use of several groundwater basins and water exchanges among water users along its length. The South Coast Conduit is also integrated with water treatment plant operations at the City of Santa Barbara Cater Water Treatment Plant, which provides treated water to the city, the Montecito Water District, the Carpinteria Valley Water District, and the Goleta Water District Corona Del Mar Water Treatment Plant, which provides treated water to the Goleta Valley. A series of integrated projects to protect the South Coast Conduit's integrity and increase its utility, reliability, and flexibility are an important part of this IRWMP.

The City of Santa Barbara and public agencies with interest in the operation of Gibraltar Dam have cooperated to establish the "Upper Santa Ynez River Operations Agreement." The members of the Cachuma Conservation Release Board, the Santa Ynez River Water Conservation District Improvement District No. 1, the Santa Ynez River Water Conservation District, and the City of Lompoc established the "Cachuma Project Settlement Agreement." These documents establish cooperative operation of two of the three reservoirs on the Santa Ynez River to account for:

- Loss of capacity due to siltation (Gibraltar Reservoir)
- Downstream releases consistent with the Gin Chow Judgment (Gibraltar)
- Reservoir operations to moderate peak storm flows (Cachuma)
- Reservoir releases for downstream water rights under SWRCB orders (Cachuma)
- Reservoir releases for downstream steelhead in accordance with the Cachuma Project Biological Opinion
- Conjunctive use of water rights releases and releases for the steelhead fishery
- Downstream water quality improvement based on mixing State Water Project water with Cachuma water at Bradbury Dam

- Conjunctive use of Below Narrows Account water in Cachuma Reservoir with the Lompoc Plain groundwater basin (pending approval to modified WR 89-18 by the SWRCB)

These agreements establish a high degree of integration of facilities planning and Cachuma Project operations affecting the Santa Ynez River, and minimize legal processes that could otherwise frustrate effective regional water management.

The Santa Ynez River/State Water Exchange Agreement was executed in 1993 between Santa Ynez River Water Conservation District Improvement District No. 1, Central Coast Water Authority, Carpinteria Valley Water District, Goleta Water District, La Cumbre Mutual Water Company, Montecito Water District, Summerland County Water District (merged with Montecito Water District in 1995), and the City of Santa Barbara for the purpose of the long-term exchange of all or a portion of Cachuma Project water available to Improvement District No. 1 for an equal amount of State Water Project water available to the South Coast Cachuma Project/ State Water Project contractors. Through this mechanism, Improvement District No. 1 avoids construction, operation, and maintenance of a water treatment facility, and the South Coast Cachuma Project/ State Water Project contractors avoid certain costs of pumping and retreating the State Water Project water and construction of a separate pipeline to Cachuma through the Central Coast Water Authority's acquisition of the Santa Ynez pipeline.

The Coastal Branch of the State Water Project is operated by the Central Coast Water Authority on behalf of 12 public agencies, the U.S. Air Force, three private interests, and San Luis Obispo County. This project and its operation integrate treated water supply operations along its 110-mile length, delivering water to 23 separate entities. In addition to its direct delivery function, the Coastal Branch is the vehicle for intra- and interregional water exchanges and sales. This integration of supply and delivery capacity is an essential part of meeting the region's long-term supply needs and allowing effective response in emergency circumstances, including prolonged drought. The Coastal Branch is also integrated with the Cachuma Project and relies upon Cachuma Project facilities, such as the South Coast Conduit, Tecolote Tunnel, and Lake Cachuma, for deliveries to the South Coast. The coordinated use of these facilities eliminated the need to construct a costly separate delivery system for State Water Project water.

3.3.3 Integrated Management of Emergency Operations

Agencies preparing Urban Water Management Plans (UWMPs) include a section describing a "Water Shortage Contingency Plan" with elements such as water shortage emergency response, supplemental water supplies, long-term additional water supply options and irrigation and/or urban water shortage policies.

Emergency Response Plans include provisions for interruptions to water and wastewater services.

3.3.4 Interagency Adaptive Management Response to Changing Circumstances

Water related projects now incorporate an adaptive management approach. Southern California steelhead management issues were addressed beginning in the early 1990s through an interagency "consensus group" focusing on the Santa Ynez River, which resulted in a comprehensive Fish Management Plan for the lower river and a federal Biological Opinion for Cachuma operations. Fisheries management is addressed in the Santa Barbara, San Luis Obispo, and Ventura counties region through the "Tri-Counties Funding for Improved Salmonid Habitat (FISH) Team." Despite explicit Congressional acknowledgement of the loss of fish resources when Congress approved the Cachuma Project in the mid-20th century, local water agencies understood the need to address protection of public trust resources and changing community values in a proactive, constructive manner decades later.

Storm water and other nonpoint source pollution issues continue to be addressed through a regional "interagency committee" begun several years before the adoption of the state's Phase II regulations. Communities throughout the region developed a template for addressing the state's "General Permit."

4

4 Responsible Entities, Major Infrastructure, and Water Supplies

In Santa Barbara County, a range of local agencies are responsible for various elements of water resource management. The discussion below provides an overview of current operations and responsibilities, as well as major infrastructure and water supplies.

4.1 Water Service Providers

Santa Barbara County water service providers, service areas, and sources of water are shown in Table 4-1; service areas also are shown on Figure 4-1.

TABLE 4-1
Water Service Providers in Santa Barbara County

Provider	Service Area and Water Source
Carpinteria Valley Water District	**Service Area:** City of Carpinteria and unincorporated areas in the Carpinteria Valley **Source:** Carpinteria Valley Groundwater Basin, Cachuma Project, and State Water Project
Casmalia Community Services District[a]	**Service Area**: Casmalia **Source**: Santa Maria Groundwater Basin
City of Buellton	**Service Area**: City of Buellton **Source**: Buellton Uplands and Santa Ynez Riparian groundwater basins and State Water Project
City of Guadalupe[a]	**Service Area**: City of Guadalupe **Source:** Santa Maria Valley Groundwater Basin and State Water Project
City of Lompoc	**Service Area:** City of Lompoc **Source**: Lompoc Groundwater Basin
City of Santa Barbara	**Service Area**: City of Santa Barbara **Source**: Cachuma Project, Gibraltar Reservoir, Devil's Canyon Creek, Mission Tunnel, Foothill Groundwater Basin, Santa Barbara Groundwater Basin, State Water Project, recycled wastewater, and desalination (during droughts and emergencies)
City of Santa Maria	**Service Area**: City of Santa Maria **Source**: Santa Maria Groundwater Basin, State Water Project, and Twitchell Reservoir recharge
City of Solvang	**Service Area**: City of Solvang and adjacent unincorporated areas **Source**: Santa Ynez Uplands Groundwater Basin, Santa Ynez River Riparian Basin, State Water Project (acquired through contract with Santa Ynez River Water Conservation District Improvement District No. 1)

TABLE 4-1
Water Service Providers in Santa Barbara County

Provider	Service Area and Water Source
Cuyama Community Services District[a]	**Service** Area: Cuyama Valley **Source**: Cuyama Groundwater Basin.
Golden State Water Company	**Service** Area: Orcutt, Sisquoc, Lake Marie, and Tanglewood areas **Source**: Santa Maria Groundwater Basin and State Water Project water
Goleta Water District	**Service** Area: West of the Santa Barbara city limits to El Capitan State Beach **Source**: Goleta North/Central Groundwater Basin, Cachuma Project, and State Water Project. The Goleta Water District also treats and distributes reclaimed water to various golf courses, UCSB, and other sites for irrigation and agricultural purposes.
La Cumbre Mutual Water Company	**Service Area**: Hope Ranch and Hope Ranch Annex **Source**: Goleta North/Central Groundwater Basin, Foothill Groundwater Basin, and State Water Project.
Los Alamos Community Services District	**Service Area**: Los Alamos **Source**: San Antonio Groundwater Basin
Mission Hills Community Services District	**Service Area**: Mission Hills **Source**: Lompoc Groundwater Basin
Montecito Water District	**Service Area**: Montecito and Summerland **Source**: Montecito Groundwater Basin, the Cachuma Project, State Water Project, Jameson Lake, Fox and Alder creeks, and Doulton Tunnel
Santa Ynez River Water Conservation District Improvement District No. 1	**Service Area**: Santa Ynez, Chumash Indians' Santa Ynez Reservation, Los Olivos, and Ballard; also supplies domestic water to the City of Solvang **Source:** Cachuma Project, State Water Project, Santa Ynez Upland and Santa Ynez River Riparian Basins
Vandenberg Air Force Base	**Service Area:** Air Force Base and Lompoc Federal Correctional Complex **Source**: San Antonio Groundwater Basin and State Water Project
Vandenberg Village Community Services District	**Service Area**: Vandenberg Village **Source**: Lompoc Groundwater Basin

[a]Serves a disadvantaged community (DAC)

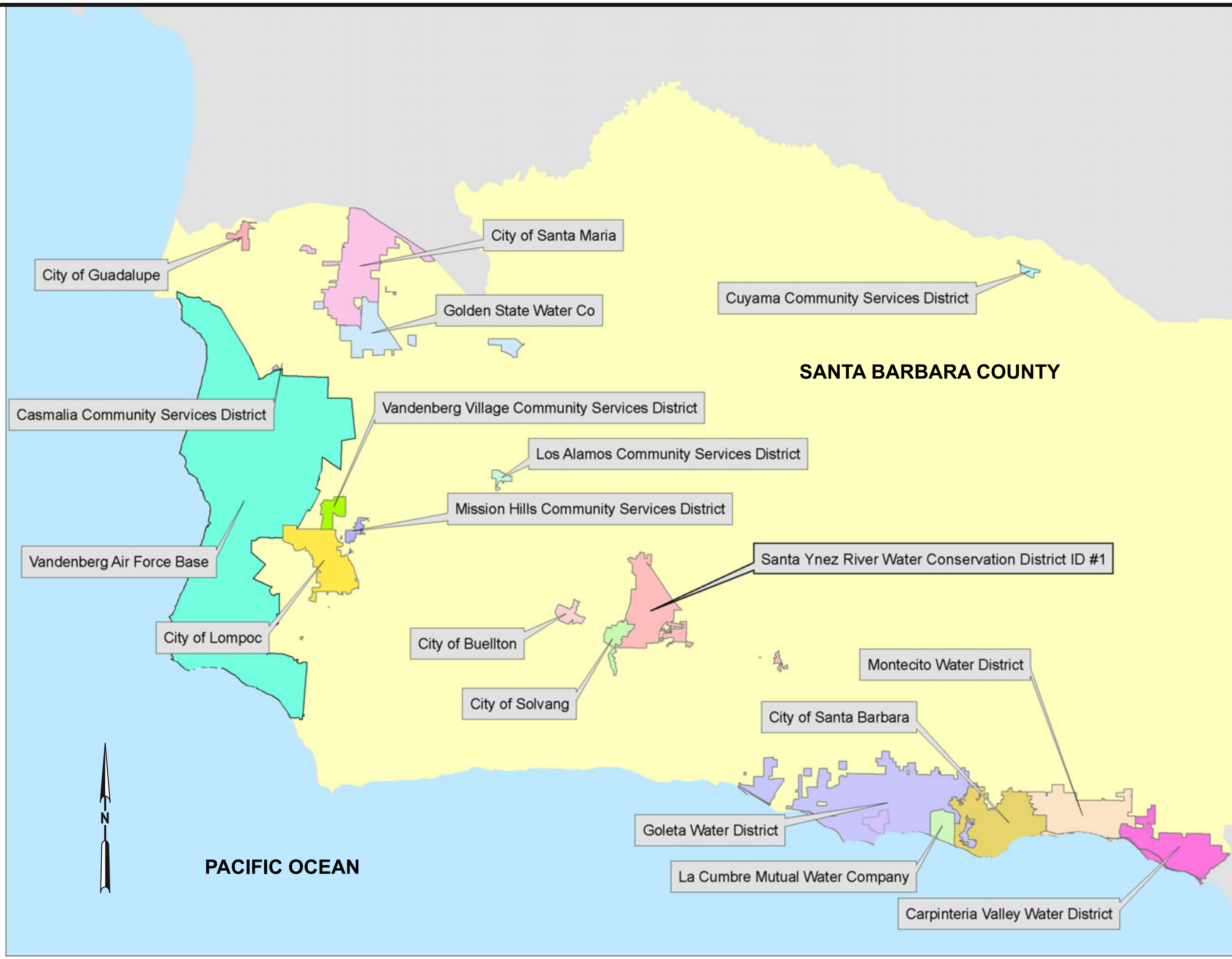

FIGURE 4-1
WATER PURVEYORS IN SANTA BARBARA COUNTY
SANTA BARBARA IRWMP

WB012007002RDD_4-1 (4/24/07)

4.2 Other Water Management Agencies

This section describes other agencies that play key roles in managing water resources within Santa Barbara County, all of which are Cooperating Partners.

4.2.1 Cachuma Conservation Release Board

The Cachuma Conservation Release Board is a joint powers agency formed in January 1973 between the Carpinteria Valley Water District, Goleta Water District, the City of Santa Barbara, and Montecito Water District. The Board was established to jointly represent the respective parties in protecting the Cachuma water rights interests of the four South Coast entities and maximizing the amounts of water that they can obtain from the Cachuma Project or other sources that may be available to them. The Cachuma Conservation Release Board, partnering with the Santa Ynez River Water Conservation District Improvement District No. 1, conducts the long-term steelhead fishery program in the Lower Santa Ynez River in accordance with a Memorandum of Understanding with the U.S. Bureau of Reclamation (Reclamation) and other parties.

4.2.2 Cachuma Operation and Maintenance Board

The Cachuma Operation and Maintenance Board is a joint powers agency that includes the five Cachuma Project Member Units. Although Reclamation owns Bradbury Dam, the Tecolote Tunnel, and the South Coast Conduit and its four regulating reservoirs, the Board has operated and maintained the Cachuma Project facilities, other than Bradbury Dam, since 1957 when it was formed to take over these responsibilities from Reclamation.

4.2.3 Central Coast Water Authority

The Central Coast Water Authority was formed in 1991 to construct, manage, and operate Santa Barbara County's 42-mile portion of the State Water Project and a regional water treatment plant. It later secured agreements with the State of California Department of Water Resources (DWR) to operate and maintain an additional 101-mile portion of pipeline and associated facilities in Santa Barbara and San Luis Obispo counties. It is presently composed of eight public agencies: the cities of Buellton, Guadalupe, Santa Barbara, and Santa Maria, Carpinteria Valley Water District, Goleta Water District, Montecito Water District, and Santa Ynez River Water Conservation District Improvement District No. 1.

4.2.4 Santa Barbara County Water Agency

The Santa Barbara County Water Agency manages a number of regional programs, which include: (1) implementation and partial funding of operational programs such as the cloud seeding program, (2) implementation of the Regional Water Efficiency Program, (3) development of countywide hydrologic data and development of hydrologic models, and (4) development of a program to identify and implement solutions to creek and ocean water pollution on the South Coast of Santa Barbara County. Included in these programs are the compilation and publication of an annual report on groundwater conditions, sediment management studies, technical support to other public agencies, and public information. Major water projects involving the Water Agency include the State Water Project (Coastal Branch Extension), Cachuma Project, and the Twitchell Project. The Water Agency administers development of the IRWMP supported by a number of local governments. The County Board of Supervisors adopted a Memorandum of Understanding with 28 local agencies in September 2006.

4.2.5 Santa Maria Valley Water Conservation District

The Santa Maria Valley Water Conservation District operates Twitchell Dam and Reservoir and supports water conservation projects within the Santa Maria Valley.

4.2.6 Santa Ynez River Water Conservation District

The Santa Ynez River Water Conservation District was formed in 1939 to protect the water rights and supplies of its constituents in the Santa Ynez River watershed with respect to diversions by South Coast agencies. It also manages releases of water from Bradbury Dam to replenish the Santa Ynez River Riparian Basin and the Lompoc Groundwater Basin and provides groundwater management planning and related activities on the uplands adjacent to the river throughout the watershed.

4.3 Wastewater Service Providers

Santa Barbara County's wastewater providers locations are shown in Figure 4-2; providers and their service areas described in Table 4-2. All are Cooperating Partners with the exception of the Santa Ynez Community Services District.

4.4 Major Infrastructure

This section describes major surface reservoirs, water distribution systems, desalination, and water and wastewater treatment facilities. Much of the county's infrastructure is more than 40 years old and needs to be upgraded or replaced in order to meet increasingly stringent regulatory requirements, including drinking water quality standards for disinfection by-products that require expensive new treatment components. As an example, increasing the reliability of wells in the Santa Ynez River alluvium requires development of a regional water treatment plant to comply with the Surface Water Treatment Rule. Infrastructure also must meet the needs of a growing population, and upgrades are needed to reduce water loss, prevent increased inflow and infiltration during storms, and improve performance.

FIGURE 4-2
WASTEWATER SERVICE PROVIDERS IN SANTA BARBARA COUNTY
SANTA BARBARA IRWMP

WB012007002RDD_4-2 (5/3/07)

TABLE 4-2
Wastewater Service Providers in Santa Barbara County

Wastewater Service Provider	Service Area
Carpinteria Sanitary District	City of Carpinteria and unincorporated areas in the Carpinteria Valley
Casmalia Community Services District[a]	Casmalia
City of Lompoc	City of Lompoc, Vandenberg Air Force Base, Vandenberg Village Community Services District
City of Buellton	City of Buellton
City of Guadalupe[a]	City of Guadalupe
City of Santa Barbara	City of Santa Barbara
City of Santa Maria	City of Santa Maria
City of Solvang	City of Solvang and portions of the Santa Ynez Valley
Cuyama Community Services District[a]	Cuyama Valley
Goleta Sanitary District	Goleta Valley (excluding the western portion)
Goleta West Sanitary District	Western portion of Goleta Valley
Laguna County Sanitation District	Orcutt and portions of unincorporated southern Santa Maria
Federal Bureau of Prisons	Lompoc Federal Correctional Complex
Los Alamos Community Services District	Los Alamos
Mission Hills Community Services District	Mission Hills
Montecito Sanitary District	Montecito
Santa Barbara County Parks Department	Cachuma Lake Recreation Area
Summerland Sanitary District	Summerland
Santa Ynez Community Services District	Portions of Santa Ynez (collection and conveyance to Solvang Wastewater Treatment Plant); also manages, operates, and maintains the Chumash Wastewater Treatment Plant
Vandenberg Village Community Services District	Vandenberg Village
Vandenberg Air Force Base	Vandenberg Air Force Base

[a]Serves a disadvantaged community (DAC)

4.4.1 Surface Storage Reservoirs and Associated Distribution Systems

The county's four major reservoirs, discussed above, are managed for various uses, including water supply, groundwater recharge, flood control, recreation, and ecological benefits. Lake Cachuma is owned and operated by the federal government. Twitchell Reservoir is owned by the federal government and operated by the Santa Maria Water Conservation District. Gibraltar Reservoir is owned and operated by the City of Santa Barbara. Jameson Lake is owned and operated by the Montecito Water District. Lake Cachuma, Gibraltar Reservoir, and Jameson Lake are all located in the Santa Ynez River Watershed. The three reservoirs that were constructed on the Santa Ynez River supply most of the water used in the South Coast area of Santa Barbara County. The largest of these is Lake Cachuma, followed by Gibraltar and Jameson reservoirs, which are located upstream. Twitchell Reservoir is located on the Cuyama River 6 miles above its junction with the Sisquoc River and lies within the Santa Maria River Watershed. Twitchell, Jameson, and Gibraltar reservoirs, and to a lesser extent Lake Cachuma, are being filled with sediment, reducing their storage capacity and making it increasingly important to enhance local water supply reliability through conservation and other methods.

The storage capacity of Gibraltar Reservoir is now approximately 7,000 acre-feet (AF); sedimentation has continued to decrease the storage capacity of the reservoir by an average of 150 acre-feet per year (AFY). This reservoir is the source of about one-third of the City of Santa Barbara's water supply. Loss of storage capacity is mitigated by the pass-through provision of the Upper Santa Ynez River Operations Agreement.

The storage capacity of Jameson Lake was originally 7,500 AF and is now approximately 5,290 AF. The unincorporated community of Montecito receives 45 percent of its water supply from Jameson Lake, Fox and Alder creeks via the Doulton Tunnel, so loss of storage capacity is an issue of concern.

Lake Cachuma was created with a storage capacity of about 205,000 AF, but its capacity has been reduced to about 189,000 AF due to sedimentation. The principal features of the Cachuma Project are Bradbury Dam, Lake Cachuma, Tecolote Tunnel and the South Coast Conduit distribution systems. Included in the main conduit system are four regulating reservoirs and Sheffield Tunnel. The South Coast Conduit is constricted between Tecolote Tunnel and Cater Treatment Plant due to decreased pipeline capacity since other facilities were added to that reach of the conduit. Additionally, the aging conduit now requires significant levels of maintenance, which could require that sections of the South Coast Conduit be taken out of service for days or weeks at a time and affect the reliability of the South Coast water supply.

Since its completion, Twitchell Reservoir has been trapping sediments from the 1,140-square mile Cuyama River watershed. Original studies estimated that 40,000 AF of sediment would accumulate in the reservoir during the first 100 years of operation. In 1981, a study found that the rate of sedimentation was about 70 percent greater than the original estimate. As of 1998, the accumulated sediment had reached an estimated 44,000 AF. The reservoir capacity is approximately 198,339 AF. Because of this, the Santa Barbara County Water Agency and the Santa Maria Valley Water Conservation District are preparing a sediment management plan that will help to ensure the continued safe operation of the reservoir's water release works and also extend the usable life of the reservoir.

4.4.2 Flood Control Infrastructure

Santa Barbara County dams are discussed in the preceding section. Other flood control infrastructure in the IRWMP planning area includes:

- 24 miles of levees along the Santa Maria River
- 42 miles of closed conduits
- 22 miles of lined channels
- 50 miles of improved earth channels
- 150 miles of unimproved earth channels
- 34 retarding and recharge basins
- 31 debris basins

4.4.3 State Water Project Facilities

The Central Coast Water Authority was formed to finance, construct, manage, and operate Santa Barbara's State Water Project facilities. Construction of the facilities to import State Water Project water to the county began in 1994, including a 42-mile extension of the State Water Project water pipeline, pumping plants, and a regional treatment plant to treat the water for both San Luis Obispo and Santa Barbara counties (Figure 4-3). The Coastal Branch portion of the State Water Project brings water 117 miles from the California Aqueduct in Kern County, through San Luis Obispo County and the Santa Maria Valley, continuing to the northerly portion of Vandenberg Air Force Base. At Vandenberg Air Force Base, the Coastal Branch connects to the 42-mile pipeline comprising the Mission Hills and the Santa Ynez Extensions. The Santa Ynez section ends at Lake Cachuma. Water is then delivered through existing facilities to the South Coast of Santa Barbara County. The Authority also constructed and operates the Polonio Pass Water Treatment Plant, located in northern San Luis Obispo County and described below. In addition, under a joint powers agreement with DWR, the Authority operates all of the Coastal Branch facilities downstream of the treatment plant.

4.4.4 Desalination Plant

The City of Santa Barbara owns a reverse osmosis desalination plant, which is adjacent to the El Estero Wastewater Treatment Plant. This plant was constructed in 1991 to 1992 by the City of Santa Barbara, Goleta Water District, and Montecito Water District as an emergency water supply in response to the severe drought lasting from 1986 to 1991. The latter two agencies are no longer participants in the desalination plant, which is currently decommissioned due to ample quantities of less expensive supplies. The desalination facility can, however, be brought into operation within 6 to 12 months if needed during drought or water shortage conditions. Just over half of the prefiltration capacity and reverse osmosis treatment modules were sold, leaving sufficient capacity to meet the City's anticipated need for approximately 3,000 AFY of production in future droughts.

4.4.5 Water Treatment Facilities

Communities in Santa Barbara County rely on different types of water supplies. As a result, a wide variety of treatment processes are in use. The following provides a description of selected treatment facilities and processes used in several communities within the county and used in San Luis Obispo County to treat State Water Project water that is delivered to Santa Barbara County. Purveyors routinely monitor water supplies for constituents in accordance with federal and state laws. The Safe Drinking Water Act is the main federal law that ensures the quality of drinking water. Under the Safe Drinking Water Act, the U.S. Environmental Protection Agency sets standards for drinking water quality and oversees the states, localities, and water suppliers that implement those standards. Maximum Contaminant Levels (MCLs) are enforceable regulatory standards under this Act and must be met by all public drinking water systems to which they apply. The California Safe Drinking Water Act was passed to build on and strengthen its federal counterpart. It authorizes the state's Department of Health Services to protect the public from contaminants in drinking water by establishing MCLs that are at least as stringent as those developed by the U.S. Environmental Protection Agency.

Montecito Water District

The Montecito Water District’s Lake Cachuma water supply is treated by the City of Santa Barbara at the City’s Cater Water Treatment Plant. Its Jameson Lake water supply is treated at the District’s Bella Vista and Doulton water treatment plants. Jameson Lake is an open reservoir situated high in the Santa Ynez Mountains. With the completion of the new 2.2-million-gallons-per-day (mgd) Bella Vista Treatment Plant in 1993, and its smaller 150,000-gallons-per-day (gpd) companion, Doulton Treatment Plant, the District has come into full compliance with the 1993 government-mandated standards.

William B. Cater Water Treatment Plant

The City of Santa Barbara constructed the William B. Cater Filtration Plant in 1964. The 1978 Joint Exercise of Powers Agreement provided for the expansion and operation of the Cater Water Treatment Plant to also treat all Cachuma water delivered to the Montecito and Carpinteria Valley water districts. The plant was expanded to its current 37-mgd capacity in 1982. The water treated at the plant may be drawn directly from the South Coast Conduit or from Lauro Reservoir. The water in the South Coast Conduit comes directly from Lake Cachuma (via the Tecolote Tunnel). The water in Lauro Reservoir is a combination of water from Gibraltar Reservoir (via the Mission Tunnel into the Penstock pipeline) and water from the South Coast Conduit. Normal operation is for Cater to draw the water from Lauro Reservoir.

Corona Del Mar Water Treatment Plant

The Goleta Water District began operating the Corona Del Mar Water Treatment Plant in 1974. Due to the plant elevation of 615 feet, water can move through the plant by gravity flow and be delivered to the vast majority of district customers without pumping. The rated nominal capacity of the plant is about 24 mgd) with a peak capacity of 36 mgd. The “raw water” received from Lake Cachuma is directed to the plant for removal of suspended matter, such as clay particles and algae, in order to meet state health standards.

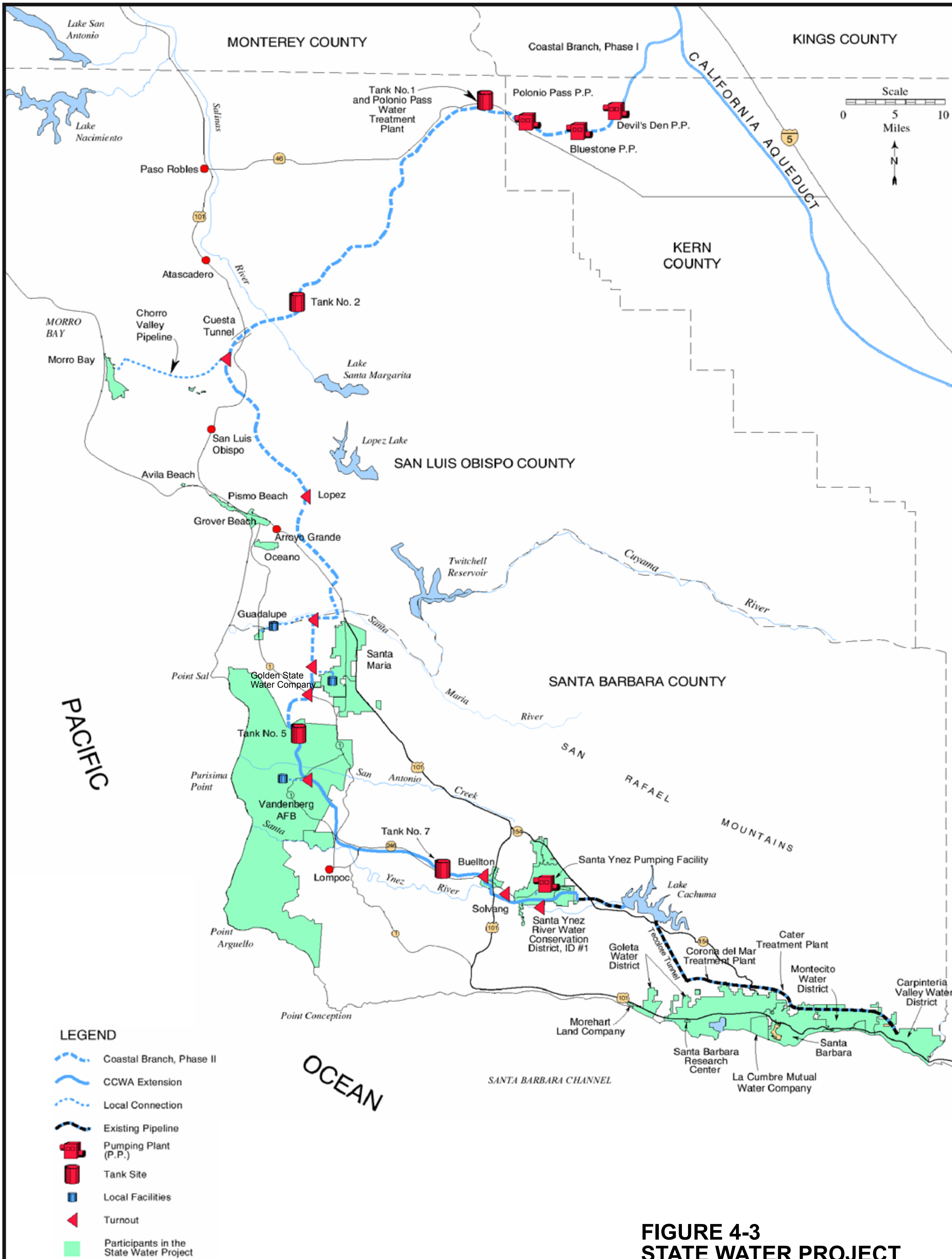

FIGURE 4-3
STATE WATER PROJECT WATER INFRASTRUCTURE IN SANTA BARBARA COUNTY
SANTA BARBARA IRWMP

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City of Lompoc Water Treatment Plant

The City of Lompoc operates nine wells of varying capacities between 250 and 2,500 gallons per minute. Groundwater is pumped from the wells to the water treatment plant for demineralization and softening. The City of Lompoc Water Treatment Plant has a peak capacity of 10 mgd with a reservoir capacity of approximately 12 million gallons of usable storage.

Polonio Pass Water Treatment Plant

State Water Project water provided to Santa Barbara County is treated at the 43-mgd Polonio Pass Water Treatment Plant in San Luis Obispo County. This treatment plant disinfects water through chloramination. Chloramines are removed from the water before it is discharged to Lake Cachuma. The detreated State Water Project water is mixed with Cachuma Project water and delivered through Tecolote Tunnel to the contractors on the South Coast. Water treated at Polonio Pass is provided directly to Santa Maria, Guadalupe, Buellton, Solvang, Santa Ynez River Water Conservation District Improvement District No. 1, and Vandenberg Air Force Base.

4.4.6 Wastewater Treatment

Wastewater service providers must address increasingly strict discharge limits for wastewater treatment plants requiring increasing costs for wastewater agencies. SWRCB General Waste Discharge Requirement for Sanitary Sewer Systems (SWRCB Order No. 2006-0003) also requires wastewater agencies to evaluate and rehabilitate sewer systems with a target of zero sewer overflows.

There are several steps to the wastewater treatment process. Wastewater enters sewers and is then transported to the wastewater treatment plant, where it receives "primary treatment." This involves removing solids that settle to the bottom, as well as floating materials.

Next the water undergoes "secondary treatment," which removes solids that are suspended or dissolved in the water. During this treatment process, chemicals are added to disinfect the water before it is released into the ocean, adjacent river, or stream, either directly or indirectly by percolation ponds or upland spreading areas. Most wastewater in Santa Barbara County is treated to this secondary level.

Finally, some treatment plants use "tertiary treatment," which filters and disinfects the water. If treated to this advanced level, wastewater (or "effluent") can be reused for such purposes as irrigation of pasture grasses, landscaping, and even some crops. Such reclaimed water is used for several purposes within the County of Santa Barbara.

The county’s primary wastewater treatment plants, their capacities, level of treatment, and uses for recycled water are shown in Table 4-3. The Lompoc Federal Correctional Complex also provides its own wastewater service. Wastewater collected from the Main Cantonment Area at Vandenberg Air Force Base is conveyed to the Lompoc Wastewater Treatment Plant. Other areas in the North Base and South Base are served by leach fields, septic tanks, and package treatment plants.

TABLE 4-3
Wastewater Treatment Facilities within Santa Barbara County

Treatment Plant	Permitted Capacity (MGD)	Level of Treatment	Recycled Water Uses
Buellton	0.65	secondary	groundwater recharge
Carpinteria Sanitary District	2.0	secondary	treatment plant landscape irrigation
City of Santa Maria	9.0	secondary	groundwater recharge
El Estero (City of Santa Barbara)	11.0	secondary/ tertiary	landscape irrigation; toilet flushing
Goleta Sanitary District and Goleta West Sanitary District	10.64	primary/blended secondary	landscape irrigation; toilet flushing
Laguna County Sanitation District	3.7	tertiary	agricultural; landscaping; industrial
Lake Cachuma County Park	0.22	secondary	none
La Purisima [a]	0.40	primary	groundwater recharge; pasture/crop irrigation
Lompoc Regional Wastewater Reclamation Plant	5.0	advanced secondary	sewer line cleaning; dust control & compaction; city street tree irrigation
Mission Hills	0.57	secondary	groundwater recharge
Montecito Sanitary District	1.5	secondary	none
Santa Ynez Band of Chumash Indians	0.2	tertiary	none
Solvang Wastewater Treatment Plant	1.0	secondary	groundwater recharge
Summerland Sanitary District	0.30	tertiary	none

Source: Family of Santa Barbara Water Providers, 2006; Cooperating Partners, 2007.

[a]Located at La Purisima State Park

4.5 Water Supplies

Water supplies include groundwater, surface water, imported State Water Project water, and recycled water; water supplies also are enhanced by the conjunctive use of surface and groundwater supplies and cloud seeding. The current average annual water supplies for Santa Barbara County total about 223,000 AFY, plus about 90,000 AFY in return flows to useable groundwater basins.

4.5.1 Groundwater

Groundwater basins are the major source of water in the county, supplying about 77 percent of Santa Barbara County's domestic, commercial, industrial, and agricultural water. The regional groundwater basins are described in Section 2. In the South County, water purveyors use groundwater as a secondary source of potable water. However, the North County is largely supported by groundwater and/or shallow, riparian basin water, both of which are recharged by surface flows.

4.5.2 Surface Water

Surface water refers to water resources that flow or are stored in surface channels (streams and rivers or lakes and reservoirs). Surface water reservoirs are an important part of the regional water supply so the loss of storage capacity is of significant concern. Gibraltar Reservoir is the source of about one-third of the City of Santa Barbara's water supply. The unincorporated community of Montecito receives 45 percent of its water supply from Jameson Lake, Fox and Alder creeks via the Doulton Tunnel. On an average annual basis, Lake Cachuma provides approximately 65 percent of the South Coast's water supply. Twitchell Reservoir is important to both the water supply and the flood protection of the Santa Maria Valley. The reservoir supplies about 20,000 AF of recharge to the Santa Maria Groundwater Basin on an average annual basis.

4.5.3 Imported Water (State Water Project)

Table 4-4 shows the amount of water to which each Santa Barbara County participant in the State Water Project has a contractual right, referred to as Table A Amount. Actual deliveries may be less than shown in Table 4-4. The primary factors affecting the amount of Table A deliveries are the availability of State Water Project supplies and the State Water Project Contractors' demands for this water. Climatic conditions and other factors can significantly alter the availability of State Water Project water in any year; a topic of growing concern for water planners and managers is global warming and the potential impacts it could have on California's future water supplies, including State Water Project supplies. The amount of water DWR determines is available and allocates for delivery in a given year is based on that year's hydrologic conditions, the amount of water in storage in the State Water Project system, current regulatory and operational constraints, and Contractors' requests for State Water Project supplies. Even in years when additional Table A supplies are available, the amount of water DWR allocates is limited to Contractors' requests.

State Water Project water has helped reduce the use of groundwater in all major basins, except the Cuyama Basin, which does not have a water purveyor that receives State Water Project water. It also has improved water quality in areas that directly receive State Water Project water and has increased the overall water supply in Santa Barbara County.

4.5.4 Water Conservation

Water conservation addresses the "demand side" of water management, and thereby constitutes an important part of stretching the county's water supplies. Through water conservation programs implemented at the regional and water purveyor level, additional water supplies become available for use within the county, reducing pressures on other water resources. Water conservation activities occur countywide through the Regional Water Efficiency Program (RWEP), in which water purveyors work cooperatively to implement conservation in the areas of residential, commercial, agricultural, and landscape programs. Additionally, regional education and public information programs help change behavior to decrease water use. Regional programs have been in place since 1990 and are staffed and funded by a multiagency team of conservation staff from the Santa Barbara County Water Agency and local water purveyors. Water purveyors also implement individual programs of particular interest within their service areas. Programs are discussed in greater detail in Section 5. Water savings through conservation programs are calculated on an annual basis by those agencies who are members of the California Urban Water Conservation Council. Council Signatories, who have committed to best management practices for water conservation by signing the Council Memorandum of Understanding, plus the conservation activities of nonmembers in the County, have resulted in the conservation of 86,660 AF during the period from 1991 to 2006. Not all water purveyors report their savings and therefore, savings may be significantly higher.

TABLE 4-4
State Water Project Table A Amounts in Santa Barbara County

State Water Project Participant	Drought Buffer (AFY)[a]	Table A Amount (AFY)
Carpinteria Valley Water District (includes Summerland)	200	2,000
City of Buellton	58	578
City of Guadalupe	55	550
City of Santa Barbara	300	3,000
City of Santa Maria	1,620	16,200
Golden State Water Company (Orcutt area)	50	500
Goleta Water District	450	4,500
La Cumbre Mutual Water Company	100	1,000
Montecito Water District	300	3,000
Morehart Land Company	20	200
Santa Barbara Research Center	5	50
Santa Ynez River Water Conservation District Improvement District No. 1	200	500
City of Solvang	0	1,550
Vandenberg Air Force Base	550	5,500
Total	3,908	39,078
Goleta Water District Additional Drought Buffer[b]	2,500	

Source: SBCWA, 2000

[a]The drought buffer entitlement of 3,908 AF increases the reliability of each project participant's Table A Amount. This can be stored for future use and/or requested in dry years when cutbacks are expected to State Water Project allocations. By storing this water and/or increasing the Central Coast Water Authority's water request in dry years, even after a percentage cutback by DWR, the project participants can reduce shortages in their entitlement deliveries.

[b]Goleta has 2,500 AFY of drought buffer, in addition to its 450 AFY, that does not have pipeline or treatment plant capacity (i.e., it is for increased reliability only).

4.5.5 Recycled Water

Recycled water must meet rigorous water quality standards before it can be reused. The type of reuse varies depending upon the level of treatment. In addition, other constituents, such as total dissolved solids (TDS), in the treated wastewater sometimes limit the use for landscape irrigation and groundwater recharge. Presently, there are two agencies in the county that treat all of their effluent to full tertiary levels. These are the Laguna County Sanitation District and the Summerland Sanitary District. The Laguna County Sanitation District produces approximately 2,400 AFY, which is used for agricultural, landscaping, and industrial purposes with recycling as its only discharge mechanism. Reverse osmosis is used to reduce TDS to improve water quality. The Summerland Sanitary District treats approximately 168 AFY, which is discharged to the Pacific Ocean.

Two other agencies treat some of their flow to tertiary levels for reuse landscape irrigation. These include the City of Santa Barbara and the Goleta Sanitary District. The City of Santa Barbara El Estero Wastewater Treatment Plant has the capacity to treat up to 1,200 AFY of tertiary effluent and currently treats 800 AFY. The Goleta Sanitary District recycled water system is operated jointly with the Goleta Water District as the purveyor and can treat up to 1,500 AFY of tertiary effluent and currently has a demand of 1,000 AFY. The City of Lompoc utilizes approximately 5 AFY of its secondary treated effluent for reuse and discharges to the Santa Ynez River. The Los Alamos Community Services District discharges all of its approximately 130 AFY of secondary effluent for pasture irrigation. Many of these agencies, as well as others not discussed, discharge to percolation ponds, the Pacific Ocean, or other water bodies.

4.5.6 Desalted Water

The City of Santa Barbara's desalination plant is discussed in Section 4.4.4.

4.5.7 Conjunctive Use

Santa Barbara's water purveyors practice the conjunctive use of surface and groundwater supplies when excess water is available to recharge groundwater basins for later withdrawal when supplies are short. Some purveyors use State Water Project water, when available, and rely on groundwater to supplement when demand is higher. Purveyors may also purchase a "drought buffer" of additional State Water Project water or bank water in a groundwater basin. Similarly, some purveyors may manage, possibly in accordance with an AB 3030 Groundwater Management Plan, the groundwater pumped and stored in groundwater basins in order to optimize the basin's overall long-term working yield. The City of Santa Barbara maintains a water well system capable of extracting up to 4,500 AFY. Most of this potential supply is kept in reserve in case of drought, since a majority of its water supply is from surface water sources outside of the watershed area. During normal years, the City's groundwater basins are allowed to recharge, with groundwater extraction generally reserved for periods of drought or other supply shortages. Pumping occurs in Storage Unit No. 1 (downtown area) and the Foothill Basin (outer State Street area). The City of Santa Barbara conducts conjunctive use water supply management activities by injecting and storing surface water in the basins.

4.5.8 Cloud Seeding

Since as early as 1948, Santa Barbara County has participated in weather modification activities in order to augment local water supplies. The County cloud seeding program is only conducted in the upper Santa Ynez and Twitchell Reservoir watersheds. The effectiveness of cloud seeding has been evaluated to demonstrate its benefits. Recent statistical studies suggest that seeding results in a maximum increase in precipitation of about 15 percent over one rain season. This translates to thousands of acre-feet of additional water captured for storage in local reservoirs. For example, in a wet year such as 1992 to 1993, approximately 20,000 AF of water was generated through cloud seeding, and this figure does not include infiltration into groundwater basins (SBCWA, 2000). The local cloud seeding program is operated between December 1 and March 30 of most years. The cost of the annual cloud seeding program is shared among the County and the water districts that receive a benefit from it.

5

5 Water Resources Management Framework

Santa Barbara County has an extensive array of plans and programs that provide an effective framework for the management of water resources. This section highlights the key elements of this framework and describes the relationship between these elements and the IRWMP. The IRWMP builds on this existing framework, identifying objectives, strategies, regional priorities, and projects that are consistent with the existing plans.

5.1 Planning Framework

5.1.1 County and City General Plans

In accordance with state law, Santa Barbara County and each of the incorporated cities have adopted General Plans that contain land use maps, goals, objectives, policies, and standards to guide development. Development can affect water resources through a variety of means, such as increasing the demand for water and wastewater services; changing rates of groundwater infiltration and recharge through the creation of impervious surfaces; increasing the amount of storm water runoff; and increasing erosion and use of chemicals that enter surface and groundwater and affect water quality. Development also can result in changes to ecosystems through mechanisms such as loss of habitat and direct impacts to species through construction. The locally adopted General Plans contain policies that are intended to protect water and ecological resources within the county and ensure that water supplies and sewage treatment are adequate. These General Plans also reflect regulatory requirements relating to nonpoint source pollution control, conservation, and other water resource regulations. Decision makers must consider a project's consistency with these policies before approving new development. A preliminary evaluation of consistency was performed on all projects in the list, recognizing that some types of projects are not subject to General Plan policies. The results are reflected in Section 8. Projects included in the IRWMP will be formally evaluated for consistency with the relevant plans by decision makers prior to their approval.

5.1.2 Los Padres National Forest Land Management Plan

The U.S. Forest Service has developed a Land Management Plan for the Los Padres National Forest (USFS, 2005), which identifies a strategic direction and program emphasis objectives that are expected to result in the sustainability (social, economic, and ecological) of the national forest and, over the long-term, the maintenance of a healthy forest. The legislative mandate for the management of national forests requires that public lands be conservatively used and managed in order to ensure their sustainability and to guarantee that future generations will continue to benefit from their many values. Forest plans are founded on the concept of sustainable use of the national forests. The plan consists of three parts. Part 1 describes the national forest in the future, the niche it occupies in the community framework, the desired conditions the Forest Service is trying to realize, and the challenges that will be faced. Part 2 includes the “tools” that resource staff will use to accomplish the plan’s objectives. Part 2 also defines and describes each of the land use zones and includes a prospectus describing the past performance history of the national forest and the anticipated performance in 3- to 5-year increments over the life of the forest plan. Part 2 also describes what types of management is expected in specific areas of the national forest and addresses the monitoring to be done to assess the effective implementation of the strategies used. Part 3 of the forest plan is the design criteria and constitutes the “rules” that the Forest Service will follow as the national forest implements projects and activities over time. Some of the IRWMP planning area is within the Los Padres National Forest, as are key major water infrastructure and waterbodies (for example, Tecolote Tunnel, Jameson Lake, Gibraltar Reservoir, South Coast Conduit, portions of the Santa Ynez River, and numerous creeks). Projects on these lands will require coordination with the U.S. Forest Service to ensure consistency with the forest plan.

5.1.3 Vandenberg Air Force Base General Plan

The Vandenberg Air Force Base General Plan guides the installation’s comprehensive planning process. It identifies essential characteristics and capabilities of the installation and assesses the potential for development. The Utility Systems component of the General Plan contains information about the existing utility infrastructure and presents a general framework for future development. It illustrates existing and planned services, including water and wastewater systems. Utility system capacities, both existing and potential, are noted to determine Vandenberg Air Force Base’s ability to support existing and future missions. The General Plan indicates that comprehensively planned and maintained utility systems are able to support mission requirements and should be developed in conjunction with the Capital Improvements Program and future land-use plans. Although the General Plan focuses specifically on development at the installation, planning efforts are related to those of the Cooperating Partners through shared water supplies (State Water Project and San Antonio Groundwater Basin) and wastewater treatment facilities (Lompoc Wastewater Treatment Plant), as well as through participation in programs such as Santa Barbara County’s Regional Water Efficiency Program (RWEP), described below.

5.1.4 Urban Water Management Plans

In 1985, statewide legislation (AB 797) was passed requiring all water purveyors with 3,000 customers or serving over 3,000 acre-feet (AF) of water for urban uses, to prepare an urban water management plan. These plans must be updated every 5 years. An urban water management plan is a comprehensive plan that addresses past, current, and future water supplies for each affected district. These plans must include a water shortage contingency plan for droughts and other water shortage emergencies, a plan for using recycled wastewater if feasible, a comprehensive assessment of all water supplies within the district, a plan for meeting future water needs, and a water efficiency plan, which includes a description of how best management practices will be implemented.

In Santa Barbara County, the Carpinteria Valley Water District, Central Coast Water Authority, City of Lompoc, City of Santa Barbara, City of Santa Maria, Goleta Water District, Montecito Water District, and the Golden State Water Company (Orcutt) have prepared Urban Water Management Plans to permit levels of water management planning commensurate with the numbers of customers served and the volume of water supplied.

The Santa Ynez River Water Conservation District Improvement District No. 1 also has prepared a Water Management Plan with a similar intent. Projects included in the IRWMP that increase water supplies and supply reliability will help meet the water demands identified in these plans.

5.1.5 Groundwater Management

Enacted in 1992, AB 3030 allows local agencies, with public involvement, to prepare, adopt, and enforce groundwater management plans for the protection of groundwater. These plans are in various stages of completion. Groundwater levels and quality are already monitored in most of the county, and thus, are not a primary focus of this IRWMP. Several cities and water districts in the region have adopted or are preparing groundwater management plans in accordance with local ordinances and agreements, as well as AB 3030. Those that are adopted are listed in Table 5-1, along with those that are subject to court actions.

TABLE 5-1
Groundwater Plans

Basin	Public Agency Participants[a]	Status
Carpinteria	Carpinteria Valley Water District	Plan Adopted
Montecito	Montecito Water District	Plan Adopted
Santa Barbara	City of Santa Barbara	Plan Adopted
Foothill	City of Santa Barbara	Plan Adopted
Goleta	Goleta Water District	Court Action[b]
Buellton Uplands	Santa Ynez River Water Conservation District City of Buellton	Plan Adopted
Santa Maria Valley	City of Santa Maria Santa Maria Valley Water Conservation District Golden State Water Company	Court Action (Pending)

[a]Other participants include private water companies and overlying property owners.

[b]The “Wright Suit” Settlement stipulates management actions in the North and Central subbasins.

5.1.6 Water Shortage Contingency Plans

Water conservation is an integral part of water resource planning in Santa Barbara County. Most local water purveyors have prepared water shortage contingency plans that identify how they will reduce demand during a shortage. These plans address water savings over and above ongoing water efficiency practices that are now an integral part of customer demand management. Ongoing (long-term) efficiency measures include best management practices (pricing, education, efficient landscapes and irrigation, efficient plumbing fixtures and appliances). Short-term water shortage contingency measures include steeply tiered (penalty) water rates, prohibitions against certain unnecessary uses of water (i.e., car washing), water rationing programs, restricted landscape irrigation (i.e., designated days for watering) and public information campaigns. Typical contingency plans are based on scenarios of shortages, such as 10 percent, 20 percent, and 30 percent reductions in supply.

The demand reduction contingencies are planned according to the severity of the water supply reduction, with the most severe restrictions being carried out during the most severe shortage. In the last local drought water demand was actually reduced by over 50 percent during the peak of the shortage.

Local plans are complemented and augmented by the Water Agency's 2004 Santa Barbara County Regional Water Shortage/Drought Management Plan. To ensure that the County's plan complements the purveyor's plans, the Water Agency created a Water Shortage/ Drought Preparedness Planning Technical Advisory Committee comprising staff from the Water Agency and local water purveyors. This group helped shape the regional plan, particularly those actions to be implemented by the Water Agency in conjunction with the individual efforts of the water purveyors. More recently, under a grant from the U.S. Bureau of Reclamation (Reclamation), the County Water Agency prepared a "Water Shortage Contingency/Drought Planning Handbook" (January 18, 2006) as a guide to assist local water districts in preparing their own contingency plans (SBCWA, 2006b).

5.1.7 Capital Improvement Plans/Master Plans

Virtually all of the Cooperating Partners have adopted Capital Improvement Plans or Facilities Master Plans, outlining the infrastructure improvements needed to correct deficiencies in their service areas and ensure the efficient functioning of their water and wastewater systems. Infrastructure projects included in the IRWMP are also included in these plans and can provide a mechanism to obtain grant funding for these much-needed projects.

5.2 Water Management and Monitoring Programs

5.2.1 Storm Water Management Programs

The Clean Water Act sets water quality standards for all contaminants in surface waters and makes it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a National Pollutant Discharge Elimination System (NPDES) permit is obtained. Point sources are discrete conveyances such as pipes or man-made ditches. Individual homes that are connected to a municipal system, use a septic system, or do not have a surface discharge do not need an NPDES permit; however, industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters.

The Municipal Storm Water Permitting Program regulates storm water discharges from municipal separate storm sewer systems (MS4s). MS4 permits were issued in two phases. Under Phase I, which started in 1990, the Regional Water Quality Control Boards (RWQCB) issued NPDES storm water permits for medium (serving between 100,000 and 250,000 people) and large (serving 250,000 people) municipalities. No Phase I communities are located in the Santa Barbara County region.

Phase II regulations expanded the scope of the NPDES program to include local municipalities serving populations of less than 100,000[1]. These local governments must design a Storm Water Management Program to include the development and implementation of six specified measures that reduce storm water pollution to the maximum extent practicable. Evaluation and reporting measures are also required. In addition, the rule sets requirements for construction activity that disturbs between 1 and 5 acres and extends a previously set deadline for municipalities that operate industrial activities regulated under Phase I.

The Phase II NPDES Program is intended to reduce adverse impacts to water quality and aquatic habitat by instituting the use of controls on the unregulated sources of storm water discharges that have the greatest likelihood of causing continued environmental degradation. Storm water discharges from urbanized areas are a concern because of the high concentration of pollutants found in these discharges. Concentrated development in urbanized areas substantially increases impervious surfaces, such as city streets, driveways, parking lots, and sidewalks, on which pollutants from human activities settle and remain until a storm event washes them into nearby storm drains. Common pollutants may include sediment, nutrients, bacteria and viruses, oil and grease, organic compounds, and gross pollutants such as trash. Storm water runoff picks up, transports, and discharges these pollutants, untreated, to waterways via storm drain systems. These discharges can result in the loss of wildlife habitat, reduced aesthetic value, and contamination of recreational waterways that can threaten public and aquatic health. Pollutants of concern in Santa Barbara County are sediment, oil and grease, phosphorous, copper, and bacteria.

Santa Barbara County is responsible for implementing the storm water management program in the unincorporated urbanized areas of the South Coast, Santa Ynez Valley, and Santa Maria Valley. The cities of Carpinteria, Santa Barbara, Goleta, Buellton, Solvang, Lompoc, and Santa Maria are responsible for implementing independent storm water management programs. The storm water management programs define strategies and guidelines for the protection of water quality and reduction of pollutant discharges to the maximum extent practicable. Through existing environmental programs and services as well as established land development policies, the local jurisdictions have a number of programs that meet the intent of the NPDES Phase II regulations and the state General Permit requirements.

Best management practices for each of the six minimum control measures being implemented in the IRWMP planning region include, but are not limited to, educational programs for children, informational materials, community events, storm drain markers, storm water hotline/creeks information numbers, neighborhood-based outreach, Web sites,

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[1] In agricultural areas, runoff is being addressed through the state of California's Agricultural Waiver Program, which is a program adopted on the Central Coast in 2004 by the RWQCB to regulate wastewater discharges from irrigated land. It allows the RWQCB to waive waste discharge requirements for growers who enroll in the program and commit to certain steps, including attending 15 hours of approved education training, completing a Farm Water Quality Plan, implementing best management practices in the Farm Plan, and participating in an individual or cooperative monitoring program. In Santa Barbara County, the Agricultural Waiver Program is coordinated by the Southern San Luis Obispo and Santa Barbara Counties Agricultural Watershed Coalition. Additionally, the state's Agricultural Water Quality Grant Program provides funding for projects that reduce or eliminate nonpoint source pollution discharge to surface waters from irrigated agricultural lands. Funding is available from Propositions 40 and 50 (but through a section of Proposition 50 other than that which defines the IRWMP process). Grants for Nonpoint Source Pollution Control projects from Clean Water Act Section 319 funding is also available through this program. Thus, nonpoint source pollution from irrigated agriculture is not the focus of this IRWMP, because other programs and funding sources are available.

and business outreach programs. Additionally, post-construction best management design criteria, such as low impact development criteria are being studied and considered.

The IRWMP includes projects, described in Section 8, that are consistent with and will help implement the goals of the storm water management programs.

5.2.2 Water Monitoring Programs

Groundwater Well Monitoring and Data Collection

The Santa Barbara County Water Agency currently monitors 283 wells for depth to groundwater throughout the county in cooperation with the United States Geological Survey (USGS). Individual water districts monitor many more wells. The County and local water districts cooperate with the USGS to collect and publish groundwater data. There are historical records on many more sites than are currently being measured. These records were developed for a number of purposes, including USGS investigations, prior inclusion in the County monitoring network, or measurements to address specific issues. The current monitoring network is sufficient to accurately reflect groundwater conditions throughout the County while being measured with a reasonable amount of resources. Sufficient data/information to better understand shallow groundwater quality in certain areas (Western Santa Maria basin) are lacking. In other areas, such as the Santa Ynez River Riparian Corridor, significant data have been developed to support ongoing management.

Local water districts and municipalities currently monitor or fund monitoring of many sites in addition to those measured by Santa Barbara County. Agencies that currently have cooperative agreements with the USGS for groundwater monitoring besides the County Water Agency are: the Carpinteria Valley Water District, City of Santa Barbara, Goleta Water District, Santa Ynez River Water Conservation District, Reclamation, City of Lompoc, and the Santa Maria Valley Water Conservation District. Agencies that provide information for this report but are not participants in the USGS program are Montecito Water District, the City of Santa Maria, and Golden State Water Company. Monitoring frequencies vary among agencies and wells and reflect the data needs of the individual agency.

Of the 283 wells currently monitored by the Santa Barbara County Water Agency, 27 sites include water quality monitoring. Although partially funded through Water Agency programs, this groundwater quality data is collected directly by USGS. Other information is gathered by the RWQCB, or local water agencies. Additionally, through the Cachuma Resource Conservation District’s mobile lab program, farmers are trained to monitor and record groundwater quality, allowing them to manage crop irrigation in a way that minimizes the amount of nutrients entering the groundwater.

Surface Water Monitoring

Surface water quality monitoring is performed by a number of federal, state, and local agencies, as well as interested educational institutions, organizations, and individuals. These monitoring efforts are performed to accomplish a wide variety of objectives, including serving as the basis of surface water quality improvements.

Project Clean Water

Project Clean Water was established in 1998 to identify and implement solutions to creek and ocean water pollution on the South Coast. The County of Santa Barbara and the cities of Santa Barbara and Carpinteria are joined in this effort by members of groups such as the Urban Creeks Council, the Audubon Society, the Surfrider Foundation, Heal the Ocean, CURE, Santa Barbara Channelkeeper, Coalition of Labor, Agriculture & Business, Environmental Defense Center, and the Community Environmental Council, as well as many community members. The County of Santa Barbara's Public Health Department monitors 20 beaches on a weekly basis, year-round. Water samples are tested for indicator bacteria (total coliform, fecal coliform, and enterococci) and compared to standards, as mandated by AB 411. Beaches with test results above the acceptable standards are placed under warning status and are resampled 2 days later. Data are available in the local newspapers and at http://www.sbcphd.org/ehs/ocean.htm, the Public Health Department Web site.

Annual Bioassessment Program

Beginning in 2000, the County of Santa Barbara began an annual bioassessment program, which involves collecting and analyzing physiochemical and biological (including benthic macroinvertebrates) data from local streams using standardized methods adapted from the U.S. Environmental Protection Agency's Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers. The study area includes approximately 35 miles of the southern Santa Barbara County coast from the Rincon Creek watershed at the Santa Barbara/Ventura County line west to Gaviota Creek.

Creek Walks

The County of Santa Barbara Public Works Department walks most creeks in the County on an annual basis. Flood Control staff walk the same creeks every year. Project Clean Water staff walk the unincorporated urbanized portions during the late summer/early fall in areas most likely to have water quality impacts. Local city staff and special interest groups also conduct organized creek walks and scheduled monitoring of the creeks, which contributes to the overall understanding of the region's watersheds and highlights the problem areas.

Santa Ynez River Monitoring

Surface- and groundwater monitoring in the Santa Ynez River watershed has occurred for decades. Surface flow, groundwater levels, and water quality are monitored by several local agencies and the USGS. Monitoring efforts include:

USGS Stream Gauging

The USGS operates several stream gages on the Santa Ynez River. Data collected is available from the USGS Web site and is used for several purposes. High flow data are used for public safety purposes including winter storm operations at Bradbury Dam. Low flow data are used for managing the river-flow to meet water right requirements and fish protection objectives. The program relies on both federal agencies and local cooperators for funding; County Flood Control District and Water Agency are both major participants.

USGS Water Quality Measurements

Water quality measurements are made by the USGS as part of stream gauging and groundwater monitoring. Data collected is available from the USGS Web site and is used for several purposes including monitoring suitability of water quality for beneficial uses, monitoring the salt content of the water rights releases, and habitat suitability for fish habitat.

Flow and Water Quality Measurements as Part of Steelhead Trout Studies

Since 1994, federal, state and local agencies have monitored conditions in the Santa Ynez River to develop a plan for protecting and enhancing the local steelhead trout population. Water quality monitoring includes field measurements of temperature, specific conductance, and oxygen levels. These measurements are summarized in annual reports prepared by the Cachuma Conservation Release Board staff. The studies are conducted in accordance with the Cachuma Project Biological Opinion and the Lower Santa Ynez River Fish Management Plan under a Memorandum of Understanding among the Cachuma Conservation Release Board, Santa Ynez River Water Conservation District Improvement District No. 1, Reclamation, and other parties.

Stream and Groundwater Monitoring as Part of Water Rights Orders

Releases from Bradbury Dam, stream flow, and groundwater adjacent to the Santa Ynez River are monitored by Reclamation and the USGS in accordance with State Water Resources Control Board Order WR 89-18. Results are analyzed and reported in annual reports by Reclamation and the Santa Ynez River Water Conservation District, which are available from these agencies.

Monitoring by Operators of Public Water Supply Systems

Water quality monitoring is required of each operator of a public water supply system. The Cities of Lompoc, Buellton, and Solvang, and the Santa Ynez River Water Conservation District Improvement District No. 1 each may operate wells close to the Santa Ynez River such that their water quality is influenced by the river. The water quality monitoring results from these wells may be obtained from the respective entity owning the well.

Monitoring by Operators of Sewage Treatment Plants

Water quality monitoring of discharge is required of each sanitary treatment plant operator that discharges to surface water. Records of such discharges are submitted to the Central Coast RWQCB and may be obtained from that agency.

Central Coast Ambient Monitoring Program

The Central Coast Ambient Monitoring Program is the Central Coast RWQCB's regionally scaled water quality monitoring and assessment program. The purpose of the program is to provide scientific information to Regional Board staff and the public, to protect, restore, and enhance the quality of the waters of central California.

The Central Coast Ambient Monitoring Program monitoring strategy for watershed characterization calls for dividing the Central Coast Region into five watershed rotation areas and conducting synoptic, tributary based sampling each year in one of the areas. Over a 5-year period, all of the Hydrologic Units in the Region are monitored and evaluated. In addition to the synoptic site selection approach, additional monitoring sites are established in each area to provide focused attention on watersheds and water bodies of special concern.

The program uses a variety of monitoring approaches to characterize the status and trends of coastal watersheds, including:

- Rapid bioassessment using benthic invertebrates
- Conventional water quality parameter analysis
- Chemical analysis of tissue, water, and sediment
- Toxicity evaluations
- Habitat assessments
- Sedimentation evaluations

Data are available on the organization's Web site: http://www.ccamp.org/ccamp/ccamp.htm.

Long-term Ecological Research Project

The Santa Barbara Coastal Long-term Ecological Research Project is focused on investigating the relative importance of land and ocean processes in structuring giant kelp forest ecosystems. As a component of this project, several researchers are focusing on characterizing nutrient loading and developing a model to predict future nutrient export from these watersheds resulting from projected changes in land use. Biweekly base flow and storm water are sampled from Gaviota, Refugio, Arroyo Hondo, Arroyo Burro, Mission, Santa Monica, Franklin and Carpinteria creeks (2003-04 program). Data are available through the Web site: http://sbc.lternet.edu/catalog/style/skins/sbclter/index.jsp.

Santa Barbara Channelkeeper

Santa Barbara Channelkeeper has established Stream Teams in both the Ventura and Santa Barbara area. The purpose of these teams is to monitor water quality and involve citizen volunteers in the protection of their local watershed while providing educational opportunities and fostering environmental stewardship. The Channelkeeper's Goleta Stream Team collects data at 11 sites throughout the Goleta Slough watershed on a monthly basis. Parameters measured by these teams of volunteers include dissolved oxygen, pH, conductivity, turbidity, temperature, flow, nitrate, orthophosphate, and indicator bacteria. Data and analysis are disseminated through the organization's Web site (www.stream-team.org), as well as a quarterly newsletter.

South Coast Watershed Characterization Study and Ongoing Monitoring

The County partnered with the City of Santa Barbara to evaluate water quality concerns through the South Coast Watershed Characterization Study in 1998. The four major creeks–Rincon, Sycamore, Mission, and Arroyo Burro–were sampled. The results identified indicator bacteria as the pollutant of concern in these watersheds. Since that time, the City has expanded its storm water monitoring program in order to better determine the sources and types of pollutants discharged to creeks and the ocean. Over the past 5 years, the City has sampled storm drains, creeks, lagoons, and ocean water. Dry weather efforts focus primarily on indicator bacterial pollution and physical parameters such as temperature, turbidity, and pH. To date, the City has identified specific storm drain outlets that are most likely to discharge urban runoff that contains indicators of certain contaminants.

As a result of sampling thus far, the City has identified known and suspected pollutants of concern. These pollutants are targeted with the implementation of best management practices identified in the City of Santa Barbara Storm Water Management Program. Indicator bacteria and total phosphorus have been identified as known pollutants of concern based on storm samples containing levels that are consistently above appropriate water quality criteria. Oil and grease is identified as a known pollutant of concern based on the occasional visual observation of oil sheens in creeks during periods of runoff.

Although there is no clear indication that other potential storm water pollutants (such as sediment, nitrate, pesticides, and certain metals) are present in detectable amounts, the City continually revises and improves its monitoring efforts in order to determine the presence and sources of storm water pollutants. In addition to its dry weather and storm monitoring program, in 2004, the City funded research partnerships with USGS and the University of California, Santa Barbara to begin identifying the sources of indicator bacteria and to develop better methods of monitoring the presence of harmful bacterial pollutants in surface waters. The City's reports on progress and findings are shared with other local agencies, nongovernmental organizations, and the public, on an annual basis as well as periodically through newsletters and individual mailings.

Agricultural Cooperative Monitoring Program

The Cooperative Monitoring Program represents a watershed approach to meeting monitoring requirements as set forth in the Conditional Agricultural Waiver. Fifty (50) sites on the Central Coast, including 14 sites in Santa Barbara County, are monitored on a regular basis to see whether implementation of farm-level water quality and environmental management practices are improving water quality.

5.2.3 Other Water Quality Improvement Programs

Local jurisdictions have a system of regulations to protect their waterways and the ocean from pollution and degradation. Additional local agency programs include:

- **Microbial Source Tracking Research.** Microbial source tracking is used to develop DNA-based tools for tracking fecal pollution in creeks and to identify sources of indicator bacteria. The City of Santa Barbara contracts with University of California, Santa Barbara, to conduct microbial source tracking.
- **Bioassessment.** Bioassessment uses benthic macroinvertebrate surveys and an index of biological integrity to assess and track the health of creeks for aquatic organisms.
- **Restoration and Water Quality Project Assessment.** Local agencies use restoration and water quality treatment assessment to determine the success of projects in lowering microbial and chemical pollution levels and improving water quality for aquatic organisms. Local agencies are examining the effectiveness of several creek restoration and water quality improvement projects that should result in decreased pollution levels, improved water quality parameters, or both. Many projects are in development, and baseline data is being collected presently for pre- and post-project comparisons.
- **Creek Cleanups.** While the relationship between garbage in creeks and water quality is unclear, it is apparent that cleaning debris from creeks helps to keep debris off beaches and out of the ocean. Local jurisdictions contract with an outside vendor to clean creeks on a weekly basis. Trash, furniture, appliances, bicycles, mattresses, and grocery carts are collected as well as any other material that does not belong in the creek.
- **Storm Drain Filters.** In an effort to clean water before it enters the City of Santa Barbara's water systems, 100 special storm drain filters have been installed in key

locations including the City's Yanonali Street Annex Yard and at the intersection of West Haley Street at Brinkerhoff. These filters capture debris, garbage, and sediment that otherwise would flow to the creeks.

- **Street Sweeping Program.** Several jurisdictions employ street sweeping programs to improve water quality by keeping trash, debris, and sediment out of storm drains and creeks.

5.2.4 Conservation Programs

Both regional and service area-specific programs that focus on water conservation activities occur in Santa Barbara County. Santa Barbara County's RWEP was established in December, 1990 to promote the efficient use of urban and agricultural water supplies in Santa Barbara County, and to provide information and assistance to the 18 local water purveyors within the County.

The RWEP provides coordination for cooperative efforts among purveyors, acts as a clearinghouse for information on water efficiency technology, manages specific projects, and monitors local, state, and national legislation concerning efficient water use. The RWEP is housed at the Santa Barbara County Water Agency, whose staff work cooperatively with water purveyor staff to implement conservation projects throughout the County. Individual water purveyors work with County staff on projects, as well as implement their own conservation programs within their service areas.

A multi-agency team of conservation staff meets regularly to ensure that water conservation goals are being met. In addition to the Santa Barbara County Water Agency, partnering water providers, who provide staff time or funding to regional programs include: City of Buellton, Carpinteria Valley Water District, Casmalia Community Services District, Cuyama Community Services District, Golden State Water Company, Goleta Water District, City of Guadalupe, La Cumbre Mutual Water Company, City of Lompoc, Los Alamos Community Services District, Mission Hills Community Services District, Montecito Water District, City of Santa Barbara, City of Santa Maria, Santa Ynez River Water Conservation District Improvement District No. 1, City of Solvang, Vandenberg Air Force Base, and Vandenberg Village Community Services District. Of these, the Carpinteria Valley Water District, City of Santa Barbara, City of Santa Maria, Goleta Water District, Montecito Water District, Santa Barbara County Water Agency, and Santa Ynez River Water Conservation District Improvement District No. 1 are also members of the California Urban Water Conservation Council, and are committed to implementing water conservation best management practices.

There are seven focus areas of conservation activities within Santa Barbara County:

- School Education
- Public Information
- Commercial, Industrial, and Institutional
- Landscape/Outdoor Water Use
- Residential/Indoor Water Use

- Agricultural
- Coordination/Administration

School Education

Regional school education programs include participation in the State of California Department of Water Resources (DWR) statewide Water Education Committee, free educational materials and curricula distribution to teachers, the Water Awareness High School Video Contest, a Book Bag Lending Program, and classroom presentations for K-12 grades. Through these programs, students and teachers gain exposure to water conservation ideas. Additional programs for individual water purveyor districts include an elementary school art contest and after-school program in Lompoc, and extensive classroom programs by many water purveyor staff in the Cities of Santa Barbara, Lompoc, Santa Maria, and in the Goleta, Carpinteria Valley and Montecito water districts.

Public Information

The RWEP and individual water purveyors work towards an integrated, cohesive message about the importance of water conservation countywide. This is accomplished through an annual Summer Media Campaign, a cooperative Web site (www.sbwater.org), interpretative signage along the Santa Maria Bike Path and at water purveyor facilities, and production and distribution of informative brochures and a regional newsletter. The regional group of purveyors has created a logo to promote a shared message, and this is used on publications, in public service announcements, and on the Web site. Water Awareness Month in May includes tours of local demonstration gardens and the City of Santa Barbara Desalination facility. Staff from many purveyors attend public events including Earth Day, Boy and Girl Scout activities, Lompoc Environment Fair, and others. All purveyors as well as the County Water Agency are available to respond to information requests by citizens.

Commercial, Industrial, and Institutional

Water efficiency in local businesses is an important target area for Santa Barbara's RWEP and water purveyors. Programs include the Green Awards Consortium, which honors businesses that save water among other environmentally friendly activities; a Lodging Industry Program, which distributes water-saving tips on door hangars and table tents to local hotels; as well as the Save Water, Save a Buck Rebate Program, which offers rebates to commercial, industrial, and institutional water users who retrofit their businesses with water efficient toilets, urinals, and clothes washers. Other programs include the Rinse and Save Program, which retrofits restaurants with efficient pre-rinse spray nozzles; the Conductivity Controller Retrofit Program, which rebates controllers on commercial cooling towers; and the Waterless Urinal Installation Program, retrofitting County facilities with waterless urinals. Water district and County staff work on these programs in varying capacities to provide an integrated commercial water efficiency program throughout the County.

Landscape/Outdoor Water Use

Landscape programs are a major focus of the RWEP and purveyor activities, because as much as 50 percent of customer water use often goes to outdoor water use. A weather-based irrigation controller program that retrofits residential landscapes with weather-based irrigation controllers is underway. The Green Gardener Program in Santa Barbara and Santa Maria offers classes to landscape professionals on green practices with an emphasis on efficient irrigation. Other cooperative programs include the Garden Wise Guys TV show, a locally produced television show on sustainable landscaping; the Landscape Water Budget Program, which provides customers with customized water budgets for their landscapes; and large landscape irrigation evaluations, provided by staff of the Cachuma Resource Conservation District staff. Landscape facilities include the Santa Maria Valley Sustainable Garden, which demonstrates technology and plantings that reduce water use; several "water-wise" installations at water purveyor facilities throughout the County; and five California Irrigation Management Information System network weather stations throughout the County, providing localized evapotranspiration data used in landscape programs. The City of Santa Barbara also uses a landscape ordinance to regulate the installation of new landscapes and ensures they are making efforts to reduce water use.

Residential/Indoor Water Use

Many local water purveyors provide in-home water checkups (audits) that educate customers about water efficient appliances and leak detection. In some cases, residential landscape audits are also offered. The RWEP Web site promotes these services and offers County residents a clearinghouse for residential and indoor water saving information. The City of Lompoc offers rebates on water efficient toilets, clothes washers, and dishwashers. The City of Santa Barbara and the City of Santa Maria offer free 2-gallon-per-minute showerheads to all city residents upon request.

Agricultural

RWEP partners work closely with the Cachuma Resource Conservation District to promote the Irrigation Evaluation Program on agricultural lands within the County. The District's mobile lab visits farms to evaluate water use and make suggestions for increasing efficiency. Staff analyze the distribution uniformity of the sprinklers; provide an estimate of seasonal evapotranspiration, effective rainfall, leaching, and irrigation water requirements; test pumping plants for energy efficiency; and measure the water quality by testing pH, electrical conductivity, nitrates, hardness, and iron in the irrigation water.

Coordination/Administration

The RWEP acts as a clearinghouse for water conservation information and programs. Tasks include surveying water providers and collecting data on water production and rates, water planning coordination including integrated regional water management planning and drought planning activities, and information sharing. Information sharing includes attending state and national meetings on topics related to water conservation, working closely with the California Urban Water Conservation Council on implementing programs and reporting on conservation activities, as well as coordinating among all the water purveyors within Santa Barbara County on cooperative programs within the RWEP. The

RWEP also provides information and training to local water conservation staff. This includes legislative updates, information on new water conserving technologies, reporting to local agencies on regional programs, and workshops on various water efficiency topics. The RWEP also serves an oversight role for shared conservation projects including financial management of shared grants and project management activities such as budgeting, scheduling, and logistics.

Multiple benefits result from using water efficiently, including saving energy, reducing flow into wastewater treatment facilities, and minimizing the need to develop new supplies, which comes with associated costs. Individual water consumers can also benefit by saving money on their water and energy bills when using water efficiently. The IRWMP includes projects that enhance existing conservation programs and will help increase water supply reliability, which is essential to effective regional water management for years in which water is in short supply.

5.2.5 Clean Marina Program

Nonpoint source pollution in the City of Santa Barbara Harbor is addressed through the Clean Marina Program. The program goal is to achieve and maintain, via feasible means and alternatives, a clean harbor environment for people, aquatic life, and seabirds. The Clean Marina Program requires annual review by the Harbor Commission. Program Elements include (1) facilities for boaters, (2) water quality monitoring, (3) best management practices, (4) pollution prevention and abatement projects, (5) education, and (6) compliance and enforcement. In 2006, Santa Barbara Harbor earned the "Clean Marina" certification from the state, one of only a handful of public marinas to have earned this distinction. Santa Barbara Harbor received a score of 96 percent, far exceeding the minimum requirement for Clean Marina certification.

Since 1997, landside harbor activities have been regulated under an NPDES General Industrial Storm Water Permit. This permit requires a Storm Water Pollution Prevention Plan, a comprehensive plan document, the goal of which is to prevent discharge of pollutants into the harbor. Under the plan, the harbor area is inspected quarterly, with areas or operations needing improvement noted and addressed.

5.2.6 Weed Management Programs

The Santa Barbara County Weed Management Area is a multiagency coalition concerned with the invasion of farms, rangeland, and native plant and animal habitat by non-native weeds. The Santa Barbara County Weed Management Area conducts invasive weed control projects and coordinates and educates members towards the common goal of reducing the impact of harmful non-native weeds and enhancing the viability of agricultural, horticultural, and native ecosystems in Santa Barbara County. The program recently has been involved with pampas grass control projects in the Goleta Slough and in the vicinity of the Arroyo Burro; it currently is working with the Carpinteria Creek Watershed Coalition on the rehabilitation of Carpinteria Creek for steelhead habitat and will be leading an effort to control *Arundo donax* and *Tamarix spp*. on the Santa Ynez River. The latter project is included in the IRWMP, which also contains projects to improve steelhead habitat in the Santa Ynez watershed and on the South Coast and improve riparian and other sensitive habitats in the Carpinteria area, Goleta Slough, Arroyo Burro, and elsewhere in the county.

Thus, the IRWMP is consistent with and may be used to obtain funding for projects proposed by the Santa Barbara County Weed Management Area.

5.2.7 Vector Control Programs

The Mosquito and Vector Management District is a local governmental agency providing multifaceted health and safety protection to the residents of Santa Barbara County including mosquito breeding source monitoring and control. Some of the projects included in the IRWMP would increase wetlands and other areas where mosquitoes may breed; therefore, project proponents will coordinate closely with the district to ensure that mosquito abatement issues are appropriately addressed.

5.2.8 City of Santa Barbara Watershed Action Plans

In 2004, the City of Santa Barbara's Creeks Restoration and Water Quality Improvement Division initiated the development of watershed action plans for the Arroyo Burro, Mission Creek, Sycamore Creek, and Laguna Creek watersheds, as part of the City's Creeks Restoration/Water Quality Improvement Program. A watershed action plan will be multi-objective and may cross jurisdictional boundaries, as it covers all water-related issues and resources, including flooding, bank stability, groundwater, creek restoration, fisheries and stream habitat enhancement, and water quality. A watershed action plan comprehensively looks at contributing factors and cause-and-effect relationships on a watershed-wide scale. It identifies and coordinates program and individual project development needs, aimed at solving identified problems (stressors), with the agencies in the best position to implement them.

6

6 Stakeholder Involvement and Coordination

6.1 Introduction

The Santa Barbara Countywide IRWMP has been developed through active stakeholder involvement in a collaborative process. The high level of participation from a broad spectrum of stakeholders has created a strong foundation for future cooperative planning and project implementation in the region.

Two stakeholder groups have worked together to develop the IRWMP. The Cooperating Partners who have guided and funded the planning process are made up of water and wastewater agencies and districts (including privately owned water companies), cities, joint powers authorities, and the County of Santa Barbara. Public stakeholders who have participated throughout the planning process include agricultural, environmental, academic, and disadvantaged communities. The organizational structure of the IRWMP is presented in Figure 6-1. State and federal agencies have played an advisory role.

6.2 Cooperating Partners Involvement

Agencies in Santa Barbara County have worked together to coordinate water-related activities for many years, including the formation of a joint powers agency to manage Lake Cachuma water and participation in the State Water Project through CCWA. Since May of 2002, a regional stakeholder group has been working together to identify and assess water related projects listed in local and regional planning documents.

In early 2006, Santa Barbara County initiated efforts to expand regional participation for the preparation of an IRWMP. All water management entities in the region were contacted and encouraged to participate in initial organizational meetings. These meetings resulted in the signing of a Memorandum of Understanding between the various agencies and organizations during the summer of 2006. These participants are known as the IRWMP Cooperating Partners.

The Cooperating Partners, listed in Section 1, represent all geographical areas of the region and virtually every governmental agency with responsibility for water resource management. Among all the special districts, only one very small community services district is not actively involved. Only one city is not participating, but it is neither a water purveyor nor a wastewater service provider because three participating special districts provide its citizens' water and wastewater needs. This broad level of support marks a new level of regional engagement.

The County of Santa Barbara Water Agency (Water Agency) has been the lead administrative agency throughout the development of the IRWMP. The Water Agency has been responsible for overseeing and guiding the consulting team preparing the IRWMP and coordination with Cooperating Partners. Approximately half of the cost of preparing the IRWMP was shouldered by the Water Agency, and the other half was split among the Cooperating Partners. Shared funding demonstrated the Cooperating Partners' commitment to the IRWMP process.

The Steering Committee of the Cooperating Partners is an inclusive and active committee made up of Cooperating Partners that have committed to participating in a leadership role in the development of the IRWMP. This has involved attending all or most of the Cooperating Partner meetings, contributing to document content, and participation in document review. Most Cooperating Partners have participated on the Steering Committee. Participation on the Steering Committee is voluntary.

The Cooperating Partners have met on a bimonthly or monthly basis with consistently strong representation from agencies and districts. These meetings have been open to the public in conformance with the Brown Act and announced 72 hours in advance on the IRWMP Web site, with agendas also posted at the meeting sites and at the County public notice bulletin board at the County Administration Building. Copies of meeting presentations and materials were provided to those in attendance and made available on the Web site. Copies of materials have been e-mailed to those Cooperating Partners not in attendance and other individuals or organizations upon request. Over 30 Cooperating Partner representatives attended the first meeting of the Cooperating Partners on September 28, 2006. The high level of participation has been steady throughout the planning process and is expected to continue in the months and years ahead. Cooperating Partners meeting notes are available for review on the IRWMP Web site.

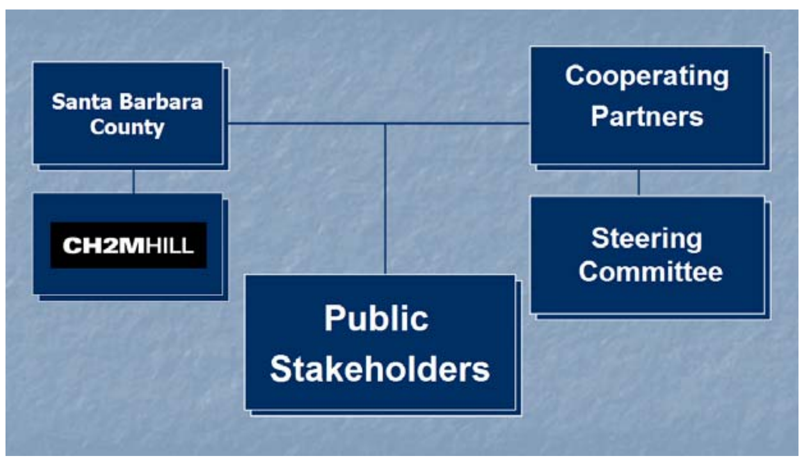

FIGURE 6-1
IRWMP Organization Chart

The "Outreach and Public Involvement Plan," developed in September 2006, guided the IRWMP outreach efforts. The meeting schedule for the Cooperating Partners and public stakeholders and the "Outreach and Public Involvement Plan" are provided in Appendix B.

6.3 Public Stakeholder Participation

Other participants in the development of the IRWMP include interested public stakeholders. The public stakeholders have participated in the planning of the IRWMP and influenced decisions by attending stakeholder workshops and Cooperating Partner meetings. This group has provided review and comments on development of objectives, water management strategies, regional priorities, key issues and challenges, the project evaluation process, the Draft IRWMP, and Final IRWMP. The public stakeholders represent the general public, the business community, disadvantaged communities, the media, and the agricultural, environmental groups, and academic institutions.

Public stakeholders include representatives from Heal the Ocean, Southern San Luis Obispo and Santa Barbara Counties Agricultural Watershed Coalition, Community Environmental Council, Santa Barbara Channelkeeper, Surfrider Foundation, Santa Barbara City Creeks Committee, Santa Barbara County Special District Association, Southern California Wetlands Recovery Project, Environmental Defense Center, and the Dunes Center.

6.3.1 Stakeholder Outreach Workshops

A total of eight public stakeholder outreach workshops were held during the development of the IRWMP. Each series of two workshops occurred alternately in a South County then North County location.

The workshop schedule was as follows:

- 1st Workshops – October 23 and 24, 2006
- 2nd Workshops – December 5 and 6, 2006
- 3rd Workshops – January 3 and 4, 2007
- 4th Workshops – April 23 and 24, 2007

At each public workshop, stakeholders were provided with comprehensive background materials and updated on the planning process (Figure 6-2) through both presentations and written materials. Dialogue and questions were encouraged and received throughout the presentations. Comments and questions were noted in meeting minutes and incorporated into the planning process, where appropriate. Public Feedback Forms were available at each meeting providing a means to submit comments in writing. Electronic comments also were encouraged. Copies of PowerPoint presentations from the public workshops are available on the IRWMP Web site.

Public notification of stakeholder outreach workshops occurred in advance of each workshop and utilized a variety of media outlets and public forums to convey meeting details. Media outlets and public forums included:

- Santa Barbara News-Press, Goleta Valley Voice, The Lompoc Record, Santa Barbara Daily Sound, Santa Maria Times, Santa Ynez Valley News, Santa Ynez Valley Journal, Santa Maria Sun, Santa Barbara Independent, Casa, and Family Life.

- Community facilities such as county and city office buildings and the Watershed Resource Center where fliers were posted. The notice from third Workshop series is included in Appendix B.
- Cooperating Partners' constituents and organizations were informed of the IRWMP process on a regular basis using mailings and meetings to both inform and encourage participation.
- The Carpinteria newspaper, Coastal View, published an article, written by County Water Agency staff, regarding the IRWMP process with an emphasis on the public and stakeholder component. The article was published on January 11, 2007.

6.3.2 Electronic Outreach

Several mechanisms and processes were used to expand stakeholder participation in the preparation of the IRWMP. The Cooperating Partners utilized contact names from existing contact lists to create the Master E-mail Outreach List.

The Master E-mail Outreach List included agricultural, watershed, wetland, environmental, nongovernmental organizations, community-based organizations, and other individuals.

In addition, stakeholders contacted other stakeholders, and the contact list grew to include an ever-widening circle of participants. For example, the Santa Barbara Surfrider Foundation regularly published notice of the Santa Barbara IRWMP public stakeholder meetings through their monthly newsletter that reaches over 2,000 people and organizations.

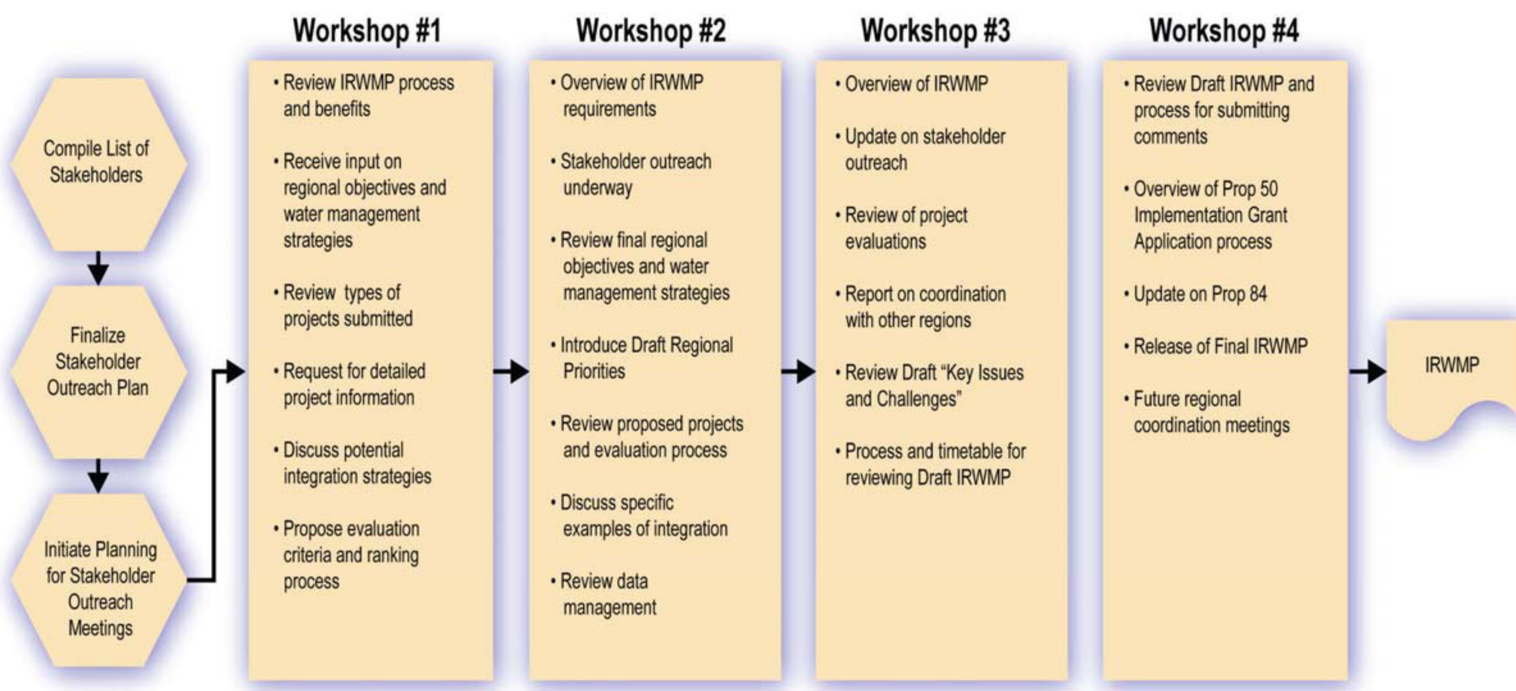

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FIGURE 6-2
IRWMP STAKEHOLDER PROCESS
SANTA BARBARA IRWMP

6.3.3 Dedicated Web Site

Santa Barbara County operates a Web site (www.countyofsb.org/pwd/water/irwmp.htm) dedicated to facilitating IRWMP communications with all stakeholders in the region.

The Web site includes the following information:

- Schedule for Cooperating Partner Steering Committee meetings, public stakeholder workshops, and major milestones for the project
- Draft IRWMP
- Final IRWMP
- List of Cooperating Partner agencies and organizations
- Meeting minutes and presentations
- Contact information
- Important documents relating to the development of the IRWMP
- Links to other regional planning efforts and pertinent state documents

Throughout the IRWMP process, the Web site presented various elements of the IRWMP including the proposed project list and project details, regional priorities, key issues and challenges, objectives, and water management strategies.

6.3.4 Targeted Outreach

Cooperating Partners conducted targeted outreach to various stakeholder groups to inform participants of the IRWMP process, encourage participation, and solicit feedback.

- **Santa Barbara County Task Force of the Southern California Wetlands Recovery Project** – The Task Force met Thursday, October 5, 2006. A representative from the Cooperating Partners attended, participated in a discussion, and answered questions regarding the Santa Barbara Countywide IRWMP. In addition to addressing the group, the Santa Barbara County Water Agency Manager briefed the chairman of the Task Force.
- **DWR/SWRCB Town Hall Meeting** – Santa Barbara IRWMP representatives attended a "Town Hall Meeting" with DWR and SWRCB sponsored by the Southern California Water Dialogue and the Los Angeles County Flood Protection Agency; the meeting focused on the Proposition 50 IRWMP planning and grant process.
- **Elected Officials and Agency Boards of Directors** – Elected officials have been engaged in the IRWMP process. The Memorandum of Understanding was approved by the boards of all 29 Cooperating Partners organizations, including the Santa Barbara County Board of Supervisors. A member of the Santa Barbara County Board of Supervisors attended the second Stakeholder Workshop in December 2006. The Santa Barbara County Water Agency Manager made a presentation to a joint meeting of the boards of two Cooperating Partners, Vandenberg Village Community Services District and

Mission Hills Community Services District, with attendance by Vandenberg Air Force Base staff.

- **City Creeks Advisory Committee** – The City of Santa Barbara Creeks Division staff was presented with information and received an IRWMP update in January 2007.
- **Creek Week** – IRWMP fliers were distributed, and announcements were made at Creek Week (from October 7 to 15, 2006), which is a week long event focused on protecting watersheds and improving water quality. It is sponsored by multiple county and city agencies and nonprofit organizations.
- **Santa Barbara County Agricultural Advisory Committee (AAC)** – Representing the Cooperating Partners, the Deputy Director of Santa Barbara County Flood Control, gave a presentation to the AAC on the proposal to develop an IRWMP to utilize funds authorized by Proposition 50. The AAC represents agricultural interests from throughout the county and it serves as a standing advisory group to the County Agricultural Commissioner's office. The AAC was interested in how agriculture was going to be represented in the development of the IRWMP and wanted to be assured that agriculture would not be negatively impacted. The AAC has received regular updates from the Santa Barbara County Water Agency Manager on November 9, 2006, and on February 8, March 8, and April 4, 2007.
- **University of California, Santa Barbara, Donald Bren School of Environmental Science and Management –** A representative of the Cooperating Partners made a presentation on the IRWMP to graduate students enrolled in the "Advanced Study of Water Policy" class taught by Dr. Robert Wilkinson.
- **Santa Barbara Special Districts Association –** A presentation on the IRWMP process was given to the monthly meeting of the Santa Barbara Special Districts Association, which includes organization's water issues and related topics such as vector control, public health protection, and other relevant topics. The presentation was given on February 26, 2007.
- **Goleta Slough Management Committee –** A presentation to the Goleta Slough Management Committee, a nonprofit group, took place on February 8, 2007.
- **Goleta Valley Chamber of Commerce** – A presentation on the IRWMP was made to the Goleta Valley Chamber of Commerce on February 22, 2007.
- **Chumash Tribe** – A representative of the Cooperating Partners has initiated dialogue on development of the IRWMP with the Chumash Tribe from the Santa Ynez Valley area. The Cooperating Partners recognize the need to expand this dialogue in the future.
- **Sanitation Agency Managers' Association** – The Santa Barbara County Water Agency Manager made a presentation to the Sanitation Agency Managers' Association encouraging participation by wastewater agencies.
- **Citizen's Planning Association –** The Santa Barbara County Water Agency Manager met with and gave a presentation to the Citizen's Planning Association in Lompoc on March 29, 2007.

6.3.5 Cooperation and Coordination with State and Federal Agencies

The Cooperating Partners Steering Committee has consulted with several state and federal agencies throughout the IRWMP process. Consultations have been initiated by direct contact or through general communications. (See Appendix B for November 21, 2006, e-mail from County of Santa Barbara to NGOs and state and federal agencies). These agencies include:

- **Department of Water Resources** - The Cooperating Partners have been in regular communication with DWR. Consultation with DWR was initiated with Tracie Billington, Division of Planning and Local Assistance, in January 2006 during the Tri-County IRWMP meeting with San Luis Obispo, Santa Barbara, and Ventura counties. Following consultations later in the year, Ms. Billington recommended that the Cooperating Partners utilize Natalia Deardorff, Environmental Scientist, Division of Planning and Local Assistance, the primary point-of-contact for the region. The Cooperating Partners have had regular communication regarding the IRWMP process with Ms. Deardorff. Ms. Deardorff attended the October 19, 2006, Cooperating Partners meeting in Santa Barbara. The Cooperating Partners had a special meeting with DWR staff including Tracie Billington, Joseph Yun, and Brett Wyckoff in Los Angeles on January 30, 2007, to review and receive feedback on the Initial Draft IRWMP. Consultations have continued with Ms. Billington and Ms. Deardorff throughout the planning process.
- **State Water Resources Control Board** – Initial contact was made with Shahla Farahnak, Director of the SWRCB Water Recycling Funding Program and primary Proposition 50 contact for the SWRCB, during a Southern California Water Dialogue meeting. Communications have continued with the Central Coast Regional Water Quality Control Board.
- **Central Coast Regional Water Quality Control Board** – The Santa Barbara IRWMP has coordinated with Corinne Huckaby, Sanitary Engineering Associate, Central Coast Regional Water Quality Control Board (RWQCB) in San Luis Obispo. Ms. Huckaby has reviewed an internal draft IRWMP (dated 1/12/07) and made several suggestions regarding the appropriate balance of types of projects, the need to be specific and detailed, and the need for matching funds. She also has suggested incorporating more water quality projects and mentioning the watershed working groups that are associated with various water quality projects.
- **Vandenberg Air Force Base** – Communications with Vandenberg Air Force Base were initiated in early October 2006 by the County of Santa Barbara (representing the Cooperating Partners). Relevant planning documents were requested from Vandenberg Air Force Base. Base staff attended a December 11, 2006, presentation on the IRWMP and committed to provide the county with relevant water planning documents. In 2007, the County received pertinent planning documents. Vandenberg Air Force Base has been informed about projects with potential to impact the base or those that would benefit from base participation.

6.3.6 Outreach to Other Regions

The Santa Barbara Countywide IRWMP process included several meetings and interactions with neighboring regions.

- **Tri-County Meeting, January 25, 2006 –** The "IRWMP Opportunities and Challenges Workshop" included participation by San Luis Obispo, Santa Barbara, Ventura, and the Greater Los Angeles regions and was held on January 25, 2006, in Santa Barbara County. Representatives from the State included Tracie Billington, DWR; Scott Couch, State Water Board; and Bill Hoffmann and Macaria Flores, Regional Water Boards. This meeting provided an opportunity to discuss differing IRWMP approaches being undertaken in each region, the potential of future consolidation of regions, the use of watershed versus county boundaries, and regional goals and objectives.

  Following a presentation by Tracie Billington, DWR, a panel discussion ensued entitled "Future of Integrated Regional Water Management Planning in California and Related Benefits." The panelists included: E.J. Remson, The Nature Conservancy, presenting the habitat and preservation perspective; Paavo Ogren, San Luis Obispo County, presenting his views from the regional water management perspective; Tracie Billington, DWR, presenting the state perspective on IRWM planning; and Don Davis, City of Ventura, presenting the local government perspective. Other speakers included Mark Hutchinson, San Luis Obispo County; Kate Rees, Santa Barbara County; Lynn Rodriquez, Ventura County; and Tom West, Greater Los Angeles region.

- **Watersheds Coalition of Ventura County** – The Cooperating Partners consulted with and attended meetings of the Watersheds Coalition of Ventura County (Coalition). Specifically, the Santa Barbara County Water Agency Manager attended the October 5, 2006, Coalition meeting.

  Representatives from the Cooperating Partners met with Lynn Rodriquez, Project Manager for the Watersheds Coalition of Ventura County IRWMP, on December 5, 2006, to discuss the Ventura IRWMP process and details for another Tri-County meeting in January 2007. Ms. Rodriquez also attended the public stakeholder meeting on December 5, 2006, in the South Coast region. She shared many of her "lessons-learned" and experiences with the over 25 people gathered to learn more about the Santa Barbara IRWMP. Ms. Rodriquez also attended the January 17, 2007, Cooperating Partners meeting.

- **Central Coast Regional Meeting** – Representatives of the Santa Barbara IRWMP Cooperating Partners have participated in multiple meetings throughout 2007 with Central Coast Region representatives. The meetings have included agency representatives from the Central Coast region including Santa Cruz County, Pajaro Valley Water Management Agency, Salinas Valley, Monterey County Water Resources Agency, Monterey Peninsula Water Management District, San Luis Obispo County, and Santa Barbara County. Agreement has been reached by all parties that long-term interests are best met by working together to develop a coherent approach to benefit all planning subregions within the Proposition 84 Central Coast funding area.

6.3.7 Outreach to Disadvantaged Communities and Environmental Justice Concerns

The Steering Committee of the Cooperating Partners has been working with several disadvantaged communities (DACs) in the region to help them become part of the IRWMP process and to ensure submittal of projects. Section 2.4 contains a discussion on DACs, and Section 6 includes details on DAC projects.

A potential obstacle to implementing this part of the IRWMP is that the DACs lack the staff and expertise to engage effectively in the planning and grant applications process. The Cooperating Partners recognize that one or more of the Cooperating Partners will need to take a lead role in working with each DACs to support project planning and implementation.

- City of Guadalupe – The City of Guadalupe is in the northwestern extremity of Santa Barbara County, immediately south of the Santa Maria River. The Steering Committee has been in contact with the consulting engineering firm that represents Guadalupe. Two representatives from Guadalupe attended the first Cooperating Partners meeting. The City has inferior water and wastewater services that are in need of upgrading. The IRWMP includes the "Guadalupe Wastewater Treatment Plant Reuse Improvements Project," which will provide treatment improvements, new effluent transfer capability, and potential improvements to a 20-acre wetland site located within the city limits.
- Cuyama – Cuyama is located in the northeastern corner of Santa Barbara County. The Cooperating Partners have been in consultation with the Manager of the Cuyama Community Services District. In addition, he attended the first Stakeholder Workshop in Santa Maria. The Cuyama Community Services District has proposed the "Wastewater Treatment Plant Effluent Disposal Project." This project involves installing two percolating ponds for effluent disposal instead disposing the effluent into Salisbury Creek. The disposal into Salisbury Creek will result in mandatory penalties, starting by March 31, 2007, and which the district can ill afford.
- Casmalia – Casmalia is located north of Vandenberg Air Force Base. The area has significant environmental justice issues that were underscored in December 2006 when bacterial contamination of drinking water supplies resulted in a "boil water" order. The water supply system in Casmalia needs to be upgraded in order to prevent similar incidents in the future. The Director of the Santa Barbara County Laguna Sanitation District has been working with the Director of the Casmalia Community Services District to help identify needs and options. A project is proposed to replace deficient infrastructure such as water pipelines and tank facilities, update buildings and facilities to comply with design and code requirements, and make improvement to the existing well facility.

7

7 Key Issues, Plan Objectives, Regional Priorities, and Water Management Strategies

IRWMP objectives and regional priorities were established by the Cooperating Partners to address the key issues requiring regionwide solutions, as well as those affecting individual watersheds. Water management strategies also were identified to be used in resolving those issues. While the explicit statement of these strategies is new, addressing them is not. Given ongoing efforts to meet identified local water supply, water quality, and environmental protection concerns, much has been accomplished over the past few decades. The focus of these efforts has been, and continues to be, ever-improving efficiency of water use, improving water treatment, attaining water quality standards, and enhancing habitats. Currently, for the purpose of seeking integrated regional water management funding from the state under Proposition 50, the Cooperating Partners decided that grant requests should focus on two major needs:

1. Meeting water quality objectives in the central and northern parts of the county to increase effluent reuse and improve quality of groundwater return flows and surface discharges

2. Meeting water supply efficiency and reliability in the southern part of the county

The relationship between regional objectives, priorities, strategies, and existing needs is discussed in this section.

7.1 Key Regionwide and Watershed-specific Issues

7.1.1 Overview

As described in Section 5, a number of existing plans, programs, and agreements have resulted in the effective management of many Santa Barbara water resources. However, areas of concern remain, particularly in relation to:

- The need to replace, rehabilitate, or upgrade aging infrastructure serving the general population and especially disadvantaged communities

- Risk of illness, especially in disadvantaged communities, from inadequate drinking water and pollution from wastewater

- Water supply reliability, stemming from multiple factors, including the variable reliability of State Water Project water, the loss of storage capacity in the four major reservoirs, and the need for water supplies to serve a growing population

- The need to operate and maintain water and wastewater systems in a manner that minimizes impacts to sensitive habitats and species and complies with federal, state, and local regulatory requirements

- Overdrafted groundwater basins in North County
- Water quality impairments in both groundwater and surface water bodies, including pollution of creeks and ocean water, especially from sediment runoff
- Potential harm to people and property from flooding
- The need for emergency planning to address potential impacts to water and wastewater facilities from floods, earthquakes, fires, as well as planning for (and responding to) periodic droughts

7.1.2 Regionwide Issues

The regionwide issues are consistent with the initiatives for ensuring reliable water supplies identified in the California Department of Water Resources (DWR) *California Water Plan 2005*; that is, implementing integrated regional water management and improving areawide water management systems.

The following describes those issues that are considered most critical to the entire region.

- **Emergency Response**. Water supplies or water quality could prove to be inadequate during emergencies. The ability to provide water service during severe emergencies (for example, earthquake, large wildfire, or extreme drought) may be reduced through damage to infrastructure or a shortage of supplies in a given area, resulting in potential adverse health and safety impacts.
- **Regionwide Water Management System**. Numerous challenges are inherent in managing a complex, integrated, regional water supply system that moves water from one end of the region to the other in order to meet community needs. Water supply reliability needs to be increased given limited and variable water supplies and periodic droughts.
- **Water Quality Standards**. Water management entities responsible for ensuring acceptable water quality for both public health protection and environmental stewardship must comply with increasingly stringent state and federal water quality requirements, including those for impaired water bodies, while also respecting property rights.

The current integrated regional water management commitment will extend for at least the next several years. As the planning process continues to meet the goals of efficient water utilization and improving water quality, it will remain viable and ongoing. In the short-term, the integrated regional water management process has identified the region's primary needs as more efficient water use through improved water and wastewater treatment in the northern and central portions of the county; and increased reliability and efficiency through conjunctive use and system flexibility in the southern portion.

7.1.3 Watershed-specific Issues

On a watershed-specific basis, water issues evident in one location may be similar or even identical to issues in another area, but the most pressing water-related problems vary considerably from watershed to watershed within the IRMWP planning region. The following issues are those currently considered to be the most important in each watershed.

These are also those of importance to the state as a whole, involving public health issues facing disadvantaged communities (DACs); public safety impacts from flooding, surface water (including ocean water) and groundwater quality impacts from point sources and nonpoint sources; environmental protection; water rights; water supplies; the need to comply with regulatory requirements; and water supply reliability.

Santa Maria River and Cuyama River

Public Health. The public faces risk of illness, especially in DACs, from inadequate drinking water and pollution from wastewater. A number of water bodies are impaired, and groundwater has elevated levels of nitrates in some areas.

Public Safety. People and property may experience potential harm from flooding.

Groundwater Overdraft. The Cuyama Groundwater Basin is in overdraft, causing increased pumping lift for agricultural users.

San Antonio Creek

Public Health and Environmental Protection. Sedimentation of creeks is a concern.

Groundwater Overdraft. The San Antonio Groundwater Basin is in overdraft, causing increased pumping lift for agricultural users.

Jalama Creek

Public Health and Environmental Protection. Surface water quality in Jalama Creek and the ocean may be affected as a result of saturation of the leach fields at Jalama Beach.

Santa Ynez River

Integrated Water Management. A State Water Resources Control Board (SWRCB) decision is needed on the Cachuma Project water rights permits that support those elements of the Cachuma Project Settlement Agreement under its jurisdiction to facilitate integration of water supply, downstream water rights, and public trust resources.

Water Supply Reliability. Issues include reliance on the Lompoc Uplands Groundwater Basin, in the face of growth, as a single water source; lack of diversity in viable water sources in City of Solvang; and water supply source management and interconnection between Santa Ynez River Water Conservation District Improvement District No. 1 and Solvang.

Public Health and Environmental Protection. Issues include the need to comply with emerging wastewater discharge standards; water quality problems in shallow groundwater in the Santa Ynez Uplands; and control of noxious weeds along the Santa Ynez River.

Groundwater Overdraft. Further study of the hydrology of the Lompoc groundwater basins is needed, especially as it relates to potential overdraft in the Santa Rita subbasin.

South Coast (Multiple Small Creek Watersheds)

Water Supply Reliability. Issues include difficulty meeting peak demands; aging infrastructure, which constrains system operability; and insufficient integration of adjacent systems.

Public Safety. People and property may experience potential harm from flooding.

Public Health and Environmental Protection. Pollution of creeks and coastal waters could result from nonpoint sources and point source runoff during rain events.

7.2 IRWMP Objectives

The IRMWP objectives described below were adopted by the Cooperating Partners and reflect those four minimally required by the state: water supply, groundwater management, ecosystem restoration, and water quality. These objectives were refined to more specifically describe how the objectives should be met in light of regional issues. The four mandatory objectives also were augmented by the Cooperating Partners to reflect regional needs. Emergency preparedness was added to reflect ongoing risks to the county from droughts, other water shortages, and emergencies such as earthquakes, floods, and fires. The Cooperating Partners' interest in emergency response also has been heightened by awareness of the Hurricane Katrina experience in New Orleans. Infrastructure efficiency and reliability also was added to address the need for the replacement and rehabilitation of water and wastewater infrastructure to increase its reliability and use water resources more efficiently. Such activities are essential to the delivery of adequate water and wastewater services within the county and often result in benefits to areas targeted by the state, including water supply, groundwater management, ecosystem restoration, and water quality. For example, distribution system upgrades can both improve water quality and reduce water loss, and thus the need for imported water supplies. This objective also is consistent with the California Water Plan Update 2005, which lists maintaining and improving statewide water management systems, including improving aging facilities, as one of the state's key initiatives.

The following are the regional objectives developed for this IRWMP; those with asterisks are required by the state. Emergency preparedness and infrastructure efficiency and reliability are objectives that were developed to reflect regional needs.

*Water Supply**

Protect, conserve, and augment water supplies.

- Improve water supply reliability
- Improve system flexibility and efficiency
- Enhance local water supplies through groundwater recharge projects, conjunctive use of water supplies, water recycling, water conservation, water transfers, and precipitation enhancement
- Meet demands

- Optimize existing storage capacity
- Capture and manage runoff
- Match water quality to water use
- Desalinate seawater and brackish groundwater for reuse
- Ensure fire protection capacity
- Support appropriate recreational activities

*Groundwater Management**

Protect current and future groundwater supplies.

- Promote sustainable groundwater use
- Utilize conjunctive use
- Implement groundwater banking
- Protect and improve groundwater quality
- Implement groundwater recharge projects

*Ecosystem Restoration**

Protect and restore habitat and ecosystems.

- Protect, restore, and enhance natural processes and habitats
- Enhance recreational and educational opportunities

*Water Quality**

Protect and improve groundwater, freshwater, brackish water, ocean water, and drinking water quality.

- Meet current and future state and federal water quality standards
- Improve the quality of urban runoff, storm water, and wastewater
- Reduce erosion and sedimentation
- Utilize seawater desalination as appropriate
- Protect public and aquatic ecosystem health
- Support appropriate recreational activities

Emergency Preparedness

Ensure secure water supplies by helping local water purveying districts address the impacts of future droughts, other water shortages, and emergencies such as earthquakes, floods, and fires.

- Implement groundwater banking and conjunctive use programs and needed facilities improvements
- Maintain infrastructure and operational flexibility
- Augment surface storage
- Implement flood control measures
- Ensure emergency drinking water availability

Infrastructure Efficiency and Reliability

Maintain and enhance water and wastewater infrastructure efficiency and reliability.

- Systematically and strategically rehabilitate and replace aging water and wastewater delivery and treatment facilities
- Ensure fire protection capacity

7.3 Regional Priorities

Short-term and long-term regional priorities were defined by the Cooperating Partners in order to provide more specific direction regarding the types of projects and programs that should be implemented to meet IRWMP objectives. Short-term priorities are those that are expected to be implemented within 5 years. Long-term priorities are those expected to be implemented after 5 years, *but the short-term priorities will continue to be important in the more distant future, as well; thus, there is overlap between short-term and long-term priorities.* The regional priorities are inherently integrative because they help meet regional objectives. For example, reducing the potential for flooding can involve water supplies, groundwater management, ecosystem restoration, water quality, emergency preparedness, and infrastructure efficiency and reliability, depending on the methods used.

These priorities are based on identified needs and anticipated future challenges. For example, some major facilities such as levees and regional distribution systems are over 50 years old and need to be upgraded or rebuilt. Other facilities are believed to be susceptible to substantial damage in seismic events, potentially leaving the area without adequate water supplies during the key emergency response period. These priorities reflect the need for “new” projects/initiatives. These do not reflect the substantial effort being made to meet ongoing public needs and protect the local environment. Those efforts are briefly described in Sections 2 through 5 and are assumed to continue. The short-term and long-term priorities described below are not listed in order of importance.

7.3.1 Short-term Priorities (5 years)

- Protect public safety by reducing the potential for flooding in strategic areas through infrastructure improvements such as levee reinforcement, channel modifications, floodplain restoration, and increasing reservoir storage capacity.
- Increase water supply reliability by developing new water sources; maximizing the efficient use of existing sources, including recycled water used for landscaping, irrigation, industrial and commercial purposes, desalinated water, conservation, and groundwater treatment; and strategically restoring or replacing water infrastructure.
- Strategically restore and replace wastewater infrastructure to improve wastewater quality, limit the potential for adverse impacts to water quality and sensitive environmental areas through accidental releases, increase wastewater management efficiency, and meet regulatory requirements.
- Ensure the adequacy of water and wastewater facilities in disadvantaged communities (Guadalupe, Cuyama, and Casmalia).
- Improve surface and ocean water quality and reduce beach closures by replacing septic systems with sanitary sewer connections, ensuring the integrity of wastewater collection systems near the ocean and surface water bodies, improving the quality of urban runoff, reducing the amount of urban runoff that enters the ocean and surface water bodies, and developing public education programs to increase awareness of the measures individuals can take to improve water quality.
- Further define sources of groundwater contamination and develop strategies to prevent groundwater contamination and improve groundwater quality in areas with known contamination.
- Protect, restore, and enhance ecological processes in aquatic areas through water quality improvements; public education; restoration efforts, including removal of invasive species; and improved steelhead passage on strategic creeks.
- Ensure the adequacy of water supplies during droughts and emergencies such as fires, floods, and earthquakes through strategic replacement and rehabilitation of critical infrastructure.
- Develop programs and policies to increase groundwater recharge or decrease groundwater use, especially in overdrafted groundwater basins.
- Encourage cooperation in beginning to develop groundwater banking programs.

7.3.2 Long-term Priorities (5 to 20 years)

- Provide adequate water and wastewater services to meet projected growth.
- Implement regional and/or interagency conjunctive use and groundwater banking programs where supported by legal decisions and landowners.
- Promote programs, policies, and infrastructures to increase water supply sustainability through artificial recharge of local groundwater basins.

- Maximize storage capacity of existing surface reservoirs.
- Optimize the use of seawater desalination to increase water supply reliability and offset groundwater use.
- Expand distribution systems to provide recycled water to new users.
- Expand voluntary water conservation programs for residential, commercial, industrial and agricultural uses.
- Continue interagency coordination to develop opportunities to further integrate the management of water and wastewater projects and programs.
- Continue to coordinate with adjacent counties to develop strategies and programs that improve the management of regional water resources.

7.4 Water Management Strategies

The state IRWMP Guidelines identify the following 20 potential water management strategies to be considered as methods to meet the objectives identified in Section 7.1. Those marked by an asterisk must be considered to meet the minimum IRWMP standards.

Ecosystem Restoration*
Environmental and habitat protection and improvement*
Water Supply Reliability*
Flood management*
Groundwater management*
Recreation and public access*
Storm water capture and management*
Water conservation*
Water quality protection and improvement*

Water recycling*
Wetlands enhancement and creation*
Conjunctive use
Desalination
Imported water
Land use planning
Nonpoint source pollution control
Surface storage
Watershed planning
Water and wastewater treatment
Water transfers

These strategies were considered by the Cooperating Partners, as were the 25 resource management strategies identified in the State of California Department of Water Resources (DWR) California Water Plan Update 2005. Those most applicable to Santa Barbara County needs are included in the IRWMP, including those that are mandatory. These represent strategies that are already being implemented through local planning processes, such as General Plans, Urban Water Management Plans, Capital Improvement Plans/Master Plans, Groundwater Management Plans, Drought/Conservation Plans, Storm Water Management Plans, and Operational Agreements, and those that will continue to be implemented through specific projects identified in Section 8 and Appendix C. The list of water management strategies included in the IRWMP, modified to reflect regional issues, is shown below; each strategy is followed by a brief discussion of some of the integrated benefits that could result from its use. The use of strategies with multiple benefits clearly increases water planning efficiency in a cost-effective manner.

Environmental and Habitat Protection and Improvement

- Ecosystem restoration
- Wetlands enhancement and creation
- Watershed planning

Integrated Benefits

As described in the California Water Plan Update 2005 (DWR, 2005), ecosystem restoration can "improve plant and animal life, increase diversity and connectivity of habitat, help endangered species, and improve watersheds. Restoration can rehabilitate natural processes to support native communities with minimal ongoing help. Restored habitats are likely to help sustain reproduction, foraging, shelter, and other needs of fish and wildlife species… As ecosystem restoration actions help increase the health and abundance of species protected under the state and federal Endangered Species Acts, there might be fewer Endangered Species Act conflicts. As ecosystems such as wetlands and sloughs are restored, their natural pollutant filtering capabilities can improve water quality. As floodplains and seasonal lakes and ponds are restored, groundwater recharge can increase. The result will be a more reliable, higher quality water supply supported by a sustainable ecosystem. The economic benefits that improved rivers, estuaries, wetlands, wildlife, beaches, and their surrounding habitats can have in the state may far exceed the investments for restoring ecosystems." The California Water Plan Update 2005 continues, "Considering California lifestyle trends and travel and tourism as the major growth industry for the state, investments in ecosystem restoration actions may provide a high return on investment. Second only to the state's beaches, rivers are the biggest attraction for California's recreation industry. Similarly, managed wetlands and wildlife refuges provide bird watching and hunting opportunities that contribute hundreds of millions of dollars annually to California's economy."

Watershed management also results in multiple, integrated benefits through preserving ecological functions and processes while considering natural cycles (hydrologic, nutrient, and life cycles) when designing projects. The California Water Plan Update 2005 gives the following example: "elevated stream temperatures are often identified as a problem. Promoting groundwater accretion to streams and improving riparian cover often cools stream temperatures. Designing projects to allow more water to soak into the ground, less water to sheet off as runoff, protecting the soil surface from erosion by planting native plants, and stabilizing stream channels with vegetated buffers brings the stream more in line with the natural watershed cycles and sustains important ecological processes."

In addition to ecological benefits, use of this strategy can reduce the potential for flooding through the restoration of floodplains, including the removal of invasive weeds that restrict flood flows. This strategy also can improve water quality by maintaining natural vegetated stream buffers that filter pollutants and nutrients. Restoration also can stabilize creek banks, reducing erosion and resulting water quality impacts. Ecological benefits also can result from improvements to wastewater infrastructure by reducing the potential for spills into sensitive habitats and water bodies. Santa Barbara County's creeks discharge to the ocean, and impaired creek water quality also affects the water quality of the ocean in the vicinity of public beaches. Thus, improving creek water quality can improve ocean water quality and have recreational benefits. Restored ecosystems can have additional educational benefits by enhancing opportunities for activities such as bird watching and informing the public of ecosystem restoration benefits.

Surface Water Management

- Flood protection and management
- Storage (storm water capture and management)
- Banking/conjunctive use
- Urban runoff management

Integrated Benefits

Flood protection and management and storage provide multiple benefits by reducing risks to life and property and enhancing natural resources. Twitchell Reservoir, for example, is managed for both flood protection and groundwater recharge; and other reservoirs are managed for multiple purposes as well, including water supply and ecological benefits.

The banking and conjunctive use of surface water resources increases the reliability of water supplies by using or banking surface water for later use during dry years when local water is not available. This strategy can reduce the demand for groundwater, allowing the replenishment of local water supplies, and it can improve groundwater quality by banking higher quality water, such as State Water Project water.

Urban runoff management, including nonpoint source pollution management, can improve water quality, which has ecological benefits (for example, benefits to wetlands and other important aquatic and terrestrial ecosystems), and it can improve recreational opportunities and health benefits by reducing beach closures. Furthermore, capturing storm water in appropriately designed detention basins and filter swales results in several beneficial functions; flood management by reducing storm flows, erosion and sedimentation control by slowing storm water runoff, and water quality improvement through the natural benefits of absorption and filtering and settling water. This strategy also can protect groundwater quality.

Groundwater Management

- Recharge area protection
- Conjunctive use
- Groundwater remediation and aquifer remediation

Integrated Benefits

The benefits of conjunctive use are described under Surface Water Management. Recharge area protection can have ecological benefits in addition to protecting groundwater supplies. Groundwater and aquifer remediation also have water quality, supply, and reliability benefits, and local groundwater supplies serve as a stable regional water supply during disaster recovery.

Imported Water

- Increase reliability

Integrated Benefits

Imported State Water Project water has increased the reliability of local supplies, but has variable reliability; other strategies, such as the use of recycled water and groundwater banking, are used to increase the reliability of State Water Project supplies. Banking State Water Project supplies can improve local groundwater quality.

Water Supply Reliability

- Conjunctive use
- Precipitation enhancement
- Water conservation
- Water transfers
- Sharing facilities to efficiently manage infrastructure
- Emergency drinking water availability

Integrated Benefits

Precipitation enhancement is used to increase surface water supplies, which can lead to increased groundwater recharge (for example, by increasing the amount of water stored in Twitchell Reservoir) and reduced reliance on groundwater in some areas. Water conservation reduces the need for additional imported supplies, increases water supply reliability, and minimizes the amount of water and wastewater treatment required. Water conservation also meets the state's goal of using state water resources more efficiently. Sharing facilities to efficiently manage infrastructure reduces the need for additional construction, which can have adverse environmental impacts (for example, impacts to air quality, biological resources, and cultural resources), as well as high costs. Emergency drinking water availability is of critical concern in Santa Barbara County due to its history of floods, fires, and earthquakes.

Drinking Water – Treatment and Distribution

Integrated Benefits

Ensuring the adequate treatment and distribution of water is an essential strategy that is critical to the health and well-being of all residents of Santa Barbara County.

Water Quality Protection and Improvement

Integrated Benefits

Water quality protection and improvement are discussed above under Environmental and Habitat Protection and Improvement, Surface Water Management, Groundwater Management, and Imported Water.

Matching Water Quality to Water Use

Integrated Benefits

This strategy would allow water to be used in an efficient manner (for example, by using recycled water to irrigate landscaping), which minimizes the need to develop new water supplies or use existing water supplies; it also potentially reduces the amount groundwater required for higher or more beneficial uses. This strategy also may reduce the amount of treatment needed. For example, by water matching quality for agricultural and in-stream uses, water treatment may be avoided. For drinking water, appropriately matching high quality source waters can reduce the levels of pollutants and pollutant precursors that cause health concerns in drinking water. Additionally, less costly treatment options can be used when water utilities start with higher quality source waters, and water supply reliability can be enhanced simultaneously.

Water Recycling – Treatment and Distribution

Integrated Benefits

Use of recycled water can provide multiple benefits (DWR, 2005), including:

- Providing a more reliable local water supply
- Providing organic matter for use in agricultural soil conditioning and allowing for a reduction in fertilizer use
- Reducing the discharge of pollutants to water bodies, beyond levels prescribed by regulations, and allowing more natural treatment by land application
- Providing a more secure water supply during drought periods
- Providing economic benefits resulting from a more reliable water supply
- Improving groundwater and surface water quality and contributing to wetland and marsh enhancement
- Providing energy savings (the use of recycled water as a local source may offset the need for more energy-intensive projects to import water)

Desalination

- Seawater
- Brackish
- Reuse

Integrated Benefits

Use of desalinated water could minimize the need for other surface and groundwater supplies; associated benefits are described under Surface Water Management and Groundwater Management. In addition to proving an increased, more diversified water supply in general, more high quality potable water would be available during droughts, which could protect public health.

Recreational Opportunities

Integrated Benefits

Enhancing recreational opportunities can occur through Environmental and Habitat Protection and Improvement, where improvements are specifically designed for that purpose and can be an additional benefit of managing urban runoff. (For example, ocean water quality could be improved, reducing the number of beach closures).

Water and Wastewater Treatment

Integrated Benefits

Ensuring adequate water and wastewater treatment is an essential strategy that is critical to the health and well-being of all residents of Santa Barbara County. Several of the wastewater treatment plants in the county produce recycled water, which offsets use of potable water sources. This increases water supply reliability, matches water supplies with the appropriate use, and potentially reduces the impacts that could result from using surface water and groundwater supplies. Treated effluent also can be used for ecosystem restoration purposes. Water treatment also can be used to enhance water supplies; for example, by treating groundwater that was otherwise not usable.

Economic Incentives

Integrated Benefits

Economic incentives can be used to encourage water conservation, which reduces the need for additional imported supplies, increases water supply reliability, and minimizes the amount of water and wastewater treatment required. Reducing water demands may create environmental or social benefits, and avoid or delay construction of new water supply projects, which would avoid any environmental impacts resulting from their construction.

7.5 Water Management Strategies and their Integration with Objectives and Regional Priorities

Tables 7-1 and 7-2 illustrate the integration between the IRWMP objectives, regional priorities, and water management strategies. Water management strategies that could be used to implement each regional priority are shown, as are the objectives that could be met by the use of these strategies to meet regional priorities, depending on the specific methods used.

TABLE 7-1
Integration of Water Management Strategies, Regional Priorities, and Objectives – Short-term Priorities (5 Years)

Regional Priorities	Water Management Strategies Used	Objectives Met					
		Water Supply	Ground-water Manage-ment	Eco-system Restoration	Water Quality	Emergency Prepared-ness	Infra-structure Efficiency and Reliability
Short-term Priorities (5 years)							
Reduce the potential for flooding in strategic areas through infrastructure improvements such as levee reinforcement, channel modifications, floodplain restoration, and increasing reservoir storage capacity	Surface water management Environmental and habitat protection and improvement Watershed planning	X	X	X	X	X	X
Increase water supply reliability by developing new water sources; maximizing the efficient use of existing sources, including recycled water used for landscaping, irrigation, industrial and commercial purposes, desalinated water, conservation, and groundwater treatment; and strategically restoring or replacing water infrastructure.	Imported water/increase reliability Water supply reliability Drinking water—treatment and distribution Water quality protection and improvement Matching water quality to water use Water recycling—treatment and distribution Desalination Water treatment Economic incentives	X	X		X	X	X

TABLE 7-1
Integration of Water Management Strategies, Regional Priorities, and Objectives – Short-term Priorities (5 Years)

Regional Priorities	Water Management Strategies Used	Objectives Met					
		Water Supply	Ground-water Manage-ment	Eco-system Restoration	Water Quality	Emergency Prepared-ness	Infra-structure Efficiency and Reliability
Strategically restore and replace wastewater infrastructure to improve wastewater quality, limit the potential for adverse impacts to water quality and sensitive environmental areas through accidental releases, increase wastewater management efficiency, and meet regulatory requirements	Water and wastewater treatment Environmental and habitat protection and improvement Water quality protection and improvement	X	X	X	X	X	X
Ensure the adequacy of water and wastewater facilities in disadvantaged communities (Guadalupe, Cuyama, and Casmalia)	Water and wastewater treatment Drinking water -- treatment and distribution Water supply reliability	X	X		X	X	X
Improve surface and ocean water quality and reduce beach closures by replacing septic systems with sanitary sewer connections, ensuring the integrity of wastewater collection systems near the ocean and surface water bodies, improving the quality of urban runoff, reducing the amount of urban runoff that enters the ocean and surface water bodies, and developing public education programs to increase awareness of the measures individuals can take to improve water quality	Environmental and habitat protection and improvement Surface water management Water quality protection and improvement Recreational opportunities Watershed planning	X		X	X		X

TABLE 7-1
Integration of Water Management Strategies, Regional Priorities, and Objectives – Short-term Priorities (5 Years)

Regional Priorities	Water Management Strategies Used	Objectives Met					
		Water Supply	Ground-water Manage-ment	Eco-system Restoration	Water Quality	Emergency Prepared-ness	Infra-structure Efficiency and Reliability
Further define sources of groundwater contamination and develop strategies to prevent groundwater contamination and improve groundwater quality in areas with known contamination	Groundwater management Water quality protection and improvement Imported water	X	X		X		
Protect, restore, and enhance ecological processes in aquatic areas through water quality improvements; public education; restoration efforts, including removal of invasive species; and improved steelhead passage on strategic creeks	Environmental and habitat protection and improvement Surface water management Water quality protection and improvement	X		X	X		
Ensure the adequacy of water supplies during emergencies such as fires, floods, and earthquakes and during droughts through strategic replacement and rehabilitation of critical infrastructure.	Water supply reliability Water and wastewater treatment	X			X	X	X
Develop programs and policies to increase groundwater recharge or decrease groundwater use, especially in overdrafted groundwater basins	Groundwater management Imported water Water supply reliability Matching water quality to water use Water recycling	X	X		X		

TABLE 7-1
Integration of Water Management Strategies, Regional Priorities, and Objectives – Short-term Priorities (5 Years)

Regional Priorities	Water Management Strategies Used	Objectives Met					
		Water Supply	Ground-water Manage-ment	Eco-system Restoration	Water Quality	Emergency Prepared-ness	Infra-structure Efficiency and Reliability
Encourage inter-agency cooperation in beginning to develop groundwater banking programs	Surface water management Groundwater management Water supply reliability Imported water Desalination	X	X		X		

TABLE 7-2
Integration of Water Management Strategies, Regional Priorities, and Objectives – Long-term Priorities (5 to 20 Years)

Regional Priorities	Water Management Strategies Used	Objectives Met					
		Water Supply	Ground-water Manage-ment	Eco-system Restoration	Water Quality	Emergency Prepared-ness	Infra-structure Efficiency and Reliability
Long-term Priorities (5 to 20 years)							
Provide adequate water and wastewater services to meet projected growth	Surface water management Groundwater management Imported water Water supply reliability	X				X	X
Implement regional and/or interagency conjunctive use and groundwater banking programs where supported by water cases and landowners	Surface water management Groundwater management Water supply reliability Imported water Desalination	X	X		X	X	X
Promote programs, policies, and infrastructures to increase water supply sustainability through artificial recharge of local groundwater basins	Surface water management Groundwater management Water supply reliability Imported water Desalination	X	X		X	X	X
Maximize storage capacity of existing surface reservoirs	Surface water management	X	X				X

TABLE 7-2
Integration of Water Management Strategies, Regional Priorities, and Objectives – Long-term Priorities (5 to 20 Years)

Regional Priorities	Water Management Strategies Used	Objectives Met					
		Water Supply	Ground-water Manage-ment	Eco-system Restoration	Water Quality	Emergency Prepared-ness	Infra-structure Efficiency and Reliability
Optimize the use of seawater desalination to increase water supply reliability and offset groundwater use	Surface water management Groundwater management Water supply reliability Imported water Desalination	X	X				X
Expand distribution systems to provide recycled water to new users	Recycled water—treatment and distribution Matching water quality to water use	X	X				X
Expand voluntary water conservation programs for residential, commercial, industrial and agricultural uses	Water supply reliability Economic incentives	X	X				
Continue inter-agency coordination to develop opportunities to further integrate the management of water and wastewater projects and programs	All strategies could be involved	X	X		X	X	X
Continue to coordinate with adjacent counties to develop strategies and programs that improve the management of regional water resources	All strategies could be involved	X	X	X	X		

8

8 Strategic Approach for Plan Implementation

This section describes how the IRWMP is to be utilized, outlining the strategic approach that is used to link regionwide and watershed-specific issues with the need for specific projects. The methods used to identify and prioritize projects are also described, along with detailed information regarding those projects that are currently thought to be the highest priority.

For the purpose of seeking integrated regional water management funding from the state, the Cooperating Partners determined that Proposition 50 grant requests should focus on two overarching needs: (1) more efficient water use in the northern and central portions of the county through improved water and wastewater treatment to meet standards; and to allow effluent reuse and improved quality of surface discharges and returns to groundwater; and (2) increased reliability and efficiency through conjunctive use and system flexibility in the southern portion of the county.

8.1 Strategic Approach

A straightforward, linear path is followed to relate place-specific issues to regional objectives, priorities, and strategies in order to identify projects needed to resolve these issues. The following schematic presents this strategic approach.

Places	→	Key Issues	→	Objectives	→	Priorities	→	Strategies	→	Projects
By addressing both the region as a whole and its major watersheds…	→	…the Cooperating Partners identified the most pressing issues, problems, and challenges…	→	…identified objectives to meet regional needs…		….and set regional priorities to provide more specific direction…	→	…using strategies from the state's Proposition 50 Guidelines and California Water Plan Update 2005…	→	….to identify projects to solve problems and meet objectives

The logic sequence shown above was developed to ensure that specific projects that met countywide needs were included in the IRWMP. In this way, the list of substantial issues that challenge agencies and special districts in one or more parts of the region was narrowed to specific projects to address key problems. Projects have not yet been identified to address all of the countywide problems, and as discussed in Section 10, the IRWMP will be used as a mechanism to develop solutions to existing problems, as well as to identify new issues and methods for their resolution.

The linkages between regionwide issues, objectives, priorities, strategies, and the Tier I projects are shown in Table 8-1. Some regionwide issues, such as addressing the developing TMDLs, the need for more conservation, and the need for continued integrated regional water management planning, will require cooperative efforts by regionwide entities. Other regionwide issues will be addressed by individual agencies developing projects that collectively will work together to resolve issues that are important to the county as a whole. The linkages between watershed-specific issues, objectives, priorities, strategies, and Tier I projects are shown in Table 8-2. In some cases (such as San Antonio Creek and Santa Ynez River watersheds), projects have not yet been developed to address specific local concerns, but the IRWMP may be used as the mechanism to do so.

8.2 Project Solicitation and Prioritization

Projects required to address countywide issues were solicited from the Cooperating Partners, as well as other interested stakeholders within Santa Barbara County through the outreach efforts outlined in Section 6. All projects received were evaluated and prioritized according to the following criteria:

1. Readiness to proceed
    a. California Environmental Quality Act (CEQA) process has been initiated or completed
    b. Costs have been adequately estimated
    c. Schedule, including project timeframe and milestones, has been prepared
2. One or more regional objectives are addressed
3. One or more water management strategies are utilized
4. One or more regional priorities are addressed
5. One or more statewide priorities are addressed
6. The project is likely consistent with applicable general plan
7. The project will not cause long-term significant adverse impacts, including long-term adverse impacts to agriculture
8. The project serves a disadvantaged community (DAC)

Each criterion was assigned one point, including readiness to proceed; a single point was awarded in a category if any one of the three subcriteria were met. The highest scoring projects, with scores of 7 or above, were considered to be the highest priority projects for the near-term (Tier I projects) and are shown in Table 8-3 and Figure 8-1; the corresponding project descriptions are shown in Appendix C-1. Further prioritization of these projects will be conducted by the Cooperating Partners as they consider which projects are appropriate candidates for grant funding.

Descriptions of the projects with scores below 7 (Tier II projects) are included in Appendix C-2, and tables showing the consistency of all projects with the regional objectives, regional priorities, water management strategies, and statewide priorities are included in Appendix D-6.

TABLE 8-1
Linkages between Regionwide Issues and Projects

Watershed	Key Issues	Objectives	Regional Priorities[a]	Strategies[b]	Project Examples[c]
All	**Emergency Response:** Inadequate backup supplies for severe emergencies (earthquake, large wildfire, extreme drought), with potential adverse health and safety impacts	Water supply	Ensure the adequacy of water supplies during drought and emergencies	*Water supply reliability*	Interconnect: Goleta and City of Santa Barbara Modifications to the South Coast Conduit Other projects still to be developed
All	**Improve Regionwide Water Management System:** Challenges inherent in managing a complex, integrated, regional water supply system; increased water supply reliability needed	Water supply Groundwater management Water quality	Expand voluntary water conservation programs Encourage expanded cooperation in conjunctive use	*Water conservation* *Water transfers* *Conjunctive use*	Water efficiency rebates and incentives Goleta Water District and Carpinteria Valley Water District injection well projects to improve conjunctive use
All	**Water Quality Standards:** Comply with state and federal requirements for impaired water bodies, while also respecting property rights	Water quality	Improve surface and ocean water quality	*Water quality protection and improvement*	Wastewater treatment plant upgrades for City of Guadalupe, City of Santa Maria, Laguna County Sanitation District and Vandenberg Village Community Services District. Watershed working groups for South Coast beaches
All	**Implement IRWMP:** Current Integrated Regional Water Management commitment is only short-term	All	Continue interagency coordination	*All strategies in state's IRWMP Guidelines*	Develop a Memorandum of Understanding for IRWMP governance

Notes:

[a]The text is verbatim from language approved as regional priorities by the Cooperating Partners, as presented in Section 7.

[b]The italicized words are verbatim from the state's Proposition 50 Guidelines; many strategies are already being implemented, but in some cases specific projects are needed to enhance current efforts.

[c]The projects listed in the "Projects" column are examples of those that scored highest in the Cooperating Partners' project evaluation process. They are not necessarily the projects that would be included in an application for a project implementation grant; specific criteria for project selection will be developed for the grant application. More information on these projects can be found in appendices to this IRWMP.

DAC: Disadvantaged community

TABLE 8-2
Linkage between Watershed-specific Issues and Projects

Watershed	Key Issues	Objectives	Regional Priorities[a]	Strategies[b]	Project Examples[c]
Santa Maria River and Cuyama River	**Public Health:** Risk of illness, especially in DACs, from inadequate drinking water and pollution from wastewater; impaired water bodies; elevated levels of nitrates in groundwater in some areas	Water supply Water quality Infrastructure efficiency and reliability	Ensure the adequacy of water and wastewater treatment facilities, especially in DACs	*Water and wastewater treatment* through improved drinking water treatment and distribution systems; upgrades to wastewater treatment systems	Casmalia water system improvements Guadalupe wastewater treatment plant improvements Cuyama wastewater treatment plant effluent disposal Cuyama water tower repair Expansion of Santa Maria wastewater treatment plant
	Public Safety: Potential harm to people and property from flooding	Emergency preparedness Flood control	Protect public safety by reducing the potential for flooding	*Flood management* through levee reconstruction	Santa Maria River levee reinforcement
	Groundwater Overdraft: Overdraft in the Cuyama Groundwater Basin, causing increased pumping lift for agricultural users	Water supply	Develop programs to increase groundwater recharge or decrease groundwater use	Groundwater management	To be developed
San Antonio Creek	**Public Health and Environmental Protection:** Sedimentation of creeks	Water quality	Improve surface water quality	*Water quality protection and improvement*	Specific projects developed through implementation of Consolidated Resource Management Plan for the area
	Groundwater Overdraft: Overdraft in the San Antonio Groundwater Basin, causing increased pumping lift for agricultural users	Water supply	Develop programs to increase groundwater recharge or decrease groundwater use	Groundwater management	To be developed
Jalama Creek	**Public Health and Environmental Protection:** Saturation of the leach fields at Jalama Beach, potentially affecting surface water quality in Jalama Creek and the ocean	Water quality	Improve surface and ocean water quality	*Water and wastewater treatment*; and *Water quality protection and improvement*	Replace undersized septic tanks at county park

TABLE 8-2
Linkage between Watershed-specific Issues and Projects

Watershed	Key Issues	Objectives	Regional Priorities[a]	Strategies[b]	Project Examples[c]
Santa Ynez River	**Integrated Water Management:** A State Water Resources Control Board (SWRCB) decision is needed on the Cachuma Project water rights permits that supports those elements of the Cachuma Project Settlement Agreement under its jurisdiction to facilitate integration of water supply, downstream water rights, and public trust resources	Water supply Ecosystem restoration	Protect, restore and enhance ecological processes in aquatic areas Increase water supply reliability Protect public safety by reducing the potential for flooding	*Environmental and habitat protection and improvement* *Water supply reliability* *Storm flow management* *Surface water management* *Groundwater management* *Water quality improvement* *Conjunctive use*	No infrastructure needed; an SWRCB decision supporting the flows for fisheries and downstream water rights as provided in the Cachuma Project Biological Opinion and Settlement Agreement would facilitate integration of water supply, downstream water rights, and public trust resources
	Water Supply Reliability: Reliance on a single water source (Lompoc Uplands Groundwater Basin) in the face of increasing growth; lack of diversity in viable water sources in City of Solvang; and water supply source management and interconnection between the Santa Ynez River Water Conservation District, Improvement District No. 1 and Solvang	Water supply Groundwater management	Increase water supply reliability Provide adequate water to meet projected growth	*Water supply reliability* *Water quality improvement* *Conjunctive use*	Specific projects still in planning stage
	Public Health and Environmental Protection: Compliance with emerging wastewater discharge standards; water quality problems in shallow groundwater in Santa Ynez Uplands; control of noxious weeds along the Santa Ynez River	Groundwater management Ecosystem restoration Water quality Infrastructure efficiency and reliability	Strategically restore and replace wastewater infrastructure Protect, restore and enhance ecological processes	*Water and wastewater treatment;* *Water quality protection and improvement* *Conjunctive use* Environmental and habitat protection and improvement	Lompoc Regional Wastewater Reclamation Plant Santa Ynez Uplands projects in planning stage Arundo eradication
	Groundwater Overdraft: Need for further study of the hydrology of the Lompoc groundwater basins, especially as it relates to potential overdraft in the Santa Rita subbasin	Groundwater management	Develop programs to increase groundwater recharge or decrease groundwater use	To be determined	To be developed; conduct a study of the hydrology of the Lompoc Groundwater Basin, especially for the Santa Rita subbasin

TABLE 8-2
Linkage between Watershed-specific Issues and Projects

Watershed	Key Issues	Objectives	Regional Priorities[a]	Strategies[b]	Project Examples[c]
South Coast (multiple small creek watersheds)	**Water Supply Reliability:** Difficulty meeting peak demands; aging infrastructure constrains system operability; insufficient integration of adjacent systems	Water supply Infrastructure efficiency and reliability	Increase water supply reliability	Water supply reliability through expanding capacity of distribution system	South Coast Conduit 2nd pipeline Carpinteria Valley Water District Central Zone transmission main Goleta plant sedimentation upgrades Blended irrigation at La Cumbre Mutual Water Company
	Public Safety: Potential harm to people and property from creek flooding	Emergency preparedness Flood flow management	Protect public safety by reducing the potential for flooding	Flood management by improving flow channel capacity for large storms	Storm water management and flood control for Mission, Las Positas, San Jose, Las Vegas, and San Pedro creeks
	Public Health and Environmental Protection: Pollution of creeks and coastal waters from nonpoint sources and point source runoff during rain events	Groundwater management Ecosystem restoration Water quality Infrastructure efficiency and reliability	Improve surface and ocean water quality Develop programs and policies to increase groundwater recharge	*Water and wastewater treatment through sewers in certain septic areas; and sewer repairs* *Water recycling* *Water quality protection and improvement* *Storm water capture and management*	Sewer line extension, replacements and relocation in Goleta, Carpinteria, and City of Santa Barbara El Estero Swale restoration Goleta water reclamation facility refurbishment Goleta backwash tanks replacement

Notes:

[a]The text is verbatim from language approved as Regional Priorities by the Cooperating Partners, as presented in Section 7.

[b]The italicized words are verbatim from the state's Proposition 50 Guidelines.

[c]The projects listed in the "Projects" column are examples of those which scored highest in the Cooperating Partners' project evaluation process; they are not necessarily those which would be included in an application for a project implementation grant; specific criteria for project selection will be developed for the grant application. More information on these projects can be found in appendixes to this IRWMP.

DAC: disadvantaged community

TABLE 8-3
Santa Barbara County IRWMP Projects Scoring 7 or Above (Sorted by Watershed)

No.	Watershed	Sponsor	Project
1	All	Southern SLO and Santa Barbara Counties Ag Watershed Coalition	Santa Maria River/Oso Flaco, Santa Ynez River, and South Coast Beaches TMDLs Watershed Working Groups
2	All	Water Purveyors and the County Water Agency	Regional Water Conservation Rebates, Incentives, and Promotion
3	Cuyama	Cuyama Community Services District	Wastewater Treatment Plant Effluent Disposal
4	Cuyama	Cuyama Community Services District	Water Tower Repair
5	Jalama	Santa Barbara County Parks	Jalama Beach County Park Septic System Improvements
6	Santa Maria	Casmalia Community Services District	Casmalia Water System Improvements
7	Santa Maria	City of Guadalupe	Guadalupe WWTP Reuse Improvements
8	Santa Maria	City of Santa Maria	Wastewater Treatment Plant Expansion
9	Santa Maria	Laguna County Sanitation District	Wastewater Reclamation Plant Upgrade
10	Santa Maria	Santa Barbara County Flood Control District	Santa Maria River Levee Reinforcement
11	Santa Ynez	Agricultural Commissioner's Office *Doing Business As* Santa Barbara County Weed Management Area	Santa Ynez River Arundo Eradication
12	Santa Ynez	Cachuma Conservation Release Board/Santa Ynez River Water Conservation District Improvement District No.1	Quiota Creek, Fish Passage Enhancements
13	Santa Ynez	Santa Ynez River Water Conservation District Improvement District No. 1	Gallery Well Filtration Facility
14	Santa Ynez	Vandenberg Village Community Services District	Lompoc Regional Wastewater Reclamation Plant
15	South Coast	Cachuma Operation and Maintenance Board	South Coast Conduit 2nd Pipeline - Upper Reach
16	South Coast	Carpinteria Sanitary District	Bluffs Sewer Relocation
17	South Coast	Carpinteria Sanitary District	Carpinteria Creek Overhead Crossing Replacement
18	South Coast	Carpinteria Valley Water District	Central Zone Transmission Main/ASR Demonstration Well
19	South Coast	Carpinteria Valley Water District	Recycled Water Feasibility Study
20	South Coast	City of Santa Barbara	Braemer Area Sewer Extension
21	South Coast	City of Santa Barbara	El Estero Swale Restoration
22	South Coast	City of Santa Barbara	Elings Park Solid Waste Assessment Test/Corrective Action Plan

TABLE 8-3
Santa Barbara County IRWMP Projects Scoring 7 or Above (Sorted by Watershed)

No.	Watershed	Sponsor	Project
23	South Coast	City of Santa Barbara	Las Positas Storm Water Management
24	South Coast	City of Santa Barbara and Santa Barbara County Flood Control District	Lower Mission Creek Flood Control and Rehabilitation
25	South Coast	City of Santa Barbara	Old Mission Creek Storm Water Management and Restoration
26	South Coast	Goleta Sanitary District	Fairview Avenue Sewer Line Installation
27	South Coast	Goleta Sanitary District	Mattorral Way Creek Arial Crossing Sewer Replacement
28	South Coast	Goleta Sanitary District	Modoc Road New Sewer Line Installation
29	South Coast	Goleta Sanitary District	Water Reclamation Facility 2007 Refurbishment
30	South Coast	Goleta Water District	ASR Well Rehabilitation and Construction
31	South Coast	Goleta Water District	Backwash Tank Replacement at 4 Wells
32	South Coast	Goleta Water District	Cathedral Oaks Pipeline Replacement
33	South Coast	Goleta Water District	Corona Del Mar Water Treatment Plant - Sedimentation Basin Effluent Upgrades
34	South Coast	Goleta Water District	Downstream Reservoir Meters
35	South Coast	Goleta Water District	Interconnect with City of Santa Barbara
36	South Coast	La Cumbre Mutual Water Company	Blended Irrigation
37	South Coast	La Cumbre Mutual Water Company	Iron and Manganese Removal Plant
38	South Coast	Santa Barbara County - Project Clean Water	Diversion of Non-storm Flows from Storm Drain System to Sanitary System
39	South Coast	Santa Barbara County Flood Control District	Las Vegas and San Pedro Creeks, Goleta
40	South Coast	Santa Barbara County Flood Control District	San Jose Creek Improvements (Goleta)

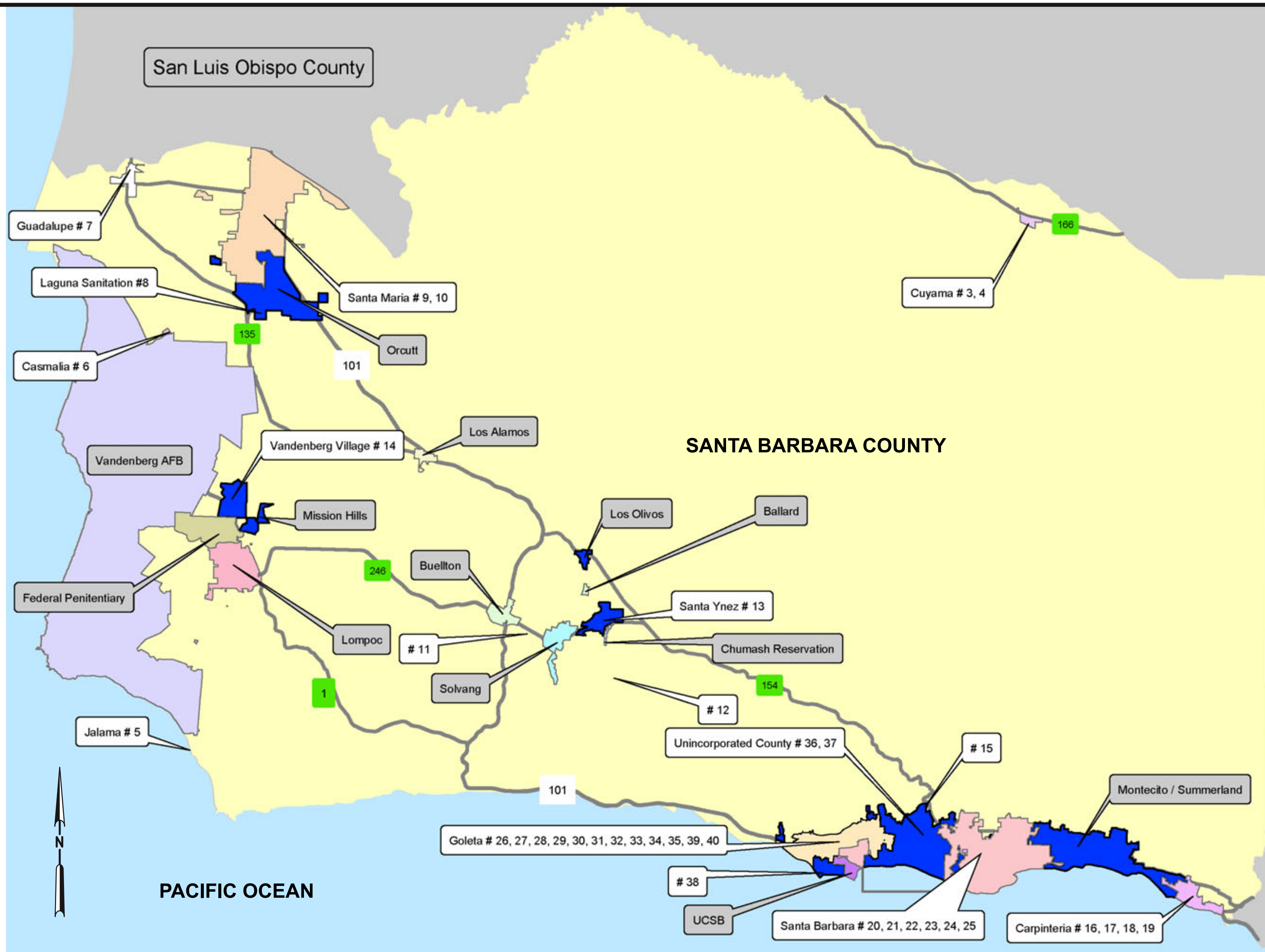

FIGURE 8-1
TIER I PROJECTS BY APPROXIMATE LOCATION
SANTA BARBARA IRWMP

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Figures 8-2 and 8-3 illustrate the process that was used to identify projects and ensure that they were integrated, using a mix of plan objectives and water management strategies. The projects also were reviewed to ensure that they addressed the needs of individual geographic areas and the region as a whole; and would result in an array of integrated, multiple benefits. Additionally, projects were evaluated in terms of their potential to assist in meeting the following statewide priorities established by the California Department of Water Resources (DWR) and the State Water Resources Control Board (SWRCB):

- Reduce conflict between water users or resolve water rights disputes, including interregional water rights issues
- Implementation of total maximum daily loads (TMDLs) that are established or under development
- Implementation of Regional Water Quality Control Board (RWQCB) Watershed Management Initiative Chapters, plans, and policies
- Implementation of the SWRCB's Nonpoint Source Pollution Plan
- Assist in meeting Delta Water Quality Objectives
- Implementation of recommendations of the Floodplain Management Task Force
- Implementation of recommendations of the Desalination Task Force
- Implementation of recommendations of the Recycling Task Force
- Implementation of recommendations of the State Species Recovery Plan
- Address environmental justice concerns
- Assist in achieving one or more goals of the CALFED Bay-Delta Program.

As shown in Table 8-4 and Appendix D-3, both the highest ranking projects and the entire suite of projects use a broad range of water management strategies to meet plan objectives, regional priorities, and statewide priorities. This plan is a living document, intended to provide a planning framework over the next 20 years, and as the longer-term projects included in Appendix C-2 become better defined, or as regional priorities change, they may be reclassified as higher priority projects through the adaptive management process outlined in Section 10. Additionally, the IRWMP will serve as a mechanism for identifying new projects designed in accordance with the regional objectives, priorities, and management strategies using the logic sequence outlined above.

TABLE 8-4
Summary of Overall Evaluation Matrix

Criteria		Total Number of Projects That Met Criteria	Total Number of Top Tier Projects That Met Criteria
Readiness to Proceed	CEQA Process Initiated or Completed	39	27
	Costs Adequately Estimated	44	30
	Schedule Prepared	36	22
	Overall Readiness to Proceed	55	37
One or More Regional Objectives Are Addressed		97	40
One or More Water Management Strategies Are Utilized		97	40
One or More State Priorities Are Addressed		76	40
One or More Regional Priorities Are Addressed		95	40
Lack of Significant Long-term Adverse Impacts, Including Impacts to Agriculture		65	40
Consistency with General Plans		82	40
Disadvantaged Community		4	4

	Watershed	Readiness	Objectives	Strategies	State Priorities	Regional Priorities	No Adverse Impact	Consistency w/Gen Plans	Disadv. Community	⇨	Total Criteria Met
Project 1		●	●	●	●	●	●		●	⇨	7
Project 4		●	●	●	●	●	●	●		⇨	7
Project 2		●		●				●		⇨	3
Project 3		●		●	●	●	●	●		⇨	6
Project 5		●	●		●	●	●			⇨	5

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FIGURE 8-2
PROJECT EVALUATION PROCESS
SANTA BARBARA IRWMP

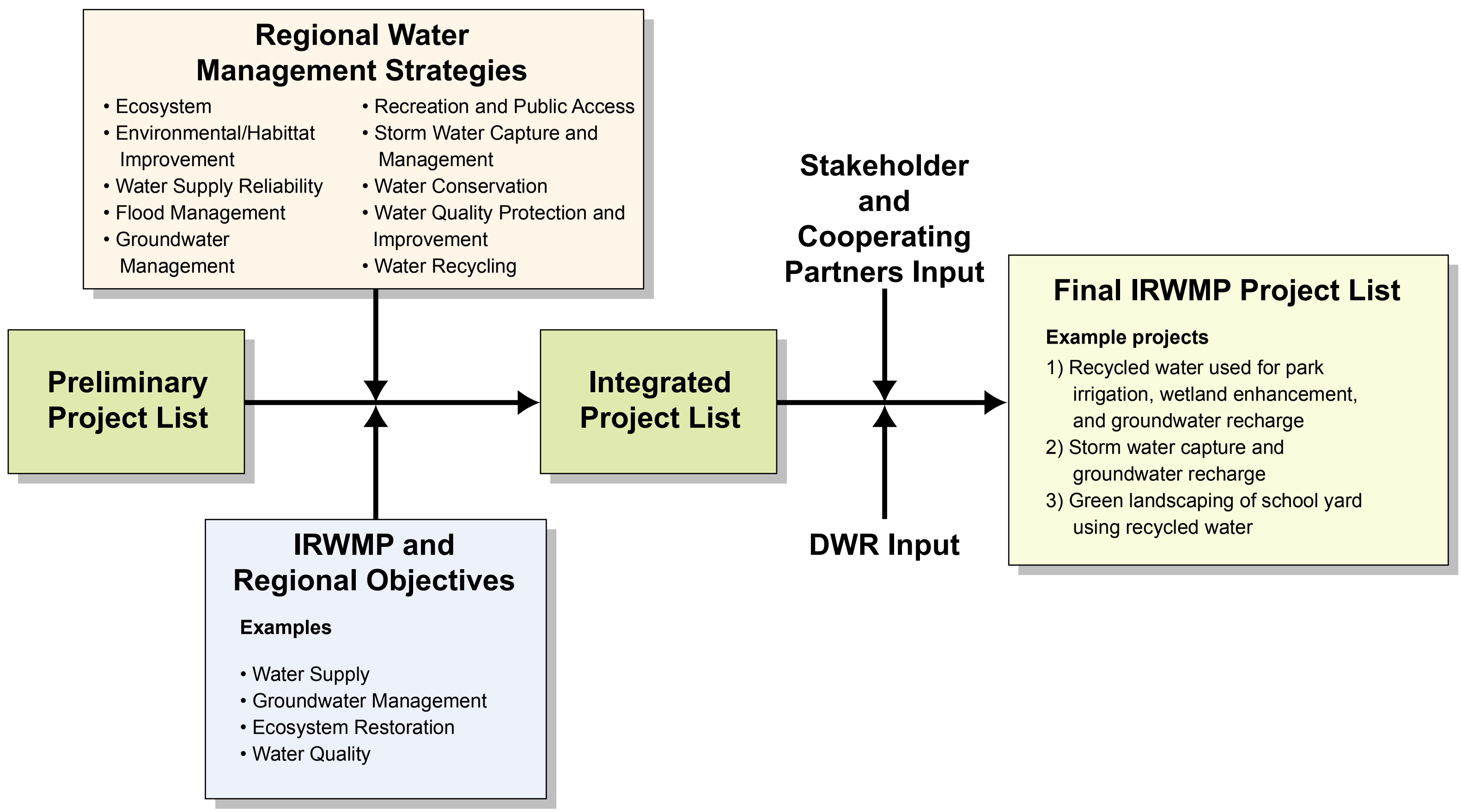

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FIGURE 8-3
PROJECT INTEGRATION
SANTA BARBARA IRWMP

8.3 Descriptions of Current High Priority Projects

The projects described in detail on the following pages are currently considered to be the highest priority projects based on the evaluation process outlined above. Their locations are shown on Figure 8-1. These projects were identified by the Cooperating Partners based on their specific needs identified through technical studies, water quality monitoring, Capital Improvement Plans, Urban Water Management Plans, and other planning mechanisms; a number of projects also are required to meet regulatory standards. As such, they are considered technically feasible. Due to the number of projects included in the plan, costs for implementing each project have not been included at this time. Costs estimates for implementing specific projects will be provided as part of specific grant applications. Estimated start and end dates for each project are included in Table 8-5; the precise start dates will be dependent upon receipt of funding, with corresponding changes to the end dates.

TABLE 8-5

Timeline for the Implementation of High Priority Projects

No.	PROJECT NAME	2008	2009	2010	2011	2012	2013	2014	2015
1	Santa Maria River/Oso Flaco, Santa Ynez River, and South Coast Beaches TMDLs Watershed Working Groups	2008 through undetermined end date							
2	Regional Water Conservation Rebates, Incentives, and Promotion	In progress and continuing							
3	Cuyama Wastewater Treatment Plant Effluent Disposal Project	2008 through 2009							
4	Cuyama Water Tower Repair Project	2008 through 2009							
5	Jalama Beach County Park Septic System Improvements	2008 through 2009							
6	Casmalia Water System Improvements Project	2008 through 2009							
7	Guadalupe Wastewater Treatment Plant Reuse Improvements Project	2008 through 2010							
8	Santa Maria Wastewater Treatment Plant Expansion	2008 through 2010							
9	Laguna County Sanitation District Wastewater Reclamation Plant Upgrade	2008 through 2010							
10	Santa Maria River Levee Reinforcement	2008 through 2012							
11	Santa Ynez River Arundo Eradication Project	2008 through 2014							
12	Quiota Creek, Fish Passage Enhancements Project	2008 through 2009							
13	Gallery Well Filtration Facility	2008 through 2009							
14	Lompoc Regional Wastewater Reclamation Plant	2008 through 2010							
15	South Coast Conduit 2nd Pipeline - Upper Reach	2008 through 2009							
16	Bluffs Sewer Relocation Project	2008 through 2010							
17	Carpinteria Creek Overhead Crossing Replacement Project	2008 through 2009							
18	Central Zone Transmission Main/ASR Demonstration Well	2008 through 2011							
19	Recycled Water Feasibility Study	2008 through 2009							
20	Braemer Area Sewer Extension Project	2008 through 2009							
21	El Estero Swale Restoration Project	2008 through 2009 [1]							
22	Elings Park Solid Waste Assessment Test-Corrective Action Plan	2008 through 2009							
23	Las Positas Storm Water Management Project	2008 through 2011							
24	Lower Mission Creek Flood Control and Rehabilitation Project		2009 through 2014						
25	Old Mission Creek Storm Water Management and Restoration Project	2008 through 2009							
26	Fairview Avenue Sewer Line Installation Project				2011 through 2015				
27	Mattorral Way Creek Aerial Crossing Sewer Replacement Project	2008 through 2009							
28	Modoc Road New Sewer Line Installation Project				2011 through 2015				
29	Water Reclamation Facility 2007 Refurbishment Project	2008 through 2009							
30	ASR Well Rehabilitation and Construction Project		2009 through 2010						
31	Backwash Tank Replacement at 4 Wells Project	2008 through 2009							
32	Cathedral Oaks Pipeline Replacement Project			2010					
33	Corona Del Mar Water Treatment Plant – Sedimentation Basin Effluent Upgrades Project	2008 through 2009							
34	Downstream Reservoir Meters Project	2008 through 2009							
35	Interconnect with City of Santa Barbara Project	2008 through 2009							
36	Blended Irrigation Project	2008 through 2009							
37	Iron and Manganese Removal Plant Project	2008 through 2009							
38	Non-Storm Water Diversion, Isla Vista		2009 through 2010						
39	Las Vegas and San Pedro Creeks Flood Control Improvements	2008 through 2012							
40	San Jose Creek Flood Control Improvements	2008 through 2011							

LEGEND

In Progress and Continuing

Timeline

Funding assumed available October 1, 2008.

[1]The project can be implemented as soon as there is concurrence among various agencies regarding the resolution of issues associated with hazardous materials onsite.

Project Number and Name

No. 1 Santa Maria River/Oso Flaco, Santa Ynez River, and South Coast Beaches TMDLs Watershed Working Groups

Project Sponsor

Southern San Luis Obispo and Santa Barbara Counties Agricultural Watershed Coalition

Watershed

All

Project Description

This project will fund seed money to form watershed working groups for the lower Santa Maria River/Oso Flaco Waterbodies, Santa Ynez River and the South Coast Beaches for the express purpose of managing the TMDL process in these watersheds. Fecal coliform, nitrate, and ammonia TMDLs for Santa Maria River Oso Flaco are in progress. Also, the following TMDLs are being investigated: Santa Barbara County Beaches Bacteria, Santa Maria River Pesticides and Santa Ynez River Nutrients. All of the above named TMDLS are scheduled to occur in the next 3 to 8 years. All TMDLs will require a substantial investment of resources from a variety of agencies, special districts, irrigated agriculture, ranchers and the general public. TMDLs have the potential to become controversial. Generally, the more controversial and contentious, the more expensive the process. Watershed working groups have the potential to create a collaborative approach to solve a specific set of problems as well enable disparate interests to formally chart a strategic course.

Need for the Project

At present, there are no organized watershed working groups organized on these specific waterbodies. There are watershed working groups on subwatersheds such as the Oso Flaco, Gaviota, San Jose, Carpinteria Creek, and Rincon Creek Watershed Working Groups. Consequently, there are no overarching vehicles to approach the larger TMDL process in a strategic and cost effective manner. Additionally, without formal, watershed working groups, it will very difficult to pursue outside funding sources to pay for professional fees or special projects.

Estimated Start and End Date

2008 through 2015

Potential Funding Sources

Grant funding will be used to form initial watershed working groups. The working groups will then pursue specific funding to pay for watershed specific projects.

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

Aquatic life, wildlife, and birds will benefit from improved water quality as a result of the TMDL process. Drinking water supplies from nearby wells will be safeguarded by reducing surface water sources of contamination. Pathogen exposure of surfers and other people taking part in water recreation activities will be reduced along the South Coast of Santa Barbara County. Water quality will be improved at several state and county parks. Other projects may be an indirect result of the formation of watershed working groups.

Statewide Priorities Addressed

Reduce water user conflicts/resolve water rights disputes

Implement TMDLs

Implement RWQCB Watershed Management Initiative

Implement SWRCB's Nonpoint Source Pollution Plan

Project Number and Name

No. 2 Regional Water Conservation Rebates, Incentives, and Promotion

Project Sponsor

Water Purveyors and the County Water Agency

Watershed

All watersheds

Project Description

The program aims to generate water savings and achieve actual reduction in overall demand as well. Program elements include rebates for plumbing fixtures, irrigation devices, and new technology to promote conservation. The program rebates, incentives and promotions can apply in multiple sectors: residential, commercial, municipal, and industrial, depending on the specific rebate or incentive. Current demand is below 14,000 AFY, compared to demand of 16,300 AFY in 1988 when the current program began to be developed.

Need for the Project

Although water conservation programs have been in place and effective within Santa Barbara County, there remains considerable opportunity for new and expanded programs in all parts of the region, especially using rebates, incentives, and other promotions. The most promising sectors for such programs are in the commercial, industrial, and municipal sectors.

Estimated Start and End Date

In progress and continuing

Potential Funding Sources

Water rate revenue from participating purveyors with potential augmentation from grants, especially from Reclamation

Percent of Matching Funding that Will Be Provided

50 percent

Regional and Local Benefits

Conservation not only offsets the need for additional water supplies, but also reduces costs associated with ordering water deliveries or reactivating water supply projects, and reduces the amount of additional transfers required from other parts of the state. Conserved water also means more water available for other purposes, such as environmental needs.

Statewide Priorities Addressed

Help achieve CALFED Bay Delta program goals

Project Number and Name

No. 3 Wastewater Treatment Plant Effluent Disposal Project

Project Sponsor

Cuyama Community Services District

Disadvantaged Community

Yes

Watershed

Cuyama

Project Description

The project involves installation of two percolating ponds for effluent disposal.

Need for the Project

NPDES Permit requires that Cuyama Community Services District complies with Effluent Limitation No. D.1. by May 31, 2007. If the District continues to dispose of effluent by discharging into Salisbury Creek, the result will be mandatory penalties, and the permit will not be renewed.

Estimated Start and End Date

2008 through 2009

Potential Funding Sources

Grant funds, a waiver from matching funds is also being sought

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

Installation of appropriate effluent disposal mechanisms will guarantee protection of the environment downstream and ensure that the rate-paying customers, who are members of a DAC, are receiving service.

Statewide Priorities Addressed

Implement TMDLs

Implement SWRCB’s Nonpoint Source Pollution Plan

Address environmental justice concerns

Project Number and Name

No. 4 Water Tower Repair Project

Project Sponsor

Cuyama Community Services District

Disadvantaged Community

Yes

Watershed

Cuyama

Project Description

The elevated water tower, which stands 100 feet tall, requires complete repair to the interior and additional repair to the exterior for its operation to continue. Cleaning and coating will be done, and new electric pump controls will be installed.

Need for the Project

The water tower is over 50 years old, and it has never been serviced. It provides the pressure for the water to the New Cuyama Townsite. If it is not repaired, it will reach the point where it will not function.

Estimated Start and End Date

2008; will be completed within one year

Potential Funding Sources

Grant funds, a waiver from matching funds is also being sought

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

The water tower is an essential element of the Cuyama water supply, and its repair will allow water service to continue to this DAC.

Statewide Priorities Addressed

Address environmental justice concerns

Project Number and Name

No. 5 Jalama Beach County Park Septic System Improvements

Project Sponsor

Santa Barbara County Parks Department

Watershed

Santa Ynez

Project Description

Replace undersized septic tanks at eight locations within Jalama Beach County Park

Need for the Project

Installation will increase wastewater retention time in tanks, thus reducing the amount of solids entering the leach field system, particularly during peak use season. Existing leach fields risk becoming saturated under current conditions, causing park restrooms to close to preclude leach field overuse and contamination from surfacing wastewater.

Estimated Start and End Date

2008; will be completed within one year

Potential Funding Sources

Proposition 50 Clean Beach Initiative Program

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

The project will continue to ensure that water quality in nearby Jalama Creek and the ocean is protected, and it will enhance recreational opportunities by keeping the park restrooms functional.

Statewide Priorities Addressed

Implement SWRCB’s Nonpoint Source Pollution Plan

Project Number and Name

No. 6 Casmalia Water System Improvements Project

Project Sponsor

Casmalia Community Services District

Disadvantaged Community

Yes

Watershed

Santa Maria

Project Description

The town of Casmalia uses a well located approximately 4.5 miles north of the town off Black Road just north of Highway 1. The project involves the design and construction for replacement of water pipelines and tank facilities to replace deficient infrastructure, upgrading electrical building and facilities to comply with code requirements, and improvements to the existing well facility. The service connections will also be upgraded or replaced.

Need for the Project

Casmalia's water supply system is in serious need of upgrades in order to meet regulatory requirements and protect public health. Water samples collected in November 2006 indicated the presence of both total coliform and E. coli bacteria, and all residents were directed to boil their water before drinking it. The community of Casmalia was started as a company town with the water well and distribution system owned by the Casmite Corporation. The Casmite Corporation no longer operates these facilities, and therefore would like to transfer them to the Casmalia Community Services District, which to date only operates the service connections. In order to transfer the facilities, upgrades to comply with design and code requirements are necessary as well as a new distribution system located in legal rights-of-way. Once the complete system is updated and functional, the Casmalia Services District can take over full water service operation.

Estimated Start and End Date

2008 through 2009

Potential Funding Sources

Grant funds

Percent of Matching Funding that Will Be Provided

Casmalia is a DAC, and a waiver from the matching funds requirement is being sought.

Regional and Local Benefits

The project is essential to providing Casmalia, a DAC, with a safe, secure water supply that is managed in an efficient manner. This project will also provide a public health improvement with respect to management and regulation.

Statewide Priorities Addressed

Reduce water user conflicts/resolve water rights disputes

Address environmental justice concerns.

Project Number and Name

No. 7 Guadalupe Wastewater Treatment Plant Reuse Improvements Project

Project Sponsor

City of Guadalupe

Disadvantaged Community

Yes

Watershed

Santa Maria

Project Description

The project will consist of (1) treatment improvements, (2) new effluent transfer capabilities, and (3) potential improvements at a 20-acre wetland site located within city limits. Treatment improvements will consist of alterations to the lagoon treatment process to limit effluent total suspended solids caused by algae growth. These improvements are currently under study, but may include headworks improvements, increased lagoon mixing, a chemically enhanced settling process, or lagoon covers. New effluent disinfection capability will be accomplished using either sodium hypochlorite chlorination, or ultraviolet disinfection. Effluent transfer capabilities will include piping and valve improvements to the existing effluent discharge location, and a new transfer pump station and approximately 3 miles of new pipeline routed to the wetland site. Improvements at the wetland site are being studied, but may include flow control structures and enhancements for public use.

Need for the Project

The project is intended to accomplish the following: (1) Allow compliance with effluent requirements for total suspended solids during periods when algae growth challenges compliance capability; (2) provide effluent disinfection to improve the health and safety of people and animals potentially coming in to contact with areas where effluent has been applied; and (3) increase opportunities for effluent reuse beyond the single application area currently employed. A planned use is for wetland enhancement within the city limits.

Estimated Start and End Date

Phase I: 2008 through 2009

Phase II: Completion - 2010

Potential Funding Sources

Local match from development impact fees

Percent of Matching Funding that Will Be Provided

30 percent

Regional and Local Benefits

The project will improve effluent quality in the City of Guadalupe, a DAC, and will improve health and safety at the sites where effluent is applied, through enhanced suspended solids removal and effluent disinfection. In addition, the introduction of additional water to the 20-acre wetland will improve this unique habitat site and provide a beneficial and attractive enhancement to the downtown Guadalupe area, potentially increasing tourism and development.

Statewide Priorities Addressed

Address environmental justice concerns.

Reduce water user conflicts/resolve water rights disputes

Implement floodplain management task force recommendations

Implement recycling task force recommendations

Project Number and Name

No. 8 Wastewater Treatment Plant Expansion

Project Sponsor

City of Santa Maria

Watershed

Santa Maria

Project Description

Revision to the current permit to allow for greater permitted flow, environmental review and completion of the expanded preliminary and final facility design, in order to begin construction in 2008. The project also includes a new wastewater supervisory control and data acquisition system. The actual construction will be budgeted in the next 2-year budget cycle, commencing in 2008 and projected for completion in 2010, at which point in time we expect the expanded facilities to be able to accommodate a 12.5 mgd flow capacity. Facilities envisioned for construction include, but are not limited to: new ponds for sludge drying and percolation, augmented pretreatment facilities, a new primary clarifier and trickling filter, standby power equipment, an updated telemetry system, and rehabilitation/reconstruction of infrastructure using outdated technology.

Need for the Project

The current daily flow at the wastewater treatment plant ranges from 8.5 to 9.0 million gallons per day (mgd) approaching the permitted capacity of 9.5 mgd. Phase I of the plant expansion, completed in 1997, increased the capacity by 3 million gallons and incorporated a new SCADA system, construction of head works, a sludge thickener, and additional drying beds. In order to maintain service levels, sustain current growth, and protect public health, the capacity of the facility must be elevated to 10.5 mgd by 2007 and to 12.5 mgd by 2010. The wastewater treatment plant expansion continues a long-term Utilities Master Plan project that meets the City's wastewater needs through 2016. Completion of this project maintains service levels, sustains projected growth, and protects public health.

Estimated Start and End Date

Construction will be completed in two phases. The first phase will begin in 2008, and the second will begin as soon thereafter as necessary to stay ahead of projected growth in the City. Both phases should be completed before the end of 2010.

Potential Funding Sources

The City matching funds will be paid from revenues procured from the collection of growth mitigation fees. The fees that will be used are those collected as conditions to the permits issued in the orderly development of Santa Maria.

Percentage of Matching Funds that Will Be Provided

50 percent

Regional and Local Benefits

Improvement of groundwater quality within the basin underlying the wastewater treatment plant.

The wastewater treatment plant is the central facility for treatment of sewage collected from rural development throughout Santa Barbara and San Luis Obispo counties. The City uses micro turbines to convert methane (a byproduct of sludge digestion in wastewater treatment) into electricity to reduce demand for energy from the grid. The project will initially include at least eight new percolation ponds. These ponds will be used to recharge the Santa Maria Groundwater Basin with resource of quality superior to the background with respect to total dissolved solids (TDS). The City has augmented the permanent open space in the valley by purchasing 260 acres of land for development as an open network of ponds and lagoons.

Statewide Priorities Addressed

Reduce water user conflicts/resolve water rights disputes

Implement TMDLs

Implement RWQCB Watershed Management Initiative

Implement recycling task force recommendations

Project Number and Name

No. 9 Laguna County Sanitation District Wastewater Reclamation Plant Upgrade

Project Sponsor

Laguna County Sanitation District

Watershed

Santa Maria

Project Description

The project involves plant capacity improvements and upgrades to facilitate treatment of wastewater and discharge of recycled water. The District provides wastewater, treatment, and disposal services to the Orcutt and southern unincorporated Santa Maria areas. The District's method of discharge has always been through the reuse of treated wastewater. Recently, the District completed an upgrade to reduce salt in the discharge and increase treatment to tertiary levels in order to comply with regulatory requirements and reuse water for enhanced beneficial uses. The proposed improvements will expand capacity by adding additional tertiary treatment and disinfection processes as well as new discharge distribution facilities.

Need for the Project

The District is anticipating significant growth in the very near future pursuant to the County's Orcutt Community Plan. An expansion from 3.7 million gallons per day (mgd) to 5.5 mgd is anticipated in 2010.

Estimated Start and End Date

Detailed planning and permit review is expected to begin in 2008. Construction is anticipated from 2009 to 2010.

Potential Funding Sources

Grant funds and Connection Fees (developer impact fees).

Percent of Matching Funding that Will Be Provided

50 percent

Regional and Local Benefits

The plant has a capacity of 3.7 mgd (4,145 AFY). The project will increase the capacity to 5.5 mgd (6,161 AFY). Current flow is 2.4 mgd (2,689 AFY) and the projected flow is 4.8 mgd (5,377 AFY) by 2019. 100 percent of the water is recycled.

The project will benefit water supply, water reuse, salt removal, water quality, drought protection, and potentially groundwater recharge.

Statewide Priorities Addressed

Implement recycling task force recommendations

Project Number and Name

No. 10 Santa Maria River Levee Reinforcement

Project Sponsor

Santa Barbara County Flood Control District

Watershed

Santa Maria

Project Description

The project includes modifications to the Santa Maria River Levee. The first phase would place a sheetpile wall, or other alternative, along the length of the Santa Maria River Levee between Suey Crossing and U.S. Highway 101, a distance of approximately 3,300 feet.

Need for the Project

The 24-mile-long Santa Maria River Levee, constructed of sand with a rock rip rap facing, has degraded over the 40 years since its completion in 1963. Degradation has reached the point of reducing the effectiveness of the levee in withstanding the forces of the river and increasing the risk of levee failure, which could flood adjacent neighborhoods as well as the City of Santa Maria.

Estimated Start and End Date

2008 through 2012

Potential Funding Sources

Grant funding

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

This project will provide protection for people, property, and the environment from flooding.

Statewide Priorities Addressed

Implement floodplain task force recommendations

Project Number and Name

No. 11 Santa Ynez River Arundo Eradication Project

Project Sponsor

Agricultural Commissioner's Office, doing business as Santa Barbara County Weed Management Area

Watershed

Santa Ynez

Project Description

This project aims to define the extent of *Arundo donax and Tamarix spp*. on the Santa Ynez River and eradicate both species from the riparian corridor.

Need for the Project

Arundo donax and *Tamarix spp.* are noxious and invasive weeds. Both species are regulated by the California Department of Agriculture and the County of Santa Barbara Agricultural Commissioner as a noxious weed and are considered invasive by the California Invasive Plant Council. Both currently are limited in distribution on the Santa Ynez River, especially in comparison to other riparian systems in Santa Barbara County and California.

The Santa Ynez River is a major river within Santa Barbara County running along the entire width of the county. It is a primary source of water and recreation. Funding to control arundo, tamarisk, and other invasive weeds is needed to protect, restore, and conserve riparian habitat in the county before the problem gets out of hand. The County of Santa Barbara has an opportunity to control an incipient infestation, which is less expensive to control than a widespread infestation. The Santa Clara River in Ventura and Los Angeles counties serves as an example of the need for this project. The Santa Clara River is suffering from a major infestation of arundo; a multimillion dollar project is being proposed for an arundo eradication project there.

Arundo donax displaces native plants and associated wildlife species because of the massive stands it forms (Bell 1994, Gaffney and Cushman 1998). Competition with native species has been shown to result from monopolization of soil moisture and by shading (Dudley unpublished data). It clearly becomes a dominant component of the flora and was estimated to comprise 68 percent of the riparian vegetation in the Santa Ana River (Douthit, 1994). As *Arundo donax* replaces riparian vegetation in semiarid zones, it reduces habitat and food supply, particularly insect populations, for several special status species such as least Bell's vireo, southwestern willow flycatcher, and yellow-billed cuckoo (Frandsen and Jackson, 1994; Dudley and Collins, 1995). Unlike native riparian plants, *Arundo donax* provides little shading to the in-stream habitat, leading to increased water temperatures and reduced habitat quality for aquatic wildlife. At risk are protected species such as arroyo toad, red-legged frog, western pond turtle, Santa Ana sucker, arroyo chub, unarmored three-spined stickleback, tidewater goby, and southern steelhead trout, among others (Franklin, 1996). In the Sacramento-San Joaquin Delta region *Arundo donax* interferes with levee maintenance and wildlife habitat management (Perrine, personal communication).

Arundo donax is also suspected of altering hydrological regimes and reducing groundwater availability by transpiring large amounts of water from semiarid aquifers. It alters channel morphology by retaining sediments and constricting flows, and in some cases may reduce stream navigability (Lake, personal communication, TNC 1996).

Dense growth presents fire hazards, often near urbanized areas, more than doubling the available fuel for wildfires and promoting postfire regeneration of even greater quantities of *Arundo donax* (Scott, 1994; Gaffney and Cushman, 1998). Uprooted plants also pose clean-up problems when deposited on banks or in downstream estuaries (Douthit, 1994) and during floods create hazards when trapped behind bridges and other structures. Although often planted for erosion control, *Arundo donax* can promote bank erosion because its shallow root system is easily undercut and bank collapse may follow.

Continued on next page

No. 11   Santa Ynez River Arundo Eradication Project, continued

There is debate as to whether *Tamarix spp.* is a consequence (Anderson, 1996) or a cause (Lovich and de Gouvenain, 1998) of environmental changes associated with its presence and proliferation. Regardless, the presence of *Tamarix spp.* is associated with dramatic changes in geomorphology, groundwater availability, soil chemistry, fire frequency, plant community composition, and native wildlife diversity. Geomorphological impacts include trapping and stabilizing alluvial sediments, which results in narrowing of stream channels and more frequent flooding (Graf, 1978). *Tamarix spp.* has been blamed for lowering water tables because of its high evapotranspiration rate, and, on a regional scale, dense *Tamarix spp.* groves use far more water than native riparian plant associations (Sala et al., 1996).

Soil salinities increase as a result of inputs of salt from glands on *Tamarix spp.* leaves. The dome-shaped glands consist of at least two cells embedded in the epidermal pits (Decker, 1961). Increased salinity inhibits growth and germination of native riparian species (Anderson 1996). Leaf litter from drought-deciduous *Tamarix spp.* increases the frequency of fire. *Tamarix spp.* is capable of resprouting vigorously following fire and, coupled with changes in soil salinity, ultimately dominates riparian plant communities (Busch, 1995).

Although *Tamarix spp.* provides habitat and nest sites for some wildlife (for example, white-winged dove, *Zenaida asiatica*), most authors have concluded that it has little value to most native amphibians, reptiles, birds, and mammals (Lovich and de Gouvenain, 1998).

Estimated Start and End Date

2008 through 2014

Potential Funding Sources

County of Santa Barbara, California Department of Fish and Game, U.S. Fish and Wildlife Service, National Fish and Wildlife Foundation, DWR

Percent of Matching Funding that Will Be Provided

30 percent

Regional and Local Benefits

The increasing spread of invasive weeds is a pressing concern throughout Santa Barbara County, and this is one of a number of efforts to eradicate such species in sensitive riparian habitats. The weeds are detrimental to habitat and water conservation and increase the risk of flooding and erosion in riparian systems. They displace native plants thus degrading habitat and reducing biodiversity. They use more water than native plants and increase the risk of fire, flooding, and erosion along riparian areas. Additionally, the Santa Ynez River has regional significance as one of the major rivers in the county, serving as a source of water, recreation, and habitat for a number of listed fish and bird species. Control of both arundo and tamarisk will benefit water quality, water use/groundwater, flood control, farming, recreation, and resource management. The Santa Ynez River is designated as a Critical Coastal Area (CCA).

Statewide Priorities Addressed

Implement floodplain task force recommendations

Project Number and Name

No. 12 Quiota Creek, Fish Passage Enhancements Project

Project Sponsor

Cachuma Conservation Release Board/Santa Ynez River Water Conservation District Improvement District No. 1

Watershed

Santa Ynez

Project Description

The project involves improvement of endangered steelhead passage on Quiota Creek by replacing two temporary bridges on Refugio Road that have damaged low flow (Arizona) crossings below, with prefabricated bridges that span the entire creek and re-grade the stream channel to restore natural conditions. This project is part of a broader watershed-scale planning effort that encompasses a comprehensive analysis of nine low flow passage impediments on Quiota Creek and proposed alternatives for each crossing considering passage flows, migration barriers, design criteria, and cost.

Need for the Project

There are two significant reasons to implement this project. First, the current Santa Ynez River steelhead run is estimated at 100 to 200 fish – perhaps the largest remaining population of southern steelhead, which was federally listed as endangered in 1997. These fish depend on the tributaries downstream of Bradbury Dam for spawning and rearing habitat. The quality of the lower watershed habitat is limited, however, by factors such as low surface flows, high water temperatures, passage impediments, sedimentation and lack of streamside canopy. Quiota Creek contains some of the best habitat in the Lower Santa Ynez River watershed, but fish have limited access due to passage impediments from low flow crossings along Refugio Road. Modifications of these impediments will open up approximately 3 miles of excellent stream habitat for steelhead. Removal of all nine Quiota Creek passage impediments was recommended in the Lower Santa Ynez River Fish Management Plan published in October 2000.

The second reason is that Refugio Road is an important access road for landowners along Quiota Creek, as well as for those residing at the top of the coastal mountains and on the coastal side of the watershed. The road is essential for fire fighting efforts and serves as a critical escape route for local landowners during emergencies such as fire, flood, or landslide. Providing local residents with a safe and reliable road is an important objective of the project and for the County of Santa Barbara.

Estimated Start and End Date

2008; will be completed within one year

Potential Funding Sources

California Department of Fish and Game, Fisheries Restoration Grant Program, California Coastal Conservancy, National Marine Fisheries Service, and Cachuma Member Agencies

Percent of Matching Funding that Will Be Provided

20 percent

Regional and Local Benefits

The project will improve riparian and riverine environments along 1.3 miles of stream channel and improved access to approximately 3 miles of habitat for migrating steelhead/rainbow trout. The project also will offer reduced erosion potential and improved riparian corridor connectivity. The Lower Santa Ynez River Fish Management Plan identified improvements throughout the region that would improve steelhead habitat, including the removal of fish barriers along Quiota Creek. This project is part of a broader watershed-scale planning effort and, thus, will contribute to the improvement of steelhead habitat throughout Santa Barbara County. Improved riparian corridor is also a regional benefit. The proposed permanent bridges will help keep Refugio Road open during storm events. Refugio Road links the South Coast with the Santa Ynez Valley and is an important County access road for landowners and a critical access road for emergency vehicles, as well as an egress for residents during any type of emergency.

Statewide Priorities Addressed

Reduce water user conflicts/resolve water rights disputes

Implement RWQCB Watershed Management Initiative

Implement State Species Recovery Plan

Project Number and Name

No. 13 Gallery Well Filtration Facility

Project Sponsor

Santa Ynez River Water Conservation District Improvement District No. 1

Watershed

Santa Ynez

Project Description

The proposed Gallery Well Filtration Facility Project involves the construction of a packaged filtration facility inclusive of infrastructure designed to produce a capacity of 1 MGD (700 gpm) approximately matching the production of an existing Gallery Well. In addition to complying with the Department of Health Service (DHS) requirements to filter water under the Surface Water Treatment Rule, the Gallery Well Filtration Facility will control the Trihalomethamne (THM's) and meet the appropriate stage 2 disinfectant/disinfection by-product standard which will allow the District to provide potable water to its customers from a well that has been inactive.

Need for the Project

The Department of Health Services (DHS) requires filtration of all surface water sources and groundwater under the influence of surface water. The existing Gallery Well noted in this project is located within the Santa Ynez River alluvium basin and has been classified by DHS as a source requiring filtration. Since there are no filtration facilities within the District, the Gallery Well's production has been curtailed due to its lack of compliance with the EPA/DHS Surface Water Treatment Rule. Lack of production at this site has resulted in the indefinite suspension of 515 acre-feet per year of water production. Additionally, the District may not utilize the Gallery Well or Lake Cachuma source at any time without any additional filtration and disinfection treatment facilities being constructed in full compliance with the Surface Water Treatment Rule.

In 2004, the Santa Ynez Band of the Chumash Indians brought on-line its wastewater treatment plant, which treats .15 mgd. Effluent is discharged into Zanja de Cota Creek, which is a live stream tributary to the Santa Ynez River. The Gallery Well is located downstream of the confluence of the Zanja de Cota Creek and Santa Ynez River. Because of its Federal sovereign status, the Santa Ynez Band of the Chumash Indians only complies with Federal EPA standards with no State or local control. Filtration is needed to protect all District alluvium wells in the Santa Ynez River downstream of this new facility.

Estimated Start and End Date

2008 though 2009

Potential Funding Sources

Funding for this project will come from Prop 50 grant funding and the District's Construction Reserves.

Percentage of Matching Funds that Will be Provided

10 percent

Regional and Local Benefits

Reduction of THM's and UV disinfection will provide safeguards against water quality upstream.

Statewide Priorities Addressed

Reduce water user conflicts/resolve water rights disputes

Help meet Delta Water Quality Objectives/

Implement RWQCB Watershed Management Initiative

Implement recycling task force recommendations

Project Number and Name

No. 14 Lompoc Regional Wastewater Reclamation Plant

Project Sponsor

Vandenberg Village Community Services District

Watershed

Santa Ynez

Project Description

Upgrade the Lompoc Regional Wastewater Reclamation Plant to improve reliability and meet new, more stringent discharge requirements. Upgrade treatment level from secondary to tertiary (including nutrient removal). Construct two new oxidation ditches and three new secondary clarifiers. Replace influent pumping station and sludge thickening equipment. Replace the current chemical disinfection system with an ultraviolet disinfection system. Install a new supervisory control and data acquisition system.

Need for the Project

The plant was constructed in 1974 as a regional facility to treat wastewater from the City of Lompoc, Vandenberg Village, and Vandenberg Air Force Base. It has performed well but it is old and needs to be rehabilitated and upgraded. Vandenberg Village Community Services District depends on the regional plant to treat all the wastewater from Vandenberg Village, a civilian residential community of 6,000 people (only 2,400 ratepayers). A long-term agreement with the City of Lompoc conveys 17.8 percent of the plant capacity rights to the Vandenberg Village Community Services District. The District is required to fund 17.8 percent of capital improvements to the plant. The estimated construction cost of this project is $87.4 million making the District's 17.8 percent share $15.6 million. This places considerable financial strain on a relatively small number of ratepayers.

Estimated Start and End Date

2008 through 2010

Potential Funding Sources

User fees will pay for the 10 percent matching funding for this project, and all subsequent operations and maintenance expenses for the plant.

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

This project will improve the quality of the wastewater which is treated at the plant and then discharged into the San Miguelito Creek (a tributary to the Santa Ynez River). It will benefit the habitat of the river, downstream recreational users, and the Lompoc Groundwater Basin. About 90 percent of the treated wastewater percolates into this basin, which serves as the primary source of water supply for City of Lompoc, Vandenberg Village, and Mission Hills.

Statewide Priorities Addressed

Implement TMDLs

Project Number and Name

No. 15 South Coast Conduit 2nd Pipeline - Upper Reach

Project Sponsor

Cachuma Operation and Maintenance Board

Watershed

South Coast

Project Description

The 2nd Pipeline Project will improve the reliability, integrity, and capacity of the South Coast Conduit. This project consists of installing 7,800 feet of 48-inch pipe in the vicinity of the existing 48-inch South Coast Conduit and connecting the three control structures in this reach. This second pipeline will facilitate maintenance of the original pipeline, create redundancy, and increase the South Coast Conduit capacity to original design levels to better meet the water supply needs of the South Coast communities.

Need for the Project

The 2nd Pipeline Project will improve the reliability, integrity, and capacity of the South Coast Conduit. The South Coast Conduit is the primary source of water for the 200,000 residents of the South Coast communities of Santa Barbara County. This system delivers water from Lake Cachuma through the Tecolote Tunnel to the South Coast Member Units (the City of Santa Barbara, Goleta Water District, Montecito Water District, and Carpinteria Valley Water District) through 26 miles of pipeline from Goleta to Carpinteria. The South Coast Conduit was installed in the 1950s and is constructed of reinforced concrete pipe. Over the years of service, the South Coast Conduit has been mostly trouble-free, but recently significant maintenance needs have been identified. One section of the South Coast Conduit is of primary concern; this section consists of 7,800 feet of 48-inch pipe and connects the South Portal of the Tecolote Tunnel to the Corona Del Mar Water Treatment Plant. The current plan is to add a second section of pipeline in the vicinity of the existing South Coast Conduit. This will allow continued water deliveries to be made through the existing pipeline with minimal interruptions during construction of the new pipeline. The new pipeline will improve system reliability by constructing a new modern pipeline with greatly improved integrity. It will improve long-term reliability by allowing either pipeline to be removed from service for maintenance without interruption of water deliveries through the other pipeline. This will facilitate improved maintenance and will reduce the number of unscheduled shutdowns due to emergency repairs. The increased capacity will help with delivery issues that have occurred over the last 30 years and as other infrastructure ages this added capability will greatly increase the reliability of the water supply to these communities. The improved South Coast Conduit reliability, redundancy, and capacity will ensure the ability of the South Coast Conduit to meet the current and future water demand requirements of the South Coast communities.

Estimated Start and End Date

2008 through 2009

Potential Funding Sources

Local Member Unit Assessments, Long-term Capital Improvements Loan, and grant funding

Percent of Matching Funding that Will Be Provided

15 percent

Regional and Local Benefits

As noted above, the South Coast Conduit is the primary source of water for the 200,000 residents of Santa Barbara County South Coast communities. The 2nd Pipeline Project will improve the South Coast Conduit reliability, redundancy, and capacity will ensure the ability of the South Coast Conduit to meet the current and future water demand requirements of the South Coast communities.

Statewide Priorities Addressed

Reduce water user conflicts/reduce water rights disputes

Project Number and Name

No. 16 Bluffs Sewer Relocation Project

Project Sponsor

Carpinteria Sanitary District

Watershed

South Coast

Project Description

The project includes (1) relocation of approximately 6,000 linear feet of existing gravity sewer pipeline from the current location along edge of Carpinteria Bluffs to within Carpinteria Avenue, and (2) reconstruction of the inverted siphon crossing under Carpinteria Creek at Carpinteria Avenue. This pipeline is exposed within the creek bed, and flow has been temporarily diverted to another pipeline to prevent the discharge of sewage in the event the siphon is physically damaged.

Need for the Project

The existing sewer pipeline is located along the top edge of the Carpinteria Bluffs. A significant portion of the pipeline corridor is located within Environmentally Sensitive Habitat (coastal sage scrub). The pipeline is subject to surface erosion and has failed on at least one occasion, causing discharge of raw sewage to the Pacific Ocean. This failure required emergency realignment and construction within the banks of Garrapata Creek. The existing pipeline is difficult to access for maintenance and emergency response. Relocation to Carpinteria Avenue would significantly reduce the failure threat and would remove the sewer infrastructure from the Carpinteria Bluffs. The new pipeline would be easily accessible for maintenance purposes. Replacement of the inverted siphon crossing of Carpinteria Creek would remove the existing exposed pipe, which may be a barrier to the passage of southern steelhead trout. The new siphon would be more reliable and would have a lower potential for blockages and resultant sewer overflows into Carpinteria Creek.

Estimated Start and End Date

2008 through 2010

Potential Funding Sources

Development Impact Fees from future users (for example resort development), grant funding, and limited capital improvement funds.

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

The Carpinteria Bluffs Preserve is important to the Santa Barbara region; local citizens joined with the Land Trust for Santa Barbara County and raised the money to purchase the land, which contains walking trails, a bikeway, and a 6-acre area for soccer and baseball fields. The Carpinteria Bluffs also contain undisturbed grasslands and coastal sage that serve as foraging grounds for birds. This project will eliminate the potential for pipe failure and sewage discharge to the Carpinteria Bluffs, Garrapata Creek, and the Pacific Ocean, benefiting ocean and creek water quality and biological resources. The removal of infrastructure will enhance the natural setting enjoyed by those who frequent the bluffs. The project also will eliminate the need to remove or impact Environmentally Sensitive Habitat for pipeline maintenance, emergency response or repair. Relocation of the pipeline will facilitate pipeline maintenance and reduce potential for sewer overflow and associated impacts to public health and the environment.

Statewide Priorities Addressed

Implement SWRCB’s Nonpoint Source Pollution Plan

Help meet Delta Water Quality Objectives

Project Number and Name

No. 17 Carpinteria Creek Overhead Crossing Replacement Project

Project Sponsor

Carpinteria Sanitary District

Watershed

South Coast

Project Description

The project includes removal of an existing 14-inch diameter cast iron sewer pipe suspended over Carpinteria Creek, where it crosses a public bicycle path immediately north of U.S. Highway 101. Failure of pipe or pier supports would result in direct discharge of untreated sewage to Carpinteria Creek. Replacement of the suspended line would enhance the natural setting within the creek corridor.

Need for the Project

The existing sewer pipeline is a cast iron segmented pipe suspended over Carpinteria Creek. In addition to the visual impacts of this infrastructure on the natural setting, the suspended pipeline has a relatively high failure potential, and the resultant impacts to the Carpinteria Creek habitat are significant. The pipe has failed previously when the cable suspension system was damaged due to extreme temperatures during a brushfire. Replacement would provide for a much less vulnerable conveyance system.

Estimated Start and End Date

2008 through 2009

Potential Funding Sources

Grant funding and limited capital improvement funds.

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

As discussed in Section 2, Santa Barbara County creeks are at risk from a variety of factors, including sewage discharge. The project will eliminate the potential for pipe failure and sewage discharge to Carpinteria Creek. Removal of infrastructure will enhance the natural setting of the Carpinteria Creek corridor and surrounding environment. Replacement will minimize the potential for sewer overflows within this sensitive watershed. This project will have direct local benefits, but also contribute to the improvement of regional water quality and biological resources.

Statewide Priorities Addressed

Implement SWRCB's Nonpoint Source Pollution Plan

Help meet Delta Water Quality Objectives

Project Number and Name

No. 18 Central Zone Transmission Main and Aquifer Storage Recovery (ASR) Demonstration Well Project

Project Sponsor

Carpinteria Valley Water District

Watershed

South Coast

Project Description

Construct a large diameter water transmission main (18 to 22 inches in diameter) approximately 1.25 miles long connecting existing wells, Carpinteria Valley Water District distributions systems, the South Coast Conduit and a 3-million-gallon tank. Construct an ASR demonstration well and groundwater production facility with associated transmission piping.

Need for the Project

Carpinteria Valley Water District blends local groundwater with imported surface waters in order to meet state and federal health-related water quality regulations. These regulations require that water systems reduce total Trihalomethanes and Haloacetic acids to 80 parts per billion and 60 parts per billion on all of the worst sample sites in the system by 2012. In order to blend efficiently and leverage the limited groundwater supply, ultimately ensuring that that surface water entering the system will be blended with groundwater to reduce formation of TThms and Haa5s, the District has constructed a tank for groundwater storage, a new well, and a blending system. The missing piece to the current system is a transmission main that would allow the District to hook up one existing well to the new tank, a new ASR capable well, and filtration plant with some associated piping to connect to the proposed transmission main. This would provide redundancy to the system and ensure there will always be groundwater available for blending, as well as allow the District operations staff the flexibility to manage the water supply more efficiently. In addition to water quality benefits, the new system will allow the District to offset demands placed on the South Coast Conduit and Cater Treatment Plant by using local groundwater supply in high peak times rather than burdening the South Coast transmission system. Further in an emergency or natural disaster setting the District will be able to offset or provide water supply back towards the communities of Santa Barbara and Montecito as well as Carpinteria form its groundwater supply. Finally, the project is a first step in developing a potential groundwater banking project.

Estimated Start and End Date

2008 through 2011

Potential Funding Sources

Grant funds and revenues

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

This project will complete the Carpinteria Valley Water District water system, provide redundancy, ensure groundwater availability for blending, and increase water management efficiency. The project therefore will benefit the District service area, but also will allow the District to offset demands placed on the South Coast Conduit and Cater Treatment Plant, thus providing a more regional benefit, as well. Additionally, during an emergency or natural disaster, the District will be able to offset or provide water supply to the communities of Santa Barbara and Montecito, as well as Carpinteria, from its groundwater supply. Finally, the project is a first step in developing a potential groundwater banking project. Other benefits to drinking water quality include lowered disinfectant byproduct s and improved taste and odor.

Statewide Priorities Addressed

Reduce water user conflicts/resolve water rights disputes

Project Number and Name

No. 19 Recycled Water Feasibility Study

Project Sponsor

Carpinteria Valley Water District

Watershed

South Coast

Project Description

The project is the study of the feasibility of developing a recycled water system in the Carpinteria Valley. The study will include an analysis of cost related to implementing a recycle project, the potential users of such a water supply, the economics of a recycled water supply verses the current and potential new water supplies, and the environmental benefits of a recycled water supply project.

Need for the Project

Carpinteria Valley is situated at the southerly end of Santa Barbara County's South Coast and receives water through the Cachuma Project, local groundwater, and the State Water Project. Reliance on local water sources can reduce continued dependence on imported water that has questionable reliability as California's water supply becomes more and more stressed. By critically looking at the feasibility of using some of the wastewater for irrigation uses, the Carpinteria Valley policy makers can better make decisions on how much to invest into this potential new water supply.

Estimated Start and End Date

2008; will be completed within one year

Potential Funding Sources

Revenue from Carpinteria Valley Water District and grant monies.

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

The project will reduce discharge of secondary wastewater into the ocean and increase water supply reliability through the creation of a new water supply. This also will reduce dependence on State Water Project water.

Statewide Priorities Addressed

Reduce water user conflicts/resolve water rights disputes

Implement TMDLs

Implement RWQCB Watershed Management Initiative

Help meet Delta Water Quality Objectives

Project Number and Name

No. 20 Braemer Area Sewer Extension Project

Project Sponsor

City of Santa Barbara

Watershed

South Coast

Project Description

The project involves extension of the City sewer system to serve approximately 100 properties not currently served by municipal sewer. A preliminary feasibility design study has been completed. The extension would include up to approximately 10,000 feet of 8-inch gravity sewer mains and up to 3,000 feet of 3-inch force mains. The area to be served is on the coastal plain adjacent to the ocean.

Need for the Project

The project would provide sewer connections for approximately 100 properties, most of which are currently occupied by single family residences served by septic systems. Some septic systems appear to be functioning adequately, while some have failed or are about to fail.

Estimated Start and End Date

2008 through 2009

Potential Funding Sources

Property owner assessment, plus potential grant funding

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

Creek and ocean water contamination is a regional problem. Eliminating septic tanks through this project will remove existing sources of contamination, potentially improving creek and ocean water quality. The project will provide the infrastructure to allow approximately 100 residences to abandon septic tanks and connect to City sewer.

Statewide Priorities Addressed

Implement SWRCB’s Nonpoint Source Pollution Plan

Project Number and Name

No. 21 El Estero Swale Restoration Project

Project Sponsor

City of Santa Barbara

Watershed

South Coast

Project Description

The project involves restoration and enhancement of a degraded wetlands and adjacent area next to El Estero Wastewater Treatment Plant. The area is classified as habitat for the southwestern pond turtle, a California Species of Concern.

Need for the Project

This project will achieve compliance with requirements under state and local wetlands protection regulations.

Estimated Start and End Date

The project will be implemented as soon as there is concurrence among various agencies regarding the resolution of issues associated with hazardous materials onsite.

Potential Funding Sources

Wastewater rate revenues and potential grant funding.

Percent of Matching Funding that Will Be Provided

50 percent

Regional and Local Benefits

The loss of wetlands and habitat for special status species is a regional concern. This project will help achieve improvement in Laguna Channel water quality with wetlands restoration. Approximately 0.75 acres of habitat for southwestern pond turtle will be restored.

Statewide Priorities Addressed

Implement RWQCB Watershed Management Initiative

Implement State Species Recovery Plan

Project Number and Name

No. 22 Elings Park Solid Waste Assessment Test-Corrective Action Plan

Project Sponsor

City of Santa Barbara

Watershed

South Coast

Project Description

Elings Park is the site of one of the City's old open air dumps. Gas monitoring at the site shows methane gas above lower explosive levels. This dump was abandoned prior to the promulgation of landfill requirements. California Code of Regulations (CCR) Title 27 Section 20080(e) establishes that dumps abandoned/inactive on or before November 27, 1984, are not immediately subject to the Closure and Post-Closure Maintenance requirements of CCR Title 27. Additionally, Title 27, Section 20080(g) gives the Regional Board discretion in deciding if the persons/entity responsible for discharges of waste at the dump will be required to develop and implement a detection-monitoring program. Thus, if groundwater monitoring shows water quality is impaired, such persons/entity may be required to develop and implement an acceptable corrective action program. Depending on the level (extent and degree) of groundwater quality impairment, an acceptable corrective action program may include a proposal for the installation of a final cover system, a gas extraction system and/or the implementation of an acceptable groundwater treatment alternative.

Need for the Project

In 2005 and 2006, Solid Waste Assessment Testing Activities were performed in compliance with the above regulations and under direction from the County of Santa Barbara and the RWCQB. Groundwater monitoring reports from this project indicate that concentrations of volatile organic compound constituents were detected in groundwater samples collected from groundwater monitoring at the site. Volatile organic compound constituents detected in groundwater samples collected at the site include: benzene detected at a concentration of 1.2 micrograms per liter (μg/L); Chlorobenzene detected at concentrations of 5.3 μg/L and 3.1 μg/L; 1,4-Dichlorobenzene detected at concentrations of 5.7 μg/L (MW-3A) and 3.5 μg/L (PII1); cis-1,2-Dichloroethene detected at a concentration of 14.1 μg/L; PCE detected at a concentration of 14.8 μg/L; and TCE detected at a concentration of 4.3 μg/L. The benzene concentration detected is in excess of the drinking water MCL for benzene (1.0 μg/L). The cis-1,2-Dichloroethene and PCE concentrations detected are in excess of the drinking water MCL for cis-1,2-Dichloroethene (6.0 μg/L) and PCE (5.0 μg/L). Concentrations of other volatile organic compound constituents detected in groundwater samples collected at the site during the 4Q05 groundwater monitoring event do not exceed the applicable state drinking water MCLs for the respective volatile organic compound constituents.

Estimated Start and End Date

2008 through 2009

Potential Funding Sources

City of Santa Barbara and potential grant funding

Percent of Matching Funding that Will Be Provided

20 percent

Regional and Local Benefits

This project will lessen the impact of leachate from the dump to groundwater as well as potentially treat the groundwater, improving groundwater quality. This project will also benefit public health and safety, because this site is now a park used by numerous residents for varied purposes, including soccer, BMX, offleash dog walking, hiking, hang gliding, weddings, picnics, and summer camps. Due to the high levels of methane present, it is necessary to monthly monitor the gas levels. The project will eliminate the high methane levels.

Statewide Priorities Addressed

Implement SWRCB's Nonpoint Source Pollution Plan

Project Number and Name

No. 23 Las Positas Storm Water Management Project

Project Sponsor

City of Santa Barbara

Watershed

South Coast

Project Description

This is a low-impact development project that retrofits the existing Santa Barbara Golf Club with best management practices for water quality treatment and peak flow reduction. The primary purpose is to detain and treat urban storm runoff, which enters the golf course from surrounding neighborhoods, in order to improve water quality downstream in Las Positas Creek, the Arroyo Burro Estuary, and Arroyo Burro Beach.

Need for the Project

Extensive monitoring of Las Positas and Arroyo Burro creeks indicates concentrations of fecal indicator bacteria that exceed the recreational contact standards. Arroyo Burro County Beach Park, a popular beach located at the mouth of Arroyo Burro Creek, is posted frequently during low flow and storm conditions with warnings of bacterial pollution. Monitoring of storm water runoff entering and exiting the golf course shows that both sources contain high levels of indicator bacteria. Efforts to locate hotspots, such as a neighboring playground, have not helped to rule in or rule out specific sources of pollution. Elevated peak flows during storms, due to urbanization of the watershed, have led to increased erosion and sedimentation rates in Lower Arroyo Burro Creek. In addition to degrading the stream channel, high peak flows discourage the implementation of restoration or water quality improvement projects in the watershed.

Estimated Start and End Date

2008 through 2011

Potential Funding Sources

Grant funds will be pursued for construction. The City Creeks Division will fund final design and match funding for any grants that are received to construct the project. The City will identify the operating and maintenance costs during project design and set aside funds to operate and maintain the project beginning with the Fiscal Year 2008 budget.

Percent of Matching Funding that Will Be Provided

25 percent

Regional and Local Benefits

The project will treat 140 cubic feet per second, which is equal to 100 percent of a 10-year storm runoff over the 106-acre drainage area. By reducing sediments, pollutants, and peak flow rates, this project will improve water quality and beneficial uses such a recreation and wildlife habitat. Hydrology studies show that the project will reduce peak runoff volumes during 100-year storm events by over 50 percent. During smaller events; that is, up to 10-year events, the project will detain and treat nearly 100 percent of the runoff. Depending on how long storm water is detained, up to 90 percent of sediment and associated pollutants could be removed during detention. Runoff from smaller storms (approximately two per year) and nuisance flows will be treated primarily by filtration through a series of bioswales, which are predicted to remove 20 to 80 percent of suspended pollutants. Therefore, a substantial reduction in indicator bacteria concentrations is expected in flow exiting the golf course. Furthermore, reduced peak flows will decrease erosion and sedimentation downstream. Lower on Las Positas Creek, flow will be reduced by 10 percent during a 100-year event.

The project will establish native landscapes that can support bird populations and enhance the 100-acre open space of the golf course. The project will be implemented in conjunction with maintaining playability and aesthetic standards for the public golf course. The project will also serve as a demonstration on natural treatment systems for the Santa Barbara residents that use the golf course as well as school groups and other educational institutions.

Statewide Priorities Addressed

Reduce water user conflicts/resolve water rights disputes

Implement RWQCB Watershed Management Initiative

Implement SWRCB's Nonpoint Source Pollution Plan

Project Number and Name

No. 24 Lower Mission Creek Flood Control and Rehabilitation Project

Project Sponsor

City of Santa Barbara and Santa Barbara County Flood Control District

Watershed

South Coast

Project Description

This 1.3-mile-long project includes the removal of concrete channel walls, banks, and bed to be replaced with natural stream bed features and vegetated, stabilized banks, using the “joint planting” strategy, where live riparian cuttings are used to stabilize and reinforce the soil upon which large boulders and other natural elements are stacked. The project includes replacement of several bridges that span over Mission Creek, including Mason Street, Haley Street, Cota Street, and Ortega Street bridges.

Need for the Project

Lower Mission Creek is one of the deteriorated urban creeks in the region with the potential to provide habitat and passage for endangered species, migratory birds, and aquatic life. The project will improve and ultimately protect habitat and passage for the endangered steelhead trout and tidewater goby. Both of these endangered species have been documented and tracked in lower Mission Creek, and the opportunity to provide fish passage up the watershed has been a County and City goal for numerous years. The project will also significantly reduce flood risks for the lower urban area of Santa Barbara, improve water quality, and improve ground water percolation.

Estimated Start and End Date

2009 through 2014

Potential Funding Sources

Santa Barbara County Flood Control South Coast Zone Assessment, City Streets Program, U.S. Army Corps of Engineers, Continuing Authority Program ($7 million, maximum), and City Creeks Division (Measure B).

Percent of Matching Funding that Will Be Provided

50 to 80 percent

Regional and Local Benefits

In addition to restoring the creek channel, improving habitat, and providing fish passage up the watershed, the project also includes removal of invasive and non-native plants and trees and installation of native plants and trees. The restored stream channel will also reduce stream velocities and increase the wetland area. This not only improves water quality and habitat for aquatic life and birds, but also improves urban runoff filtration and natural treatment of pollutants.

Statewide Priorities Addressed

Implement RWQCB Watershed Management Initiative

Implement SWRCB’s Nonpoint Source Pollution Plan

Implement State Species Recovery Plan

Project Number and Name

No. 25 Old Mission Creek Storm Water Management and Restoration Project

Project Sponsor

City of Santa Barbara

Watershed

South Coast

Project Description

The project includes construction of wetland detention ponds to filter storm water runoff from a 700-acre subwatershed and restoration of approximately two acres of riparian habitat along Old Mission Creek, including stabilization of 700 linear feet of creek channel, construction of 0.3 acres of new wetland habitat, and removal and replacement of non-native plants with native plants.

Need for the Project

The Old Mission Creek Storm Water Detention and Creek Restoration Project is a priority project because water quality in Old Mission Creek is high in bacteria and provides significant flow to the main Mission Creek Channel. The high bacteria levels contribute to water quality problems in Mission Creek and ultimately the city beaches, which frequently exceed the water contact standards. The project site is also located immediately downstream of an existing creek restoration project at Bohnett Park, as well as a newly constructed low flow ultraviolet water quality treatment project, providing the opportunity to link these two important habitat areas and treat all the low flow and storm water runoff within this subwatershed. In addition, the site is one of the largest floodplains available in the city to implement storm water treatment and has been identified as an ideal location for water quality treatment and restoration by a number of technical studies.

Estimated Start and End Date

2008 through 2009

Potential Funding Sources

City of Santa Barbara and IRWMP

Percent of Matching Funding that Will Be Provided

25 percent

Regional and Local Benefits

The project will result in treatment of 700 acres of urban storm water runoff with high bacteria levels. An additional benefit will result in the primary water supply to Lower Mission Creek and estuary during the low flow dry season (May through October).

The project will result in restoration of over 700 liner feet of creek channel and channel banks and will include removal of invasive non-native plants and trees and installation of native plants and trees. It will also result in construction of approximately 3 acres of new wetland habitat.

Statewide Priorities Addressed

Implement RWQCB Watershed Management Initiative

Implement SWRCB’s Nonpoint Source Pollution Plan

Implement State Species Recovery Plan

Project Number and Name

No. 26 Fairview Avenue Sewer Line Installation Project

Project Sponsor

Goleta Sanitary District

Watershed

South Coast

Project Description

Install approximately 6,340 feet of new sewer line along Fairview Avenue in Goleta, Santa Barbara County. The current sewer line in this area ranging from 8 to 15 inches in diameter will be abandoned in place. The location of the new sewer pipeline will be moved to the east and placed in a less environmentally sensitive area.

Need for the Project

The length of sewer line proposing to be replaced along Fairview Avenue has a relatively high volume of inflow and infiltration of storm water into the sewer system, which will be eliminated by replacing this sewer line. The new location will be located away from a tributary to Goleta Slough which is an environmentally sensitive area and a Critical Coastal Area.

Estimated Start and End Date

2011 through 2015

Potential Funding Sources

Goleta Sanitary District Capital Project Fund and Grant Funding

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

The replacement of this sewer line will reduce inflow and infiltration of storm water that results in increased capacity for conveyance and treatment of sewage downstream, which may reduce sewer line surcharges and needs for increased capacity. It will reduce and/or eliminate the sanitary sewer overflows that have the potential to directly impact waters of the state. This project will help protect the environmentally sensitive Goleta Slough, a Critical Coastal Area, and enhance recreational activities at the Goleta Beach County Park, whose recreational activities include swimming, fishing, boating, and scuba diving.

Statewide Priorities Addressed

Reduce water user conflicts/resolve water rights disputes

Implement SWRCB’s Nonpoint Source Pollution Plan

Implement recycling task force recommendations

Project Number and Name

No. 27 Mattorral Way Creek Arial Crossing Sewer Replacement Project

Project Sponsor

Goleta Sanitary District

Watershed

South Coast

Project Description

Replace the sewer pipe and bridge which crosses San Antonio Creek north of U.S. Highway 101. The existing bridge and abutments are no longer structurally sound due to earth movement, erosion, and deterioration of the concrete and steel materials.

Need for the Project

The existing bridge crossing and pipe have structural deficiencies jeopardizing the structural integrity of the sewer creek crossing. Structural failure would cause serious environmental damage to the San Antonio Creek ecosystem.

Estimated Start and End Date

2008; will be completed within one year

Potential Funding Sources

Goleta Sanitary District Capital Project Fund and Grant Funding

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

This project will protect the local environment from interruption raw wastewater conveyance and protect the San Antonio Creek waterway from spills resulting from structural failure affecting the sewer line.

Statewide Priorities Addressed

Implement recycling task force recommendations

Project Number and Name

No. 28 Modoc Road New Sewer Line Installation Project

Project Sponsor

Goleta Sanitary District

Watershed

South Coast

Project Description

Install approximately 5,918 feet of new sewer line along Modoc Road near Cieneguitas Creek in Goleta, Santa Barbara County. The new sewer line in this area will range in size from 6 to 8 inches in diameter.

Need for the Project

The new sewer line proposed for this area will serve a future housing project that may be developed in the area bound by Modoc Road, Vista Clara Road and Encore Drive.

Estimated Start and End Date

2011 through 2015

Potential Funding Sources

Goleta Sanitary District Capital Project Fund and Grant Funding

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

Installation of appropriate wastewater conveyance will avoid the use of septic tanks for planned developments, helping protect local environment from potential nonpoint source pollution. ‘

Statewide Priorities Addressed

Implement SWRCB’s Nonpoint Source Pollution Plan

Project Number and Name

No. 29 Water Reclamation Facility 2007 Refurbishment Project

Project Sponsor

Goleta Sanitary District

Watershed

South Coast

Project Description

Refurbish the filter valves and automated valve operators located in the reclaimed water filter process. The scope of the work will include the purchase and installation of 16 valves, valve shafts and electric valve operators.

Need for the Project

The water reclamation facility provides recycled wastewater to the Goleta Valley for primarily irrigation uses. The use of reclaimed water has reduced the demand on the potable water supplies. This project is necessary to refurbish the primary mechanical components of the reclamation filters ensuring a reliable and dependable recycled water supply.

Estimated Start and End Date

2008; will be completed within one year

Potential Funding Sources

Goleta Water District

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

This project will ensure reliable recycled water supply reducing the demand on potable supplies. It will also provide irrigation water for parks and recreation areas throughout Goleta.

Statewide Priorities Addressed

Reduce water user conflicts/resolve water rights disputes

Implement SWRCB's Nonpoint Source Pollution Plan

Implement recycling task force recommendations

Project Number and Name

No. 30 ASR Well Rehabilitation and Construction Project

Project Sponsor

Goleta Water District

Watershed

South Coast

Project Description

Rehabilitate one existing well and construct one new well, to more efficiently manage the Goleta Groundwater Basin and the Goleta Water District conjunctive use program.

Need for the Project

In order to efficiently manage the Goleta Groundwater Basin and the Goleta Water District conjunctive use program, one existing well needs to be rehabilitated and another well needs to be constructed.

Estimated Start and End Date

2009 though 2010

Potential Funding Sources

Goleta Water District general fund and grant funding

Percent of Matching Funding that Will Be Provided

40 percent

Regional and Local Benefits

This project will improve conjunctive use capability through improved efficiency of groundwater supply management.

Statewide Priorities Addressed

Reduce water user conflicts/resolve water rights disputes

Help meet Delta Water Quality Objectives

Implement recycling task force recommendations

Help achieve CALFED Bay-Delta Program Goals

Project Number and Name

No. 31 Backwash Tank Replacement at 4 Wells Project

Project Sponsor

Goleta Water District

Watershed

South Coast

Project Description

The project includes replacement of undersized backwash tanks used in treatment of groundwater for four wells. When replaced, larger tanks will reduce and potentially eliminate waste of water to drain. Water used for backwash can be retreated and injected to groundwater basin and/or supplied for potable use instead of wasting.

Need for the Project

The backwash tanks are currently undersized. When replaced, larger tanks will reduce and potentially eliminate waste of water to drain. Water used for backwash can be retreated and injected to groundwater basin and/or supplied for potable use instead of wasting.

Estimated Start and End Date

2008 through 2009

Potential Funding Sources

Goleta Water District general fund and grant funding

Percent of Matching Funding that Will Be Provided

50 percent

Regional and Local Benefits

The project will provide conservation of water supply, offsetting potable water use and will reduce the production of wastewater.

Statewide Priorities Addressed

Reduce water user conflicts/resolve water rights disputes

Help achieve CALFED Bay-Delta Program Goals

Project Number and Name

32 Cathedral Oaks Pipeline Replacement Project

Project Sponsor

Goleta Water District

Watershed

South Coast

Project Description

Replace 1,800 feet of 12-inch-diameter pipe with 20-inch-diameter pipe. This project will reduce pressure losses and thereby increase volume flow to meet peak demands and emergency fire flows.

Need for the Project

Reduce pressure losses and thereby increase volume flow to meet peak demands and emergency fire flows.

Estimated Start and End Date

2010; will be completed within one year

Potential Funding Sources

Goleta Water District general fund and grant funding

Percent of Matching Funding that Will Be Provided

50 percent

Regional and Local Benefits

Benefits for this project include increased emergency water supply and fire fighting capability.

Statewide Priorities Addressed

Help achieve CALFED Bay-Delta Program Goals

Project Number and Name

No. 33 Corona Del Mar Water Treatment Plant – Sedimentation Basin Effluent Upgrades Project

Project Sponsor

Goleta Water District

Watershed

South Coast

Project Description

The proposed project will include modifications and upgrades to the District's existing Corona Del Mar Water Treatment Plant. Modifications will include:

- Replacement of deteriorated and inefficient effluent launders
- Installation of new plate settlers within the sedimentation basin
- Modification and upgrade of the combined effluent channels for improved efficiency
- Replacement of the deteriorated filter backwash troughs

Need for the Project

The District's Corona Del Mar Water Treatment Plant has been in service for over 30 years. Although upgrades to the plant have occurred over the last several years, many components of the plant are deteriorated and still in need of replacement and upgrade. The upgrades described above will significantly improve the plant efficiency and quality of water produced by the plant.

Estimated Start and End Date

2008 through 2009

Potential Funding Sources

Goleta Water District Capital Improvement Project Fund and Grant Funding

Percent of Matching Funding that Will Be Provided

25 percent

Regional and Local Benefits

The proposed improvements will reduce the amount of flocculent that reaches the filters and reduce the amount of filter aid required during the filtration process. This in turn will reduce the amount of sludge produced during filter backwash.

The modifications and upgrades will result in significant improvement to the plant's overall treatment efficiency. Maintenance tasks will be simplified saving time and money. Less filter aid (chemical) will be used also reducing operating costs by approximately $5,000 annually. The project will replace several plant components that have outlived their design life, such as the launders and filter backwash troughs. This will improve reliability by replacing aging unreliable components of the plant.

Statewide Priorities Addressed

Help achieve CALFED Bay-Delta Program Goals

Project Number and Name

No. 34 Downstream Reservoir Meters Project

Project Sponsor

Goleta Water District

Watershed

South Coast

Project Description

Install meters downstream of Goleta Water District storage reservoirs to measure area demands, determine areas of unaccounted water, minimize losses and optimize efficiency.

Need for the Project

Measure area demands, determine areas of unaccounted water, minimize losses and optimize efficiency.

Estimated Start and End Date

2008 through 2009

Potential Funding Sources

Goleta Water District general fund and grant funding

Percent of Matching Funding that Will Be Provided

50 percent

Regional and Local Benefits

The project will reduce loss of water in the distribution system, and optimize the efficiency of serving water which will offset needs for other sources of potable water.

Statewide Priorities Addressed

Help achieve CALFED Bay-Delta Program Goals

Project Number and Name

No. 35 Interconnect with City of Santa Barbara Project

Project Sponsor

Goleta Water District

Watershed

South Coast

Project Description

The project includes a pipeline and pump station connection between the water systems of Goleta Water District and City of Santa Barbara. This will provide the ability to supply water from one agency to the other during big peak demands and emergencies. This will also increase the amount of water that can be delivered to other agencies downstream from the City of Santa Barbara.

Need for the Project

This project provides the ability to supply water from one agency to the other during big peak demands and emergencies. It will also increase the amount of water that can be delivered to other agencies downstream from the City of Santa Barbara.

Estimated Start and End Date

2008 through 2009

Potential Funding Sources

Goleta Water District, City general fund, and grant funding

Percent of Matching Funding that Will Be Provided

50 percent

Regional and Local Benefits

Increased water supply reliability to several water districts and cities: Goleta Water District, City of Santa Barbara, Montecito Water District, and City of Carpinteria.

Statewide Priorities Addressed

Reduce water user conflicts/resolve water rights disputes

Help achieve CALFED Bay-Delta Program Goals

Project Number and Name

No. 36 Blended Irrigation Project

Project Sponsor

La Cumbre Mutual Water Company

Watershed

South Coast

Project Description

Use of nonpotable groundwater from a well exceeding iron and manganese levels by blending with water from a 31-acre lake located on a golf course, to offset the state water usage. The proposal is to install a wet well, intake structure, and variable frequency drive pump station to pump lake water into the irrigation system.

Need for the Project

The proposed lake pump house would make available a source of groundwater currently unusable for domestic use. This would further diversify the La Cumbre Water supply and free higher quality water for more appropriate uses. Currently during peak demand periods, La Cumbre Water is at full capacity. The Blended Irrigation Project would allow La Cumbre Water to meet peak demand at 62 percent capacity and provide 38 percent reserve capacity for reliability.

Estimated Start and End Date

2008 through 2009

Potential Funding Sources

La Cumbre Mutual Water Company funding and grant funding

Percent of Matching Funding that Will Be Provided

100 percent

Regional and Local Benefits

This project will provide a greater percentage of State Project Water and increased water quality water for domestic customers. It will also provide more appropriate use of lower quality water for recreational uses.

Statewide Priorities Addressed

Implement recycling task force recommendations

Project Number and Name

No. 37 Iron and Manganese Removal Plant Project

Project Sponsor

La Cumbre Mutual Water Company

Watershed

South Coast

Project Description

This project includes construction of a 2,150-gallons per minute iron and manganese removal treatment plant, treating groundwater for domestic potable water service. The source water is approximately four times limit for these parameters. Treated water would offset state water usage and provide approximately 38 percent reserve capacity for reliability to domestic users.

Need for the Project

Currently the plant is at maximum capacity in the summer time. Adding a treatment plant would create a needed margin of safety to keep up with demand if one of our wells were to fail during high peak demand periods. Currently during peak demand periods, La Cumbre Water Company is at full capacity. The Iron and Manganese Removal Plant would allow La Cumbre Water Company to meet peak demand at 62 percent capacity.

Estimated Start and End Date

2008 through 2009

Potential Funding Sources

La Cumbre Mutual Water Company funding and grant funding

Percent of Matching Funding that Will Be Provided

100 percent

Regional and Local Benefits

This project makes groundwater available for potable domestic service, offsetting imported water needs.

Statewide Priorities Addressed

Help meet Delta Water Quality Objectives

Project Number and Name

No. 38 Non-Storm Water Diversion, Isla Vista

Project Sponsor

County of Santa Barbara

Watershed

South Coast

Project Description

The project is located in Isla Vista, one of the most densely populated communities in California and home of the UCSB campus. Most runoff in Isla Vista is treated with a trash/gross solids separator. There are four such solid separators. Pollutants that are smaller than 0.185 inch are passed through the separators. These pollutants are then discharged, untreated, onto the beach. Due to commercial and residential water use (i.e., landscape overwatering, car washinig, hosing paved surfaces, etc.) low flows are discharged from the storm drain system and onto the beach on a daily basis year-round. This project will divert flows from the storm drain system into the sanitary collection system during dry periods, eliminating all non-storm water discharges and its associated pollutants. Educational signage and student-oriented information will be provided to communicate benefits of project.

Need for the Project

An unhealthy assemblage of pollutants is generated from runoff on urban surfaces. Discharges off gutters, driveways, and commercial areas occur year-round. Pollutants that are carried by these non-storm water flows range from vehicle emissions (oil drips, cleaners, copper, zinc, etc.) to food wastes and bird droppings hosed off outside areas of restaurants and bars. Regular testing of bacteria from non-storm water runoff shows elevated levels of indicator bacteria, which means beachgoers in Isla Vista are exposed to a higher risk of illness. This project will protect ocean water quality and human health at the beaches in Isla Vista during non-rainy periods.

Estimated Start and End Date

2009 through 2010

Potential Funding Sources

County of Santa Barbara's Project Clean Water program, Shoreline Preservation Fund (a UCSB student grant source)

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

Santa Barbara County is responsible for water quality in storm drain discharges in the area of Isla Vista. This project will achieve the objectives of the municipal operations section of the County's Storm Water Management Program by treating and removing pollution conveyed by the storm drain system. The protect will human health and improve ocean water quality by preventing pollutants from being discharged onto the beach. The project will improve water quality of urban runoff into the Santa Barbara Channel, an area used for fishing and water contact sports. This project addresses D-7 Water Quality Priorities related to beach closure issues and implementation of Phase II of the NPDES Storm Water Program. It also addresses Urban Management 3.6A by improving controls for existing surface water runoff through pollution prevention. The results will be quantifiable through ongoing monitoring of diverted flows.

Statewide Priorities Addressed

Implement TMDLs

Implement RWQCB Watershed Management Initiative

Implement SWRCB's Nonpoint Source Pollution Plan

Project Number and Name

No. 39 Las Vegas and San Pedro Creeks Flood Control Improvements

Project Sponsor

Santa Barbara County Flood Control District

Watershed

South Coast

Project Description

This project consists of the construction of two improved reinforced concrete box culverts along San Pedro Creek and Las Vegas Creek in Goleta.

Need for the Project

During storm events, parts of Calle Real and U.S. Highway 101 are sometimes closed, and numerous homes and businesses are subject to flooding. The cleanup costs associated with the flooding in past storm events is significant. Construction of these culverts will greatly improve the capacity of the drainage system and reduce the flood hazard to adjacent properties.

Estimated Start and End Date

2008 through 2012

Potential Funding Sources

Caltrans, South Coast Flood Zone

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

This project will provide protection for people, property and the environment from flooding.

Statewide Priorities Addressed

Implement recycling task force recommendations

Project Number and Name

No. 40 San Jose Creek Flood Control Improvements

Project Sponsor

Santa Barbara County Flood Control District

Watershed

South Coast

Project Description

The project includes modifications to the San Jose Creek, primarily affecting the tops of the existing banks, in order to increase channel capacity.

Need for the Project

Large portions of Old Town Goleta need to be protected from risk of flooding because they are within the San Jose Creek's 100-year flood zone, an area mapped by the Federal Emergency Management Agency as a special flood hazard area.

Estimated Start and End Date

2008 through 2011

Potential Funding Sources

The City of Goleta is likely to submit this project to the Federal Emergency Management Agency for a Pre-Disaster Mitigation Grant.

Percent of Matching Funding that Will Be Provided

10 percent

Regional and Local Benefits

This project will provide protection for people, property and the environment from flooding.

Statewide Priorities Addressed

Implement floodplain management task force recommendations

9

9 Compliance with Statewide Priorities, Benefits, and Impacts from IRWMP Implementation

This section summarizes the overall compliance of Santa Barbara County's ongoing and future water management actions with the statewide priorities, describes the overall benefits that will result from the implementation of the IRWMP, as well as the beneficial and adverse impacts that could result from implementing the IRWMP, focusing on the impacts to individual environmental resources from the implementation of specific projects. This section also addresses obstacles to IRWMP implementation.

9.1 Compliance with Statewide Priorities

As described in preceding sections, the issues facing the Santa Barbara countywide region are consistent with those identified as being important to the state; and the project prioritization process considered whether individual projects included in the IRWMP complied with the statewide priorities identified in the state's Proposition 50 Guidelines. Each statewide priority identified in the Guidelines is shown below in italics, followed by a description of how the IRMWP complies with the priority. In some cases, compliance is occurring through established programs or agreements described in this IRWMP; in others, compliance will occur through the implementation of specific projects.

Reduce conflict between water users or resolve water rights disputes, including interregional water rights issues

After decades of contentious disagreements and litigation, conflicts between water users and water rights disputes are being addressed through a series of agreements, including the Cachuma Project Settlement Agreement, Upper Santa Ynez River Operations Agreement, Wright Suit Settlement, and the Santa Maria Adjudication (Section 3). Development and implementation of projects through the IRWMP will demonstrate the ability of multiple entities to work together effectively in ways that honor the water rights covered by these various agreements.

Implementation of TMDLs that are established or under development

No Total Maximum Daily Loads (TMDLs) are currently in place in Santa Barbara County; however, several are under development, including TMDLs in Santa Maria and Oso Flaco for both nitrates and fecal coliform, Santa Barbara County beaches for bacteria, Santa Maria River for pesticides, and Santa Ynez River for nutrients. Table 2-3 identifies impaired water bodies within the county, and Appendix A identifies scheduled dates for the implementation of specific TMDLs. The Santa Maria River/Oso Flaco, Santa Ynez River, and South Coast Beaches TMDLs Watershed Working Groups Project, described in Section 8, will fund seed money to form watershed working groups for the lower

Santa Maria River/Oso Flaco Waterbodies, Santa Ynez River, and the South Coast Beaches for the express purpose of providing input to the TMDL process in these watersheds. Projects that will help address specific water quality impairments are shown in Table 9-1. Additionally, the IRWMP provides a mechanism for developing additional projects to address issues such as water quality concerns in the impaired water bodies.

TABLE 9-1
Projects with Linkages to TMDLs or 303(d) Listed Water Bodies

Project Name	Sponsor	Location	Water Body	Impairment Addressed
Bluffs Sewer Relocation Project	Carpinteria Sanitary District	Eastern portion, City of Carpinteria	Carpinteria Creek, Pacific Ocean	Pathogens (creek) Fecal coliform (ocean) Total coliform (ocean)
Guadalupe Wastewater Treatment Plant Reuse Improvements Project	City of Guadalupe	Western Santa Maria basin	Santa Maria River, Estuary	Proposed TMDLs: Bacteria Nitrate
Braemar Area Sewer Extension	City of Santa Barbara	Calle Real/Hope Avenue area	Arroyo Burro Creek, Pacific Ocean	Pathogens (creek) Total coliform (ocean)
Las Positas Stormwater Management	City of Santa Barbara	Calle Real/ Las Positas Road area (golf course)	Arroyo Burro Creek, Pacific Ocean	Pathogens (creek) Total coliform (ocean)
Cuyama Effluent Disposal	Cuyama Community Services District	Cuyama Valley	Tributary to Cuyama River/ Santa Maria River	Proposed TMDLs: Bacteria Nitrate
Jalama Beach Park Septic System Improvements	County Parks Department	Mouth of Jalama Creek	Pacific Ocean at Jalama Creek	Fecal coliform (ocean) Total coliform (ocean)
Watershed working groups (countywide)	Agricultural Watershed Coalition	Countywide	Countywide	Proposed TMDLs: All 303(d) listings
Lompoc Regional Wastewater Reclamation Plant	Vandenberg Village Community Services District	North side, Lompoc basin	Lower Santa Ynez River	Nutrients

Implementation of Regional Water Quality Control Board (RWQCB) Watershed Management Initiative chapters, plans, and policies

The Central Coast Watershed Management Initiative chapter is in the process of being revised, although the Water Quality Priorities have been updated and include the following:

Agriculture – Addressing water quality impacts from irrigated agriculture, a major land use in the region that has been identified as a potential source of impairment for many of the waterbodies on the 303(d) list (constituents of concern include nutrients, pesticides and sediment) by implementing the conditional waiver for irrigated lands.

In Santa Barbara County, runoff from commercial, irrigated lands is being addressed through the Central Coast RWQCB's Conditional Waiver for Irrigated Lands program, and will be addressed through TMDLs, which are in development (Sections 2 and 5). Groundwater quality impacts from agricultural activities are being addressed through the mobile lab program (Section 5) and the Conditional Waiver program through the implementation of management measures.

TMDLs – Developing and implementing TMDLs throughout the region

See the discussion under TMDLs above.

Urban Runoff – Addressing beach closure issues, implementing Phase II of the National Pollution Discharge Elimination System (NPDES) Storm Water Program.

Urban runoff and beach closure issues are being addressed through Project Clean Water and Storm Water Management Plans developed by Santa Barbara County and individual cities, as well as through programs and educational efforts by local agencies (Section 5). The IRWMP also includes projects to address this issue, including the Las Positas Storm Water Management Project, which will detain and treat urban storm runoff from surrounding urban areas that enters a golf course to improve water quality downstream in Las Positas Creek, the Arroyo Burro Estuary, and Arroyo Burro Beach. Additionally, the Lower Mission Creek Flood Control and Rehabilitation Project will improve urban runoff filtration and the natural treatment of pollutants, and the Old Mission Creek Storm Water Management and Restoration Project will result in the treatment of 700 acres of urban storm water runoff. These projects could help reduce beach closures.

Implementation of the State Water Resources Control Board (SWRCB) Nonpoint Source Pollution Plan

The Nonpoint Source Pollution Plan adopts a number of management measures as goals for six Nonpoint Source Pollution categories (agriculture, forestry, urban areas, marinas and recreational boating, hydromodification, and wetlands/riparian areas/vegetated treatment systems).

In agricultural areas, runoff is being addressed through the Central Coast RWQCB's Conditional Waiver for Irrigated Lands program (Section 5).

Urban runoff and beach closure issues are being addressed through Project Clean Water and Storm Water Management Plans developed by the County and individual cities, as well as through educational efforts by local agencies (Section 5).

Nonpoint Source Pollution in the Los Padres National Forest is addressed by the U.S. Forest Service through its management plan.

Nonpoint Source Pollution in the Santa Barbara marina is addressed through the Clean Marina Program (Section 3).

A number of projects involving the restoration of wetlands and riparian areas are underway in Santa Barbara County, some examples of which are included in Section 2. Additionally, a number of projects that will improve water quality through wetland restoration are included in this IRWMP, including the El Estero Swale Restoration Project, Lower Mission Creek Flood Control and Rehabilitation Project, and the Old Mission Creek Storm Water Management and Restoration Project.

Assist in meeting Delta Water Quality Objectives

Decision 1641 is an action by the SWRCB to establish water quality objectives for water uses in the Delta. The Bay/Delta Water Quality Control Plan was developed as a means to attain these water quality objectives and includes the following components: implementation of flow objectives for specific water quality criteria in the Bay-Delta Estuary; a petition to change the point of diversion for the Central Valley Project and State Water Project in the southern Delta; and a petition for change in place of use and purpose of use of the Central Valley Project. The potential for actions within Santa Barbara County to assist in achieving these goals is through the increase in the reliability of local water supplies, as will result from a number of projects included in the IRWMP, thereby reducing the potential need for additional imported water supplies from the Bay-Delta region. Projects that will increase water supply reliability include: Santa Ynez River Arundo Eradication; South Coast Conduit 2nd Pipeline; Central Zone Transmission Main; Santa Ynez River Arundo Eradication; South Coast Conduit 2nd Pipeline - Upper Reach; Central Zone Transmission Main; Carpinteria Valley Water District's Recycled Water Feasibility Study; Casmalia Water System Improvements; Regional Water Conservation Rebates, Incentives, and Promotion; Cuyama Water Tower Repair, Goleta Sanitary District's Water Reclamation Facility 2007 Refurbishment Project; Goleta Water District's Aquifer Storage and Recovery (ASR) Well Rehabilitation and Construction, Backwash Tank Replacement at Four Wells, Cathedral Oaks Pipeline Replacement, Corona Del Mar Water Treatment Plant-Sedimentation Basin Effluent Upgrades, Downstream Reservoir Meters, and Interconnect with City of Santa Barbara; La Cumbre Mutual Water Company's Blended Irrigation Project and Iron and Manganese Removal Plant; Santa Maria River/Oso Flaco, Santa Ynez River, and South Coast Beaches TMDLs Watershed Working Groups; and Vandenberg Village's Lompoc Regional Wastewater Reclamation Plant.

Implementation of recommendations of the floodplain management task force

Recommendations include, but are not limited to, floodplain mapping, land use planning in areas affected by flooding, alluvial floodplain management, repetitive loss reduction, and flood warning and local community flood response programs.

Such programs are already in place in Santa Barbara County, and the IRWMP includes additional projects that will enhance flood protection, including the Santa Ynez River Arundo Eradication Project, Lower Mission Creek Flood Control and Rehabilitation Project, Las Vegas and San Pedro Creeks Flood Control Improvements, and Santa Maria Levee Project.

Implementation of recommendations of the desalination task force

Recommendations include use of desalination, where economically and environmentally appropriate, as an element of a balanced water supply portfolio, which also includes conservation and water recycling to the maximum extent practicable.

As discussed in Section 4, the City of Santa Barbara owns a desalination plant, which could be reactivated as needed to supplement ongoing conservation and recycling programs.

Implementation of recommendations of the recycling task force

Recommendations include:

- Local agencies should engage the public in an active dialogue and participation using a community value-based decision-making model in planning water recycling projects. Public participation activities should go beyond the minimum requirements of state and federal environmental laws, perhaps being reinforced by state funding agencies requiring a comprehensive public participation process as a condition for receiving state funds.
- Local agencies should create well-defined recycled water ordinances. Local regulatory agencies should effectively enforce these ordinances.
- Local agencies should maintain strong source control programs and increase public awareness of their importance in reducing pollution and ensuring a safe recycled water supply.
- Local agencies are encouraged to perform economic analyses in addition to financial analyses for water recycling projects to provide transparency regarding the true costs and benefits of projects.

Santa Barbara County has several sources of recycled water (Section 4), and the IRWMP contains several more projects that will enhance use of recycled water, including the Guadalupe Wastewater Treatment Plant Reuse Improvements Project, which will use treated wastewater to provide water to a 20-acre wetland site, and the Water Reclamation Facility 2007 Refurbishment Project, which will provide the infrastructure upgrades needed to ensure a reliable supply of recycled water. Additionally, the IRWMP has resulted in new dialogues between water and wastewater providers within the county (refer to Section 6), and resulting suggestions included performing a market study to determine the potential for using more recycled water.

Implementation of recommendations of the state species recovery plan

Santa Barbara County contains a number of listed species (Section 2), and a number of habitat enhancement projects are ongoing (e.g., those in Carpinteria Marsh, Goleta Slough, Devereux Slough, and Arroyo Burro). The IRWMP contains a number of projects that will enhance habitat in areas containing listed species, including the Santa Ynez River Arundo Eradication Project, Quiota Creek Fish Passage Enhancements Project, Bluffs Sewer Location Project, El Estero Swale Restoration Project, Las Positas Storm Water Management Project, and the Lower Mission Creek Flood Control and Rehabilitation Project.

Address environmental justice concerns

The IRWMP includes four high priority projects that will improve much-needed water and wastewater treatment services in the three disadvantaged communities (DACs) present in Santa Barbara County, thereby addressing environmental justice concerns. The City of Guadalupe has inferior water and wastewater systems that are in need of upgrading. The City of Guadalupe Wastewater Treatment Plant Reuse Improvements Project will improve the quality of wastewater discharge, benefiting the health and safety of community members, and allowing the treated water to be used for a wetland enhancement project. The community of Casmalia has a critical need for water system improvements that will ensure it has a safe, secure water supply. In December 2006, bacterial contamination of its drinking water resulted in a "boil water" order. The Casmalia Water System Improvements Project will replace deficient infrastructure such as water pipelines and tank facilities, update buildings and facilities to comply with design and code requirements, and make improvements to the existing well facility. Two essential projects also will improve water quality and drinking water in Cuyama. The Wastewater Treatment Plant Effluent Disposal Project will allow Cuyama to avoid mandatory penalties and have its NPDES permit renewed. Additionally, if Cuyama's 50-year-old water tower is not repaired, it will soon reach the point where it will not function.

Assist in achieving one or more goals of the CALFED Bay-Delta Program

The CALFED Bay-Delta Program objectives focus on water quality, ecosystem quality, water supply reliability, and levee system integrity in the Bay-Delta area. The potential for actions within Santa Barbara County to assist in achieving these goals is through the increase in the reliability of local water supplies, as will result from a number of projects included in the IRWMP, thereby reducing the potential need for additional imported water supplies from the Bay-Delta region. Projects that will increase water supply reliability are described under "Assist in meeting Delta Water Quality Objectives."

9.2 Overall Benefits of the IRWMP

9.2.1 Projects that Address Specific Regional Issues and Challenges

The key issues and challenges facing Santa Barbara County were identified by the Cooperating Partners through the IRWMP process, and they are reflected in the objectives, regional priorities, and water management strategies identified in this plan. Projects that met these objectives and regional priorities were then developed using a variety of water management strategies. Example projects are shown in Tables 8-1 and 8-2, and the complete list of highest priority projects is shown in Table 8-3. The plan also includes an adaptive management element, described in Section 10, which outlines a process for modifying and developing new projects to reflect changing regional needs.

9.2.2 Projects that Are Consistent with State of California Program Preferences

The benefits of the IRWMP also are demonstrated by the following discussion, which shows the consistency of the plan with the program preferences established by the state.

Include Integrated Projects with Multiple Benefits

Integration can occur through multiple means, as discussed below.

Integration through Use of Multiple Water Management Strategies

The integration between the IRWMP's water management strategies, regional objectives, and regional priorities, and the multiple benefits that result from such an approach are discussed in Section 7. As shown in Table 8-4 and Tables D-1 through D-5 in Appendix D, the highest priority projects and the entire suite of projects included in the IRWMP use a wide range of water management strategies to achieve the plan objectives and meet regional priorities, thus, resulting in an inherently integrated plan.

Integration through Use of the Same Water Management Strategies

Other ways of achieving integration are through the implementation of multiple projects using the same water management strategy. For example, several IRWMP projects will enhance recycled water supplies, and thereby countywide water supply reliability (Guadalupe Wastewater Treatment Reuse Improvements; Regional Water Conservation Rebates, Incentives, and Promotion; Water Reclamation Facility 2007 Refurbishment). Additionally, a number will remove invasive weeds, remove barriers to fish passage, and restore riparian areas (Santa Ynez River Arundo Eradication, Lower Mission Creek Flood Control and Rehabilitation, Old Mission Creek Storm Water Management and Restoration, Quiota Creek, Fish Passage Enhancements). Together they contribute to a greater benefit to the affected resources than if they were implemented in isolation.

Integration Resulting from Projects with Multiple Benefits

Additionally, most projects included in the IRWMP have multiple regional and local benefits (Section 8), and each project is therefore integrated through the linkage of resources that will benefit from its implementation. For example, eradicating *Arundo donax* and *Tamarix spp*. along the Santa Ynez River will reduce the risk of flooding, erosion, and fire, and increase biodiversity, improve water quality, minimize water consumption, and increase groundwater availability, improve soil chemistry, and improve river access for recreational users. The Quiota Creek Fish Passage project, for example, will improve riparian and riverine environments along 1.3 miles of stream channel and improve access to approximately 3 miles of habitat for migrating steelhead/rainbow trout. The project also will offer reduced erosion potential and improved riparian corridor connectivity, and the proposed permanent bridges will help keep Refugio Road open during storm events. Refugio Road links the South Coast with the Santa Ynez Valley and is an important County access road for landowners and a critical access road for emergency vehicles, as well as an egress for residents during any type of emergency.

Integration with Other Projects Not in the IRWMP

Integration also occurs through linkage with other projects, including those that are not part of the Plan. For example, several IRMWP projects will benefit Arroyo Burro and Goleta Slough and will complement other restoration projects in those areas. Mission Creek, which runs through downtown Santa Barbara, also represents a prime opportunity to integrate the goals of flood control, habitat enhancement, and recreational opportunities, as well as complement other ongoing creek improvements, both upstream and downstream. After years of debate, planning, and design, the Lower Mission Creek Flood Control and Restoration Project is ready to move ahead, and will address a 1.3-mile length of Lower Mission Creek. It will be a multiphase project designed to increase the carrying capacity of the creek from an 8-year event to a 20-year event, remove concrete channels, create a wider channel and natural streambed features for bank stabilization, replace several bridges, improve creek water quality, and remove invasive and non-native vegetation. Habitat and fish passage for several endangered species (southern steelhead trout and tidewater goby) will be enhanced as a result of the project, while also reducing the potential for severe flooding, which occurred in the downtown area in 1995 and 2005. The project has integrated a variety of funding sources, including federal highway grants, County Flood Control assessments, City street repair funds, and potential Army Corps of Engineer funding.

Integration with Other Management Plans and Programs

The IRWMP is also integrated through linkage with other Santa Barbara County water management plans and programs described in Section 3, including General Plans, Urban Water Management Plans, Storm Water Management Plans, Water Shortage Contingency Plans, Capital Improvement Plans, and Operations Agreements, as well as weed management programs. The IRWMP contains projects and strategies that are either specifically included in these plans or that help meet the Plan goals and objectives. As an example, the projects that will remove fish barriers from local creeks (the Quiota Creek Fish Passage Project, Bluffs Sewer Relocation Project) are part of a watershed-scale planning effort to improve steelhead habitat throughout Santa Barbara County.

Geographic Integration

Integration also can occur geographically; for example, multiple projects have been included in the IRWMP that will increase tidal circulation and reduce storm water discharges into Goleta Slough, which is a 303(d) impaired water body. Other projects will benefit riparian areas within Carpinteria or the City of Santa Barbara.

System Integration

IRWMP projects sponsored by individual agencies also are integrated through their role in the overall system of which they are a part. For example, the Central Zone Transmission Main Project will complete the Carpinteria Valley Water District water treatment and distribution system, allowing it to comply with state and federal health standards, while providing redundancy to the system. The South Coast Conduit 2nd Pipeline Project also is an essential element of the Cachuma Operation and Maintenance Board system and is needed to improve the South Coast Conduit reliability, redundancy, and capacity to ensure the ability of the conduit to meet the current and future water demand requirements of the South Coast communities. The improvements to water systems in the DACs (Casmalia, Cuyama, and the City of Guadalupe) are critical elements needed to ensure that these communities have safe and reliable water and wastewater systems.

Integration through Interagency Cooperation

Integration also can occur through cooperative efforts between agencies, as exemplified by the Goleta Water District and City of Santa Barbara Interconnect Project, which will provide the ability to supply water from one agency to the other during big peak demands and emergencies. Additionally, the Central Zone Transmission Main and ASR Demonstration Well Project will provide a means to supply water to the southern (downstream) communities of the South Coast Conduit reach in the event its capacity is reached or interrupted. This project will further increase the water supply reliability of the South Coast Conduit system.

Support and Improve Local and Regional Water Supply Reliability

The IRWMP includes a number of projects that will improve water supply reliability. For example, the South Coast Conduit 2nd Pipeline Project will improve the reliability, integrity, and capacity of the Conduit, which is essential to the delivery of water supplies to the current and future population of the South Coast. As noted immediately above, the Central Zone Transmission Main and ASR Demonstration Well Project will further increase the water supply reliability of the South Coast Conduit system. Other projects will improve treatment and distribution systems, allowing them to comply with state and federal health standards, while increasing reliability. Operation of the Santa Barbara County Regional Water Conservation Program, which increases reliability of water supplies through a reduction in water consumption, also is included as a project. Specific projects that will improve water supply reliability are listed above under "Assist in meeting Delta Water Quality Objectives."

Contribute Expeditiously and Measurably to the Long-term Attainment and Maintenance of Water Quality Standards

Several projects meet this program preference. One IRWMP project will fund seed money to form watershed working groups for the lower Santa Maria River/Oso Flaco Waterbodies, Santa Ynez River and the South Coast Beaches for the express purpose of managing the TMDL process in these watersheds. Other projects will provide infrastructure improvements that allow water and wastewater purveyors to meet regulatory standards (Central Zone Transmission Main and ASR Demonstration Well, Casmalia Water System Improvements, Corona Del Mar Water Treatment Plant – Sedimentation Basin Effluent Upgrades, Vandenberg Village Lompoc Regional Wastewater Reclamation Plant). Another project involves groundwater assessment testing and development of a Corrective Action Plan (Elings Park Solid Waste Assessment Test-Corrective Action Plan).

Eliminate or Significantly Reduce Pollution in Impaired Waters and Sensitive Habitat Areas, Including Areas of Special Biological Significance

The IRWMP includes a number of infrastructure projects that will reduce pollution in sensitive habitat areas by relocating infrastructure that has previously discharged sewage into those areas; other projects will improve discharges to Goleta Slough, a 303(d) listed water body. The plan also includes a number of habitat restoration projects and creek rehabilitation projects that will improve water quality.

Include Safe Drinking Water and Water Quality Projects that Serve Disadvantaged Communities

The IRWMP includes four high priority projects that will serve DACs. The community of Casmalia has a critical need for the water system improvements that will ensure that it has a safe, secure water supply. The City of Guadalupe Wastewater Treatment Plant Reuse Improvements Project will improve the quality of wastewater discharge, benefiting the health and safety of community members, and allowing the treated water to be used for a wetland enhancement project. Two essential projects also will also improve water quality and drinking water in Cuyama. The Wastewater Treatment Plant Effluent Disposal Project will allow Cuyama to avoid mandatory penalties and have its NPDES permit renewed. Additionally, if Cuyama's 50-year-old water tower is not repaired, it will soon reach the point where it will not function.

Include Groundwater Management and Recharge Projects

Several long-term projects are included in the plan, including the Vandenberg Village Community Services District Lompoc Groundwater Basin Recharge Study, and the Central Coast Water Authority Groundwater Banking Opportunities Study, which will identify agencies that may benefit from a groundwater banking program both within the Water Authority service area and in the central valley of California. The study also will identify and prioritize benefits, risks, and costs associated with several scenarios. The Water Authority also submitted a project for the design and construction of a groundwater bank near the Polonio Pass Water Treatment Plant in San Luis Obispo County. This plan will be dependent on the results of the recently initiated Paso Robles Groundwater Basin Water Banking feasibility study and additional studies yet to be determined. In most years, several thousand acre-feet of State Water Project water are lost because they cannot be taken into storage. This study will identify mechanisms to better utilize State Water Project water supplies and maintain reserves for use during droughts. Another project submitted, the Central Zone Transmission Main and ASR Demonstration Well Project will be a first step in evaluating and demonstrating the viability of artificial recharge in a local groundwater basin using treated surface water, which may lead to a regional groundwater banking program within the South Coast area.

9.2.3 Beneficiaries of IRWMP Implementation

The projects included in this IRWMP will benefit the residents of Santa Barbara County as a whole, as well as those residing in specific watersheds. The disadvantaged communities of Casmalia, Cuyama, and Guadalupe will benefit from the implementation of four water and wastewater projects that will ensure that service is provided in a manner that meets regulatory requirements and protects public health. As shown in Tables 8-3 and 8-4, the highest priority projects will directly address those issues of the most pressing concern in Santa Barbara County, and residents will benefit from the improved ability to manage water resources, including specific improvements in water supply reliability, ecosystem restoration, water quality, emergency preparedness, and the strategic rehabilitation and replacement of aging infrastructure. Additionally, the IRMWP provides a mechanism for ongoing coordination between those entities that manage water resources, as well as for the identification of additional projects in the future to address water resources concerns. These factors will result in more efficient water management planning, benefiting all county residents.

9.3 Resource-specific Impacts

Each project included in the IRWMP is required to undergo the appropriate level of review under the California Environmental Quality Act (CEQA) and where there is federal involvement, the National Environmental Policy Act (NEPA). Mitigation measures for significant environmental impacts will be developed at that time, as needed, and projects also will be required to obtain permits including conditions that will minimize impacts. Opportunities for public comment on project impacts will be provided as part of the CEQA/NEPA process.

The following is a preliminary overview of the types of impacts that could occur from the implementation of the projects included in this IRWMP. The project evaluation criteria include “lack of significant long-term adverse impacts, including impacts to agriculture,” and based on the preliminary evaluation performed, most projects are not expected to result in long-term adverse impacts. Adverse impacts generally would be short-term, resulting from construction activities, while long-term impacts generally are expected to be beneficial, because sensitive habitats, including habitats for sensitive species, would be enhanced; surface and groundwater quality would be improved; water supply reliability would be increased; flood protection would be increased; and the ability to provide water during emergencies would be enhanced.

9.3.1 Aesthetic/Visual Resources

Overall, impacts from plan implementation will be beneficial, because a number of projects will restore degraded areas. Most infrastructure improvements will be located in already developed areas and will not contribute to an adverse impact to visual resources. Areas disturbed by pipeline construction will be required to be revegetated; thus, no long-term visual impacts will occur.

9.3.2 Agricultural Resources

The IRWMP will not result in adverse impacts to agricultural resources; projects will not result in the loss of agricultural lands, nor will agricultural water supplies be adversely affected.

9.3.3 Air Quality

Short-term air quality impacts will result from construction, but contractors will have to comply with the County Air Pollution Control District's requirements, which will minimize impacts. No long-term air quality impacts are expected.

9.3.4 Biological Resources

Short-term impacts to some biological resources could occur during construction activities, but it is anticipated that they could be mitigated through measures such as scheduling construction to avoid breeding seasons, use of best management practices and other standard measures. Overall, the IRWMP will result in beneficial impacts to biological resources because it includes a number of habitat restoration projects, including the removal of barriers to steelhead passage and weed eradication projects. It also includes a number of infrastructure projects that will result in reduced risks from sewage spills and maintenance activities in environmentally sensitive areas.

9.3.5 Cultural Resources

Impacts to cultural resources could occur during construction, but it is anticipated that they could be mitigated through standard measures, such as conducting site record searches and surveys prior to construction, monitoring sensitive areas, avoiding known sites, and data recovery.

9.3.6 Environmental Justice/Disadvantaged Communities

The IRWMP includes four high priority projects that will improve much-needed water and wastewater treatment services in the three disadvantaged communities (DACs) present in Santa Barbara County, thereby addressing environmental justice concerns. The City of Guadalupe has inferior water and wastewater systems that are in need of upgrading. The City of Guadalupe Wastewater Treatment Plant Reuse Improvements Project will improve the quality of wastewater discharge, benefiting the health and safety of community members, and allowing the treated water to be used for a wetland enhancement project. The community of Casmalia has a critical need for the water system improvements that will ensure that it has a safe, secure water supply. In December 2006, bacterial contamination of its drinking water resulted in a "boil water" order. The Casmalia Water System Improvements Project will replace deficient infrastructure such as water pipelines and tank facilities, update buildings and facilities to comply with design and code requirements, and make improvements to the existing well facility. Two essential projects also will also improve water quality and drinking water in Cuyama. The Wastewater Treatment Plant Effluent Disposal Project will allow Cuyama to avoid mandatory penalties and have its NPDES permit renewed. Additionally, if Cuyama's 50-year-old water tower is not repaired, it will soon reach the point where it will not function.

9.3.7 Geology and Soils

All construction will be required to comply with the appropriate engineering standards given the soils and seismic hazards present at each construction site, which will mitigate impacts to geology and soils.

9.3.8 Hazards and Hazardous Materials

Construction could potentially result in spills of hazardous materials (for example, fuels, oils, and lubricants), but these impacts could be mitigated through the use of best management practices. Facilities, such as water and wastewater treatment facilities, use hazardous materials, but they will be used in accordance with all regulatory requirements, which will mitigate any potential impacts.

9.3.9 Hydrology and Water Quality

Overall, impacts to hydrology and water quality will be beneficial, because a number of IRMWP projects will improve groundwater, surface water, or drinking water quality. Additionally, the IRMWP contains a number of projects that will improve flood control and enhance the production and use of recycled water. Some include habitat restoration elements, which will have beneficial impacts to biological resources; others will enhance flood protection by adding improvements to areas that have already been modified.

9.3.10 Land Use and Planning

No significant land use changes or inconsistencies with policies are anticipated.

9.3.11 Noise

Noise will be limited to short-term construction activities, and impacts will be reduced through adherence to local restrictions on hours of construction.

9.3.12 Population and Housing

No impacts to housing will occur. The IRWMP will increase the reliability of supplies needed to serve the projected population growth.

9.3.13 Public Services

Public services (for example, fire and police protection) will not be adversely affected by the IRWMP. Beneficial impacts to fire protection will occur to the extent that the reliability of water supplies is enhanced, redundant systems are developed, and water supplies are available at the appropriate pressure.

9.3.14 Recreation

The IRWMP will have an overall beneficial impact to recreation by improving water quality at local beaches (for example, Arroyo Burro, Goleta Beach) and by providing irrigation water for parks; TMDLs will also improve water quality at recreational areas.

9.3.15 Transportation and Circulation

Transportation impacts will be limited to short-term impacts from construction activities.

9.3.16 Utilities/Service Systems

Beneficial impacts to water and wastewater treatment, water supplies, and storm water management will result from the implementation of IRWMP projects. Conversion of septic systems to sewer systems and other projects will benefit water quality, as will the enhancement of water and wastewater treatment processes. Storm water management will be enhanced through the projects that will improve the region's ability to manage urban runoff.

9.4 Possible Obstacles to IRWMP Implementation

Implementation of the IRWMP could face several potential obstacles. The lack of grant funding from Proposition 50 would be a significant obstacle. Those agencies included in the Santa Barbara countywide team believe that with the completion of the IRWMP in late May 2007, the region will be in a good position to compete for Proposition 50 Round 2 funding. The region is optimistic that most of the Cooperating Partners and other organizations will support the adoption of the IRWMP and that this will not become an obstacle to state agency support of the region's Proposition 50, Round 2, Step 1 application.

Lack of agreement among the Cooperating Partners on a number of issues could become an obstacle. However, to date, the Cooperating Partners have been able to resolve all challenges, including differing priorities and objectives, with full consensus. The Cooperating Partners are meeting regularly to develop a future governance structure; prepare for the administrative and consulting support needed to prepare the Proposition 50 application; keep up regular outreach; and to develop the necessary supporting information for a successful grant application.

Public stakeholders have participated throughout the IRWMP development process. All Cooperating Partner meetings have been open to the public; a series of eight public stakeholder meetings were expressly organized to reach out to the public; the public review period for the draft IRWMP exceeded that mandated by the state; and information has been made available to the public through the IRWMP Web site. The Cooperating Partners hope to further increase public participation as the IRWMP process grows and matures. Lack of participation by key public organizations could be an obstacle to truly integrated solutions to regional challenges.

Once the final list of projects is selected for the Proposition 50 Round 2 process, there could be disagreement over the inclusion of certain types of projects. For example, a project supported by one agency may not find the same level of support from some members of the environmental community or permitting agencies. If not resolved, this could present a potential obstacle to implementation of the IRWMP. In order to avoid this potential problem, public input will be obtained prior to selecting projects to be included in grant applications. The public and agencies will have an opportunity to comment on individual projects during their environmental review and permitting processes, and opportunities will be available during this time to modify the projects to avoid or minimize impacts to the environment.

9.5 Ongoing Support and Financing

Potential sources of financing for each Tier I project are described in Chapter 8. Each implementing agency will be responsible for obtaining funding for its own projects, including funding for operation and maintenance of those projects requiring construction. Projects that do not require construction, such as studies and working groups, will not require ongoing operation or maintenance. However, recommendations and related work flowing from these studies will be the responsibility of the agencies identified throughout the studies.

9.6 The IRWMP's Role in Future Planning Efforts

As an added benefit, development of the IRWMP has served as a catalyst for discussions between the Cooperating Partners and other stakeholders regarding ways to increase integrated water resource management planning within Santa Barbara County. Some of these discussions led to some of the projects included in this plan; others resulted in the identification of issues and needs to be further explored in the future through the cooperative structure established by the IRWMP. The IRWMP will also serve as a mechanism for further evaluation of regional issues and the means to resolve those issues through the adaptive management process outlined in Section 8. Issues currently under consideration include:

- The need to conduct a market analysis to determine if there is sufficient additional demand for recycled water, requiring the capacity of existing facilities to be more fully utilized or expanded along with expansion of distribution systems.
- The need to rethink ways of co-managing improvements in water quality, environmental protection, and food safety during crop production. Food safety issues associated with food-borne E. coli outbreaks from the consumption of leafy greens has created an apparent conflict between water quality management practices and food safety/good agricultural practices.
- Consideration of the use of the City of Santa Barbara' desalination facility; in the event of a drought, it could be further utilized under an inter-regional partnership where areas with significant groundwater resources fund operation of desalination facility and exchange for State Water Project water during wet years (allowing recharge of basins), with desalination capacity reserved for South Coast use during droughts.
- The need to develop additional water resources and better integrate adjacent water system infrastructure in the Santa Ynez watershed, including infrastructure serving the

City of Solvang and Santa Ynez River Water Conservation District Improvement District No. 1.

- Ways of improving the effectiveness of water conservation programs:
  - How to evaluate the effectiveness of existing water conservation programs
  - How to improve educational outreach programs, especially for high schools
  - How to develop more effective water conservation programs for the commercial/industrial sector
  - How to coordinate with the state's emphasis on water conservation through landscape-related programs
  - How to incorporate water conservation measures into new residential and commercial development
- The need to review groundwater data in the County archives to determine groundwater quality trends in several watersheds (e.g., Santa Maria, Santa Ynez, and Carpinteria).

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10 Plan Performance, Data Management, and Ongoing Coordination

This section describes the methods that will be used to evaluate projects and plan performance, as well as adaptive management strategies that will be used to add new projects and modify the current list of projects and overall plan as needed. Methods used to manage data obtained through the plan implementation are also covered in this section as is ongoing coordination with local, state, and federal agencies.

10.1 Technical Analysis and Plan Performance

Local agencies and organizations have conducted numerous studies and developed a considerable amount of information related to water management within Santa Barbara County that serves as the foundation of this IRWMP. This IRWMP incorporates an adaptive management approach intended to allow it to stay current in light of evolving needs, local and statewide priorities, management strategies, technology, and funding requirements. Adaptive management is a planning and implementation framework in which ongoing monitoring is used to evaluate implementation and change course to optimize results when necessary. It is based on an iterative feedback loop of plan adjustment, implementation, and monitoring. Resource managers learn from experience and adjust appropriately as new knowledge, priorities, and issues come to light. Through adaptive management, the IRWMP will be a dynamic document that may redefine regional objectives, priorities, water management strategies, and projects as needed to respond to changing conditions. It also will allow for the continuing development of solutions to ongoing issues.

Individual elements of the IRWMP already include adaptive management, and changes to those elements will be coordinated with the overall IRWMP adaptive management strategy. For example, several other planning procedures have regular review and re-evaluation, including the Urban Water Management Plans and Santa Barbara County's Groundwater Report, which summarizes monitoring information described in Section 3. As required by the Urban Water Management Planning Act, California Water Code, Section 10610 et seq., Urban Water Management Plans must be updated every 5 years, in years ending in zero and five. Additionally, Santa Barbara County's Groundwater Conditions Report is updated biennially. Summary reports on these activities will be coordinated with the IRWMP management process.

The IRWMP's overall adaptive management framework will be implemented in the following manner in accordance with the established governance practices described in Section 1:

1. IRWMP managers will conduct a biennial review and produce a 5-year report summarizing progress made in achieving IRWMP goals, including the tracking of funded projects, modifications to projects, and development of new projects as a result

of the plan. The results of the biennial review and the 5-year report will be posted on the IRWMP Web site (http://www.countyofsb.org/pwd/water/irwmp.htm). The performance of implemented projects will be compared to original project objectives to ensure objectives were met.

2. IRWMP objectives, priorities, and water management strategies will be evaluated during the biennial review and modified appropriately. The need to develop different projects to better meet the plan objectives and regional issues will be considered, as will the need to modify existing projects. Projects that may be deleted (for example, because their purpose has been met through another project or because conditions have changed) also will be considered at this time.

3. Minor adjustments to planning assumptions, operations, or actions will be adopted as necessary. If significant changes to the approved IRWMP are found to be required in the biennial review or the 5-year IRWMP report, the plan will be revised and submitted for approval by Cooperating Partners as necessary.

4. IRWMP managers will supplement the sections of the IRWMP affected by changes to Urban Water Management Plans and the Groundwater Report every 5 years.

5. Stakeholder outreach will continue on an annual basis during IRWMP implementation, both to inform local stakeholders of progress and to solicit feedback regarding plan effectiveness and evolving priorities. In addition, IRWMP managers will solicit input via the Web site and e-mail from all interested parties and distribute that information at stakeholder meetings.

6. IRWMP managers will continue to develop the adaptive management framework itself by periodically reviewing its effectiveness and adjusting accordingly. For example, should it come to light that outreach or updates occur too frequently or infrequently, the schedule will be adjusted.

10.2 Data Management

The management of data is an integral component of the IRWMP process. The Santa Barbara IRWMP has three major goals relating to data management: (1) to facilitate timely sharing of information to stakeholders as well as state and federal databases; (2) to provide for consistent monitoring techniques and data quality; and (3) to identify where data gaps exist. Available data in the Santa Barbara area is currently maintained using Geographic Information System (GIS).

Information from the Santa Barbara IRWMP will be available to stakeholders through the use of a Web site, which will be supported by the Water Agency. This will continue the existing warehousing of water resources-related data that the Water Agency has currently undertaken for the region. The Water Agency will ensure data accessibility at other relevant County Web sites through the Water Agency site. IRWMP stakeholder meetings will serve as the primary venue for information sharing. Other settings where information can be shared include quarterly project progress meetings, monthly agency coordination meetings, public workshops, e-mail subscription lists, and monthly e-mail newsletters. These forums will serve to continue to facilitate the ongoing data sharing between stakeholders as well as the expansion of the existing Water Agency data warehousing activities.

Santa Barbara County will maintain existing water resources-related and IRWMP-related data and will make it available to the public on the Santa Barbara County Water Agency Web site located at: http://www.countyofsb.org/pwd/water/index.htm. This site will also provide the forum for sharing of reports, public meeting dates, agendas, meeting minutes, and annual reports. All data used to support development of the IRWMP will be outlined in a database and available for review on the Web site, which also will provide links to information available on partner agency Web sites.

The County has been asked by the Cooperating Partners to act as the administrative agency for data management. In this capacity, the County would track, review, manage, and report on pertinent issues related to the IRWMP, as well as report and track project progress. The management of existing data will be incorporated into the County GIS system. The relevant data will be revised and updated as part of future IRWMP efforts. In addition, where appropriate, data management will be coordinated with state and federal databases in a format consistent with the Surface Water Ambient Monitoring Program (SWAMP) and Groundwater Ambient Monitoring Assessment (GAMA). This coordination could include submission of annual reports regarding groundwater and surface water monitoring. As part of the IRWMP process, partner agencies will also work to determine specific reporting requirements and formats to facilitate more effective and efficient future data sharing.

Existing reports and data are under review as part of this effort to determine their applicability to the IRWMP and identify gaps in existing data. Identification of existing data gaps is a vital component of the IRWMP process. The process of identifying data gaps will continue throughout the IRWMP process, because new issues will arise as information is gathered and projects are formulated and refined. Once data gaps have been identified, recommendations regarding how best to address them will be developed. The Cooperating Partners also will compile and develop consistent procedures for data collection and monitoring.

10.3 Ongoing Coordination

As previously described, the County of Santa Barbara, water and wastewater entities, and all cities within Santa Barbara County, except one, are Cooperating Partners; additionally, local planning decision makers have been involved in the preparation of this IRWMP through regular communications through the Cooperating Partners and periodic reviews of the plan. Land use planning decision makers will continue to be involved, particularly through review, approval, and permitting of individual projects as they are developed and implemented.

Most Cooperating Partners have a long history of working with state and federal agencies, such as State of California Department of Water Resources (DWR), State Water Resources Control Board (SWRCB), Regional Water Quality Control Board (RWQCB), California Department of Fish and Game, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and the U.S. Bureau of Reclamation to address water management issues in the county. This coordination will continue as the IRWMP is implemented, particularly through the process of reviewing and permitting individual projects.

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Appendix 1-B: South Coast Recycled Water Development Plan, RMC, 2013

SBC IRWMP
Santa Barbara County

Santa Barbara County IRWM Plan 2013

South Coast Recycled Water Development Plan

Final Report

December 2013

Acknowledgements

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List of Abbreviations

AFY	acre feet per year
ASR	aquifer storage and recovery
CCR	California Code of Regulations
CDPH	California Department of Public Health
CECs	constituents of emerging concern
CPC	California Plumbing Code
CSD	Carpinteria Sanitary District
CVWD	Carpinteria Valley Water District
CWC	California Water Code
DAC	Disadvantaged Communities
DWR	Department of Water Resources
EPA	Environmental Protection Agency
ft	feet
GIS	Geographic Information System
gpm	gallons per minute
GSD	Goleta Sanitary District
Guidelines	EPA's Guidelines for Water Reuse
GWD	Goleta Water District
GWSD	Goleta West Sanitary District
hp	horsepower
IPR	Indirect Potable Reuse
IRWM	Integrated Regional Water Management

kWh/af	kilowatt-hours per acre-foot
LCMWC	La Cumbre Mutual Water Company
LF	linear feet
MF	microfiltration
MG	million gallons
mg/L	milligrams per liter
mgd	million gallons per day
MMD	maximum monthly demand
MSD	Montecito Sanitary District
MWD	Montecito Water District
NOI	notice of intent
NPDES	National Pollutant Discharge Elimination System
NPR	Non-potable reuse
NTU	Nephelometric Turbidity Units
NWRI	National Water Research Institute
O&M	operating and maintenance
plan	South Coast Recycled Water Development Plan
psi	pounds per square inch
RO	Reverse osmosis
RWQCB	Regional Water Quality Control Board
SB	City of Santa Barbara
Recycled Water Plan	South Coast Recycled Water Development Plan
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
UV	ultraviolet light
USBR	United States Bureau of Reclamation
UWMP	Urban Water Master Plan
WDR	Waste Discharge Requirements
WRF	Water Reclamation Facility
WRR	water reuse requirements
WWTF	Wastewater Treatment Facility (for El Estero & Montecito)
WWTP	Wastewater Treatment Plant (For Goleta, Summerland and Carpinteria)

Executive Summary

Background

In 2010, Santa Barbara County Integrated Regional Water Management (IRWM) Region held a series of meetings to consider inclusion of focused studies in the Proposition 84 IRWM Planning Grant application. At a meeting of the Santa Barbara IRWM Cooperating Partners (the regional IRWM management group) and public stakeholders on August 19, 2010, several potential studies were considered in the IRWM Plan update. At that time, it was decided to include a South Coast Recycled Water Development Plan (Recycled Water Plan) as part of the IRWM Plan 2013 planning grant funding request to the Department of Water Resources (DWR). The Recycled Water Plan was originally conceived by the 2007 IRWM Plan. The funding request was granted by DWR and the Recycled Water Plan was approved as a part of the IRWM Plan 2013.

A focused stakeholder process was next established to support the development of the Recycled Water Plan. The plan's purpose is to identify technical, institutional, political, and social opportunities to advance the use of recycled water and address related constraints for implementation. The stakeholder planning goals are to increase regional supply, improve the quality of the water being discharged into the ocean, and increase the region's self-sufficiency by reducing dependency on imported water. The Recycled Water Plan Workgroup was organized to guide the planning process. The Workgroup members involved in this plan are listed below in **Table ES-1**.

Table ES-1: Recycled Water Plan Workgroup

Carpinteria Sanitary District	Heal the Ocean
Carpinteria Valley Water District	La Cumbre Mutual Water Company
City of Santa Barbara	Montecito Sanitary District
Goleta Sanitary District	Montecito Water District
Goleta Water District	Santa Barbara County Water Agency
Goleta West Sanitary District	Summerland Sanitary District

Plan Components

In the Recycled Water Plan, opportunities are identified to potentially restructure or integrate previously envisioned local projects and expand potential end uses to maximize regional objectives and potentially provide multiple benefits to multiple stakeholders. This plan identifies the opportunities and constraints of advancing recycled water generation and use in the south coast subregion and outlines the next steps to implementing potentially cost-effective, feasible projects as elements of the Region's water management portfolio. The scope of work for this plan consists of the following components:

- Initiate stakeholder process through IRWM Plan 2013 outreach process
- Conduct literature review of pertinent subregion systems and planning activities
- Summarize current and anticipated recycled water regulations and policies
- Describe existing recycled water treatment, wastewater treatment, storage, and delivery systems
- Identify potential customers and uses
- Identify treatment options to meet water quality needs
- Identify distribution system needs

- Identify potential near-term projects for implementation to meet expanded uses
- Identify constraints to the implementation of projects and next steps to address constraints and advance projects
- Coordination with Cooperating Partners on integration of the Recycled Water Plan into the IRWM Plan 2013

As part of the south coast subregion planning effort, the participating stakeholders decided to formulate two time frames - near-term and long-term. Near-term potential projects could be implemented over the next ten years, and the potential long-term projects could be implemented over the next 20 to 30 years.

Available Recycled Water Supplies

Table ES-2 shows near-term and long-term potential wastewater available to produce recycled water for future users at each wastewater plant in the plan area. Note that the maximum potentially available flow for future recycled water demands is based on the projected secondary wastewater flow minus the existing recycled water usage times a peaking factor (2.0) to account for maximum day demand. While the peaking factor may vary from system-to-system and year-to-year, a factor of 2.0 was deemed reasonable based on existing system and potential future recycled water users in the area.

Table ES-2: Potentially Available Recycled Water Supplies

Wastewater Treatment Plant	Projected Average Daily Secondary Wastewater Flow (MGD)		Existing Recycled Water (MGD)	Maximum Potentially Available for New Recycled Water Supply (MGD)[1]	
	Near-Term	Long-Term		Near-Term	Long Term
Carpinteria WWTP	1.6	1.6	--	1.6	1.6
El Estero WWTF[2]	8.0	8.5	0.76	6.48	6.98
Goleta WWTP	6.5	7.0	0.7	5.1	5.6
Montecito WWTF	1.0	1.0	--	1.0	1.0
Summerland WWTP	0.14	0.14	--	0.14	0.14
Total	**17.24**	**18.24**	**1.46**	**14.32**	**15.32**

Notes:

1. Maximum potentially available supplies based on projected secondary wastewater flow minus the existing recycled water usage times a peaking factor (2.0 typically) to account for maximum day demand. Peak hour demands are assumed to be met via diurnal storage facilities.
2. Amount of existing recycled water is the actual recycled wastewater being served due to the need for potable water blending.

Identification of Potential Recycled Water Demands

Potential recycled water demands were developed based on previous agency studies as well as updates provided by the participating agencies. Near- and long-term potential recycled water demands were identified based on specific agency criteria which took into consideration their local water and wastewater settings.

For the near-term, an estimated average annual demand of 67 AFY of new recycled water use is projected by the agencies. A potential of an additional 4,854 AFY of recycled water demand was also identified for the long-term planning horizon. Along with the existing recycled water demands, the total identified potential recycled water use in the subregion could reach 6,556 AFY. This does not include the potential agricultural users in the Goleta and Montecito areas. Carpinteria Valley Water District's potential long-term demand does include agriculture demand identified by the District during this plan.

Table ES-3 provides a summary of the existing and potential future demands for the near- and long-term planning periods. Only the City of Santa Barbara and Goleta Water District have included potential near-term demands.

Table ES-3: Existing and Potential Recycled Water Demand Summary by Agency

Agency	Average Annual Recycled Water Demand (AFY)				
	Existing	Potential Near-Term		Potential Long-Term	
		Additional Demand	Subtotal	Additional Demand	Total
Goleta WD	785	27	**812**	72	**884**
City of Santa Barbara[1]	850	40	**890**	266	**1,156**
La Cumbre MWC	--	--	**0**	130	**130**
Montecito WD	--	--	**--**	1,786	**1,786**
Carpinteria VWD	--	--	**--**	2,600	**2,600**
Totals	**1,635**	67	**1,702**	4,854	**6,556**

Notes:
1. Demand does not include approximately 300 AFY of internal plant use of recycled water.

Recycled Water Treatment Needs

A summary of recycled water regulations was conducted as part of this plan and outlines the many Federal, State, and local regulations that recycled water systems must meet. In California, the level of treatment required is primarily based on three conditions:

- Type of user as dictated in Title 22 and by the Department of Health and Safety
- Local groundwater basin requirements as dictated by the local RWQCB
- Specific end-user water quality needs

For this plan, the majority of the potential users are urban irrigation and commercial uses. Therefore, the typical processes that meet the Title 22 requirements are tertiary filtration and disinfection. **Table ES-4** provides a summary of the improvements needed at each of the plants in the plan area.

Recycled Water Distribution System Needs

Design criteria were developed to help identify the near- and long-term distribution improvements and to evaluate potential alternatives. Criteria for peaking of flows, pipeline sizing, storage, pumping facility were developed to help determine facility sizes and costs. Existing system improvements were also considered for the Goleta and Santa Barbara systems as near- and long-term system expansions would not be possible without addressing current needs. Potential near- and long-term projects were then created utilizing existing system capacities and the identified potential distribution systems.

Table ES-4: Existing Wastewater Treatment Plants and their Treatment

Wastewater Treatment Plant	Existing Treatment	Near-Term Needs	Long-Term Needs
Goleta WWTP	Tertiary	None	None
El Estero WWTF	Tertiary	Install MF/RO units in place of existing filters.	None
Montecito WWTF	Secondary	None planned	Expand to Tertiary treatment. If agriculture is served, MF/RO will also be needed
Summerland WWTP	Tertiary	Exploratory	Exploratory
Carpinteria WWTP	Secondary	None planned	Expand to tertiary treatment. If agriculture is served, RO will also be needed

Analysis Approach

The following steps were conducted to develop the potential recycled water projects and options:

- Identify potential customer for both near- and long-term
- Assess recycled water supply and treatment needs through 2030
- Establish planning criteria and distribution system needs

Using this information, potential recycled water projects and options were developed through a series of iterative steps that identified projects with the highest likelihood of implementation.

For the Goleta and Santa Barbara areas, near- and long-term projects and options were developed from each agency's most recent recycled water studies and refined based on discussions with the individual agencies. For the Montecito and Carpinteria areas, potential long-term projects and options were developed via a phased approach. The initial phased projects were developed to serve only potential users located near the WWTPs. Subsequent phases were extended out from the initial phase projects until all identified demands were included or the maximum available wastewater flow was fully allocated.

Table ES-5 presents a summary of the near- and long-term projects for each of the four areas within the south coast region. This table illustrates the order of magnitude of effort for implementing the various projects. Capital and unit costs vary greatly due to a variety of factors including local conditions, project scale, and rehab or expansion of existing systems versus completely new recycled water systems. Therefore, each agency will need to determine the benefits and costs of the potential projects to its own water resource needs and other circumstances, as comparison of projects between areas has limited value. **Figure ES-1** shows on overview of the existing and potential near- and long-term projects identified in this plan for the south coast region.

Benefits to the Region

As part of the IRWM Plan 2013, the County has a collective goal of serving 7,035 AFY of recycled water by 2035. Of that total, 2,293 AFY is expected to be recycled water from the south coast subregion. To reach this goal, the Goleta Water District plans to expand to 870 AFY from 785 AFY, and the City of Santa Barbara plans to expand to 1,423 AFY from 1,150 AFY. This target could be surpassed if the Montecito or Carpinteria areas are able to move forward with implementation of their potential reuse projects.

Table ES-5: Summary of Estimate Potential Project Costs[1] – All Areas

Project Area	Potential Demand (AFY)	Estimated Capital Costs	$/AF[2]
Near-Term Projects			
Goleta Area[3]	812	$3,749,000	$300
Santa Barbara Area[3]	891	$16,100,000	$1,300
Total Near-Term	**1,703**	**$19,849,000**	**$800**
Long-Term Projects			
Goleta Area	58	$8,758,000	$11,000
Santa Barbara Area (Includes SB-Option 1)	371	$6,510,000	$1,300
Montecito (Includes M-Option 2)	659	$17,535,000	$1,900
Carpinteria	811	$20,993,000	$1,900
Total Long-Term	**1,899**	**$53,796,000**	**$2,100**
Total (Near + Long-Term)	**3,602**	**$73,645,000**	**$1,500**

Notes:
1. Estimated costs include constructions costs and markups for implementation (planning, engineer, etc.) and contingencies. These costs are intended present order of magnitude level unit costs so that some level of prioritization of costs may be utilized by future project planning efforts.
2. $/AF is the capital unit costs and does not include any operations and maintenance costs.
3. Near-term projects demands also include existing system user demands.

Near- and long-term recycled water projects provide a variety of benefits to individual agencies, the south coast subregion of Santa Barbara County, and Santa Barbara County as a whole. Benefits can be identified by the performance measures and the objectives achieved by the projects. The Santa Barbara County IRWM Plan 2013 has identified eight regional objectives of which recycled water projects achieve five of those objectives.

Recycled water projects benefit the region by developing and maintaining a diversified mix of water resources, augmenting supplies by using recycled water for landscaping or other non-potable uses, improving wastewater quality, utilizing technology to manage waste in an economical and environmentally sustainable manner, reducing wastewater discharges into the ocean, maintaining and enhancing water and wastewater infrastructure efficiency and reliability, planning for and developing infrastructure for disadvantaged communities, and helping the region plan and adapt to climate change.

The Recycled Water Plan will assist in meeting the following IRWM Plan 2013 objectives:

- Protect, Conserve, and Augment Supplies
- Protect and Improve Water Quality
- Maintain and Enhance Water and Wastewater Infrastructure Efficiency and Reliability
- Plan for and Adapt to Climate Change
- Equitable distribution of benefits as measured by new planning or implementation projects, the volume of water recycled, and the number of new infrastructure improvements

Santa Barbara County IRWMP
South Coast Recycled Water
Development Plan

RMC
Water and Environment

N

0 0.5 1 2 Miles

Recycled Water System
- Existing
- Potential Near-Term
- Potential Long-Term

Water Agencies
- Carpinteria VWD
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Other Features
- US/State Highway
- City Boundary
- County Boundary
- Railroad
- WWTP

Potential Recycled Water Systems

Figure ES-1

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Findings: Constraints and Next Steps

Several potential projects were identified for both the near- and long-term opportunities. These projects range from ones that are expanding existing systems to projects that were developed on a more conceptual level for the long-term. The findings from this Study are a summary of the results of the literature review, regulatory review, potential project identification and cost estimates, and committee meetings.

Potential Constraints

During this planning process, several types of constraints to expanding recycled water use were discussed by the planning stakeholders. These constraints range from user specific concerns and specific project challenges to agency and regional constraints or challenges. The constraints to each project or agency can vary depending on a variety of factors. Listed below are the identified constraints to implementing the potential recycled water projects.

- **User Constraints**
  - Water quality can be a concern to users due to high Total Dissolved Solids (TDS) in the region's wastewater supplies.
  - Cost of conversion to recycled water from potable water can be a major challenge to some customers.
  - Customer viability can impact a projects revenue and long-term feasibility as customer can move, close their businesses, or change their water or water quality demands based on economic or other factors.
- **Project Challenges**
  - Construction of recycled water projects can result in a number of potential impacts to the community. These impacts must be considered as part of the planning, design, environmental documentation, system startup, and customer conversion processes.
  - Timing or phasing of projects need to be in sync with public and political support as well as financing availability.
  - Expansion of recycled water systems can be limited by the hydraulic capacity of existing facilities and customer demand usage patterns.
  - Recycled water use can be limited by available wastewater flows, especially in peak season demand periods.
  - Future regulations and the potential need to utilized future technologies can present a challenge to project implementation and create uncertainty in the decision-making process. Indirect potable reuse projects can face significant regulatory challenges and can take several years to address and implement.
- **Agency Challenges**
  - Substantial economic cost/benefit analyses should be performed when determining the feasibility of potential recycled water projects. Many recycled water projects have unique challenges, and therefore, it is important when evaluating the feasibility of recycled water projects that all the direct and secondary benefits be considered in comparison to the costs.
  - Financing of projects can be a major project implementation challenge, and many projects will need to plan ahead in conjunction with other capital improvement projects, address cost-sharing arrangements, and/or look for external funding sources.

  - Customers can have concerns over using recycled water due to the cost of conversion public health and safety, and the impacts of water quality on the applied use.
  - Recycled water systems have a relatively high lifecycle cost. Major improvements to the Goleta Water District's and the City of Santa Barbara's existing recycled water systems are necessary to allow for future expansions of these systems.
  - Water agencies must coordinate and establish agreements with the corresponding wastewater agency as all of the area's wastewater treatment plants must be upgraded to serve recycled water.
  - Public awareness programs, such as those conducted by the Goleta Water District and the City of Santa Barbara, are important aspects of recycled water planning and on-going operations that help to address potential concerns regarding public health and safety concerns, as well as recycled water qualities.
- **Regional Challenges**
  - Several potential projects involve multiple agencies and will required institutional agreements to be able to address cost and benefits concerns for each agency involved in the project.
  - The region has a significant agriculture sector that could use recycled water. However, there are water quality constraints that need to be addressed via additional treatment as well as addressing the cost difference between recycled water and current ground or untreated surface waters that the majority of the agricultural sector uses as water supply.
  - Implementation of many of the potential projects may require external funding, which could come from State or Federal sources.

Next Steps

The following summarizes the findings and recommended steps at both a regional and area (or agency) level and are based on the implementation needs of the identified potential projects and the constraints noted above.

- To support the decision-making process, the value of recycled water to the region as a whole, along with other conservation measures, needs to be more fully assessed by the water agencies on a regional basis in terms of supply reliability. The region relies heavily on imported water supplies, and recycled water can help to provide a more reliable water supply portfolio. As part of this assessment, the avoided costs that recycled water provides in terms of wastewater disposal and water supply costs need to be more fully identified and evaluated.
- For recycled water projects employing reverse osmosis treatment, the reduction in salts, nutrients, and other constituents of concern could provide benefits to the region, especially to groundwater basins. Such projects should be considered as possible management strategies in the development of the Salt/Nutrient Management Plans in the individual basins in the region.
- To expand recycled water use to more users, additional efforts may be needed to address customer recycled water quality needs, including golf courses, industrial/commercial users, and agricultural users.
- Agencies should consider a regional approach to pursuing project funding needs under the State of California's IRMW/Proposition 84 bonds, the State Water Resources Control Board (SWRCB) for recycled water planning studies, and the United States Bureau of Reclamation's (USBR) Title XVI program.

- Many of the identified projects will involve multiple agencies, and will therefore require institutional level agreements. Typically, these projects involve the local water purveyor and wastewater agency and are typically more straightforward arrangements. However, multiple water agencies have been identified for some potential projects, notably the City of Santa Barbara options to serve the La Cumbre County Club and the Santa Barbara Cemetery, which are both located outside the City of Santa Barbara's water service area. The underlying financial issues should be addressed early in the planning process.
- For the Carpinteria area, as well as other areas that may want to consider IPR, such projects typically take 10 or more years to fully implement from initial concept planning stages. In addition to the typical reuse project planning and design work, IPR projects also require extensive groundwater analysis, modeling, testing, treatment process pilot studies, a program to educate and address public concerns, and extensive discussions/negotiations with regulatory agencies.
- Many of the projects will require environmental documentation. Depending on the timing and overlap of the projects, multiple projects could be included in one environmental documentation effort, or a programmatic EIR/EIS could be developed.

Chapter 1 Introduction

1.1 Background

In 2010, the Santa Barbara County Integrated Regional Water Management (IRWM) Region held a series of meetings to consider inclusion of focused studies in the Proposition 84 IRWM Planning Grant application. A meeting of the Cooperating Partners (the regional IRWM management group) and public stakeholders on August 19, 2010, reviewed several potential studies to be included as components of the IRWM Plan 2013. The stakeholders determined that focus studies would be beneficial to the region, and that it would be beneficial to include a recycled water plan assessing overall supply and demand and opportunities and constraints for expanding use of recycled water.

A focused stakeholder process was next established to support the development of the Recycled Water Plan, which was originally conceived under the 2007 IRWM Plan. The plan's purpose is to identify technical, institutional, political, and social opportunities to advance the use of recycled water and address related constraints for implementation. Stakeholders look to recycled water to increase regional supply, improve the quality of the water being discharged into the ocean, and increase the region's self-sufficiency by reducing dependency on imported water. The Recycled Water Plan stakeholder process is a part of the larger outreach process of the IRWM Plan 2013.

The Recycled Water Plan process included Cooperating Partner agencies and organizations, other south coast water and wastewater agencies, and public stakeholders. The Santa Barbara County Water Agency participated in and provided lead agency administrative support for the Recycled Water Plan.

1.2 Plan Components

Building on recent and current recycled water planning activities in the south coast subregion, this Recycled Water Plan considers the findings of previous studies as well as current thinking and has facilitated discussion among the subregion's water retail and wastewater treatment agencies from a regional perspective. As recognized in the DWR IRWM Propositions 84 and 1E Guidelines, applying a regional approach to recycled water planning can lead to strategies that result in synergies and efficiencies in the utilization of financial and water resources. In this plan, opportunities are sought to potentially restructure or integrate previously envisioned local projects and expand potential end uses. This plan identifies the opportunities and constraints of advancing recycled water generation and use in the south coast subregion and outlines the next steps towards implementing potentially cost-effective, feasible projects as elements of the Region's water management portfolio.

The scope of work consists of the following components:

- Initiate stakeholder process through IRWM Plan 2013 outreach process
- Conduct literature review of pertinent subregion systems and planning activities
- Summarize current and anticipated recycled water regulations and policies
- Describe existing recycled water treatment, wastewater treatment, storage, and delivery systems
- Identify potential customers and uses
- Identify treatment options to meet water quality needs
- Identify distribution system needs
- Identify potential near-term projects for implementation to meet expanded uses
- Identify constraints to the implementation of projects and next steps to address constraints and advance projects

- Coordination with Cooperating Partners on integration of the plan with IRWM Plan 2013

1.3 Stakeholder Process

1.3.1 Initiation of Stakeholder Process

The IRWM Plan 2013 includes participation of two stakeholder groups - the Cooperating Partners and public stakeholders. Cooperating Partner stakeholders are members of the Cooperating Partners, which is the regional water management group for the Santa Barbara County IRWM program. Cooperating Partner stakeholders are representatives of governmental or non-profit organizations with an interest in or authority over water resources. Public stakeholders are stakeholders who have been identified as having a stake in the IRWM process and/or have shown an interest in being included in the IRWM Plan 2013 process.

A collaborative working relationship between Cooperating Partner and public stakeholders was established early in the planning process. Stakeholders worked together in August and September 2010 to write, with the assistance of consultants, the scope for the Recycled Water Plan that became part of the IRWM Plan 2013 planning grant application.

A conference call regarding south coast recycled water planning was held on Tuesday, August 31, 2010, with the goal of identifying and scoping elements to be included in the plan. Any interested stakeholders unable to attend the conference call were contacted separately by the consultants and updated on the meeting discussion and outcomes. Potential elements of the plan that were considered included a literature review of existing recycled water planning documents, analysis of regulations, identification of existing systems, potential urban and agricultural customers and uses, distribution systems to serve new customers, barriers including environmental, water quality, political, and social issues, and the most cost-efficient approach to expansion. Stakeholders contributed existing recycled water planning documents (UWMPs, recycled water master plans, feasibility studies, etc.) to assist consultants in the writing of the scope of work.

The scope of work was reviewed by Laura Peters, Sr. Engineer, Water Resources, IRWM Regional Planning Branch, Regional Partnerships Section, DWR, and formerly with the State Water Resources Control Board (SWRCB), Division of Financial Assistance, Recycled Water Program. Ms. Peters gave positive feedback and commented on topics that should be included in the scope of work because they are required by the State Board for SWRCB grants or low interest loans are included in the scope of work.

The Cooperating Partner stakeholders reviewed a draft and final scope of work outline in early September 2010. The Cooperating Partners involved in scoping the Recycled Water Plan in 2010 are listed below in **Table 1-1**.

Table 1-1: Recycled Water Plan Workgroup

Carpinteria Sanitary District	Heal the Ocean
Carpinteria Valley Water District	La Cumbre Mutual Water Company
City of Santa Barbara	Montecito Sanitary District
Goleta Sanitary District	Montecito Water District
Goleta Water District	Santa Barbara County Water Agency
Goleta West Sanitary District	Summerland Sanitary District

1.3.2 Stakeholder Outreach

The stakeholder process for the Recycled Water Plan was coordinated through the IRWM Plan 2013. In late 2011, public stakeholders were identified using the existing IRWM stakeholder contact list that had been frequently updated since the submittal of the original IRWM Plan in 2007. Stakeholder outreach in the region has been active due to organizing efforts centering on periodic grant applications, IRWM planning meetings, the DWR Regional Acceptance Process, as well as regular and on-going outreach. The Cooperating Partner stakeholders and public stakeholders were also asked to supplement the stakeholder lists with additional names of individuals and groups relevant to the process. The public announcements regarding the development of the IRWM Plan 2013 and the Recycled Water Plan have resulted in new public and Cooperating Partner stakeholders.

1.3.3 Workgroup Outreach and Organization

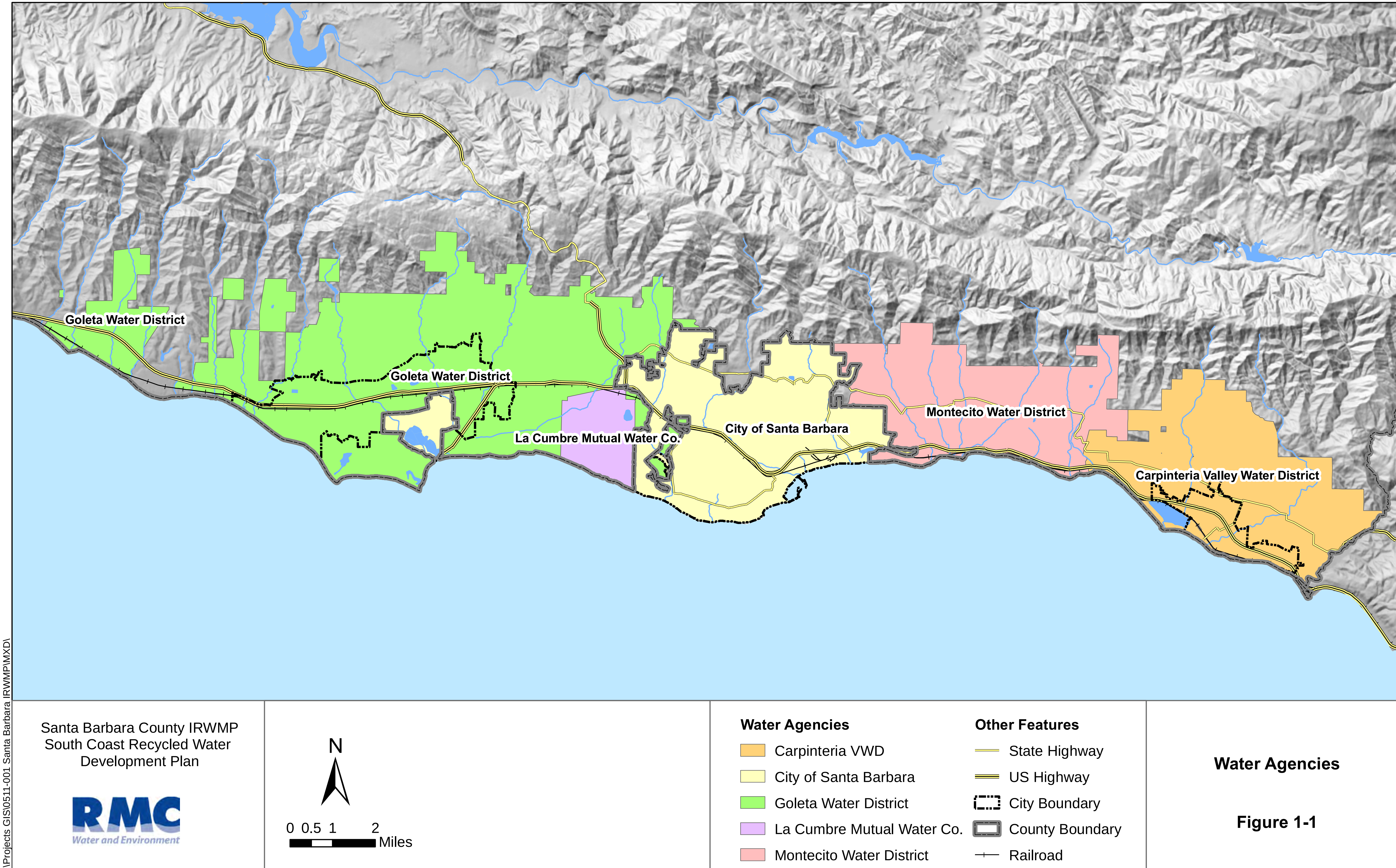
The IRWM Plan 2013 Kick-Off Meeting on December 7, 2011 was announced to and attended by all interested public stakeholders and Cooperating Partner stakeholders. The meeting was publicized in the local press and on the IRWM website. The intent to form the IRWM Plan 2013 South Coast Recycled Water Plan Workgroup was announced during this meeting. The workgroup was populated by stakeholders over the next month.

On January 19, 2012, the Recycled Water Plan Kick-Off meeting was held at the City of Santa Barbara Public Works offices at 619 Garden Street to organize a workgroup to guide the planning process. The Recycled Water Plan Workgroup, made up of representatives of south coast water and wastewater agencies, the County of Santa Barbara Water Agency, and Heal the Ocean, is listed in **Table 1-2**. The location of the water and wastewater agencies is shown in **Figures 1-1** and **1-2**, respectively. The workgroup was responsible for conducting regular meetings, providing input on task execution, and reviewing draft and final draft versions of the planning document.

The workgroup reports to the Cooperating Partners through the Cooperating Partners Steering Committee. The Cooperating Partners are represented by the County Water Agency (designated lead agency for the Prop 84 Santa Barbara County Region IRWM Plan 2013 [IRWM Plan 2013]). The Cooperating Partners are responsible for delivering a technically sound and updated IRWM Plan 2013 to DWR per the contract dated October 7, 2011.

Table 1-2: Recycled Water Plan Workgroup Members

Kathleen Werner	Goleta Sanitary District
Hillary Hauser	Heal the Ocean
James O. Hawkins	Heal the Ocean
Theresa Lancy	City of Santa Barbara
Rebecca Bjork	City of Santa Barbara
Alison Jordan	City of Santa Barbara
Craig Murray	Carpinteria Sanitary District
Mike Mudugno	Carpinteria Sanitary District
Chris Rich	Goleta Water District
Brooke Welch	Goleta Water District
Bob McDonald	Carpinteria Valley Water District
Charles Hamilton	Carpinteria Valley Water District
Mark Nation	Goleta West Sanitary District
Diane Gabriel	Montecito Sanitary District
Tom Mosby	Montecito Water District
Mike Alvarado	La Cumbre Water Company
Jim McManus	Summerland Sanitary District
Hilary Campbell	2nd District, Supervisor Janet Wolf
Bret Stewart	County Water Agency
Matt Naftaly	County Water Agency
Peter Meertens	RWQCB



Santa Barbara County IRWMP
South Coast Recycled Water
Development Plan

RMC Water and Environment

Water Agencies

Figure 1-1

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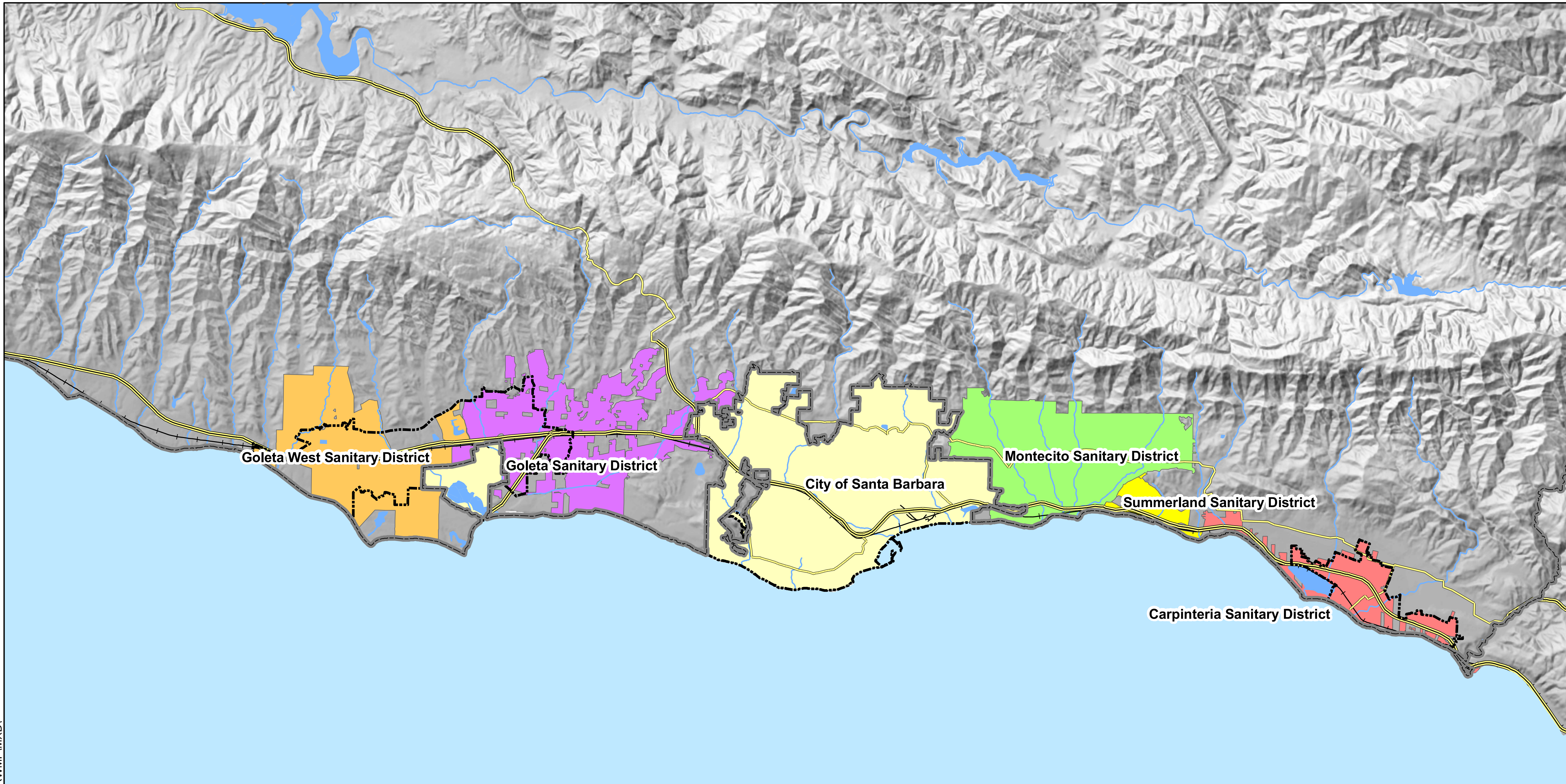

Santa Barbara County IRWMP
South Coast Recycled Water
Development Plan

RMC
Water and Environment

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Wastewater Agencies

- Carpinteria Sanitary District
- City of Santa Barbara
- Goleta Sanitary District
- Goleta West Sanitary District
- Montecito Sanitary District

Other Features

- State Highway
- US Highway
- City Boundary
- County Boundary
- Railroad

Wastewater Agencies

Figure 1-2

At the January 19, 2012 Kick-Off meeting, the scope of work and plan objectives were discussed. In addition, the workgroup participants agreed upon a set of guidelines that were crafted to make operations of the workgroup as open and fair as possible. The guidelines identify the team's formal authority, what it may do with and without permission, and with areas of shared responsibilities or areas in which team members are expected to initiate action to support others. Workgroup participants who are members of the Cooperating Partners were required to possess clear authority to represent agency or organization. Workgroup members also agreed to the following: provide expertise; provide requested information in a timely manner (adhering to project deadlines and schedule); participate in all meetings; attend IRWM Plan 2013 public meetings; to make decisions by consensus when possible and by a majority vote when full consensus was not possible; review and approve technical memorandums, and review the draft and final document.

Two public stakeholders who attended the January 19, 2012 meeting expressed their opinion that current water quality standards for recycled water were not adequate from a public health perspective and urged the workgroup to plan the issue. The Santa Barbara County Water Agency and project consultants advised that investigating this issue is not within the DWR approved scope of the project and that time and funding available limits any expansion of that scope. The stakeholders were urged to take the matter up with the appropriate State regulating agencies, which include the Department of Public Health and the State Water Resources Control Board. The Recycled Water Plan, however, includes information on the potential treatment options to remove constituents of emerging concern (CECs).

1.3.4 Public Stakeholder Outreach

Public stakeholders were welcome to attend all recycled water workgroup meetings but are not voting members. Time was made available at the end of every meeting for public comments. In accordance with the DWR approved scope of work, public stakeholders participated in general IRWM Plan 2013 public meetings and gave input on draft and final versions of the Recycled Water Plan.

Public input into the development of the IRWM Plan 2013 is outlined in the DWR approved "Work Plan: Appendix 2, Scope of Work: Santa Barbara County/South Coast Subregion, Recycled Water Development Plan" that is part of the Santa Barbara County IRWM Plan 2013 planning grant application and DWR - Santa Barbara County IRWM Plan 2013 contract. The scope of work provides as follows, "the public will be invited to attend the aforementioned meetings (workgroup meetings) to provide input on scoping. The public also will have the opportunity to comment on this plan when the Santa Barbara County IRWM Plan Update 2013 public meetings are held."

Chapter 2 Literature Review

As a first step toward developing the Recycled Water Plan, the Cooperating Partners supplied previous recycled water planning documents and project implementation information. During monthly progress meetings, the Cooperating Partners reviewed and discussed the existing system and facilities, previously studied projects, and current agency plans. Pertinent documents reviewed during the planning process included:

Carpinteria Sanitary District

- Wastewater Collection System Master Plan, April 2005

Carpinteria Valley Water District

- Water Reliabilities Strategies 2030, February 2006

City of Santa Barbara

- Water Supply Planning Study, August 2009

Goleta Water District and Goleta Sanitary District

- Reclaimed Water Project Study, January 1999

Goleta West Sanitary District

- Proposed New Wastewater Treatment Plant Site and Treatment Alternatives Evaluation, July 2004

Heal the Ocean

- Cost of Tertiary Wastewater Treatment for Southern Santa Barbara County, August 2001

Water Reclamation Research, September 2000

- California Ocean Wastewater Discharge Report and Inventory, March 2010

Montecito Water District and Montecito Sanitary District

- Water Reclamation Study, January 1991

Appendix A contains a complete list of the documents and data collected as part of the review effort. The following sections describe key points and summaries of each recycled water planning and project implementation efforts.

2.1 Carpinteria Sanitary District

Wastewater Collection System Master Plan, April 2005

The Wastewater Collection System Master Plan analyzed Carpinteria Sanitary District's (CSD) wastewater collection system for the planning period between 2004 and the ultimate build out of CSD's identified service area.

The Master Plan identified the following findings that are relevant to the plan:

- Within CSD's service area, the primary land use is residential, with limited commercial, industrial, public, and agricultural secondary land uses.
- There is a significant visitor population year-round, peaking in the summer months.
- The existing average wastewater flow at CSD's Wastewater Treatment Plant (WWTP) is 1.4 MGD, based on flow monitoring at the treatment plant. Flow rates have dropped measurably after

a peak in 1998. System flow appears to be a function of annual rainfall and the system is likely subject to significant infiltration and inflow.

- The existing WWTP has a permitted capacity of 2.5 MGD. Daily influent flows averaged 1.4 MGD in 2002, which represents 54% of permitted capacity. Average daily flows peaked in 1998 at 1.73 MGD, which is 69% of permitted capacity. State regulations typically require wastewater agencies to initiate expansion of treatment capacity when they reach 80% of their permitted capacity. Based on available information, the ultimate system flow, including flows from future development, is not expected to exceed the permitted capacity of the plant. Ultimate flows are also not expected to exceed the 80% threshold of 2.0 MGD.
- With year 2002 flows as a baseline, wastewater volumes are projected to ultimately increase to approximately 1.6 MGD. The ultimate buildout projections included annexation of several beach communities not currently served by CSD. However, it was noted that potential to vary from interim and ultimate flow projections is significant in a small community like Carpinteria. In addition, system flows have historically varied with annual rainfall totals.
- Significant variations in annual average daily flows have been observed. It is recommended that the District carefully monitor flows and flow trends at the WWTP. Controlling inflow and infiltration within the collection system may be critical to avoid a capacity expansion of the WWTP as flows trend upward.

2.2 Carpinteria Valley Water District

Water Reliabilities Strategies 2030, February 2006

Carpinteria Valley Water District (CVWD) Water Reliabilities Strategies for 2030 lists preliminary strategies to use existing water supplies and facilities more effectively and efficiently to meet future water needs during a prolonged drought.

CVWD relies on three main sources of water supply; local groundwater from the Carpinteria Groundwater Basin, surface water from Lake Cachuma in the Santa Ynez River watershed, and from the State Water Project delivered to Lake Cachuma. The CVWD service area comprises approximately 11,098 acres and provides agricultural water supply to approximately 3,883 acres of irrigated crops and orchards.

CVWD can use their water supplies more effectively and efficiently to meet the water needs of consumers during prolonged drought periods through 2030. Water strategies such as conjunctive use, water banking, water purchases, and carryover of excess water need to be implemented during wet and normal years to be prepared for severe droughts. These strategies can be evaluated and implemented singularly, in combinations, or can be supplemented as opportunities for partnership with other creative water agencies in the region arise. By using a combination of water reliability strategies, CVWD could increase drought water supply reliability and reduce overall water supply costs.

2.3 City of Santa Barbara

Water Supply Planning Study, August 2009

The Water Supply Planning Study assesses the City of Santa Barbara's (SB) existing water supply (imported water, groundwater, recycled water) and identifies opportunities to increase SB's reliability of these supplies. The study describes opportunities to increase recycled water at properties adjacent to the existing recycled water system and to expand the existing system to serve new areas.

SB currently provides approximately 850 acre-feet of recycled water per year from El Estero Wastewater Treatment Plant on a year-round basis. The study describes the City's existing recycled water system, including the recycled water supplies, demands, distribution system, and facilities as well as opportunities for expanding the City's existing recycled water system and the issues related to expanded use.

Recommendations on ordinances and development policies, expansion of the system, and treatment process improvements are further described in the study.

2.4 Goleta Water District and Goleta Sanitary District

Reclaimed Water Project Study, January 1999

The Goleta Water District (GWD) and Goleta Sanitary District (GSD) Reclaimed Water Project Study describes the existing water reclamation facilities, reclaimed water markets, and potential reclaimed water customers. A survey of potential reclaimed water markets was conducted to identify new markets nearby the existing reclaimed water distribution facilities. The survey took place between April and July 1999. A total of 28 potential reclaimed water customers were identified. The potential markets were comprised of approximately 136 irrigated acres with an estimated annual reclaimed water use of 282 acre-feet per year. Agriculture use of recycled water is extremely sensitive to water quality and therefore was not included as potential recycled water use.

2.5 Goleta West Sanitary District

Proposed New Wastewater Treatment Plant Site and Treatment Alternatives Evaluation, July 2004

The Goleta West Sanitary District (GWSD) considered the construction of a new WWTF to allow treatment of their wastewater independent from the GSD. The Proposed New Wastewater Treatment Plant Site and Treatment Alternatives Evaluation summarize the treatment alternatives in relation to specific sites defined in the GWSD WWTF Constraints Analysis. Plant configuration alternatives were conceptually developed based on site and treatment alternatives. Additionally these alternatives were compared on a cursory level based upon both economic and non-economic factors.

2.6 Heal the Ocean

Cost of Tertiary Wastewater Treatment for Southern Santa Barbara County, August 2001

The purpose of this study was to develop sufficient data for tertiary treatment to allow the Heal the Ocean group to present their idea to the public. The data is based on at least one conceptual set of improvements at each of the five wastewater-renovation plants capable of producing tertiary-level effluent. Using these conceptual improvements, capital and annual operating and maintenance (O&M) costs for each plant was developed. The capital and annual O&M costs can be reduced to typical monthly costs for a residential unit in the respective city or district.

Findings from the study include:

- There are five independent wastewater treatment plants that serve the greater SB area of southern SB County. These plants are owned by the Goleta Sanitary District, City of SB, and the Sanitary Districts of Carpinteria, Montecito, and Summerland.
- All five of these plants fully comply with the terms of their NPDES discharge permits and two plants have established water reclamation facilities including storage and distribution systems. One plant is treating to tertiary quality now but does not meet the full redundancy guidelines of the California Department of Public Health (CDPH).
- Four of the five plants provide full secondary treatment. The Goleta Sanitary District plant provides a combination of primary and secondary treatment to the outfall. Although in full compliance with their present discharge permit, this plant must be first upgraded to secondary treatment and then be upgraded to tertiary treatment.
- Three of the five plants have sufficient space available to upgrade to tertiary treatment. The other two must take special steps to accomplish the upgrade, such as convert existing plant to a new

process or simply build the next phase of construction early to increase the number of process units to enhance reliability.

- Sewer service charges vary dramatically among service areas. Some are based on a flat annual or monthly charge, and others are based on a flat service fee plus a charge based on water consumption.
- The increase in service charge that will be required for upgrading to tertiary is acceptable to the treatment authorities so long as the majority of the public they serve is convinced of the need and is fully prepared to support the additional cost.

Conclusions reached from the study include:

- The Goleta WWTP can be upgraded by expanding the processes presently in use at the plant. The major change proposed is that of equalizing storage after primary treatment in order to optimize the treatment train by reducing the impact of wet weather flow variations.
- The El Estero WWTP is extremely limited in available land. The conclusion to convert the disinfection process to ultraviolet light (UV) (which does not require a long contact time) and use the land made available for building the effluent filters. This requires a two-phase construction approach so that the land can be made available for demolition of the existing chlorine contact channels and the construction of filters. The existing filters can be used in conjunction with the new filters to meet the full plant design capacity.
- The Carpinteria WWTP also has an extremely small site in view of the future growth anticipated in the service area. Different approaches are presented that may be feasible, but the alternative chosen to develop for costing is to expand the present plant to provide process redundancy. With that issue solved, the tertiary process facilities can be added. These would consist of continuously back-washed filters and a new UV system for disinfection before releasing the water to the outfall. The existing chlorine contact channels would be demolished, thereby making that land available for other purposes.
- The Montecito WWTF is full secondary plan that can be upgraded with the addition of filters and expanded chlorine contact channels. The solids handling facilities appear to be undersized for the present solids load. The additional solids from the filter backwash water will increase the loading, hence a parallel thickener and an aerobic digester was included in the process train.
- The Summerland WWTP already produces a filtered effluent before discharge to the outfall. The redundancy of processes is the only issue of substance here. By adding a continuous backwash filter and re-arranging the direction of flow, this plant can be considered a tertiary plant with full redundancy.
- Each of the plants must also add the appropriate sensors and alarm systems in addition to major process units to comply with the reliability standards.
- Opinion of costs for proposed systems and their probable increase in operating and maintenance costs are presented in the study.

Water Reclamation Research, September 2000

The Water Reclamation Research is a research paper developed by master student, Ian Adams, from Bren School of Environmental Science and Management, University of Santa Barbara in 2000. The research paper describes each wastewater treatments step (Primary, Secondary, Tertiary, Disinfection and Advanced Treatment), defines reclaimed water and Heal the Ocean Assessment of Water Reclamation for Santa Barbara County research on the feasibility of upgrading all secondary treatment of wastewater to tertiary treatment while expanding the uses of reclaimed water within the County boundaries. The goals and objectives of the reclaimed water program in Santa Barbara are the same as Goleta Water District and Goleta Sanitary District Reclaimed Water Project Study (CDM, 1999).

California Ocean Wastewater Discharge Report and Inventory, March 2010

Heal the Ocean's main goal is to eliminate pollutants discharged into the ocean and that one way to reduce the pollutant loading is to understand the treatment plants that discharge into the ocean. The California Ocean Wastewater Discharge Report and Inventory consolidates information on the ocean outfalls and their associated wastewater plants.

The Report and Inventory provides a complete statewide overview of specific features of coastal wastewater treatment plants and their ocean outfalls, summarizing important pollutant issues, which pose a challenge to wastewater treatment and water reclamation and reuse and mapping/reporting on the spatial relationship between wastewater discharge locations and beaches adjacent to 303(d) listed impaired water bodies and other sensitive ocean ecosystems throughout California.

Recommendations from the Report and Inventory include:

- Improving and upgrading existing wastewater treatment plants
- Increasing the use of reclaimed water as a more economic alternative to potable water for non-potable uses
- Make public education and consumer awareness a priority
- Support and increase efforts to prevent pollution at source
- Revise legislation and regulation as soon as possible to overcome barriers to use
- Support and expand collaborative planning and research
- Provide government support and funding mechanisms
- Revise the reporting protocols of the SWRCB and attendant regional boards

The Report and Inventory helps provide a comparative perspective of current sewage treatment practices, shows where reporting of treatment plant data could be improved, helps to direct future research into controlling and eliminating human sources of ocean pollution, and assists efforts by various stakeholders, such as facility managers, policy makers, community leaders, and environmental groups to improve California's water quality and supply.

2.7 Montecito Water District and Montecito Sanitary District

Water Reclamation Study, January 1991

Montecito Water District (MWD)'s and Montecito Sanitary District (MSD)'s Water Reclamation Study investigated the alternatives available to provide recycled water in Montecito. The study examined treating MSD secondary flows to Title 22 for landscape and agricultural irrigation. The study describes the existing wastewater facilities and identifies the recycled water market. The study describes treatment alternatives as well as distribution alternatives, along with their costs.

Chapter 3 Regulations Summary

This chapter describes the pertinent Federal, State, and local recycled water regulations and policies that affect the planning of the south coast subregion of Santa Barbara County's recycled water system.

3.1 Federal

3.1.1 EPA Guidelines for Water Reuse (2012)

The U.S. Environmental Protection Agency (EPA) recently released an update of its Guidelines for Water Reuse (Guidelines), which provides information and guidelines on water recycling for the benefit of utilities and regulatory agencies, particularly in the U.S. The mission of the guidelines is "to advance the beneficial and efficient uses of high quality, locally produced, sustainable water sources for the betterment of society and the environment through advocacy, education and outreach, research, and membership."

The Guidelines cover water reclamation for nonpotable urban, industrial, and agricultural reuse, as well as augmentation of potable water supplies through indirect reuse. The Guidelines were first published in 1980. Because the number of reuse applications has expanded so significantly since publication of the previous version in 2004, the 2012 version modified the format and scope of case studies to provide examples of best practices and lessons learned. **Table 3-1** is summary provided in the Guidelines that outlines the contents of each section of the Guidelines. (EPA, 2004)

Table 3-1: Organization of EPA's 2012 Guidelines for Water Reuse

Chapter	Overview of Contents
Chapter 1–Introduction	Introduction section providing the background and objectives of the Guidelines
Chapter 2 – Planning and Management Considerations	EPA's Total Water Management approach to water resources planning is described as a framework within which water reuse is integrated into a holistic water management approach. The steps that should be considered in the planning stage as part of an integrated water resources plan are then presented, followed by an overview of key considerations for managing reclaimed water supplies. These discussions cover management of supplies as well as managed aquifer recharge, which has progressed substantially since publication of the previous guidelines.
Chapter 3 – Types of Reuse Applications	A discussion of reuse for agricultural, industrial, environmental, recreational, and potable supplies is presented. An expanded discussion of indirect potable reuse (IPR) and direct potable reuse is also provided with references to new research and literature. Urban reuse practices such as fire protection, landscape irrigation, and toilet flushing were described in great detail in the 2004 guidelines and are not repeated here; however, general information regarding planning and management of reclaimed water supplies and systems that include urban reuse is provided in Chapter 2.
Chapter 4 – State Regulatory Programs for Water Reuse	An overview of legal and institutional considerations for reuse is provided in this chapter. The chapter also gives an updated summary of existing state standards and regulations. At the end of this chapter are suggested minimum guidelines for water reuse in areas where such guidance or rules have not yet been established.

Table 3-1: Organization of EPA's 2012 Guidelines for Water Reuse

Chapter	Overview of Contents
Chapter 5 – Regional Variations in Water Reuse	This new chapter summarizes current water use in the United States and discusses expansion of water reuse nationally to meet water needs. The chapter discusses variations in regional drivers for water reuse, including population and land use, water usage by sector, water rates, and the states' regulatory contexts. Representative water reuse practices are described for each region, and U.S. water reuse case studies are introduced.
Chapter 6 – Treatment Technologies for Protecting Public and Environmental Health	This chapter provides an overview of the treatment objectives for reclaimed water and discusses the major treatment processes that are fundamental to production of reclaimed water. And, while this chapter is not intended to be a design manual or provide comprehensive information about wastewater treatment, which can be found in other industry references, an overview of these processes and citations for updated industry standards is provided.
Chapter 7 – Funding Water Reuse Systems	Assuring adequate funding for water reuse systems is similar to funding other water services. Because of increased interest in using reclaimed water as an alternate water source, this chapter provides a discussion of how to develop and operate a sustainable water system using sound financial decision-making processes that are tied to the system's strategic planning process.
Chapter 8 – Public Outreach, Participation, and Consultation	This chapter presents an outline of strategies for informing and involving the public in water reuse system planning and reclaimed water use and reflects a significant shift in thinking toward a higher level of public engagement since publication of the last guidelines. This chapter also describes some of the new social networking tools that can be tapped to aid with this process.
Chapter 9 – Global Experiences in Water Reuse	With significant input from United States Agency for International Development (USAID) and the International Water Management Institute (IWMI), the chapter on international reuse has been expanded to include a description of the growth of advanced reuse globally. In addition, this chapter provides information on principles for mitigating risks associated with the use of untreated or partially treated wastewater, enabling factors for expanding water reuse, and new case studies that can provide informed approaches to reuse in the U.S.
APPENDIX A	Federal and nonfederal agencies that fund research in water reuse
APPENDIX B	Inventory of water reuse research projects
APPENDIX C	State regulatory websites
APPENDIX D	Case studies on water reuse in the U.S.
APPENDIX E	Case studies on water reuse outside the U.S.
APPENDIX F	List of case studies that were included in the 2004 EPA Guidelines
APPENDIX G	Abbreviations for Units of Measure

In states where standards do not exist or are being revised or expanded, the Guidelines can assist in developing reuse programs and appropriate regulations. The Guidelines are also useful to consulting engineers and others involved in the evaluation, planning, design, operation, or management of water reclamation and reuse facilities. In addition, an extensive chapter on international reuse is included to provide background information and discussion of relevant water reuse issues for authorities in other countries where reuse is being planned, developed, and implemented. In the U.S., water reclamation and reuse standards are the responsibility of State agencies.

A copy of the 2012 Guidelines is included in **Appendix B.**

3.2 State

3.2.1 California Water Code, Division 7

The Porter-Cologne Water Quality Control Act established the California Water Code (CWC), Division 7 to regulate water quality. The CWC, Division 7 declares that "the people of the State have a primary interest in the conservation, control, and utilization of the water resources of the State, and that the quality of all the waters of the State shall be protected for use and enjoyment by the people of the State."

The Legislative policy further declares "that activities and factors which may affect the quality of the waters of the State shall be regulated to attain the highest water quality which is reasonable, considering all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible."

The intent of the CWC is to provide statewide program for the "control of the quality of all the waters of the state to protect the quality of waters in the state from degradation." The policy also establishes the statewide program for water quality control as being administered regionally, within a framework of statewide coordination and policy. The intent of this legislative act is that "the SWRCB and each regional board shall be the principal State agencies with primary responsibility for the coordination and control of water quality. The State Board and regional boards in exercising any power granted in this division shall conform to and implement the policies of this chapter and shall, at all times, coordinate their respective activities so as to achieve a unified and effective water quality control program in this State." (CWC, 2011)

3.2.2 California Code of Regulations, Title 22 for Non-Potable Reuse

The CDPH establishes criteria and guidelines for producing and using recycled water. These criteria are codified in the California Code of Regulations (CCR), Title 22, Division 4, Chapter 3 entitled "Water Recycling Criteria". Commonly referred to as Title 22 Criteria, the treatment and effluent quality requirements are dependent upon the proposed type of non-potable reuse (NPR). In addition to these requirements, Title 22 specifies reliability criteria to ensure protection of public health.

The SWRCB and its nine Regional Water Quality Control Boards (RWQCB) are responsible for enforcing these criteria. The south coast subregion recycled water facilities are under the jurisdiction of Regional Board No. 3, the Central Coast RWQCB.

According to Title 22, treatment and effluent quality requirements are dependent upon the proposed type of water reuse. In addition to these requirements, Title 22 specifies reliability criteria to ensure protection of public health.

Treatment, Water Quality and Reliability

In general, Title 22 requires that wastewater be treated using designated processes to achieve a specified level of quality. Higher quality effluents, such as disinfected tertiary recycled water or disinfected advanced treated recycled water, may be utilized for more types of reuse with fewer restrictions. Lesser quality effluents, such as disinfected secondary effluent or undisinfected secondary effluent, have restricted uses. One of the main factors determining use restrictions is the degree to which the public has exposure or access to areas where recycled water is used and the proximity of drinking water wells and food crops. Higher levels of treatment and quality requirements are described in this section.

Title 22 requires that wastewater be oxidized, which means that its organic matter has been stabilized, is nonputrescible, and contains dissolved oxygen. Secondary treatment is necessary to produce oxidized and stabilized wastewater.

Moving beyond secondary treatment is tertiary treatment involving coagulation and media filtration or membrane filtration is required to meet Title 22 turbidity criteria measured in nephlometric turbidity units (NTU) for many types of reuse.

Title 22 (Section 60301.320) defines filtered wastewater as "an oxidized wastewater that meets the criteria in subsection (a) or (b):

(a) Has been coagulated and passed through natural undisturbed soils or a bed of filter media pursuant to the following:

(1) At a rate that does not exceed 5 gallons per minute per square foot of surface area in mono, dual or mixed media gravity, upflow or pressure filtration systems, or does not exceed 2 gallons per minute per square foot of surface area in traveling bridge automatic backwash filters [a rate that does not exceed 6 gallons per minute per square foot of surface area for cloth disc filters has been approved]; and

(2) So that the turbidity of the filtered wastewater does not exceed any of the following:

(A) An average of 2 NTU within a 24-hour period;

(B) 5 NTU more than 5 percent of the time within a 24-hour period; and

(C) 10 NTU at any time.

(b) Has been passed through a microfiltration, ultrafiltration, nanofiltration, or reverse osmosis membrane so that the turbidity of the filtered wastewater does not exceed any of the following:

(1) 0.2 NTU more than 5 percent of the time within a 24-hour period; and

(2) 0.5 NTU at any time."

Following tertiary treatment, disinfection ensures that the recycled water is safe for NPR with unrestricted public contact. According to Title 22 (Section 60301.230), "disinfected, tertiary recycled water means a filtered and subsequently disinfected wastewater that meets the following criteria:

(a) The filtered wastewater has been disinfected by either:

(1) A chlorine disinfection process following filtration that provides a CT (the product of total chlorine residual and modal contact time measured at the same point) value of not less than 450 milligram-minutes per liter at all times with a modal contact time of at least 90 minutes, based on peak dry weather design flow; or

(2) A disinfection process that, when combined with the filtration process, has been demonstrate to inactivate and/or remove 99.999 percent of the plaque-forming units of F-specific bacteriophage MS2, or polio virus in the wastewater. A virus that is at least as resistant to disinfection as polio virus may be used for purposes of the demonstration.

(b) The median concentration of total coliform bacteria measured in the disinfected effluent does not exceed an MPN [most probable number] of 2.2 per 100 milliliters utilizing the bacteriological results of the last seven days for which analyses have been completed and

> the number of total coliform bacteria does not exceed an MPN of 23 per 100 milliliters in more than one sample in any 30 day period. No sample shall exceed an MPN of 240 total coliform bacteria per 100 milliliters."

Where UV is used for disinfection, the UV system must comply with the "Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse" published by the National Water Research Institute (NWRI, 2003). For recycled water, these Guidelines specify minimum UV dose criteria for different upstream filtration technologies (media filtration, membrane filtration, and RO). The UV system must deliver, under worst operating conditions, a designated minimum UV dose at the maximum weekly flow and at the peak daily flow, as approved by CDPH for specific manufacturers and models of UV equipment.

Title 22 (Section 60320.5) specifies that other methods of treatment and their associated reliability features may be acceptable to CDPH if they are demonstrated as equivalent to the treatment methods and reliability features set forth in Title 22.

In addition to treatment and quality requirements, Title 22 contains reliability requirements and provisions for alarms to be included in the design of facilities. Title 22 (Articles 9 and 10) specify that the facilities must be designed to provide operational flexibility. Multiple treatment units capable of producing the required quality must be provided in the event that one unit is not in operation. In lieu of multiple units, alternative treatment processes, storage or disposal provisions may be provided for redundancy. Alarms are required to alert plant operators of power supply failure or failure of any treatment plant unit processes. In the event of a power supply failure, Title 22 requires the plant to provide either a standby power source or automatically actuated short-term or long-term storage or disposal provisions.

Recycled water quality sampling and analyses requirements are set forth in Title 22 (Article 6) to monitor treatment performance for compliance with total coliform bacteria limits and turbidity. The regulations also include requirements for operations personnel (Section 60325), maintenance (Section 60326), and reporting (Section 60329). Bypassing of treatment processes and/or discharge of inadequately treated effluent is not allowed (Section 60331).

To assure that recycled water facilities comply with the regulations, Title 22 (Section 60323) requires that an engineering report describing the proposed recycled water system and the means for the system complying with listed requirements be prepared and submitted to the RWQCB and CDPH for approval. The engineering report must be amended or resubmitted in the event that there are significant modifications to an existing project.

Uses of Recycled Water

Title 22 (Article 3) provides for many types of recycled water use. Table 3-2 summarizes the currently approved recycled water uses.

Table 3-2: Summary of Existing Allowable Recycled Water Uses

Allowable Title 22 Recycled Water Uses	Title 22 Section
Irrigation	
Food crops where recycled water contacts the edible portion of the crop, including all root crops	60304 (a) (1)
Parks and playgrounds	60304 (a) (2)
School yards	60304 (a) (3)
Residential landscaping	60304 (a) (4)
Unrestricted-access golf courses	60304 (a) (5)
Any other irrigation uses not prohibited by other provisions of the California Code of Regulations	60304 (a) (6)
Food crops, surface-irrigated, above-ground edible portion, and not contacted by	60304 (b)

Table 3-2: Summary of Existing Allowable Recycled Water Uses

Allowable Title 22 Recycled Water Uses	Title 22 Section
recycled water	
Cemeteries	60304 (c) (1)
Freeway landscaping	60304 (c) (2)
Restricted-access golf course	60304 (c) (3)
Ornamental nursery stock and sod farms with unrestricted public access	60304 (c) (4)
Pasture for milk animals for human consumption	60304 (c) (5)
Non-edible vegetation with access control to prevent use as park, playground or school yard	60304 (c) (6)
Orchards with no contact between edible portion and recycled water	60304 (d) (1)
Vineyards with no contact between edible portion and recycled water	60304 (d) (2)
Non food-bearing trees, including Christmas trees not irrigated less than 14 days before harvest	60304 (d) (3)
Fodder and fiber crops and pasture for animals not producing milk for human consumption	60304 (d) (4)
Seed crops not eaten by humans	60304 (d) (5)
Food crops undergoing commercial pathogen-destroying processing before consumption by humans	60304 (d) (6)
Ornamental nursery stock and sod farms not irrigated less than 14 days before harvest, sale, or allowing public access	60304 (d) (7)
Supply for impoundment	
Non-restricted recreational impoundments	60305 (a)
Non-restricted recreational impoundments, with supplemental monitoring for pathogenic organisms in lieu of conventional treatment	60305 (b)
Restricted recreational impoundments and publicly accessible fish hatcheries	60305 (d)
Landscape impoundments without decorative fountains	60305 (e)
Supply for cooling or air conditioning	
Industrial or commercial cooling or air conditioning involving cooling tower, evaporative condenser, or spraying that creates a mist	60306 (a)
Industrial or commercial cooling or air conditioning not involving cooling tower, evaporative condenser, or spraying that creates a mist	60306 (b)
Other Uses	
Dual plumbing systems (flushing toilets and urinals)	60307 (a) (1)
Priming drain traps	60307 (a) (2)
Industrial process water that may contact workers	60307 (a) (3)
Structural fire fighting	60307 (a) (4)
Decorative fountains	60307 (a) (5)
Commercial laundries	60307 (a) (6)
Consolidation of backfill material around potable water pipelines	60307 (a) (7)
Artificial snow making for commercial outdoor uses	60307 (a) (8)
Commercial car washes, not heating the water, excluding the general public from washing process	60307 (a) (9)
Industrial boiler feed	60307 (b) (1)
Nonstructural fire fighting	60307 (b) (2)
Backfill consolidation around non-potable piping	60307 (b) (3)
Soil compaction	60307 (b) (4)
Mixing concrete	60307 (b) (5)
Dust control on road and streets	60307 (b) (6)

Table 3-2: Summary of Existing Allowable Recycled Water Uses

Allowable Title 22 Recycled Water Uses	Title 22 Section
Cleaning roads, sidewalks and outdoor work areas	60307 (b) (7)
Industrial process water that will not come into contact with workers	60307 (b) (8)
Flushing sanitary sewer	60307 (c)
Groundwater recharge	60320 (a)

As noted in this table, irrigation with recycled water is a common application. Depending on the level of treatment and quality, recycled water may be used to irrigate numerous different areas (Section 60304). For example, disinfected tertiary recycled water may be used to irrigate parks and school yards; whereas disinfected secondary effluent may be used to irrigate cemeteries and freeway landscaping, and undisinfected secondary effluent may be used to irrigate non-food-bearing trees and orchards where the recycled water does not come into contact with the edible crop. Disinfected tertiary water may be used in lieu of the lesser quality recycled waters for irrigation.

Disinfected tertiary effluent may be used for non-restricted recreational impoundments (Section 60305). Disinfected secondary or tertiary effluent may be used for restricted recreational impoundments and publically accessible impoundments at fish hatcheries.

Specifically, Title 22 (Section 60301.620) defines a non-restricted recreational impoundment as “an impoundment of recycled water, in which no limitations are imposed on body-contact water recreational activities”. With regard to use of recycled water for impoundments, Title 22 (Section 60305 states:

“(a) Except as provided in subsection (b), recycled water used as a source of water supply for non-restricted recreational impoundments shall be disinfected tertiary recycled water that has subjected to conventional treatment.

(b) Disinfected tertiary recycled water that has not received conventional treatment may be used for non-restricted recreational impoundments provided the recycled water is monitored for the presence of pathogenic organisms in accordance with the following:

(1) During the first 12 months of operation and use the recycled water shall be sampled and analyzed monthly for Giardia, enteric viruses, and Cryptosporidium. Following the first 12 months of use, the recycled water shall be sampled and analyzed quarterly for Giardia, enteric viruses, and Cryptosporidium. The ongoing monitoring may be discontinued after the first two years of operation with the approval of the CDPH. This monitoring shall be in addition to the monitoring set forth in Section 60321.

(2) The samples shall be taken at a point following disinfection and prior to the point where the recycled water enters the use impoundment. The samples shall be analyzed by an approved laboratory and the results submitted quarterly to the regulatory agency.

(c) The total coliform bacteria concentrations in recycled water used for non-restricted recreational impoundments, measured at a point between the disinfection process and the point of entry to the use impoundment, shall comply with the criteria specified in Section 60301.230 (b) for disinfected tertiary recycled water.

(d) Recycled water used as a source of supply for landscape impoundments that do not utilize decorative fountains shall be at least disinfected secondary-23 recycled water.”

Title 22 (Section 60306) allows disinfected tertiary recycled water to be used for cooling purposes where mist may be created. If the application does not produce mist, then at least disinfected secondary effluent must be used.

Title 22 (Section 60307) includes provisions for many other types of reuse, as listed in **Table 3-2**. Disinfected tertiary effluent may be used for any of these NPR.

Title 22 (Section 60320) covers recycled water use for groundwater recharge of domestic water supply aquifers. Title 22 specifies that CDPH make recommendations to the RWQCB for groundwater recharge projects on a case-by-case basis. CDPH have published Draft Groundwater Recharge Criteria for indirect potable reuse.

Use Area Requirements

Under Title 22, a use area is an area of recycled water use with defined boundaries, which may contain one or more facilities where recycled water is used.

Title 22 (Section 60310) sets forth detailed use area requirements for irrigation in the vicinity of domestic water supply wells and strict limits on runoff, spray, and protection of drinking water fountains and food handling/eating areas, residences. Any connection between the recycled water and potable water systems, except as allowed under Title 17, are prohibited. Quick couplers that differ from hose bibs must be used in the recycled water piping system. Signs need to be posted to notify the public that recycled water is used at the site.

Specific requirements are contained in Title 22 (Article 5) for dual plumbed recycled water systems. Separate reports and tests are required for dual plumbed systems to demonstrate proper design, operation, and confirmation that cross-connections are not present.

3.2.3 California Code of Regulations, Title 17

Title 17, Division 1, Chapter 5 "Sanitation (Environmental)", Group 4 "Drinking Water Supplies", of the CCR (California, 2009), specifies that the water supplier must protect the public drinking water supply from contamination by implementation of a cross-connection control program. Title 17 (Group 4, Article 2) sets forth requirements for protection of the water system and specifies the minimum backflow prevention required on the potable water system for situations where there is potential for contamination to the potable water supply.

For recycled water, construction and location of backflow preventers is addressed in Title 17 as follows:

- An air-gap separation shall be at least double the diameter of the supply pipe, measured vertically from the flood rim of the receiving vessel to the supply pipe. The air-gap separation shall be located as close as practical to the user's connection and all piping between the user's connection and the receiving tank shall be entirely visible unless otherwise approved in writing by the water supplier and the health agency.
- A double check valve assembly shall conform to American Water Works Association standards and shall be located as close as practical to the user's connection and shall be installed above grade, if possible, in a manner where it is readily accessible for testing and maintenance.
- A reduced pressure principle backflow prevention device shall conform to American Water Works Association standards and shall be located as close as practical to the user's connection and shall be installed a minimum of 12 inches above grade and not more than 36 inches above grade from the bottom of the device and with a minimum of 12 inches side clearance.

An air-gap separation is defined as a physical break between the supply line and a receiving vessel. A double check valve assembly is an assembly of at least two independently acting check valves including tightly closing shut-off valves on each side of the check valve assembly and test cocks available for testing the water tightness of each check valve. A reduced pressure principle backflow preventer is a backflow prevention device incorporating not less than two check valves, an automatically operated differential relief valve located between the two check valves, a tightly closing shut-off valve on each side of the check valve assembly, and equipped with necessary test cocks for testing. Title 17 also requires that each water purveyor develop and implement its own comprehensive backflow prevention program for protecting the public water supply from contamination or pollution.

3.2.4 California Plumbing Code (2007)

The purpose of California Plumbing Code (CPC) is to establish the minimum requirements to safeguard the public health, safety and general welfare through structural strength, means of egress facilities, stability, access to persons with disabilities, sanitation, adequate lighting and ventilation, and energy conservation; safety to life and property from fire and other hazards attributed to the built environment; and to provide safety to fire fighters and emergency responders during emergency operations.

The codes of practice attempt to minimize public risk by specifying technical standards of design, materials, workmanship and maintenance for plumbing systems. The main aims of the code are (CPC, 2010):

- To ensure that planners, administrators and plumbers develop the required competency to ensure that the codes are applied and upheld;
- That standards are set to ensure that plumbing assemblies, materials and technologies are safe and effective;
- To ensure that plumbing installations meet these standards;
- To ensure safety and effectiveness continuously through the proper maintenance of these installations.

3.2.5 California DPH

In addition to the Title 22 and Title 17 regulations previously described, CDPH has other documents related to recycled water production and use:

- Guidelines for the Preparation of an Engineering Report for the Production, Distribution and Use of Recycled Water (CDPH, 2001) – This report provides a framework to assist in developing a Title 22 Engineering Report that addresses the necessary elements of a proposed of modified recycled water project to facilitate regulatory review and approval.
- Treatment Technology Report for Recycled Water (CDPH, 2007) – This report provides reference information about treatment technologies meeting filtration performance and disinfection requirements for compliance with Title 22.
- Guidance Memo No. 2003-02: Guidance Criteria for the Separation of Water Mains and Non-Potable Pipelines (CDPH, 2003) – This memorandum provides separation criteria for design and installation of drinking water and non-potable (recycled water and sewers) pipelines to prevent contamination of the drinking water supply.
- Draft Regulation for Groundwater Recharge Reuse (November, 21, 2011) – These Draft Criteria reflect the lasting "current thinking on the regulation for replenishing groundwater with recycled municipal wastewater" by CDPH. These were released to the recycled water and environmental communities for input as part of a stakeholder process to update the existing Draft Criteria that was revised as recently as August 5, 2008. Input from the reuse and environmental community on the Draft Regulations has been sent to CDPH, which is expected to issue a formal notice of Draft Regulations to the public by the end of 2012 or early 2013. Appendix C contains copies of the November 11, 2011 Draft Regulation for Groundwater Recharge Reuse and presentations made by CDPH's in December 2011 at public workshops.

3.2.6 SWRCB Recycled Water Policy

In February 2009, the SWRCB adopted Resolution 2009-0011 "Recycled Water Policy" (SWRCB, 2009a). This Recycled Water Policy sets uniform standards for how individual RWQCBs interpret and implement the Anti-Degradation Policy (SWRCB Resolution No. 68-16; SWRCB, 1968) for water recycling projects. Prior to this, water recycling projects were impacted by the differing actions of some RWQCBs based on application of the Anti-Degradation Policy. The RWQCB interpretations generally sought to prevent any change in groundwater quality, regardless of considerations around the provision to meet the “maximum benefit to the people of the State” as stated in the SWRCB Recycled Water Policy. For example, a RWQCB may have determined that any change in salinity was unacceptable, even though the change still allowed the groundwater to meet State water quality and health standards. To resolve these permitting discrepancies, the SWRCB adopted the Recycled Water Policy, which provides direction to the RWQCBs and includes key provisions that must be considered when planning and implementing recycled water projects:

- Mandate for recycled water use
- Salt/nutrient management plans
- Landscape irrigation projects’ control of incidental runoff and streamlined permitting
- Groundwater recharge
- Anti-degradation
- CECs (e.g., endocrine disrupters, personal care products or pharmaceuticals).

Mandate for Recycled Water Use

In the Recycled Water Policy, the SWRCB supports and encourages use of recycled water. Specific targets are mandated to increase recycled water use. The Recycled Water Policy requires agencies producing recycled water that is available for reuse and not being put to beneficial use to make that recycled water available to water purveyors for reuse on reasonable terms and conditions. Such terms and conditions may include payment by the water purveyor of a fair and reasonable share of the cost of the recycled water supply and facilities.

The SWRCB declared that it is a waste and unreasonable use of water for water agencies not to use recycled water when recycled water of adequate quality is available and is not being put to beneficial use. The SWRCB also acknowledged that it shares jurisdiction over the use of recycled water with the RWQCBs and CDPH and that other agencies, such as the California DWR and California Public Utilities Commission, are also involved in encouraging water reclamation.

Salt/Nutrient Management Plans

The Recycled Water Policy recognizes that some groundwater basins contain salts and nutrients that exceed or threaten to exceed water quality objectives established in the applicable Basin Plans, and not all Basin Plans include adequate implementation procedures for achieving or ensuring compliance with the water quality objectives for salt or nutrients. These conditions can be caused by natural soils, discharges of waste, irrigation using surface water, groundwater or recycled water, and water supply augmentation using surface or recycled water. The Recycled Water Policy determines that regulation of recycled water alone will not address these conditions.

The Recycled Water Policy calls for salts and nutrients from all sources to be managed on a basin-wide or watershed-wide basis in a manner that ensures attainment of water quality objectives and protection of beneficial uses. According to the SWRCB, the most appropriate way to address salt and nutrient issues is through the development of regional or subregional salt and nutrient management plans by local water and wastewater agencies, rather than through imposing requirements solely on individual recycled water projects.

The Recycled Water Policy requires every groundwater basin/sub-basin in California to have a salt/nutrient management plan. Salt/nutrient management plans need to be tailored to address the water quality concerns in each basin/sub-basin and may include constituents other than salt and nutrients that impact water quality in the basin/sub-basin. Stormwater recharge must be included in the salt/nutrient management plans because stormwater is typically lower in nutrients and salts and can augment local water supplies. The plans must address all sources of salts and nutrients to groundwater basins, including recycled water irrigation projects and groundwater recharge reuse projects. Other constituents may also be addressed if they adversely affect groundwater quality. The Recycled Water Policy requires salt/nutrient management plans to be completed and submitted to the RWQCB within five years (or seven years with an approved extension).

According to the Recycled Water Policy, each salt/nutrient management plan shall include:

- Monitoring network to provide a cost-effective means of determining whether the concentrations of salt, nutrients, and other constituents of concern as identified in the salt and nutrient plans are consistent with applicable water quality objectives. The monitoring frequency must be determined in the salt/nutrient management plan and approved by the RWQCB.
- Annual monitoring of CECs consistent with recommendations by CDPH and consistent with any actions by the SWRCB.
- Water recycling and stormwater recharge/use goals and objectives.
- Salt and nutrient source identification, basin/sub-basin assimilative capacity and loading estimates, together with fate and transport of salts and nutrients.
- Implementation measures to manage salt and nutrient loading in the basin on a sustainable basis.
- An anti-degradation analysis demonstrating that the projects included within the plan will collectively satisfy the requirements of the Anti-Degradation Policy, Resolution No. 68-16.
- The SWRCB requires each RWQCB, within one year of receipt of a proposed salt/nutrient management plan, to consider adopting revised implementation plans, consistent with Water Code Section 13242, for those groundwater basins within their regions where water quality objectives for salts or nutrients are being, or are threatening to be, exceeded. The implementation plans shall be based on the salt/nutrient management plans required by the Recycled Water Policy.

Plans which are more protective than applicable standards in the Basin Plan may be developed. However, the RWQCBs may not modify Basin Plan water quality objectives without getting full approval in accordance with existing law. Areas that have already completed a RWQCB approved salt/nutrient management plan for a basin/sub-basin that is functionally equivalent to the Recycled Water Policy requirements are exempt.

In August 2009, the SWRCB issued a memorandum (SWRCB, 2009) to all of the RWQCBs to clarify their role in implementing the Recycled Water Policy. This memorandum describes specific actions for each RWQCB:

- Initiate and participate in the stakeholder process for development of salt/nutrient management plans
- Track and report development of salt/nutrient management plans
- Input groundwater data into GeoTracker (the SWRCB database)
- Incorporate incidental runoff provisions
- Streamline permitting of eligible recycled water irrigation projects
- Implement groundwater recharge reuse provisions
- Implement anti-degradation provisions
- Cooperate with water recycling mandates, stormwater reuse, and total maximum daily loads

Landscape Irrigation Projects

The Recycled Water Policy addresses two issues for landscape irrigation projects: 1) incidental runoff and 2) streamlining permitting. Under the Recycled Water Policy, control of incidental runoff must be addressed by landscape irrigation uses:

- Incidental runoff is defined as unintended small volumes of runoff from recycled water use areas, such as unintended minimal over-spray from sprinklers that leaves the use area. Intentional overflow or over-application due to design or negligence is not considered to the incidental runoff. The Recycled Water Policy states that incidental runoff may be regulated by Waste Discharge Requirement (WDR). Regardless of how incidental runoff may be regulated, landscape irrigation projects must include an operation and maintenance plan to detect leaks and stipulate correction measures within 72 hours of the runoff or prior to the release of 1,000 gallons of recycled water.
- Sprinklers at use sites must be properly designed.
- Irrigation must be discontinued during rain events.
- Recycled water impoundments, such as ponds, must be managed so as not to overflow and discharge recycled water, unless the discharge is caused by a storm event with a magnitude greater than 25-year frequency.

The SWRCB also requires that RWQCBs streamline processing permits for recycled water landscape irrigation projects. If the project has unusual or unique site conditions, then a RWQCB may require more detailed information about the landscape irrigation system. However, most landscape irrigation projects will be permitted under a general RWQCB order. Recycled water monitoring should be conducted as well as project specific monitoring to support the development and implementation of the salt/nutrient management plan. The Recycled Water Policy specifies criteria for eligibility for streamlined permitting:

- Compliance with Title 22 Water Recycling Criteria
- Application amounts and rates, which are appropriate for the landscape at the use site
- Compliance with the applicable salt/nutrient management plan
- Appropriate use of fertilizers that accounts for nutrients present in the recycled water

Groundwater Recharge Projects

The Recycled Water Policy includes provisions for recycled water groundwater recharge projects. Approved groundwater recharge projects must comply with regulations adopted by CDPH or, in the interim until such regulations are approved, CDPH's recommendations pursuant to Water Code section 13523 for the project (e.g., level of treatment, retention time, setback distance, source control, monitoring program, etc.).

The policy also requires that such projects implement a monitoring program for CECs and a monitoring program for CECs that is consistent with any actions by the State Board and that takes into account site-specific conditions. Groundwater recharge projects shall include monitoring of recycled water for CECs on an annual basis and priority pollutants on a twice-annual basis.

A RWQCB may also impose additional requirements for a proposed recharge project that has a substantial adverse effect on the fate and transport of a contaminant plume or changes the geochemistry of an aquifer thereby causing the dissolution of constituents, such as arsenic, from the geologic formation into groundwater.

Anti-degradation

In 1968, the SWRCB adopted Resolution No. 68-16 "Statement of Policy with Respect to Maintaining High Water Quality in California". This Anti-Degradation Policy specifies:

1. "Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality water will be maintained until it has been demonstrated to the State that any change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water, and will not result in water quality less than that prescribed in the policies."
2. "Any activity which produces or may produce a waste or increased volume or concentration of waste and which discharges or proposes to discharge to existing high quality waters will be required to meet waste discharge requirements which will result in the best practicable treatment or control of the discharge necessary to ensure that (a) pollution or nuisance will not occur and (b) the highest water quality consistent with maximum benefit to the people of the State will be maintained."

The Recycled Water Policy recognizes the SWRCB Resolution No. 68-16, Anti-Degradation Policy (SWRCB, 1968) that regulates waters to achieve the highest quality consistent with the maximum benefit to the people of the State. It requires that best practicable treatment or control of waste discharges be used to maintain the highest water quality consistent with the maximum benefit to the people of the State. Specific anti-degradation issues related to groundwater recharge are also addressed in the Policy.

Landscape irrigation with recycled water is a benefit, but this NPR can affect groundwater quality over time. The SWRCB's intent is to address such impacts with the salt/nutrient management plans. As such, the Recycled Water Policy states that landscape irrigation projects may be approved:

- Without an anti-degradation analysis, provided that the project is consistent with the salt/nutrient management plan and qualifies for permit streamlining
- By demonstrating through a salt/nutrient mass balance that the project uses less than 10 percent of the available assimilative capacity of the basin/sub-basin

Constituents of Emerging Concern (CEC)

The SWRCB Recycled Water Policy included a provision establishing a Science Advisory Panel to provide guidance for developing monitoring programs that assess potential CEC impacts to public health from various water recycling practices, including groundwater recharge with recycled water. The panel was formed in May 2009 and includes six national experts in the fields of chemistry, biochemistry, toxicology, epidemiology, risk assessment, and engineering. Panelists include:

- Dr. Paul Anderson, Human Health Toxicologist, Vice President and Technical Director, Risk Assessment AMEC Earth and Environment
- Dr. Nancy Denslow, Biochemist. Associate Professor Toxicology, Molecular Biology and Proteomics, University of Florida
- Dr. Jörg Drewes, Civil Engineer Familiar with the Design and Construction of Recycled Water Treatment Facilities, Environmental Science and Engineering Division, Colorado School of Mines
- Dr. Adam Olivieri, Epidemiologist/Risk Assessor, Vice President, EOA, Inc.
- Dr. Daniel Schlenk, Environmental Toxicologist, Department of Environmental Sciences, University of California, Riverside
- Dr. Shane Snyder, Analytical Chemist Familiar with the Design and Operation of Advanced Laboratory Methods for the Detection of Emerging Constituents, R&D Project Manager Applied Research and Development Center, Southern Nevada Water Authority

Draft recommendations were submitted to the SWRCB for public comment on April 15, 2010 and final recommendations were provided on June 25, 2010[1]. The Panel held four in-person meetings and

[1] http://www.waterboards.ca.gov/water_issues/programs/water_recycling_policy/docs/cec_monitoring_rpt.pdf

numerous conference calls over the last year. The meetings included the opportunity for stakeholder input in clarifying their charge, exchange of information, dialog with the Panel and consideration of public comments on the draft report. This report provides the results from the Panel's deliberations, including four products intended to assist the State in refining its recycled water policy:

- Product #1: A conceptual framework for determining which CECs to monitor
- Product #2: Application of the framework to identify a list of chemicals that should be monitored presently
- Product #3: A sampling design and approach for interpreting results from CEC monitoring programs
- Product #4: Priorities for future improvements in monitoring and interpretation of CEC data

On October 16, 2012, the SWRCB held a hearing to adopt the CEC monitoring requirements for recycled water. However, due to numerous last minute changes, the Board continued the hearing to a future date to be determined. Based on the current draft regulations, there are numerous requirements for the sampling and testing of CECs on IPR projects. However, for standard irrigation projects, the only proposed requirements are for the monitoring of surrogates at the treatment plant. The actual surrogates are to be determined on a project specific basis. See the SWRCB's website for the latest information: http://www.waterboards.ca.gov/. Final adoption of the CEC monitoring requirements is expected in 2013

3.2.7 SWRCB General Landscape Irrigation Permit

The SWRCB adopted Water Quality Order No. 2009-0006-DWQ "General Waste Discharge Requirements for Landscape Irrigation uses of Municipal Recycled Water" (General Permit) in July 2009 (SWRCB, 2009b). This General Permit is intended to streamline the regulatory process for landscape irrigation uses of recycled water. Some projects may be unique or site-specific and not be appropriate for permitting under the General Permit; however, the majority of recycled water irrigation of landscaping at parks, greenbelts, playgrounds, school yards, athletic fields, golf courses, cemeteries, residential common areas, commercial and industrial areas (except eating areas), and along freeways, highways, and streets will be eligible for coverage under the General Permit. Participation in the General Permit is optional; in other words, agencies are not required to apply for the General Permit, even if their projects meet the criteria, but instead, they may maintain their current water reuse requirements (WRR) and WDR.

Recycled water projects covered by the General Permit must meet the following:

- Disinfected tertiary effluent in accordance with Title 22 Criteria
- Distribution of recycled water in accordance with Title 22 Criteria and Title 17 backflow and prevention requirements
- Recycled water uses in accordance with Title 22 Criteria
- All applicable requirements of the Recycled Water Policy, including salt/nutrient management
- Manage chlorine usage to prevent discharge of chlorinated recycled water that would be toxic to aquatic life
- Best management practices to prevent unauthorized discharges of recycled water, control incidental runoff and prevent overflow of impoundment

Producers and distributors of recycled water may file applications to be covered under this General Permit by completing a Notice of Intent (NOI) form, Operation and Maintenance (O&M) Plan, and pay associated application fees. The General Permit contains requirements for disinfected tertiary recycled water production, management, distribution, and use that are the same as those in Title 22 Recycled Water Criteria. Prior to commencing recycled water irrigation, the Administrator must submit an O&M Plan to the SWRCB containing specific elements:

- Operations Plan for the recycled water use areas

- Irrigation Management Plan showing that recycled water will be applied at an agronomic rate for irrigation efficiency and to minimize application of salts
- Summary of the Title 22 Engineering Report approved by CDPH
- Rules and Regulations approved by CDPH governing the design and construction of recycled water use facilities and use of recycled water
- Copies of agreements between the responsible parties for producing, distributing, and using the recycled water
- Documentation on the Recycled Water Use Supervisor's training and responsibilities

When enrolled in the General Permit, if the Producers or Distributors are subject to general or individual WDRs or WRRs, the provisions of those permits for recycled water use are replaced by the requirements of the General Permit.

3.3 Local

3.3.1 Reclamation and Discharge Permits

Permits containing water recycling requirements are issued by the RWQCB in consultation with CDPH for specific reuse projects. In some cases, the water recycling permits are appended by the RWQCB to the waste discharge requirements of the facility's National Pollutant Discharge Elimination System (NPDES) permit. In the past, the RWQCB has issued permits with water recycling requirements to individual recycling facilities as well as individual users of recycled water. Now, the RWQCBs are issuing so-called "producer/user requirements" that regulate a single recycling facility and all of its users. Furthermore, in some cases a "master reclamation permit" is issued that applies to several reclamation facilities that are part of an interconnected regional system along with all of the users of that system.

Recycled water and discharge permits for treatment plants in the plan area are listed below in **Table 3-3**. The recycled water permit requirements for the existing Goleta and Santa Barbara recycled water system are shown in **Table 3-4**.

Table 3-3: Discharge Permits in the Region

Agency	Treatment Plant	Waste Discharge Permit No. (NPDES No. & Order No.)	Master Recycled Water Permit No.
Carpinteria SD	Carpinteria WWTP	CA 0047364	--
City of Santa Barbara	El Estero WWTF	CA 0048143 R3-2010-0011	97-44
Goleta SD	Goleta WWTP	CA 0048160 R3-2010-0012	91-03
Montecito SD	Montecito WWTF	CA 0047899	--
Summerland	Summerland WWTP	CA 0048054 R3-2008-0009	--

Table 3-4: Summary of Recycled Water Permit Requirements

Agency	Treatment Plant	BOD (mg/l)	Turbidity (NTU))	Susp. Solids (NTU)	Settleable Solids	TDS (mg/l)	Cadmium (mg/l)	Lead (mg/l)
Mean								
City of Santa Barbara	El Estero WWTF	-	2	10	-	-	-	-
Goleta SD	Goleta WWTP	10	2	10	-	-	-	-
Maximum								
City of Santa Barbara	El Estero WWTF	-	5	25	0.1	1,500	0.01	5.0
Goleta SD	Goleta WWTP	25	5	25	0.1	1,500	0.01	5.0

3.3.2 Groundwater Quality Objectives

Water quality objectives for surface and ground waters are adopted by the RWQCBs for specific basins. The objectives set to protect surface and groundwater quality can vary greatly from basin to basin are often based on the existing conditions of the basin or surface water body. See the discussion above related to the proposed changes in groundwater regulations by the CDPH related to the protection of human health.

At the local level, the RWQCB responsibility is the protection of the environment, and hence the variation from one region to another or even from one basin to another. These objectives often dictate additional recycled water quality requirements if being used for groundwater recharge or for surface water augmentation or discharges.

Specific objectives for the region's groundwater basins and surface water bodies were not considered in this plan since these potential recycled water uses were not being considered by the plan partners for near-term. For the long-term, potential groundwater recharge options were discussed and basin plan objectives should be considered more closely in future analyses.

Based on the 2011 Water Quality Control Plan for the Central Coastal Basin (2011 Basin Plan), certain water quality objectives have been established for selected ground waters. These objectives are intended to serve as a water quality baseline for evaluating water quality management in the basin. The median values for ground waters are shown in **Table 3-5**.

Table 3-5: South Coast Sub-Basin Median Ground Water Objectives, mg/l

Sub-Area	TDS	Chlorine (Cl)	Sulfate (SO_4)	Boron (B)	Sodium (Na)	Nitrogen (N)
Goleta	1,000	150	250	0.2	150	5
Santa Barbara	700	50	150	0.2	100	5
Carpinteria	700	100	150	0.2	100	7

Notes:

1. Objectives shown are median values based on data averages; objectives are based on preservation of existing quality or water quality enhancement believed attainable following control point sources.

Chapter 4 Existing Wastewater Treatment Plants and Recycled Water Systems

This chapter summarizes the existing wastewater treatment plants and recycled water systems in the plan area.

4.1 Existing Wastewater Treatment Plants

This section provides an overview of the existing wastewater treatment plants and potential recycled water supplies available to the region that are owned and operated by the agencies in the south coast region of the County of Santa Barbara. Each plant is discussed individually. The existing capacities and projected flows were provided by each agency.

4.1.1 Existing Capacities

Table 4-1 provides a summary of the existing secondary and tertiary capacities, along with average daily flows for each wastewater treatment plant. The existing capacities were provided by each agency.

Table 4-1: Existing Wastewater Treatment Plants Capacity and Flows

Wastewater Treatment Plant	Existing Condition (2012)			
	Treatment Capacity (MGD)		Average Daily Flow (MGD)	
	Secondary	Tertiary	Secondary	Tertiary
Carpinteria WWTP	2.5	--	1.4	--
El Estero WWTF	11.0	2.2	8.0	0.6
Goleta WWTP	4.0	3.0	4.0	1.1
Montecito WWTF	1.5	--	0.9	--
Summerland WWTP	0.3	0.3	0.14	0.14
Totals	19.3	5.5	14.44	1.84

4.1.2 Future Capacities

Table 4-2 provides a summary of the potential future secondary and tertiary capacities, along with average daily flows for each treatment plant. The projected flows were provided by each agency.

4.1.3 Summary of Existing Wastewater Treatment Plants

Goleta WWTP

Both the GWSD and the GSD provide wastewater collection to customers within the GWD service area. Wastewater from the GWSD and the GSD is treated at the Goleta WWTP. Recycled water service within Goleta began in 1994 in response to drought conditions of the early 1990s and the Wright suit settlement.

The Goleta WWTP has a secondary capacity of 4.0 MGD and a tertiary capacity of 3.0 MGD. Currently, an average of 1.1 MGD of recycled water is being produced. The GSD is currently constructing additional processes to increase the plant’s secondary capacity to 9.0 MGD.

Table 4-2: Existing and Future Wastewater Capacities and Flows

Wastewater Treatment Plant	Near-Term (2022)				Long-Term			
	Treatment Capacity (MGD)		Average Daily Flow (MGD)		Treatment Capacity (MGD)		Average Daily Flow (MGD)	
	Secondary	Tertiary	Secondary	Tertiary	Secondary	Tertiary	Secondary	Tertiary
Carpinteria WWTP[1]	2.5	--	1.6	--	2.5	--	1.6	--
El Estero WWTF[2]	11.0	2.2	8.0	1.25	11.0	2.2	8.5	1.25
Goleta WWTP[3]	9.0	3.0	6.5	3.0	9.0	3.0	7.0	3.0
Montecito WWTF	1.5	--	1.0	--	1.5	--	1.0	--
Summerland WWTP	0.3	0.3	0.14	0.14	0.3	0.3	0.14	0.14
Totals	24.3	5.5	17.24	4.39	24.3	5.5	18.24	4.39

Notes:

1. Carpinteria Sanitary District Wastewater Collection System Master Plan, April 2005
2. 2011 average annual recycled water production; recycled water capacity is 1,400 acre-feet per year (2011 Long-term Water Supply Plan). During drought conditions, flows at the El Estero WWTF decreased from 9.5 MGD to 5.5 MGD. Therefore, it is assumed that only 5.5 MGD (1 MGD for in-plant uses and 4.5 MGD available for other uses) is the available average day flow for future reuse. The projected tertiary treatment capacities in the near- and long-term do not include the City's recently approved treatment upgrade project as that project included in the proposed projects list.
3. Per conversation with Goleta Sanitary District personal (6/19/2012), secondary treatment is currently being expanded to treat 9 MGD by 2014. Tertiary treatment capacity is dependent upon peak demand needs. If recycled water is needed, the tertiary treatment plant can treat up to 3.0 MGD of tertiary flow.

The Goleta WWTP produces secondary effluent, a portion of which is blended with primary effluent prior to ocean discharge. The rest of the flow is sent to the recycled water system. The recycled water system consists of flash mixing tanks, flocculation tanks, anthracite filters, and a chlorine contact tank. Following production, recycled water is placed in storage tanks. The tanks allow the treatment plant to operate at a steady efficient rate regardless of recycled water demand (GSD, 2011). The existing recycled water system can produce up to 3 MGD of tertiary effluent for recycling. However, the ability to fully utilize recycled water is limited by recycled water use patterns, which are typically condensed into a 12- rather than a 24-hour period, and is limited by recycled water delivery capacity and the end user demand for recycled water (GWD UWMP, 2010). Generally, demand is high during summer months, but lessens during winter months when large users such as irrigators reduce irrigation needs.

GSD has no current plans to expand the capacity of the tertiary processes. Expansion of tertiary facilities depends upon the need for expansion of GWD's recycled water demand and storage capabilities. Currently, there is 1.9 MGD of recycled water available for GWD potential customers. Although GSD has seen little-to-no increase in flows in the past ten years, projected flows are anticipated to increase 1% per year in the future.

Goleta West Sanitary District

Goleta West Sanitary District is not planning to construct a wastewater treatment plant. It is more cost effective to pay GSD for treatment and discharge of Goleta West Sanitary District's flows.

El Estero WWTF

The El Estero WWTF was constructed in 1979 with the recycled plant added in 1989 and is owned and operated by the City of Santa Barbara. The plant provides full secondary treatment and partial tertiary filter treatment, in conformance with Title 22 and consists of full secondary treatment followed by anthracite media filtration, and chlorination. The plant's tertiary capacity is 4.4 MGD. However, the disinfection processes currently limit the recycled water production to 2.2 MGD.

Influent has declined in recent years. The decline in wastewater flows is largely attributed to the success of infiltration and inflow reduction into the sewer and water conservation efforts. Average annual recycled water production flows are 0.6 MGD with a maximum monthly demand (MMD) of 1.5 MGD. To meet the City of Santa Barbara goal of no more than 300 mg/l of chloride during irrigation season, approximately 300 acre-feet per year (AFY) of potable water has historically been blended into the recycled water. More recently, however, turbidity in the recycled water has routinely exceeded the 2.0 NTU limit, which has required significantly more blending, up to 80% in recent years. This has greatly reduced the amount of recycled water being used from wastewater sources. In addition, the tertiary filters have confined space entry issues and corrosion has compromised the structural integrity of some facilities causing a process shutdown.

Currently, the El Estero WWTF filters are operated as a batch process. During the day, the plant fills both the Golf Course Reservoir and the El Estero Reservoir to their maximum levels. The filters are activated when the level in the El Estero Reservoir drops to ten feet (above the reservoir floor) and the filters are deactivated when the level in the reservoir rises to 20 feet (above the reservoir floor). Considering that the first six feet of the reservoir is required for contact time, the filters do not activate until about 3/4 of the reservoir's available 0.49 MG capacity is depleted (since useful range is between 22 and 6 feet of sidewater depth).

Based on current MMD, about 740,000 gallons is required for the Phase I system at night, and according to this value, the El Estero Reservoir will reach the 10 foot level after about four hours. The irrigation period begins at 9:00 PM, so the filters would activate at about 1:00 AM when the flow into the plant averages about 2.5 MGD. Considering that the irrigation period will last for an additional five hours, about 0.50 MG is available from the filters as additional supply.

About 290 AFY (260,000 gallons per day) of recycled water is also used at El Estero WWTF for plant processes such as spray and washwater. At full capacity, tertiary facilities must accommodate this additional process water flow. Ultimately, the effluent available from the tertiary facilities is reduced by 260,000 gallons per day since the tertiary filters and the chlorine contact basin must accommodate this internal demand.

Montecito WWTF

Montecito Sanitary District's (MSD) owns and operates Montecito wastewater treatment facility (WWTF) which has a secondary capacity of 1.5 MGD. Currently, secondary flows at the Montecito WWTF are averaging approximately 0.9 MGD. MSD and Montecito Water District (MWD) completed a water reclamation study in 1991 but have not implemented any reuse projects. Montecito is a small community, with little to no expected future growth.

The treatment plant provides secondary treatment and chemical disinfection of collected wastewater prior to discharge into the Pacific Ocean via a dedicated outfall pipe. Processed biosolids are composted and are reused as agricultural amendments.

Summerland WWTP

The Summerland Sanitary District operates and maintains a 0.3 MGD capacity tertiary treatment plant to biologically and chemically process wastewater. Effluent is discharged into the Pacific Ocean via a dedicated outfall. Although Summerland Sanitary District is interested in and exploring recycled water, no expansions are expected in the future and average day flows are expected to remain around 0.14 MGD.

Carpinteria WWTP

The Carpinteria WWTP has a secondary capacity of 2.5 MGD and is owned and operated by Carpinteria Sanitary District (CSD). The treatment plant provides secondary treatment and chemical disinfection of collected wastewater prior to discharge into the Pacific Ocean via a dedicated outfall pipe. Currently, the influent flow rate at the Carpinteria WWTP averages approximately 1.4 MGD.

CSD completed its Wastewater Collection System Master Plan in 2005. Wastewater volumes are projected to increase modestly to approximately 1.6 MGD. It should be noted that the potential to vary from interim to ultimate flow projections is significant in a small community like Carpinteria. A single high volume commercial or industrial discharger (e.g. food processing facility, commercial laundry, etc.) entering the area could skew the numbers dramatically. System flows have historically varied with annual rainfall totals. The plan was to go forward with the Master Plan (after drought).

4.2 Existing Recycled Water Systems

This section provides a brief overview of the existing recycled water systems in the south coast subregion by water agency. There are five water agencies in the south coast subregion, two of which currently serve recycled water customers in their service areas. La Cumbre Mutual Water Company, Montecito Water District, and Carpinteria Valley Water District currently do not have recycled water in their service area.

4.2.1 Goleta Water District Recycled Water System

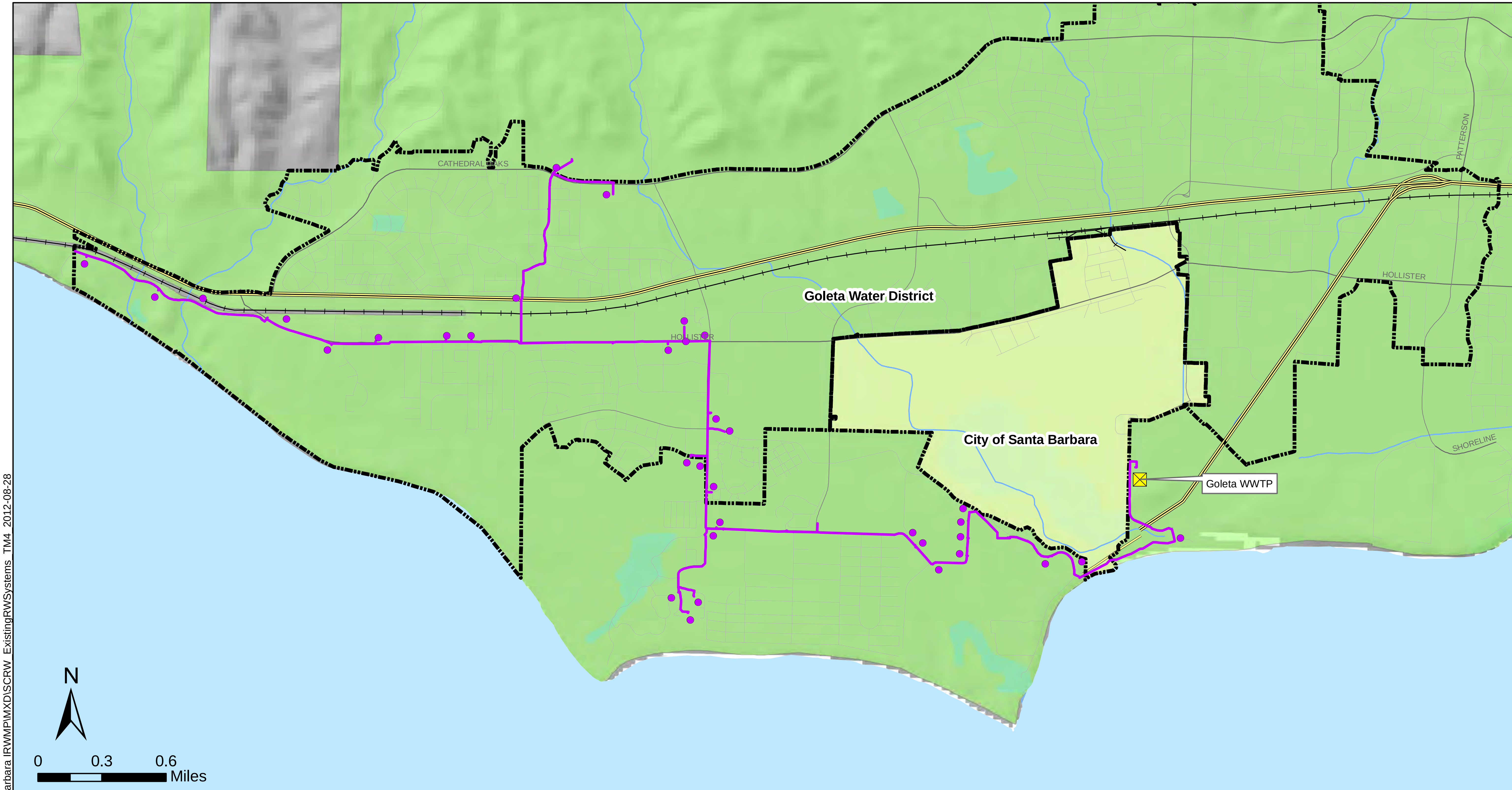
Recycled water service within Goleta began in 1994 in response to drought conditions of the early 1990s and the Wright Suit Settlement (1989). The 1989 Wright Suit Settlement served to adjudicate the groundwater resources of the Goleta North/Central Basin and assigned quantities of the basin's safe yield to various parties, including GWD and La Cumbre Mutual Water Company. The judgment also ordered GWD to bring the North/Central Basin into a state of hydrologic balance by 1998. GWD achieved compliance with this order in 1998 through the importation of State Water Project water and the development of other supplemental supplies. These supplemental supplies have offset the court-mandated reduction in pumping from the basin. Given that the basin has been adjudicated and pumping is controlled by the court, overdraft is not foreseeable in the North-Central Basin (2007 SB IRWM Plan).

The recycled water system is a joint agency project between GWD, GSD, and the University of Santa Barbara. GWD owns and operates the distribution system and provides the funding for the operation, maintenance, and capital replacements and upgrades to the entire system, including the water reclamation treatment plant, which GSD owns and operates.

Recycled water is produced at the Goleta WWTP and is supplied through GWD's recycled water distribution system to over 30 sites in the area. Water is used for irrigation, commercial use, and indoor toilet uses. **Figure 4-1** shows GWD's existing recycled water system.

Some expansion of the current system is possible without upgrades of the existing treatment or distribution system. Major expansions to the system could require additional treatment, storage, and distribution facilities depending on the size and location of demands. Economic incentives are needed for customers to convert to recycled water due to higher regulations and the need for these customers to have dedicated operating personnel responsible for the onsite use of recycled water.

GWD's existing recycled water system has a high need for maintenance and replacement of pipes and facilities due to the age of the system and corrosive soil conditions. GWD has identified several projects that are necessary to maintain and upgrade their current system. These projects are discussed in detail in Chapter 7 - Distribution System Needs.



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Water and Environment

Existing Recycled Water System
- Customer
- Pipeline

Other Features
- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies
- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Existing Recycled Water System: Goleta Water District

Figure 4-1

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4.2.2 City of Santa Barbara Recycled Water System

The City of Santa Barbara has the most extensive recycled water system in the region. The City of Santa Barbara owns and operates the El Estero WWTF, which produces recycled water for local distribution. The City initiated planning for a water reclamation project in the early 1980's. Phase I was completed in 1989 and included the addition of tertiary treatment with carbon filtration and disinfection at the El Estero WWTF, a 600,000-gallon distribution reservoir and pumping station, and 5.1 miles of distribution main. Phase II was completed in 1992, adding an additional pump station, a 1.5 million gallon reservoir, and 8.3 miles of distribution main.

In total, the City's recycled water system includes 2.1 MG of reservoir storage, three pumping stations, and 13.4 miles of distribution main. The system now provides recycled water to 61 sites that serve 440 acres of landscaped area at parks, schools, golf courses, and other large landscaped areas. In addition, several public restrooms have been retrofitted to use recycled water for toilet flushing. Recycled water is provided at a price of 80% of the potable water irrigation rate as an incentive for using recycled water and to compensate for additional irrigation requirements associated with salt leaching. **Figure 4-2** shows the City's existing recycled water system.

The City system as currently configured has the capacity to treat and deliver approximately 1,400 AFY of recycled water. Current connected recycled water demand is approximately 800 AFY, plus approximately 300 AFY process water used at the wastewater treatment plant, leaving about 300 AFY of additional capacity available for additional recycled demands. As noted earlier, the actual amount of recycled wastewater that is served is greatly reduced because of the need to blend with potable water to meet water quality limits.

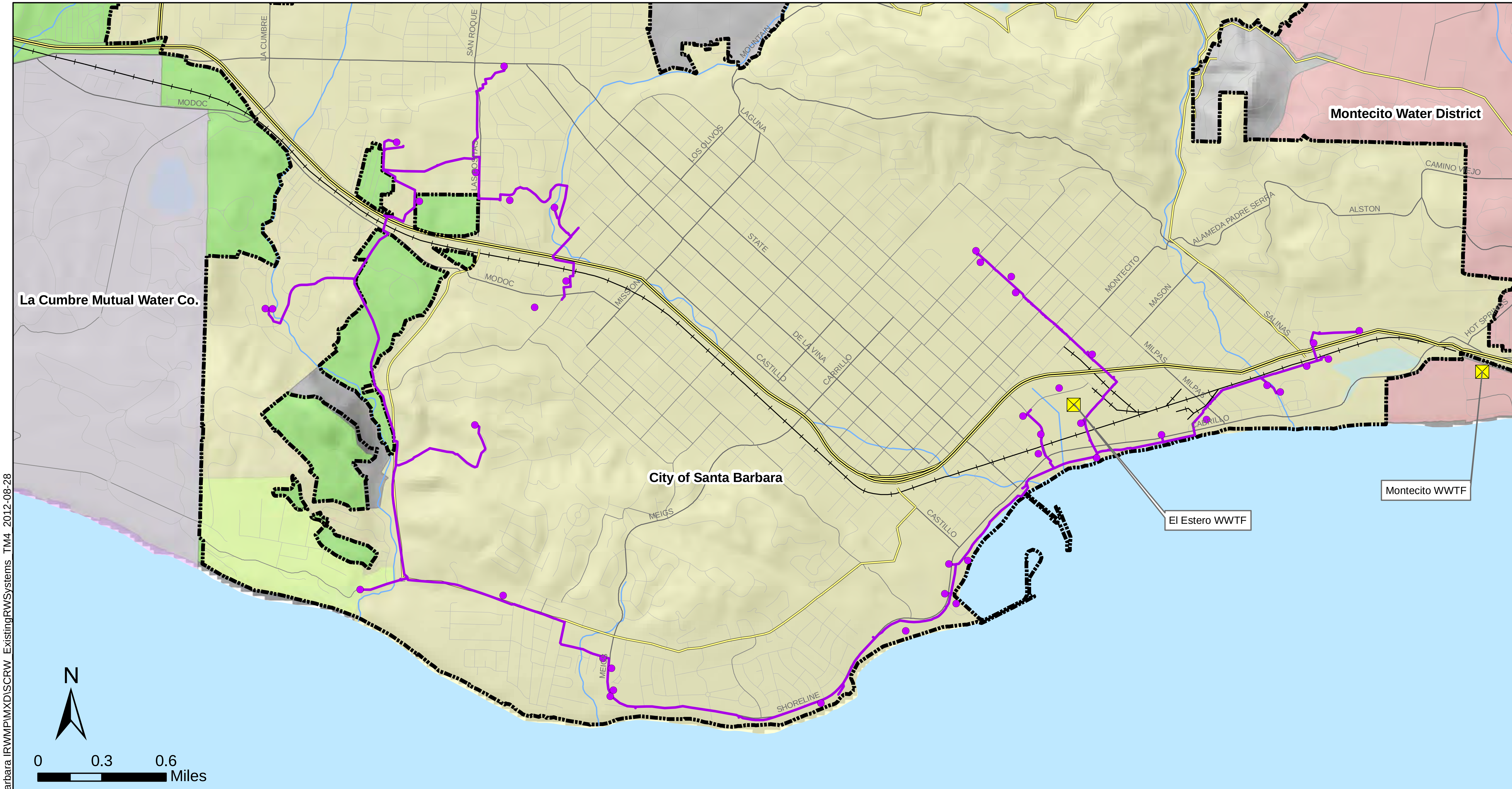
The recycled water system provides an important component of the City water supply, even with a partial potable water component needed for blending as discussed earlier. In addition, the fact that users are signed up and connected to the separate recycled water system provides increased flexibility in how the City balances the economic and water supply aspects of this source of water.

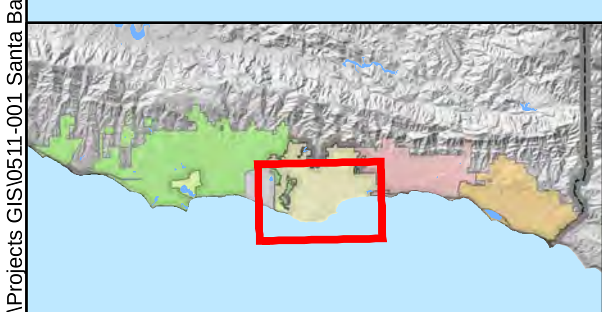
In 2009, the City completed its Water Supply Planning Study, and in 2011, the City completed its Long-Term Water Supply Plan. Through these efforts, the City concluded that recycled water is a relatively expensive source of water but a reliable way to extend potable water supplies, thereby deferring the expense of procuring additional potable supplies. Additionally, increased recycled water connections will allow flexibility in meeting regulatory demand management requirements, such as the statewide requirement to reduce gross daily per capita water consumption.

As part of the 2009 study, about 300 AFY of potential new users of recycled water were identified that could help maximize the use of the available recycled water at the El Estero WWTF. Some of these users are located adjacent to the existing system, such that the distribution costs are minimal. It is anticipated that the additional capacity will be met by maximizing uses within the current distribution system. However, as noted earlier the performance issues at the plant that are resulting in a high level of potable blending need to be addressed to make additional expansion more cost effective and to maximize the potable offset that recycled water use provides.

4.2.3 Montecito Water District

Although the Montecito Water District does not have an existing recycled water system, the District installed some purple pipe for irrigation lines as part of a Summerland Beautiful project in anticipation of serving recycled water in the future. These lines are located in various locations along Lillie Avenue and Ortega Hill Road. Such installations would reduce the cost of a future recycled water system.





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Existing Recycled Water System	Other Features	Water Agencies
Customer	WWTP	Carpinteria Valley Water District
Pipeline	State Highway	City of Santa Barbara
	US Highway	Goleta Water District
	Railroad	La Cumbre Mutual Water Co.
	City Boundary	Montecito Water District

Existing Recycled Water System: City of Santa Barbara

Figure 4-2

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4.3 Potential Recycled Water Available

Table 4-3 shows near-term and long-term potential wastewater available for future recycled water users at each wastewater plant. Note that the maximum potentially available flow for future recycled water demands is based on the projected secondary wastewater flow minus the existing recycled water usage times a peaking factor (2.0) to account for maximum day demand. While the peaking factor may vary from system to system and year to year, a factor of 2.0 was deemed reasonable based on existing system and potential future recycled water users in the area.

Table 4-3: Potentially Available Recycled Water Supplies

Wastewater Treatment Plant	Projected Average Daily Secondary Wastewater Flow (MGD)		Existing Recycled Water (MGD)	Maximum Potentially Available for New Recycled Water Supply (MGD)[1]	
	Near-Term	Long-Term		Near-Term	Long Term
Carpinteria WWTP	1.6	1.6	--	1.6	1.6
El Estero WWTF[2]	8.0	8.5	0.76	6.48	6.98
Goleta WWTP	6.5	7.0	0.7	5.1	5.6
Montecito WWTF	1.0	1.0	--	1.0	1.0
Summerland WWTP	0.14	0.14	--	0.14	0.14
Total	**17.24**	**18.24**	**1.46**	**14.32**	**15.32**

Notes:

1. Maximum potentially available supplies based on projected secondary wastewater flow minus the existing recycled water usage times a peaking factor (2.0 typically) to account for maximum day demand. Peak hour demands are assumed to be met via diurnal storage facilities.
2. Amount of existing recycled water is the actual recycled wastewater being served due to the need for potable water blending.

Chapter 5 Potential Customers

This chapter identifies potential recycled water customers in the south coast subregion. Potential recycled water demands within the subregion mainly include recycled water use for irrigation at parks, agricultural uses, golf courses, highways and schools.

5.1 Demand Approach/Source

Potential recycled water demands were developed based on previous agency studies as well as updates provided by the participating agencies. Near- and long-term potential recycled water demands were identified based on specific agency criteria which took into consideration their local water and wastewater settings. The approach and source of data for each water agency is discussed below:

Goleta Water District (GWD) provided the specific potential recycled water customers and their demand estimates. Agricultural users in the Goleta area utilize groundwater and other water sources for irrigation, especially avocados. These uses could be replaced by recycled water but would require advanced treatment (microfiltration/reverse osmosis) due to high TDS levels. Any nurseries in the area could also utilize this advanced treated water if the TDS levels were reduced to meet their needs as well.

La Cumbre Mutual Water Company (LCMWC) provided meter records from 2008 through 2011 for their top two water users that could use recycled water. Based on the meter records, a percentage was used to determine the potential recycled water demand.

City of Santa Barbara (SB) potential recycled water customers were identified from the City's 2009 Water Supply Planning Study and were updated during the study workshops. Given the extensive work done on the market as part of the 2009 Water Supply Planning Study, this study used the work previously completed to the extent possible, with current updates from SB.

Montecito Water District (MWD) potential recycled water customers were obtained from the 1991 Water Reclamation Study. The demands in the study were calculated using AFY/acre assumptions for irrigation and agriculture area. The 1991 Study identified potential customers for both developed and undeveloped land. Since very little growth has occurred since the 1991 Study, the developed land customers and demand estimates were brought forward to this Study.

Carpinteria Valley Water District (CVWD) provided two sets of data to identify potential recycled water customers. CVWD provided potable meter records for urban customers within the City of Carpinteria. Specific customer types were identified (e.g. schools, parks, irrigation (urban), commercial, etc.) and a percentage was used to determine the potential recycled water demand. All potential customers with recycled water demand estimates greater than 2 AFY were carried forward for consideration. CVWD also provided landuse data on the agricultural uses, outside the City of Carpinteria, and an AFY/acre assumption for each crop type. Currently, agriculture land is supplied with groundwater and every two years, aerial photographs are taken of CVWD service area to update their groundwater use estimate based on current crop types. Once the AFY/acre assumption was calculated for the agriculture parcels, customers with 5 AFY or greater of recycled water demand were selected. Nurseries were not included due to the sensitivity of plants in using recycled water, which has a high TDS.

The County of Santa Barbara provided a land use parcel shape file for the entire south coast subregion. For this plan, large parcels of land with specific land use types (e.g. colleges, field crops, golf courses, irrigated farms, recreation, schools, etc.) that were near current recycled water systems were identified. During the workshops, the water agencies also helped to further refine the selected parcels that could be potential long-term customers. Many of the customers identified are agriculture users, which would require higher levels of water quality and would require a greater level of economic subsidy or other financial strategies due to their current reliance on cheaper water supplies.

Appendix D lists the assumptions used to calculate the potential recycled water demand estimate by each service area. A listing of the customers and potential demands is provided in **Appendix E**.

5.2 Existing Recycled Water Demands

Currently, only the City of Santa Barbara and Goleta Water District have existing recycled water customers.

5.2.1 Goleta Water District

Based on their 2010 Urban Water Management Plan, GWD currently serves 785 AFY of recycled water. GWD has a relatively steady base of recycled water customers. For the last decade, the amount of recycled water produced and delivered has remained relatively constant, with some variation due to rainfall. Currently GWD delivers recycled water for landscape irrigation uses as well as a minor amount for toilet flushing. In years where the Goleta area receives higher than normal rainfall, demand for recycled water is low (GWD UWMP, 2010). The Goleta area has a large agricultural market, a portion of which could potentially utilize recycled water. However, there are obstacles to using recycled water for agricultural irrigation. Avocados and citrus are the dominant crops in the Goleta area and these are sensitive to dissolved minerals found in recycled water. Avocados are extremely sensitive to total dissolved solids (TDS) requiring water with TDS of less than 800 mg/L. Currently the recycled water system produces water with TDS of approximately 1250 mg/l. To deliver recycled water to agriculture would require additional and perhaps costly advanced (microfiltration [MF] and reverse osmosis [RO]) treatment (UWMP, 2010).

5.2.2 City of Santa Barbara

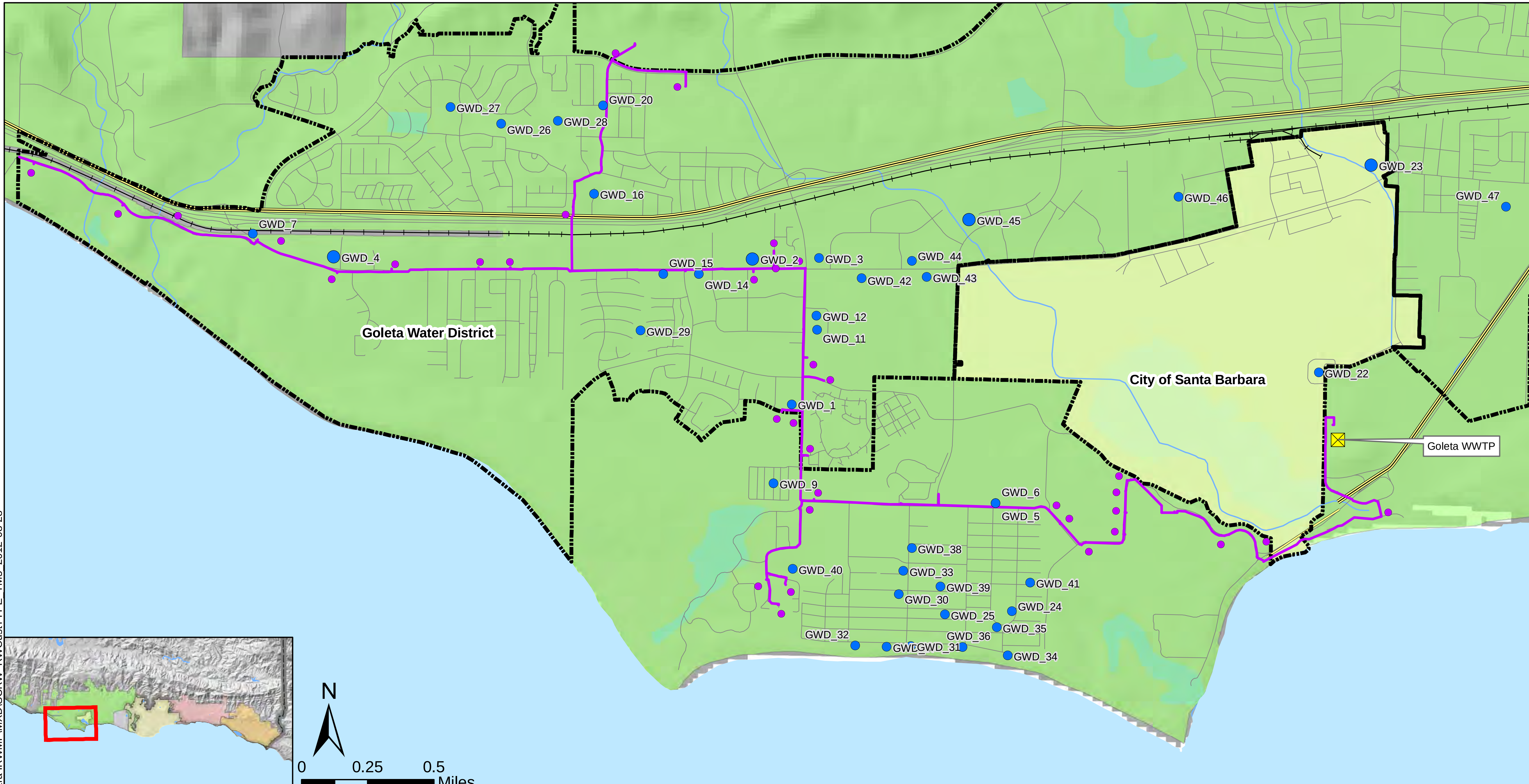
Based on its 2009 Water Supply Planning Study, the City of Santa Barbara serves recycled water to 62 recycled water sites. Most of these sites use recycled water for irrigation, with a small portion for toilet flushing at City of Santa Barbara's parks. Golf courses account for the largest portion of the City's recycled water demand. The average annual customer demand during a 5-year consumption history (2003 through 2007) was 847 AFY. About 290 AFY (260,000 gpd) of recycled water is also used at the El Estero WWTF for plant processes such as spray and washwater. This water is not included in the total recycled water used (WSPS, 2009).

5.3 Potential Recycled Water Demands

Potential recycled water customers were identified by each agency. Near-term customers were only identified for GWD and City of Santa Barbara. **Appendix E** lists both near-and long-term potential recycled water customers by water agency.

5.3.1 Goleta Water District

Potential recycled water demand for specific customers was provided by GWD. These demands are shown in **Figure 5-1**. As discussed above, County land use data was used to identify other potential customers, especially agriculture areas. **Figure 5-2** shows the parcels identified in the Goleta area. No demands were developed for these areas as their extent of water use and their potential for using recycled water is not known. For future studies, an estimate of recycled water use could be made based on the current groundwater allotment and/or actual agriculture irrigation water demand/usage. To serve recycled water to the agriculture users, a higher level of water quality would be necessary, including lower TDS levels than what the Goleta recycled water system is currently using. This would require a reverse osmosis system, which would increase the cost of producing recycled water. In addition, the cost of the recycled water would have to be subsidized or offset to these users as they currently rely on cheaper water sources. Therefore, these users were not further investigated nor included as the potential recycled water customers at this time. These potential users are included in this plan to show the extent of the potential



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Potential Recycled Water Customer

Demand (AFY)
- Less than 5
- 5 to 20
- 20 to 50
- Greater than 50

Type
- Urban Irrigation
- Agriculture
- Industrial/Commercial

Existing Recycled Water System
- Customer
- Pipeline

Other Features
- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies
- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Recycled Water Customers: Goleta Area

Figure 5-1

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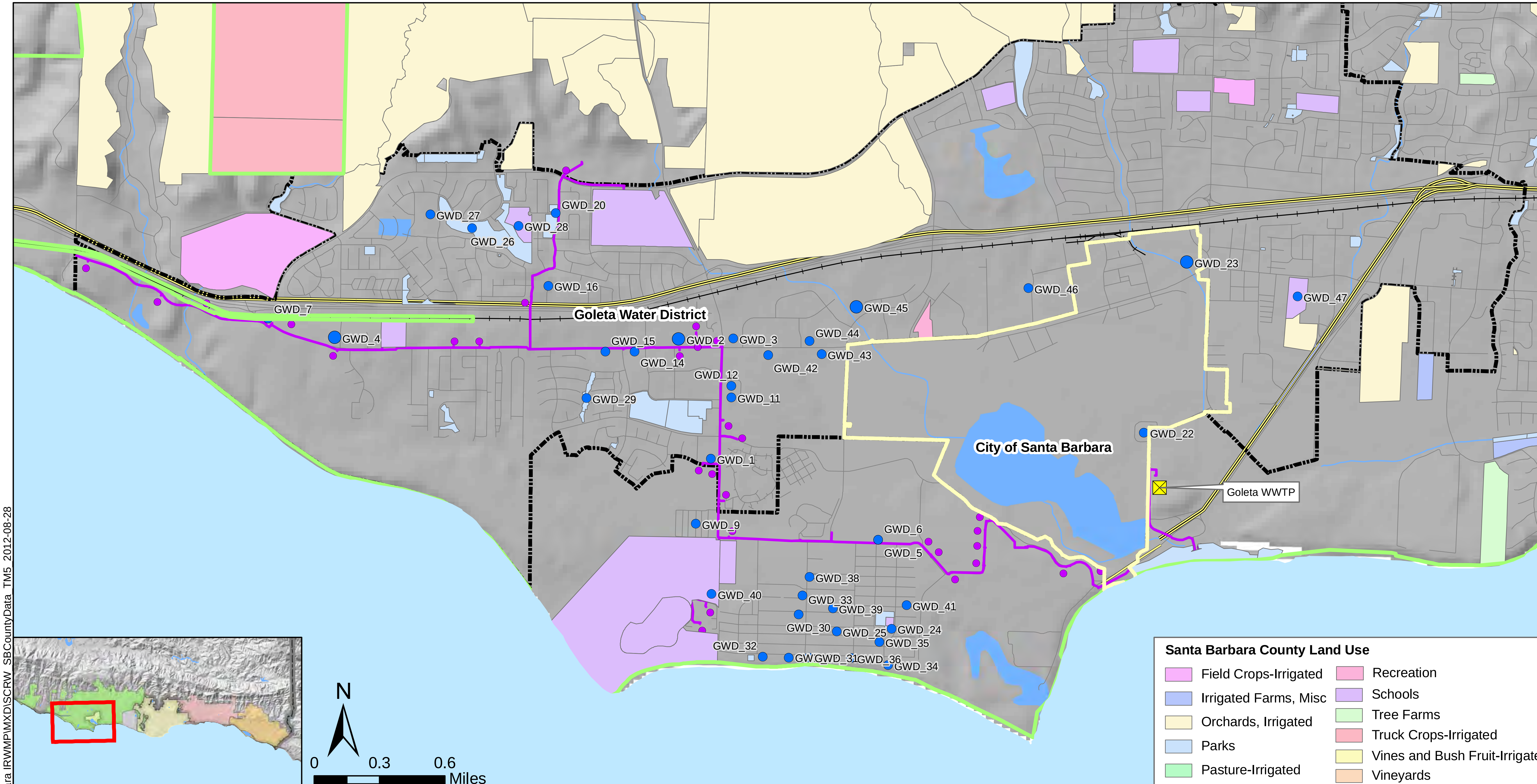


Santa Barbara County IRWMP
South Coast Recycled Water
Development Plan

RMC Water and Environment

Potential Recycled Water Customer

Demand (AFY)
- Less than 5
- 5 to 20
- 20 to 50
- Greater than 50

Type
- Urban Irrigation
- Agriculture
- Industrial/Commercial

Existing Recycled Water System
- Customer
- Pipeline

Other Features
- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies
- Carpinteria Valley Water District
- City of Santa Barbara
- La Cumbre Mutual Water Co.
- Goleta Water District
- Montecito Water District

Potential Agriculture Customers: Goleta Area

Figure 5-2

long-term use of recycled water should the supply and cost of recycled water become more economically viable to such uses and/or if groundwater usage becomes restricted due to overuse.

Near-Term Potential Recycled Water Customers

Near-term potential recycled water customers were identified as potential irrigation customers located near the existing recycled water distribution system and that have expressed an interest to GWD in using recycled water. Connecting these customers requires less cost to convert to recycled water than customers requiring lateral pipelines. Seven potential near-term customers, with a total average annual demand of 27 AFY, were identified by GWD. These include the UCSB Sierra Madre Apartments, medians along El Colegio Road, and new developments currently being constructed along the recycled water distribution system. **Figure 5-3** shows the identified potential near-term recycled water customers in the Goleta area.

Long-Term Potential Recycled Water Customers

Long-term potential recycled water customers are located farther away from the existing recycled water distribution system and require more effort and higher costs to convert to recycled water. GWD provided two groups of long-term potential customers: 1) potential conversion to recycled water for landscape irrigation and 2) potential recycled water demand that would require infrastructure expansion.

The “landscape conversion potential properties” are potential properties adjacent to the existing recycled waterline that could convert their landscape irrigation from potable to recycled water. Discussions with the respective property owners have not been conducted by GWD. These customers include UCSB’s Married Student Housing, Bella Vista Park and Santa Barbara Airport.

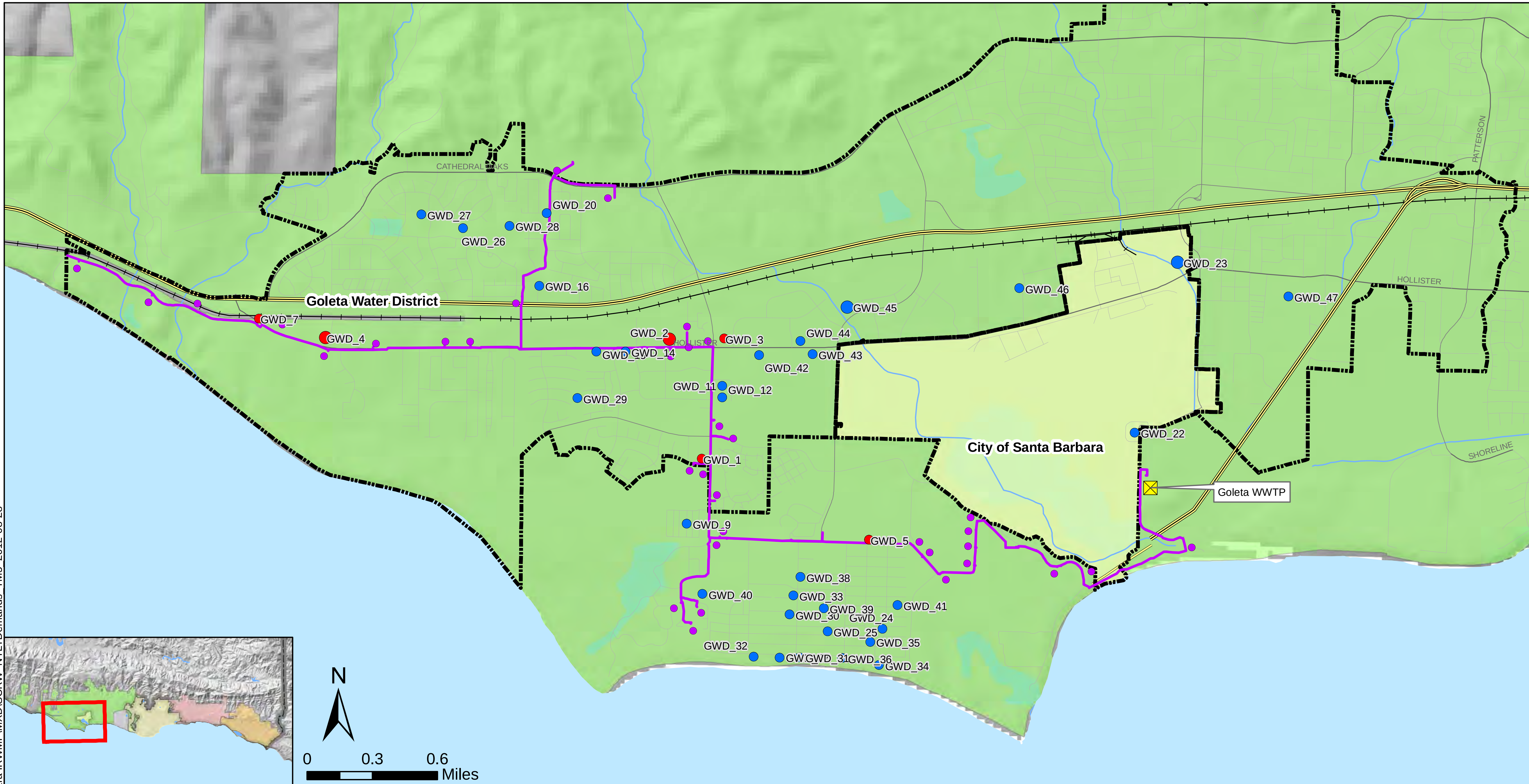
The “long-range, infrastructure expansion” potential customers are those that would require an extension from the existing recycled water distribution system or changes to the system. These customers include Twin Lakes Golf Course, and multiple parks and schools.

In total, 33 potential long-term customers, with a total demand of 73 AFY, were identified. The two types of potential long-term recycled water customers are differentiated in the Customer Table (**Appendix E**), but are grouped together in **Figure 5-3**.

As discussed above, the Goleta area has a large agricultural market, a portion of which could potentially utilize recycled water. However, there are obstacles to using recycled water for agricultural irrigation. Avocados and citrus are the dominant crops in the Goleta area and these are sensitive to dissolved minerals found in recycled water. Avocados are extremely sensitive to total dissolved solids (TDS) requiring water with TDS of less than 800 mg/L. Currently the recycled water system produces water with TDS of approximately 1250 mg/L. To deliver recycled water to agriculture would require additional and perhaps costly enhanced treatment (UWMP, 2010). Therefore, for this plan, these agricultural properties were not included as potential long-term recycled water customers.

5.3.2 La Cumbre Mutual Water Company

Two potential recycled water customers were identified in the LCMWC service area: La Cumbre Golf and Country Club and Laguna Blanca School Chase Field. Due to water quality issues and the institutional challenges of serving recycled water to LCMWD, these customers are considered potential long-term demands. Their total recycled water demand is 130 AFY, but demands may change due to the specific water quality needed at the golf courses. The two LCMWC customers are shown on the potential recycled water customers in the Santa Barbara area (**Figure 5-4**). Based on a previous study conducted for the potable water system, the Country Club does have a lake on site that can be used for diurnal storage for the irrigation system. Use of recycled water would require additional research to confirm that such an arrangement could be made using recycled water. The advantage of using this lake for diurnal storage is that it could reduce or eliminate the need to provide diurnal storage on the City of Santa Barbara’s recycled water system in connecting to this customer.



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Santa Barbara County IRWMP
South Coast Recycled Water
Development Plan

RMC
Water and Environment

Potential Long-Term Recycled Water Customer
Demand (AFY)
- Less than 5
- 5 to 20
- 20 to 50
- Greater than 50

Potential Long-Term Recycled Water System
- Customer

Potential Near-Term Recycled Water System
- Customer

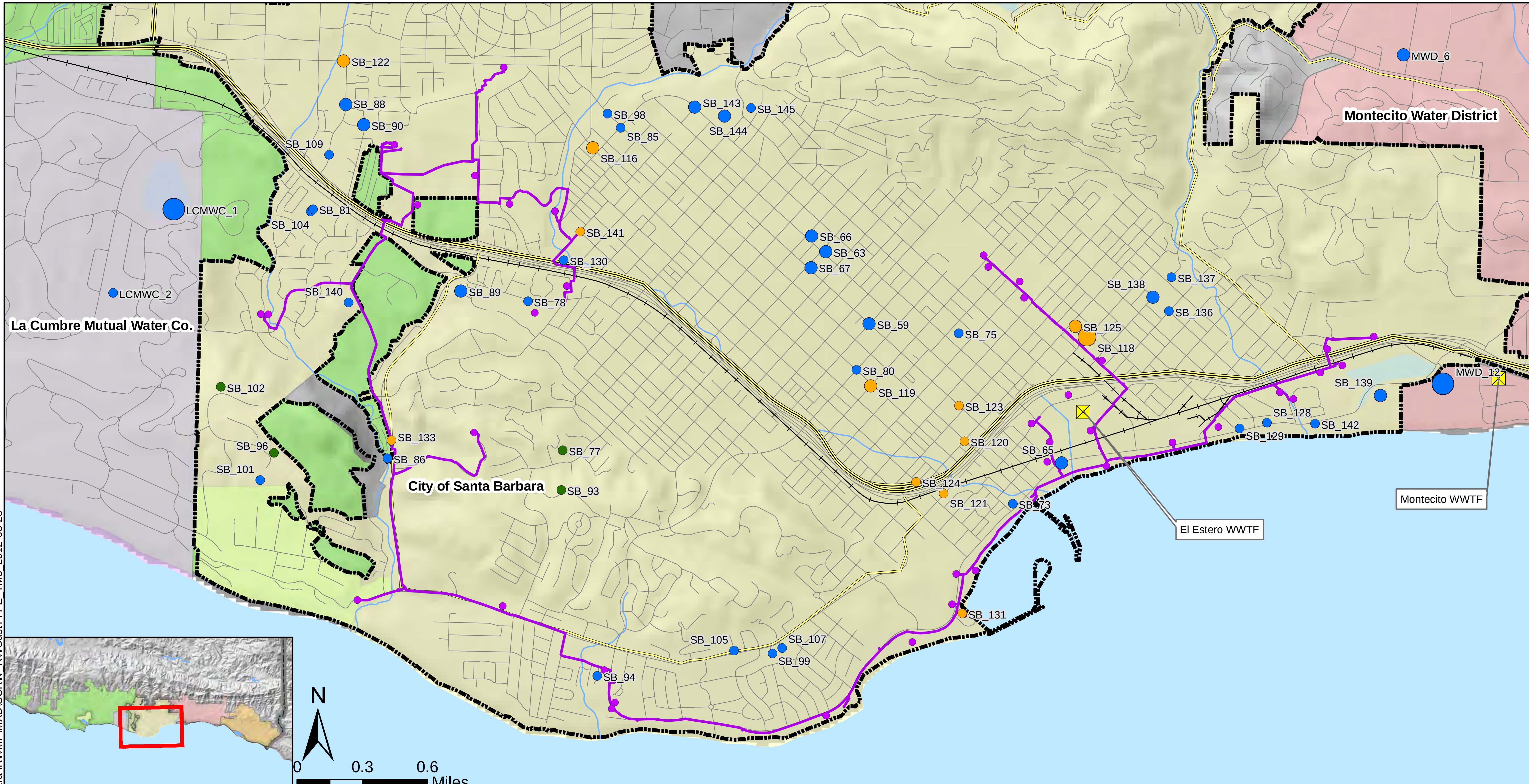
Existing Recycled Water System
- Customer
- Pipeline

Other Features
- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies
- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Near-Term and Long-Term Recycled Water Customers: Goleta Area

Figure 5-3



Santa Barbara County IRWMP
South Coast Recycled Water
Development Plan

RMC
Water and Environment

Potential Recycled Water Customer

Demand (AFY)
- Less than 5
- 5 to 20
- 20 to 50
- Greater than 50

Type
- Urban Irrigation
- Agriculture
- Industrial/Commercial

Existing Recycled Water System
- Customer
- Pipeline

Other Features
- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies
- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Recycled Water Customers: Santa Barbara Area

Figure 5-4

5.3.3 City of Santa Barbara

Most of the potential recycled water customers were identified from the 2009 Water Supply Planning Study. During workshops, the City of Santa Barbara identified the time frame of each customer and provided additional potential recycled water customers. However, at present, the City's recycled water facility is not operational, and the City Council has approved the concept of replacing the filter plant with microfiltration process system. Partial reverse osmosis is also being considered. These upgrades are necessary for the City to be able to serve recycled water without potable water blending to its current users and to be able to serve both near- and long-term customers.

Near-Term Potential Recycled Water Customers

Most of the near-term potential recycled water customers are located adjacent to the existing recycled water distribution system and require little effort to convert to recycled water. Eleven potential near-term customers, with a total demand of 49 AFY, were identified. These include several homeowner associations, First Baptist Church, and Las Positas Tennis Courts. **Figure 5-5** shows the potential near-term recycled water customers in the Santa Barbara area.

Long-Term Potential Recycled Water Customers

Long-term customers are either farther from the distribution system or are commercial/industrial type users that may have water quality concerns that need to be addressed before being served. The water quality concerns may be addressed by the City's recent decision to upgrade the recycled water treatment to advanced (MF/RO) treatment levels. A total of 43 potential recycled water customers were identified with a total demand of 266 AFY. Most of the long-term potential customers were identified in the 2009 Water Supply Study, while the rest were identified by the City during this Study. **Figure 5-5** shows the potential near-term recycled water customers in the Santa Barbara area.

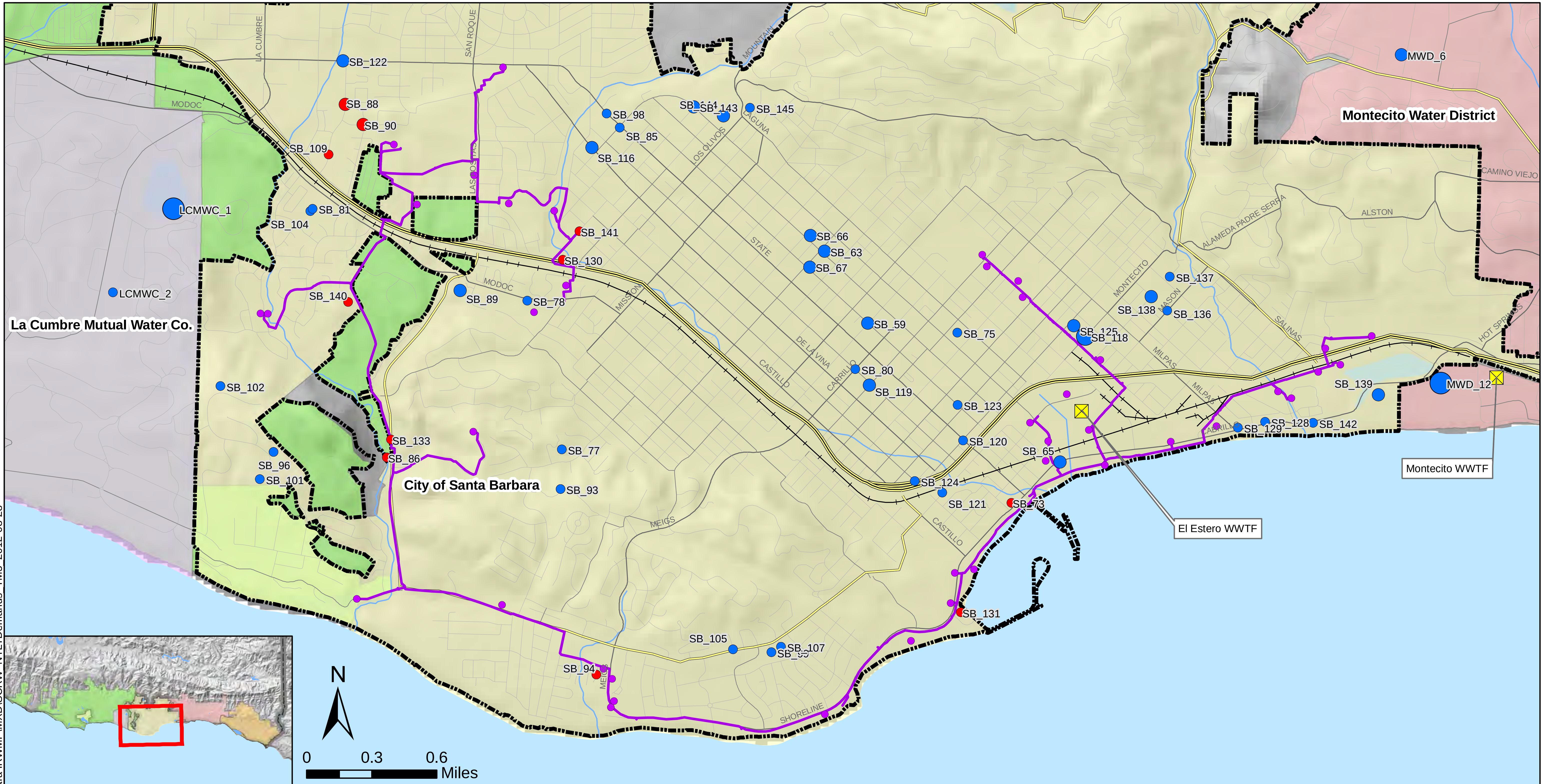
5.3.4 Montecito Water District

There has been very little growth in the MWD service area since MWD completed its 1991 Water Reclamation Study. Based on the 1991 Study, 18 of the 20 identified potential recycled water customers were carried over for use in this Study. The 18 customers, which are spread over the MWD area, have a total recycled water demand estimate of 1,786 AFY and include Caltrans irrigation areas, parks, schools and agricultural uses.

The 1991 Study identified two golf courses as two of the largest identified recycled water customers. These two courses, along with a third course in the MWD service area have drilled wells and now use groundwater to supply 90% of their water for the fairways and greens. For future studies, the amount of groundwater currently used for these golf courses could be determined and brought into the Potential Long-Term Total, especially in the event of groundwater conservation.

The largest potential recycled water customer is the Santa Barbara Cemetery, which is located very close to the Montecito WWTP. However, with MWD's new rate structure, the cemetery has also reduced its water usage. Other potential recycled water customers are agricultural uses and the above-mentioned golf courses. MWD service area is mainly residential (90% of the service area), which uses 80% of the potable water.

Figure 5-6 shows the identified potential recycled water users. Because of the high cost to produce and serve recycled water compared to MWD's current water supply costs, it is not feasible to serve recycled water in the MWD area in the near term. Therefore, the identified potential recycled water demands are considered only for the long-term.



Santa Barbara County IRWMP
South Coast Recycled Water
Development Plan

RMC
Water and Environment

Potential Long-Term Recycled Water Customer

Demand (AFY)

- Less than 5
- 5 to 20
- 20 to 50
- Greater than 50

Potential Long-Term Recycled Water System

- Customer

Potential Near-Term Recycled Water System

- Customer

Existing Recycled Water System

- Customer
- Pipeline

Other Features

- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies

- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Near-Term and Long-Term Recycled Water Customers: Santa Barbara Area

Figure 5-5

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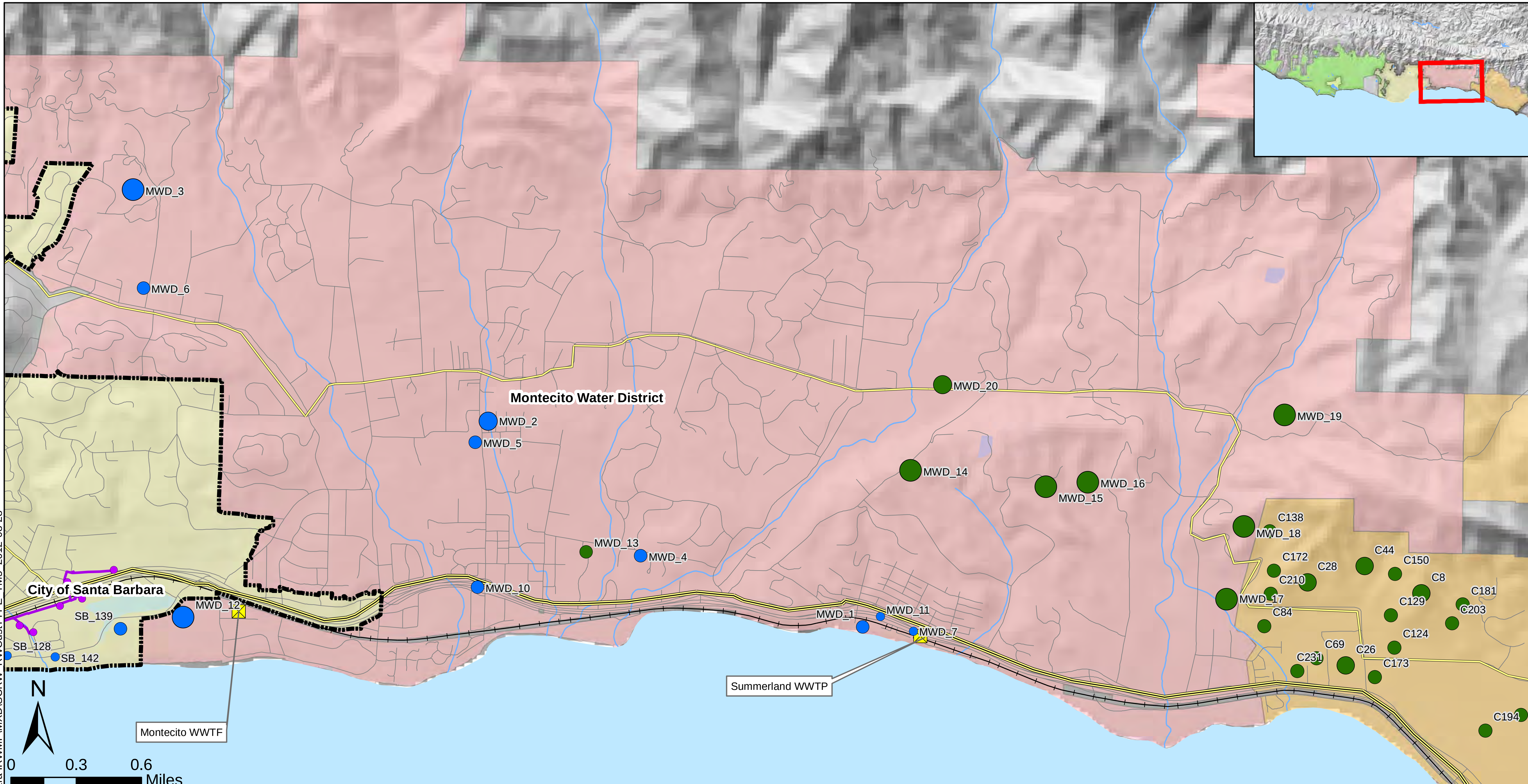

Santa Barbara County IRWMP
South Coast Recycled Water
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Potential Recycled Water Customer

Demand (AFY)
- Less than 5
- 5 to 20
- 20 to 50
- Greater than 50

Type
- Urban Irrigation
- Agriculture
- Industrial/Commercial

Existing Recycled Water System
- Customer
- Pipeline

Other Features
- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies
- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Recycled Water Customers: Montecito Area

Figure 5-6

As discussed above, County land use data was used to identify other potential recycled water uses. As shown in **Figure 5-7**, a few other parcels that use water for orchards were identified in the MWD area. Water quality needs for these orchards are the same as for Goleta and Carpinteria, in that avocados and citrus are sensitive to dissolved minerals found in recycled water. To deliver recycled water to Montecito orchards and/or agriculture uses would require additional and perhaps costly advanced treatment (UWMP, 2010). The extent of their use and specific water quality needs was not further investigated, and therefore, these demands have not been included as potential demands in this plan.

5.3.5 Carpinteria Valley Water District

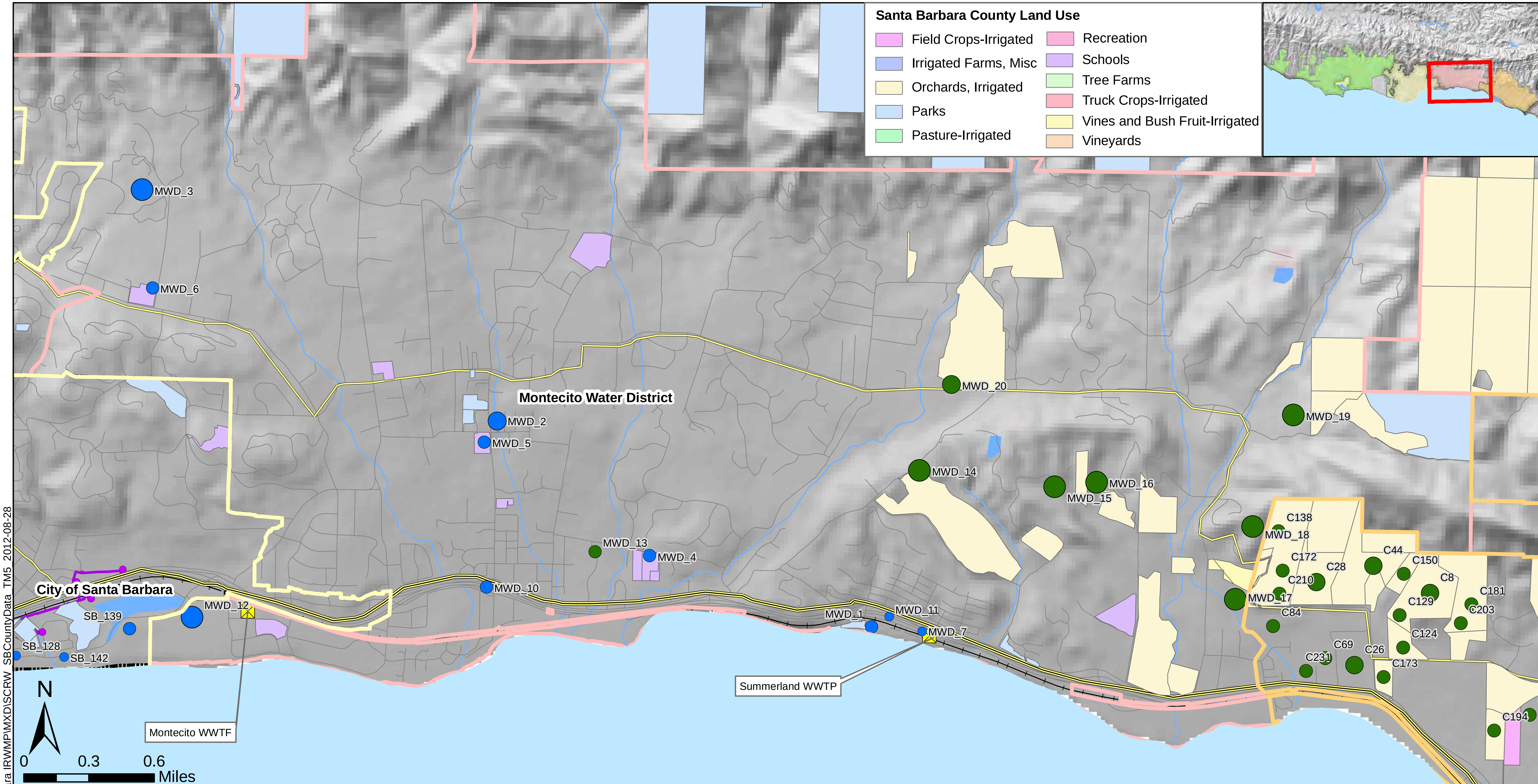
Based on the CVWD water meter records, 29 potential non-agricultural recycled water demands in the urban area of the City of Carpinteria were identified. The estimated average annual recycled water demand for these users is 142 AFY. Potential customers include hotels, parks, schools, and commercial property. **Figure 5-8** shows the identified demands in the Carpinteria area.

Based on the agriculture land use data compiled recently by CVWD, 188 agricultural properties were identified as having the potential to use recycled water. The estimated recycled water demand for these users was based on water use records and assumptions that CVWD updates regularly as part of its water supply estimates. The total estimated average annual recycled water demands for these customers is 2,485 AFY. The most common type of agricultural user identified was crop plants. Flower growers were not included due to their water quality needs. The potential recycled water users are shown in **Figure 5-8**.

CVWD has considered recycled water to meet future water demands. Acceptable uses of recycled water include irrigating crops, parks, and golf courses, as well as water needed for groundwater recharge. Because a large portion of CVWD's water supply comes from local wells, the cost-effectiveness of serving recycled water is not attractive in the near-term. In addition, most agricultural users have their own wells, so that the economics to serve these users would be difficult to meet if they were to be served recycled water, except if groundwater use becomes restricted. Therefore, all potential demands identified are considered only in the long-term for the Carpinteria area.

CVWD has been conducting studies of its groundwater basin over the past few years. There is a potential for increasing the recharge to the basin, via either surface recharge or direct injection. Based on current California regulations, indirect potable reuse (IPR) in this south coast subregion would likely require some or all of the recycled water to be treated through an RO membrane type process. While producing high quality water, such processes also produce a brine-concentrate flow that must be disposed. The most common and cost-effective disposal option for brine-concentrate flows is via ocean discharge. CVWD is also currently investigating the potential for seawater intrusion into the groundwater basin in an area at the west end of the City of Carpinteria. However, CVWD does not have any monitoring wells in this area, so that the extent of this potential problem is not currently known. Potential groundwater recharge areas and the approximate location of the potential seawater intrusion area are shown in **Figure 5-9**. No estimated recycled water demand has been developed for either type of use.

CVWD has also been involved in discussions regarding enhancement of steam flows and water quality in Carpinteria Creek to address recent concerns about aquatic life, specifically endangered steelhead trout. Two years ago a number of adult trout died in pools because of lack of water. The concept would be to provide water year round in periods of no rain, especially during the winter season when the trout enter the creek. Without adequate flows during this period, the trout cannot make it upstream to higher elevation, year-round pools where they can survive in the creek. Augmenting stream flows will also help surcharge the groundwater basin. Some of the major constraints to this stream augmentation project include, additional treatment needs, pipeline from the Carpinteria WWTP up the creek to at least Foothill Blvd., pumping needs, regulatory approvals, and the lack of a revenue source for such a project. There is no current timetable for this concept option.



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Santa Barbara County IRWMP
South Coast Recycled Water
Development Plan

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Potential Recycled Water Customer

Demand (AFY)
- Less than 5
- 5 to 20
- 20 to 50
- Greater than 50

Type
- Urban Irrigation
- Agriculture
- Industrial/Commercial

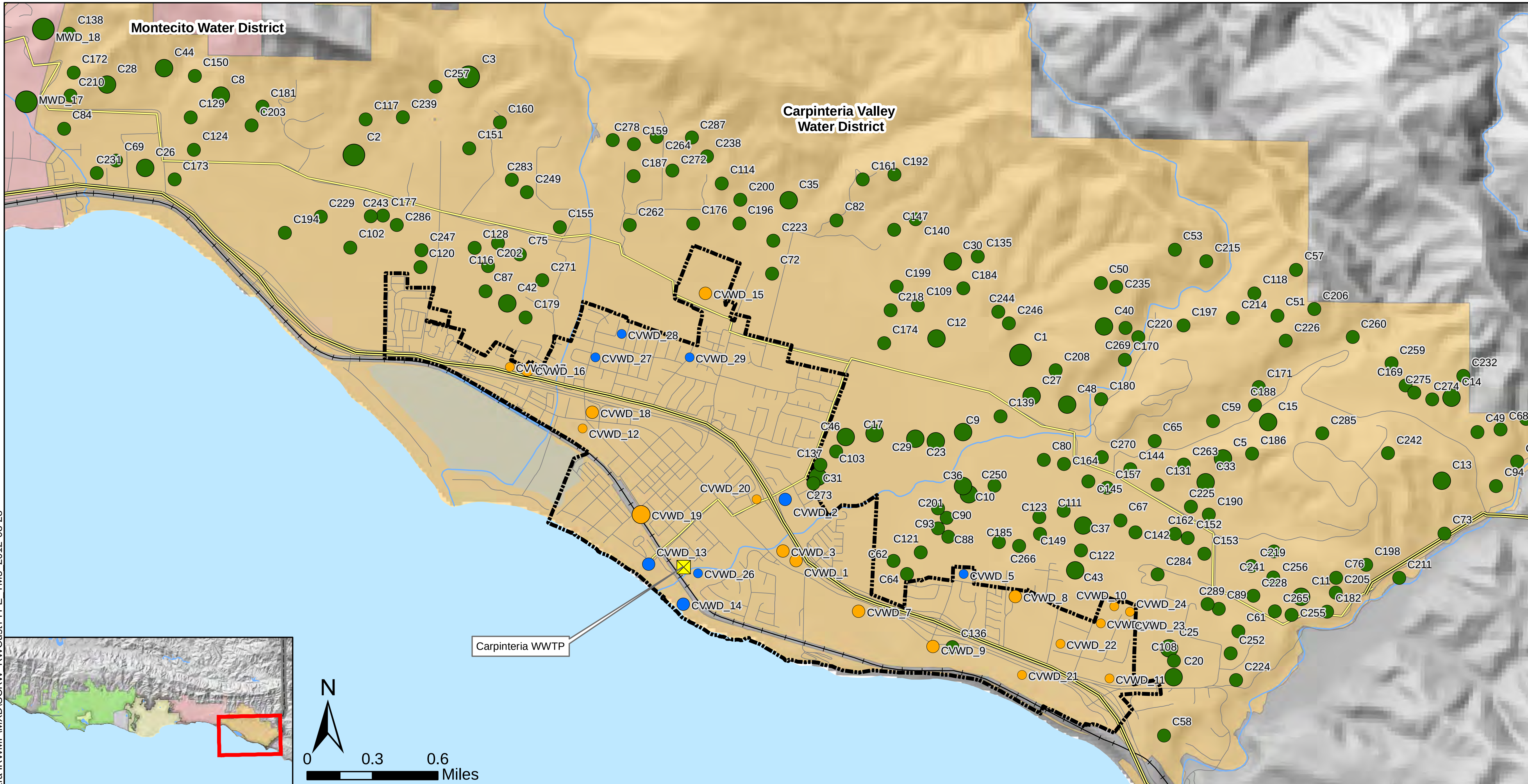
Existing Recycled Water System
- Customer
- Pipeline

Other Features
- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies
- Carpinteria Valley Water District
- City of Santa Barbara
- La Cumbre Mutual Water Co.
- Goleta Water District
- Montecito Water District

Potential Agriculture Customers: Montecito Area

Figure 5-7



Santa Barbara County IRWMP
South Coast Recycled Water
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Potential Recycled Water Customer
Demand (AFY)
- Less than 5
- 5 to 20
- 20 to 50
- Greater than 50

Type
- Urban Irrigation
- Agriculture
- Industrial/Commercial

Existing Recycled Water System
- Customer
- Pipeline

Other Features
- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies
- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Recycled Water Customers: Carpinteria Area

Figure 5-8

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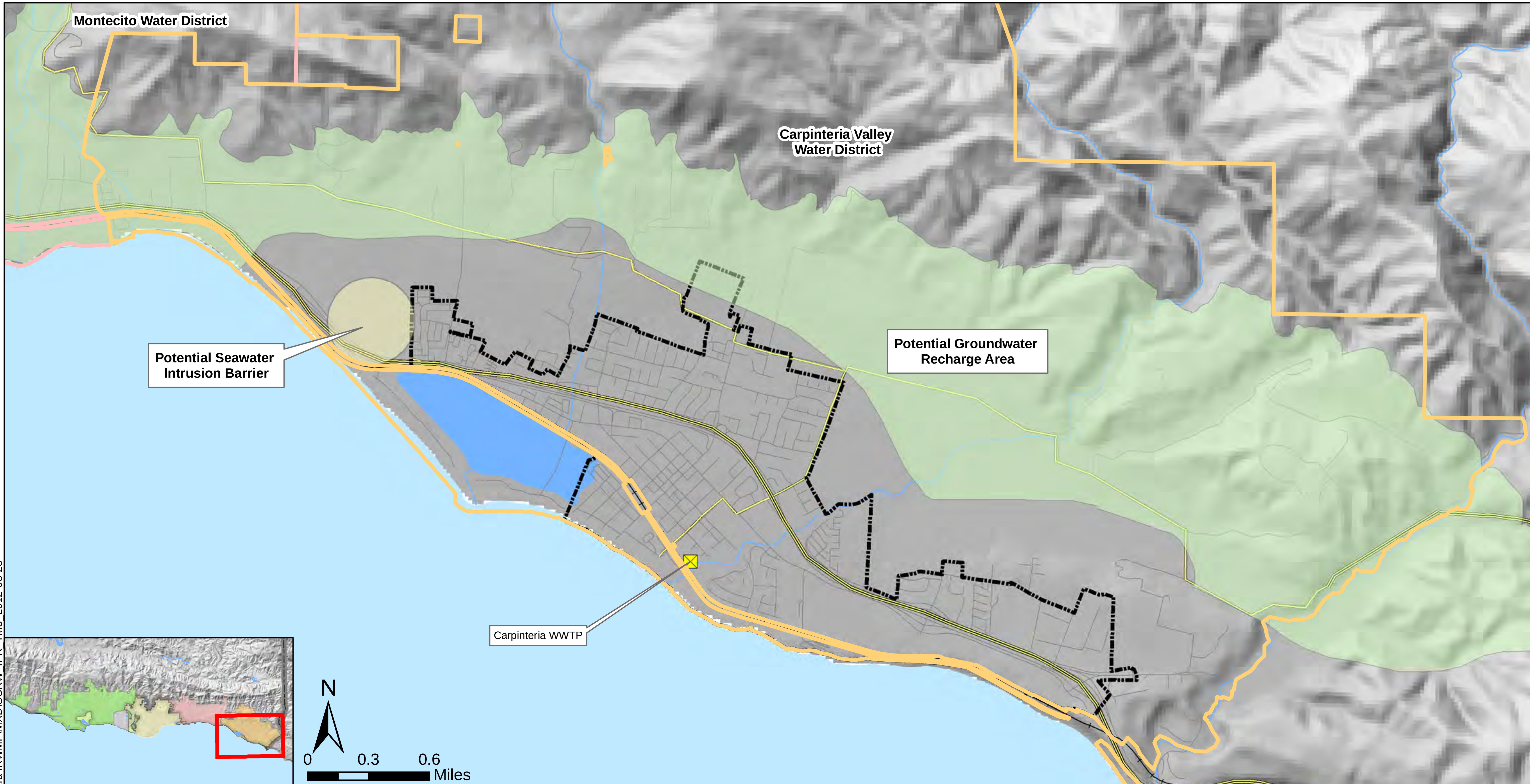

Santa Barbara County IRWMP
South Coast Recycled Water
Development Plan

RMC Water and Environment

Potential Recycled Water Customer

Demand (AFY)	Type
Less than 5	Urban Irrigation
5 to 20	Agriculture
20 to 50	Industrial/Commercial
Greater than 50	

Existing Recycled Water System

- Customer
- Pipeline

Other Features

- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies

- Carpinteria Valley Water District
- City of Santa Barbara
- La Cumbre Mutual Water Co.
- Goleta Water District
- Montecito Water District

Potential Indirect Potable Reuse Area: Carpinteria Area

Figure 5-9

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5.4 Summary of Potential Demand

For the near-term, an estimated average annual demand of 67 AFY of new recycled water use is projected by the agencies. A potential of an additional 4,854 AFY of recycled water demand was also identified for the long-term planning horizon. Along with the existing recycled water demands, the total identified potential recycled water use in the subregion could reach 6,556 AFY. This does not include the potential agricultural users in the Goleta and Montecito areas.

Table 5-1 provides a summary of the existing demands along with the potential demands for the near- and long-term planning periods. As shown in the table, only the City of Santa Barbara and Goleta Water District have included potential near-term demands. Carpinteria Valley Water District's potential long-term demands include agriculture demands as well.

Table 5-1: Existing and Potential Recycled Water Demand Summary by Agency

Agency	Average Annual Recycled Water Demand (AFY)				
	Existing	Potential Near-Term		Potential Long-Term	
		Additional Demand	Subtotal	Additional Demand	Total
Goleta WD	785	27	**812**	72	**884**
City of Santa Barbara[1]	850	40	**890**	266	**1,156**
La Cumbre MWC	--	--	**0**	130	**130**
Montecito WD	--	--	**--**	1,786	**1,786**
Carpinteria VWD	--	--	**--**	2,600	**2,600**
Totals	**1,635**	67	**1,702**	4,854	**6,556**

Notes:

1. Demand does not include approximately 300 AFY of internal plant use of recycled water.

Chapter 6 Wastewater Treatment Plant Needs

This chapter identifies the treatment needs to meet the water quality requirements needed to serve potential recycled water customers. Individual treatment costs are also discussed in this chapter.

6.1 Recycled Water Quality and Treatment Requirements

A summary of recycled water regulations was discussed previously and outlines the many Federal, State, and local regulations that recycled water systems must meet. In California, the level of treatment required is primarily based on three conditions:

- Type of user as dictated in Title 22 and by the Department of Health and Safety
- Local groundwater basin requirements as dictated by the local RWQCB
- Specific end-user water quality needs

For this plan, the majority of the potential users are urban irrigation and commercial uses. Therefore, the typical processes that meet the Title 22 requirements are tertiary filtration and disinfection. There are numerous filter types that are selected for a variety of reasons, including cost, influent water quality, effluent water quality needed, space, etc. Disinfection is typically done with chlorine via chlorine contact chambers. However, if space is limited, a UV disinfection system can also be utilized.

The RWQCB will typically impose reuse water quality standards that protect the underlying groundwater basin where the recycled water system will be utilized. Such restrictions are usually based on the current or ambient conditions of the groundwater basin. Numerous water quality requirements can be imposed depending on local conditions, but the most common parameter that reuse systems must contend with is Total Dissolved Solids (TDS). This is often because the groundwater used for municipal purposes experiences an increase in TDS once it is used and discharge back into the sewer/wastewater treatment plant system. This can also be the result of imported water having a higher TDS level than local groundwater basins. TDS restrictions are one of the most challenging for recycled water systems as the expenses are high to reduce the salt in the recycled water. Typically, this is done via an advance treatment system, which typically consists of microfiltration (MF) and reverse osmosis (RO) process. The capital costs for MF/RO systems are somewhat (10 to 30%) higher than the capital cost compared to standard filtration systems, but they tend to have much higher operating and maintenance costs due to the high energy requirements of the RO system and the need to periodically replace the membranes. Therefore, MF/RO processes are typically only employed when required by regulations or reduction of TDS is necessary.

One common problem to the south coast region is the high TDS levels seen in the wastewater flows. TDS in imported water from Lake Cachuma typically ranges from 500 to 600 mg/l. Groundwater TDS in the region is also fairly high with the Carpinteria basin ranging from 436 to 980 mg/l, Santa Barbara basin ranging from 400 mg/l to about 1,000 mg/l, Foothill basin ranging from 610 to 1,000 mg/l, and the Goleta Basin ranging from 170 mg/l to 1,400 mg/l in the North-Central sub-basin and approximately 800 mg/l in the West sub-basin. High TDS in groundwater can be both natural and can result from long-term irrigation practices by the agricultural community. TDS will also increase in sewer flows as a result of normal human water usage. Another major contributor to TDS levels in wastewater flows can stem from the use of water softeners in the community. The use of water softeners is quite prevalent in the region, and can be a major contributor to TDS levels in the wastewater supplies. The following wastewater TDS levels were reported by agencies:

- Goleta Sanitary District: 1,100 to 1,200 mg/l
- City of Santa Barbara: 1,350 mg/l (blended average of tertiary treated effluent)
- Carpinteria Sanitary District: 1,100 to 1,200 mg/l

These salinity levels can be a major impediment to recycled water usage as high TDS levels can impact the growth and quality of grass and plants (especially if above 1,000 to 1,200 mg/l), can inhibit use in some commercial applications, and can be highly infeasible for many agricultural uses. Typical solutions for addressing high salinity include the use of membrane treatment processes (typically MF/RO), blending with raw or potable water, and bans on salt exchange type water softeners.

As discussed previously, there are numerous opportunities to utilize recycled water in south coast areas where there are large agricultural users. However, many of the agricultural products grown require lower TDS levels than can be provided by standard filtration systems, and in the case of food crops, the elimination of pathogens is also required. CECs may also be a factor in the level of treatment needed to serve such users. The most common agricultural products in the region are avocados, citrus, and flowers. To serve such users recycled water would likely require some level of MF/RO treatment to reduce the TDS levels to acceptable customer levels and to address potential CECs.

As noted earlier, any IRP project would also require a MF/RO type process and would usually be accompanied by a UV and advanced oxidation processes. The amount of MF/RO as percentage of total reuse or recharge varies depending on a number of factors, including natural runoff/recharge, distance/travel time to the nearest production wells, soil aquifer treatment levels, TDS or other local groundwater quality requirements, and public perception.

6.2 Costs

Treatment costs for wastewater reuse are based on the capital costs necessary to bring each individual treatment plant to Title 22 water-quality standards. The required level of treatment varies for each plant because the cost is dependent on the required level of treatment for discharge, the existing level and capacity of treatment, and the projected quantity of flow for each treatment plant.

Upgrade from secondary to tertiary treatment typically involves the following improvements and the rough unit construction costs based on typical municipal system costs:

- Filtration ($1/gallon)
- Chlorine disinfection or UV ($1/gallon)
- Chemical handling ($0.10/gallon)
- Site work (10% of process [total of above] costs)
- Yard piping (10% of process costs)
- Electrical (20% of process costs)

The total unit construction cost for these improvements is therefore about $3.3 per gallon capacity. This unit construction cost will be used to estimate tertiary cost upgrades where recent costs information is not available. Construction costs for MF/RO processes tend to be higher than tertiary process. However, in most instances, installation of MF/RO processes does not require a tertiary filter. Unit construction costs for MF/RO are estimated to be $4.0 per gallon capacity. This unit cost includes the disinfection, chemical handling, site work, piping, and electrical components as well. For both unit costs, additional implementation (planning, engineering, etc.) and contingency costs will be applied as part of the total project cost estimates. However, O&M costs for MF/RO units tend to be much higher than tertiary process because of the need to replace membranes periodically and the higher energy and chemical needs.

6.3 Treatment Plant Improvement Needs

A summary of the existing south coast WWTPs and future treatment needed to serve recycled water is shown in **Table 6-1**. Each plant is discussed in more detail in the following sections.

Table 6-1: Existing Wastewater Treatment Plants and their Treatment

Wastewater Treatment Plant	Existing Treatment	Near-Term Needs	Long-Term Needs
Goleta WWTP	Tertiary	None	None
El Estero WWTF	Tertiary	Install MF/RO units in place of existing filters.	None
Montecito WWTF	Secondary	None planned	Expand to Tertiary treatment. If agriculture is served, MF/RO will also be needed
Summerland WWTP	Tertiary	Exploratory	Exploratory
Carpinteria WWTP	Secondary	None planned	Expand to tertiary treatment. If agriculture is served, RO will also be needed

As discussed in Chapter 3, treatment and effluent quality requirements are dependent upon the proposed type of water reuse. Tertiary treated recycled water can be used for landscape irrigation and cooling towers. Advanced treated recycled water, may be utilized for more types of reuse with fewer restrictions, such as food crops.

6.3.1 Goleta WWTP

The Goleta WWTP has a secondary capacity of 4.0 MGD and a tertiary capacity of 3.0 MGD. Currently 1.1 MGD of recycled water is being produced on average annually. GSD is currently expanding its secondary process system, but GSD does not have any plans to expand its tertiary process in the near-term. Expansion of the tertiary processes would depend on the GWD recycled water demand. As stated in Chapter 5, there is a potential recycled water demand of 1.9 MGD in the long-term (including existing demands), which could likely be served within the existing capacity of Goleta WWTP's current tertiary treatment levels during peak demand periods. Therefore, no further tertiary expansions are likely needed to meet the potential future reuse demands.

The existing recycled water system can produce up to 3 MGD of tertiary effluent for recycling. However, the ability to fully utilize recycled water is limited by recycled water use patterns, which are typically condensed into a 12- rather than a 24-hour period, and is limited by recycled water delivery and storage capacity and the end user demand for recycled water. Expansion of GWD's recycled water system is possible without further upgrades to the Goleta WWTP. However, a major expansion or increase in demand could require additional storage capacity at the plant or out in the system and additional treatment if demands exceeded 3 MGD.

Currently, TDS levels of the tertiary treatment are 1,200 milligrams per liter (mg/L). The high TDS level is mainly due to individual water softeners. The main water softener company, Rayne, previously discharged to the Goleta WWTP but currently discharges to surface water that ends up in the ocean. The RWQCB is planning to change their permit, and depending on the permit revision, GSD may have to reexamine the impact of any additional TDS.

In the Goleta area, there could be the potential to use recycled water for agricultural irrigation in the northern part of Goleta. To serve recycled water to these potential users, the salinity would need to be greatly reduced to meet agricultural water quality needs. The most common and cost effective approach would be to install MF/RO units to reduce the TDS levels. The use of MF/RO would also eliminate nearly all the pathogens and most of constituents of emerging concern. Given the demand location and size, storage capacity would also be needed. When the Goleta WWTP was built, space was reserved for future RO units and currently there are flanges in place for expansion. However, the high cost to treat, add additional distribution lines, and construct storage facilities would create a significantly higher cost for the recycled water that would need to be greatly subsidized to be equitable with current water costs, which are very low due to the use of groundwater and non-potable irrigation water in the area.

6.3.2 El Estero WWTF

The El Estero WWTF is owned and operated by the City of Santa Barbara and provides full secondary treatment and tertiary treatment for its recycled water flows, in conformance with Title 22. El Estero tertiary capacity is 4.4 MGD and recycled water production flows are 0.6 MGD on a year-round basis with a maximum month demand of 1.5 MGD. The disinfection system is currently limited to 2.2 MGD. However, at present the City's recycled water facility is not operational.

According to current regulations, recycled water produced by the City of Santa Barbara is suitable for industrial reuse, toilet flushing applications, and irrigation applications. Distributed recycled water consists of a blend of tertiary treated effluent with potable water to:

- Maintain chloride levels below 300 mg/L during the irrigation season
- Maintain TDS levels below 1,500 mg/L
- Maintain blended water turbidity at 2.0 NTU or less (Title 22)

The City of Santa Barbara's goal is to be able to deliver recycled water to its customers, without blending, for economic, regulatory and water supply reasons. Currently, tertiary effluent from El Estero WWTF is not able to meet its permit requirements without blending with potable water because of high turbidity and TDS level in the wastewater. A significant amount of the high TDS levels is due to the use of individual water softeners in the area. In addition, the plant currently has safety and access constraints, confined space entries issues, and corrosion, which has compromised structural integrity and caused process shutdown. The City of Santa Barbara is also concerned with high TDS, pathogens, and emerging contaminants. As part of the City's 2009 Study, several options for addressing these problems were initially identified. Subsequently, the City looked at several options ranging from rehabilitation of the existing filters to replacing the filters, including with MF. With the need to reduce TDS levels in the recycled water supply and to eliminate the blending of potable water, the City also looked at several demineralization options. Based on a 20-year life-cycle cost assessment of these options, the City concluded that replacing the existing filters with full MF and partial RO was the best approach, with the advantages of utilizing MF being:

- More reliability with variable effluent quality
- More effective removal of contaminants
- Easier to operate
- Allows subsequent technologies to be used (RO/UV)

Therefore, an upgrade to full MF and partial RO was recommended, and a $9.5 million project to upgrade the tertiary treatment (upgrading the tertiary filters) is currently in pre-design. Design will start in 2014 and construction is planned for 2016. The water quality goals for this project are to produce an effluent with TDS less than 1000 mg/L and chlorides less than 300 mg/L. This project would also eliminate pathogens and significantly reduce or eliminate nearly 100% of the CECs).

With the expansion and the tertiary upgrades, blending recycled water with potable water will no longer be needed. The City of Santa Barbara's current plan is to produce and use a total 1,400 AFY of recycled water by 2030. Of this total use, 1,100 AFY would serve existing and new recycled water customers and 300 AFY would be for internal plant use. The treatment capacity needs of the potential reuse projects identified in this plan should fit within the planned capacity of the upgraded treatment plant, such that no further treatment expansions will be needed.

6.3.3 Montecito WWTP

The Montecito WWTP has a secondary capacity of 1.5 MGD. Currently, Montecito WWTP secondary flow rate is averaging approximately 0.9 MGD. To produce recycled water, the Montecito WWTP would need to expand treatment beyond secondary to tertiary levels. This would require the addition of a filtration process, such as sand filters and a disinfection process, typically chlorination.

According to Metcalf & Eddy 2001 Report, Cost of Tertiary Wastewater Treatment for Southern Santa Barbara County, commissioned by Heal the Ocean, Santa Barbara, the addition of tertiary filters would generate extra solids and reduce aeration time due to the return flow. This could require the addition of a second aerobic digester and a dissolved air flotation solids thickener. Additional analysis is required to confirm these needs. The average daily flow at the Montecito WWTP is currently 0.9 MGD. To upgrade to tertiary levels, the estimated cost is $3M.

To serve recycled water to potential agricultural users, an MF/RO process or blending with potable water would be needed to reduce the TDS levels to acceptable water quality levels for the user. An MF/RO process would not likely require a tertiary filter, so the estimated cost for a 0.9 MGD MF/RO system is $3.6 M. While the capital costs for a MF/RO system are comparable to a tertiary filter, note that the operational and maintenance costs are substantially higher.

6.3.4 Summerland WWTP

The Summerland Sanitary District operates and maintains a 0.3 MGD tertiary treatment plant to biologically and chemically process wastewater. Wastewater treatment processes at the facility includes primary clarifier, activated sludge aeration basin, secondary clarifier, chlorination contact chamber, tertiary sand filter, and dechlorination basin. Effluent is discharged into the Pacific Ocean via a dedicated outfall and there are currently no recycled water customers. The sanitary district has made attempts to get grants for a recycled water feasibility study, so far without success, but the District's board of Directors still entertains a goal of providing recycled water to the Montecito Water District. Summerland Sanitary District is also examining advanced treatment processes, such as RO, to effectively remove boron and ensure a usable recycled water supply.

Although the plant has a tertiary filtration unit, according to Heal the Ocean's 2001 Metcalf & Eddy Report, some improvements are necessary to produce recycled water at required Title 22 levels. The plant currently has one filter, which is in line after the disinfection process. Title 22 standards require that the disinfection occur after the filters. In addition, to improve system reliability, a second filter is needed to be able to produce recycled water during backwash or maintenance periods. Along with those improvements, the 2001 Study also recommended the installation of a pre-manufactured continuous filtration unit and additional piping to re-route water from the existing secondary system to the filtration unit and then to the chlorination and de-chlorination systems. The average daily flow at the Summerland WWTP is currently 0.14 MGD. To upgrade to tertiary levels, the estimated cost is $500K.

6.3.5 Carpinteria WWTP

The Carpinteria WWTP has a secondary capacity of 2.5 MGD. Currently, the influent flow rate at the Carpinteria WWTP is averaging approximately 1.4 MGD. The treatment plant provides secondary treatment and chemical disinfection of collected wastewater prior to discharge into the Pacific Ocean via a dedicated outfall pipe.

To produce recycled water, the Carpinteria WWTP would need to add filtration and disinfection processes to meet Title 22 criteria. Adequate space at the facility is available to implement a recycled water project that could potentially scale up to provide tertiary treatment for the full volume of secondary effluent produced. A project of this magnitude may require the use of membrane technologies (in lieu of conventional gravity filtration) and/or the use of UV disinfection to achieve a site layout that fits within the existing plant footprint. A smaller scale project would allow for greater flexibility and would allow continued use of chemical disinfection with new or expanded chlorine contact tank capacity. If on-site recycled water storage is required for diurnal storage, a clearwell should also be considered in the site layout and consideration of available area within the plant for recycled water system improvements. The estimated cost for the tertiary and disinfection process improvements is $4.6M for the 1.4 MGD capacity system. The estimated cost for the tertiary and UV process improvements is $4.6 M for the 1.4 MGD capacity system.

To serve recycled water to potential agricultural users, an MF/RO demineralization process, or a potable water blending scheme, would be needed to reduce TDS levels to acceptable water quality levels for end users. A significant amount of the high TDS levels is due to the use of individual water softeners in the area. An MF/RO process would not likely require a tertiary filter, so the estimated cost for a 1.4 MGD MF/RO system is $5.6 M. While the capital costs for an MF/RO system are comparable to a tertiary filter, note that the operational and maintenance costs are substantially higher.

Agricultural users are currently pretreating their potable water before irrigating flowers and vegetables due to high TDS levels in the raw/potable water supplies. These users have agricultural crops that are sensitive to TDS. While serving recycled water to these users would entail higher treatment costs, one benefit to such a project would be the avoided costs that the users currently incur for pre-treating their current water supplies. Actual benefits were not quantified as it is not known how much pretreatment is currently being practiced nor what the user-end costs are.

Chapter 7 Distribution Needs

This chapter presents the conveyance, storage, and pumping needs to provide recycled water to potential customers. Distribution system needs are broken into three categories:

- **Existing system improvements**: previously identified upgrades needed for existing reuse systems
- **Near-term improvements**: improvements identified by agencies in previous studies or in this plan that are necessary for expansion of systems in the near-term planning period
- **Long-term improvements**: improvements identified primarily by this plan and through agency input or previous long-term studies that would create new recycled water systems or significantly expand existing system in the long-term planning horizon

7.1 Criteria

Design criteria were developed to help identify the near- and long-term distribution improvements and to evaluate potential alternatives. Criteria for peaking of flows, pipeline sizing, storage, pumping facility needs are summarized in **Table 7-1**.

Table 7-1: Facilities Development Criteria and Hydraulic Criteria

Item	Value	Units/Notes
Pipeline		
Max Pressure	200	psi (greater than 12-inch diameter)
Max Pressure	140	psi (12-inch diameter or less)
Min Pressure	40	psi
Existing Reuse System Pressures	60	psi (assumed if lateral branch is created)
Elevations are based on DEM shape file and from Google Earth		
Conveyance		
Design Flow		Peak hour conditions
Pressure class (minimum)		Schedule 150 (psi)
Diameters considered		6”, 8”, 12”, 16”, 20”, 24”
Max Velocity for Sizing:		5 ft / sec
C Coefficient for Headloss		130
Storage		
Diurnal storage based on storing the 24-hour peak day demand		
Pump Station & Customer Booster Pumps		
Pump Efficiency		75%
Design Flow		Peak hour conditions
Pump curves		Standard

7.2 Recycled Water Systems

When developing a recycled water system, it is also important that agencies plan for future costs to the system. In addition to regular O&M costs, recycled water systems will also require capital improvements to upkeep and invest in the recycled water system assets to ensure continued deliveries in the future. Similar to water and wastewater systems, these improvements need to be included in future capital improvement plans as part of an agency’s budget cycle process to ensure the system is functional and meeting customer needs. GWD and the City of Santa Barbara were early adopters of recycled water in this region and new technologies and practices as well as asset depreciation require continued reinvestment in their systems to maintain the existing systems and to allow for future expansions.

7.2.1 Goleta Area Recycled Water System

GWD has been serving recycled water since 1994. The recycled water production capacity is approximately 3,000 AFY. However, the ability to fully utilize recycled water is limited by recycled water use patterns, which are typically condensed into a 12- rather than a 24-hour period, and are driven by the irrigation season. While storage is available to address daily needs, storage is not available to address seasonal variability in irrigation demand. Currently GWD is delivering approximately 785 AFY.

Existing System Improvements

In recent years, the GWD recycled water distribution system has demonstrated the pace at which recycled water systems can depreciate. The GWD Infrastructure Improvement Plan has identified a number of projects to address these problems. These investments to improve the recycled water system are necessary to upkeep the system and ensure its reliability to customers. Additionally, GWD is currently identifying management strategies for coordinating customer use with timing techniques, in order to maximize the performance of existing systems. The increased use of SCADA controls are forecasted to assist in this process. GWD has identified the following upgrades to its recycled water system that are necessary to maintain the current system and are also needed for GWD to expand its system in the near-term to other users:

Recycled Waterline Relocation Project at Goleta Beach

This project will relocate approximately 800 feet of 18-inch diameter waterline to prevent damage resulting from ongoing beach erosion. This line conveys the majority of recycled water to the 19 large recycled water customers including UCSB, various golf courses, and other large landscaped areas. It will be relocated to a proposed Caltrans utility corridor adjacent to State Highway 217. Relocation is scheduled to begin in 2014 and will ensure continued service to the recycled water customers. The GWD estimated this project will cost $675,000.

One-Million Gallon Reservoir Project

Under this project, a one-million gallon (MG) recycled water reservoir will be constructed to provide storage and to reduce pumping costs associated with the distribution of recycled water. Currently, distribution of recycled water is dependent on sequential pump stations, which is inefficient and causes service interruptions when a malfunction occurs at one of the pump stations. Building a reservoir would assist in the distribution of recycled water and provide the system with continuous operations during power outages, preventive maintenance periods, and emergency failures of these station's pumps.

GWD's Infrastructure Improvement Plan identifies an underground or partially covered reservoir within its Ellwood 440 Zone that would tie into the existing recycled water system at Cathedral Oaks Road or potentially at the Glen Annie Golf Course. GWD has estimated this project to cost $2.5 million.

Recycled Water System Corrosion Protection and Pipeline Replacements

Due to corrosive soil conditions in the Goleta area and the fittings and bolts on many of the recycled waterline being poorly wrapped or not wrapped at all, GWD has experienced some leaks on its recycled water system. The recycled water system consists of approximately 51,000 feet of steel waterlines. These leaks cause service disruptions to the irrigation programs of parks, golf courses, shopping centers and the restrooms facilities of UCSB, the Post Office, and Goleta Beach State Park.

GWD is currently conducting a Corrosion Protection Study to evaluate the condition of the recycled waterlines and establish an organized program to address the corrosion problems. The potential project would implement a proactive program to repair or replace sections of GWD's recycled waterline system before corrosion caused leaks or breaks in the recycled waterlines occur and thus prevent unplanned resource expenditures and interruptions to service. Initial GWD estimates is that the program will cost $10,000 per year over 10 years ($100,000 in total) to implement. The current study will provide an updated cost and is anticipated to be completed in FY 2013-14.

Recycled Booster Station Electrical Upgrades

GWD is currently upgrading the electrical system at the GSD's wastewater treatment plant. The project involves replacement of four Variable Frequency Drives and outdated support equipment with new technology and pump controllers. GWD's estimated cost for these upgrades is $474,000.

Near-Term Improvements

As part of this plan, six recycled water users located adjacent to the GWD's existing system have been identified by GWD as potential candidates for expansion in the near term. As shown in **Figure 7-1,** these users are along the existing recycled water mainlines. Therefore, the only improvements needed to connect these potential recycled water users are short lateral segments and any necessary onsite recycled water conversion work.

Long-Term Improvements

For GWD to further expand its system to larger users, GWD has identified the following system improvements. These are in addition to the distribution pipelines necessary to connect to the new users identified as potential long-term recycled water customers as show in **Figure 7-2**, Long-term distribution improvements identified include:

Hollister Booster Station Relocation Project

The existing Recycled Water Hollister Booster Pump Station is in an underground vault that experiences occasional flooding, which could damage the motors and electrical equipment. This project is needed to eliminate the potential for flooding and safety problems associated with the existing below-ground booster pumping station.

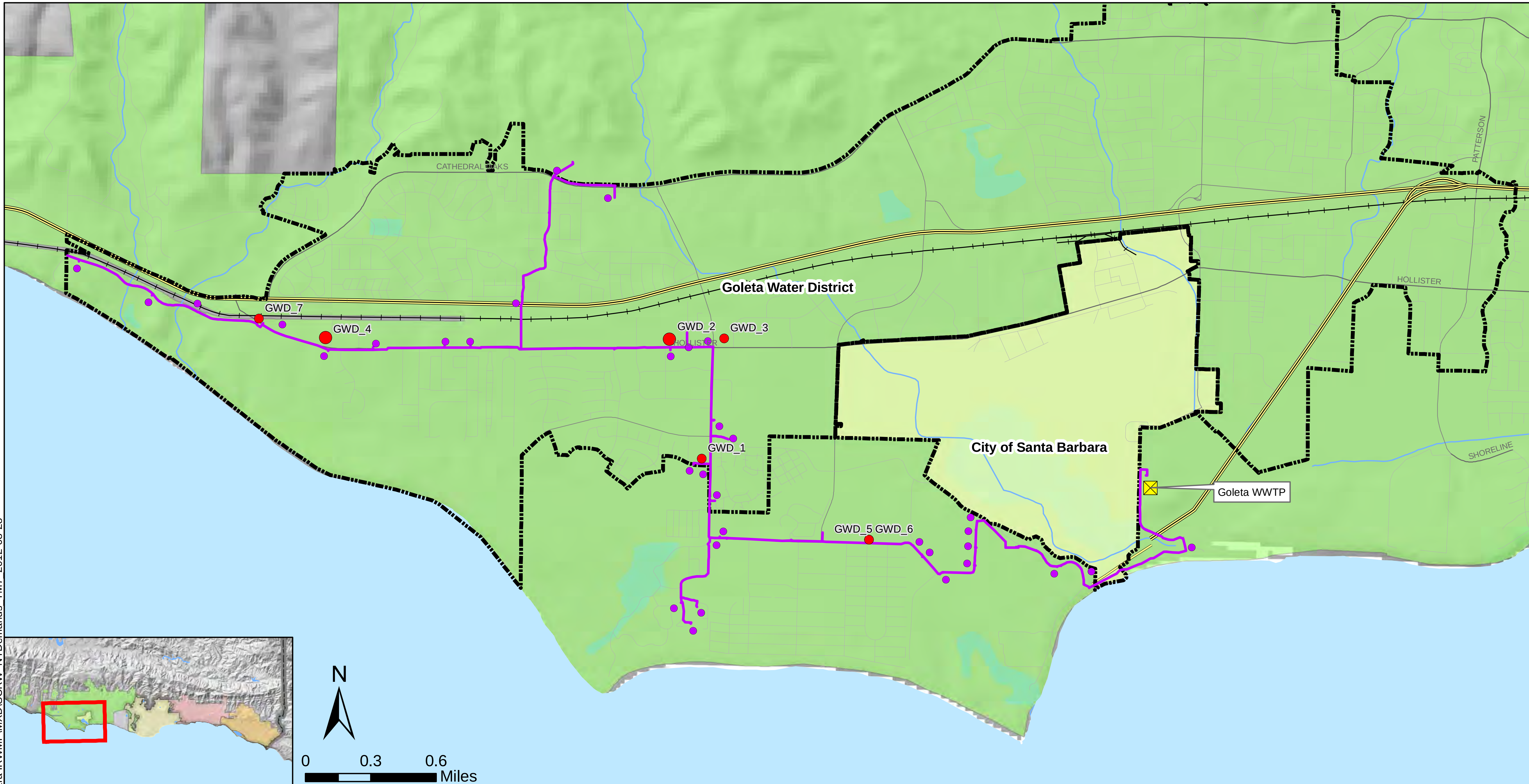
In addition, the Hollister Booster Pump Station is approximately 15 years old and has some poor design features. A new, above-ground booster pump station would be designed to be more efficient. Additionally, an above-ground pumping station would be safer and more easily accessible. The booster station will be redesigned for greater efficiency and to minimize operations and maintenance costs. All existing deteriorated pumping equipment, such as pumps, motors, and electrical equipment, would be replaced. The existing horizontal pump station would be replaced with a new vertical one. GWD estimates the cost of this project to be $2.5 million.

Pressure Regulating Vault Relocation at Glen Annie Golf Course

This project involves relocating the existing pressure-reducing vault from the Glen Annie Golf Course to a more accessible location. This valve is located on private property, which means that GWD operators need to coordinate with the golf course staff to gain access to the vault during emergencies. GWD has estimated that this project will cost about $175,000.

Cathedral Oaks Rd and Hwy 101 Overcrossing Project

This project would keep the District's recycled and potable waterlines in the roadway of the newly realigned section of Hollister Avenue in Goleta. The project would involve installation of approximately 500' of 12" PVC recycled waterline, replacing an older section of waterline that no longer aligns with the new roadway. The project will ensure waterline accessibility in any future maintenance or repair project. GWD has estimated that the recycled waterline relocation portion of the project will cost about $250,000.



Santa Barbara County IRWMP
South Coast Recycled Water
Development Plan

RMC
Water and Environment

Potential Near-Term Recycled Water Customer Demand (AFY)
- Less than 5
- 5 to 20
- 20 to 50
- Greater than 50

Potential Near-Term Recycled Water System
- Customer
- Pipeline

Existing Recycled Water System
- Customer
- Pipeline

Other Features
- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies
- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Near-Term Recycled Water System: Goleta Area

Figure 7-1

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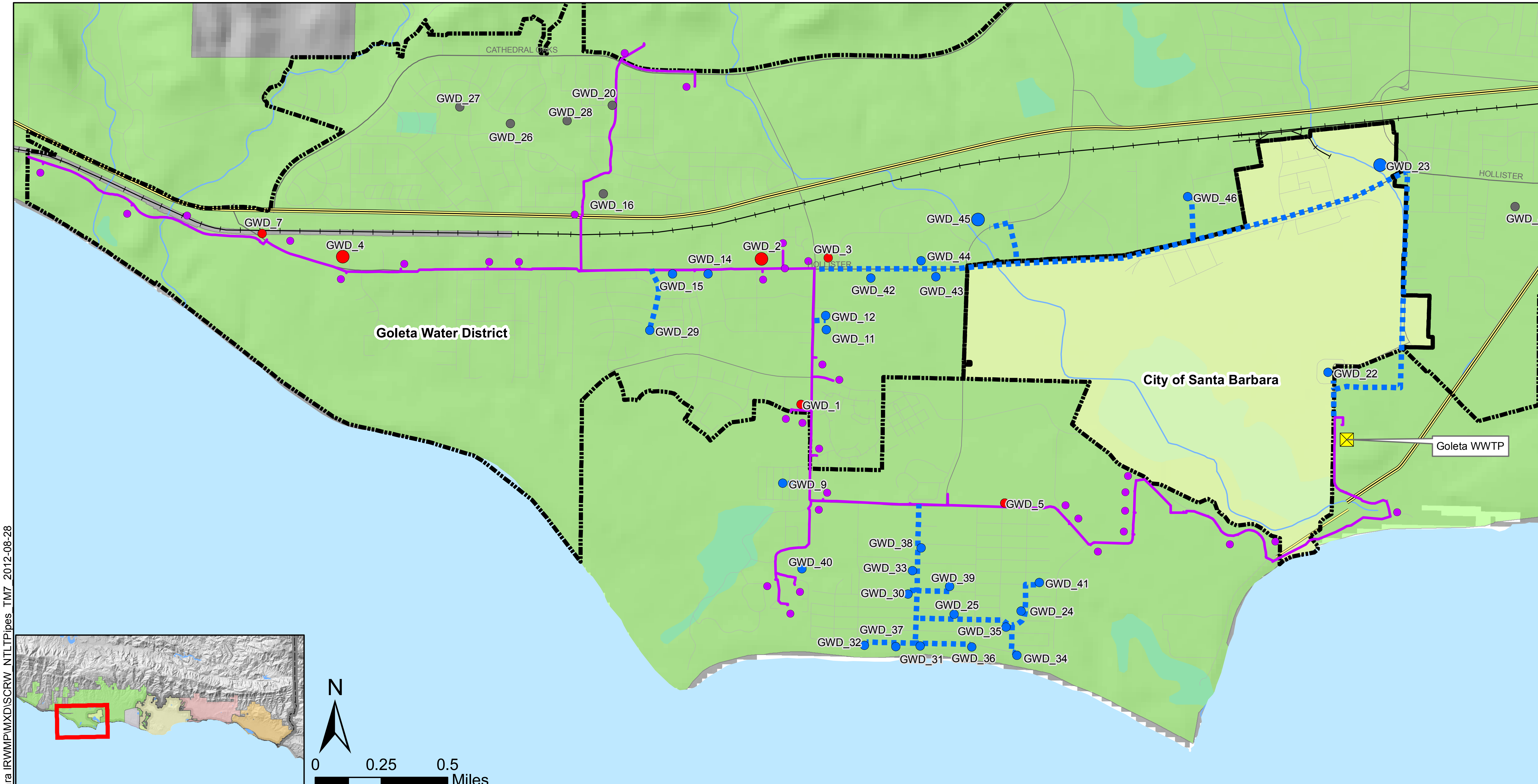

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Santa Barbara County IRWMP South Coast Recycled Water Development Plan

RMC Water and Environment

Potential Long-Term Recycled Water Customer

Demand (AFY)
- Less than 5
- 5 to 20
- 20 to 50
- Greater than 50

Potential Long-Term Recycled Water System
- Customer
- Pipeline

Potential Near-Term Recycled Water System
- Customer
- Pipeline

Existing Recycled Water System
- Customer
- Pipeline

Not associated with Near- or Long-Term System
- Customer

Other Features
- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies
- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Long-Term Recycled Water System: Goleta Area

Figure 7-2

Pipelines

As shown in **Figure 7-2**, there are several potential long-term projects that would require pipeline extensions, with one project including the looping of the existing recycled water system. The larger project would install 20,600 feet of 6-inch diameter pipeline to loop the recycled water system and would significantly improve reliability of the entire system. The recycled waterline is currently configured in a linear fashion. If the recycled waterline breaks or needs repairs, recycled water could not be delivered to all customers downstream of the break. A looped system would allow recycled water to be supplied to customers from a different area of the distribution system.

Pumping

No new pump stations are needed to expand GWD's recycled water system with the proposed projects.

Storage

GWD has identified the need for a 1-MG recycled water reservoir. With this storage capacity, potential near- and long-term expansions would not likely require additional storage beyond this 1-MG storage capacity. The looping of the system proposed in the long-term would also provide benefits to meeting peak demands in certain parts of the system.

7.2.2 City of Santa Barbara Area Recycled Water System

The City of Santa Barbara owns and operates the El Estero WWTF, which has historically produced recycled water for local distribution. Most of the recycled water is used for urban irrigation. The system has the capacity to treat and deliver 1,400 AFY. The current demand is approximately 800 AFY, plus an additional 300 AFY of in-plant process water usage. Because of high turbidity levels in the recycled water, potable water has been blended into the recycled water to meet recycled water quality requirements. However, the plant is not currently operational.

Existing System Improvements

The City of Santa Barbara's recycled water distribution system was developed in two phases. Phase I was completed July 1989, and Phase II was completed May 1991. Combined, Phase I and Phase II consist of approximately 14 miles of distribution piping to recycled water uses. Pipe diameters range from 2inches to 18inches. The Phase II Service Area is divided into two pressure zones: the Phase II northern zone is located generally north of Highway 101 and the Phase II southern zone is located generally south of Highway 101.

Expansion of the system is limited by the tertiary filters, pumping capacity, and storage cycle limitations. With the previously discussed, recommended MF/RO system replacing the existing filters, the recycled water treatment plant's performance will improve and thus eliminating a bottleneck to recycled water production and impediments to future expansion. Blending of potable water will also no longer be necessary.

Below is a summary of the existing distribution system conditions based on the City's 2009 Water Supply Planning Study.

Distribution

According to the City's 2009 Water Supply Planning Study, the existing recycled water pipes have sufficient capacity to convey the existing demands without any system pressure limitations. The 2009 Report noted that the capacity in the existing pipelines is also adequate to convey the City's goal of serving up to 1,400 AFY of recycled water in the future. Additional projects should be evaluated via a hydraulic model to verify that their pressure and flow needs will be adequate and will not impact the existing system.

Pump Station Capacity

The amount of recycled water flow that could be supplied to the Phase I and Phase II zones is limited by the existing capacity of the three pump stations. The pump stations are sized to accommodate peak hour flows to customers during their respective distribution periods. The 2009 Study notes that the system's pumping capacity is 3.3 MGD, and no additional pumping was proposed for the projects identified in that Study. Future system expansions would need to be limited in size to stay within the existing pump station limitations or would require expansion of pumping and/or storage facilities to serve users further out into the system

Storage Capacity

Most of the demand on the City of Santa Barbara's recycled system occurs at night in a nine-hour window between the hours of 9 p.m. and 6 a.m. when the El Estero WWTF's flow often averages about 2.5 MGD. Consequently, supply is limited to storage in combination with the nightly plant flow during this time period. Storage is limited under the following three scenarios:

- Delivery to the overall system is limited to the amount of recycled water that can be stored during the day (2.0 MG) plus the amount of flow treated at night (0.5 MG), totaling 2.5 MG.
- Delivery to the Phase I zone is limited to the amount of flow that is stored in El Estero Reservoir plus the amount of flow coming from the filters at night. Under the worst case scenario, about 0.5 MG is available from the filters at night plus 0.5 MG stored during the day, providing a total of 1.0 MG without blending. If maximum month demand in the Phase I system exceeds 1.0 MGD, then additional reservoir capacity will be needed for Phase I.
- Delivery to the Phase II zone is limited to the amount of flow that can be stored in the reservoir located at the Santa Barbara Municipal Golf Club during the day, except to the extent that augmented flow can be provided from the Phase I area by the La Mesa Pump Station when it is in high head mode. If maximum month demand surpasses the 1.5 MGD capacity of the Golf Course Reservoir, additional storage capacity will be needed.

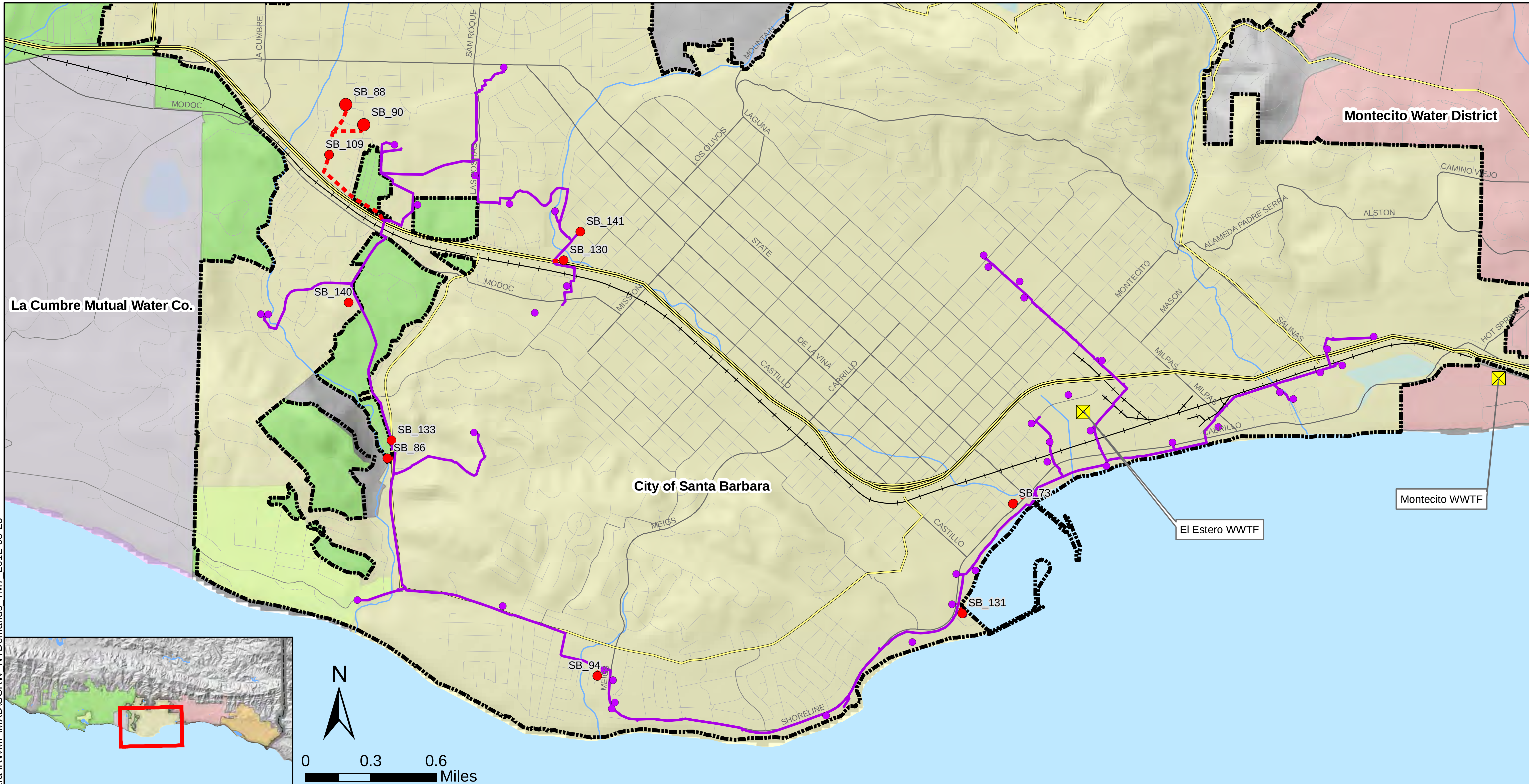
Based on the City's 2009 Study, some amount of additional reuse flow or customers can be added to the system without the need for additional pumping or storage capacities. The 2009 Study notes that the total existing storage is 2.5 MGD without blending and that the existing system only needs 1.8 MGD during maximum month demand conditions, which is equivalent to about 392 AFY of additional reuse. Approximately 300 AFY of new demand is being considered in this study, and therefore no additional storage should be needed in either the near- or long-term conditions.

Near-Term Improvements

Potential near- and long-term projects have been identified using the proposed projects from the City's 2009 Water Supply Planning Study as a basis. City of Santa Barbara staff has provided updates to the projects identified in the 2009 Study and have prioritized these potential projects for the purposes of this present Study. The potential near-term projects identified include existing recycled water customers that are expanding recycled water use to other parts of their site and the addition of new customers adjacent to the existing recycled water system. The following improvements are planned in the near-future:

Pipelines

As shown in **Figure 7-3,** there are seven near-term projects and six of them require short lateral pipeline extensions to connect to the near-term customers. These projects are estimated to require a total of 6,000 feet of 6-inch diameter pipeline to extend the existing recycled water system to these new users.



Santa Barbara County IRWMP
South Coast Recycled Water
Development Plan

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Water and Environment

Potential Near-Term Recycled Water Customer Demand (AFY)
- Less than 5
- 5 to 20
- 20 to 50
- Greater than 50

Potential Near-Term Recycled Water System
- Customer
- Pipeline

Existing Recycled Water System
- Customer
- Pipeline

Other Features
- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies
- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Near-Term Recycled Water System: Santa Barbara Area

Figure 7-3

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Pumping

The potential near-term users are relatively small, and therefore, no additional pumping capacity will probably be needed. The system has some additional pumping capacity available before the system limit of 3.3 MGD is reached.

Storage

No additional storage is needed to meet the potential near-term demands. According to the La Cumbre Mutual Water Company, a previous study of the La Cumbre Golf and Country Club indicates that onsite ponds could be used for diurnal storage, thus potentially reducing the overall system's storage needs should the La Cumbre Golf and Country Club be connected to the system.

Long-Term Improvements

The following improvements are needed in the long-term. All long-term customers and pipeline extensions are shown in **Figure 7-4**.

Pipelines

There are several potential customers identified that would require pipeline extensions. This also includes one potential project that would loop the existing recycled water system. An estimated total of 41,400 feet of 6-inch diameter pipeline would be required to serve the identified users, with approximately 25,200 feet required for the looping of the central area. Looping the system would significantly improve the reliability of service to City of Santa Barbara's customers. As the existing recycled system is configured in a linear fashion, if a recycled waterline breaks or needs repair, all customers downstream from where service is interrupted would be out of recycled water. A looped system would allow recycled water to be supplied to most of the City's customers that are located west of the El Estero WWTF.

Pumping

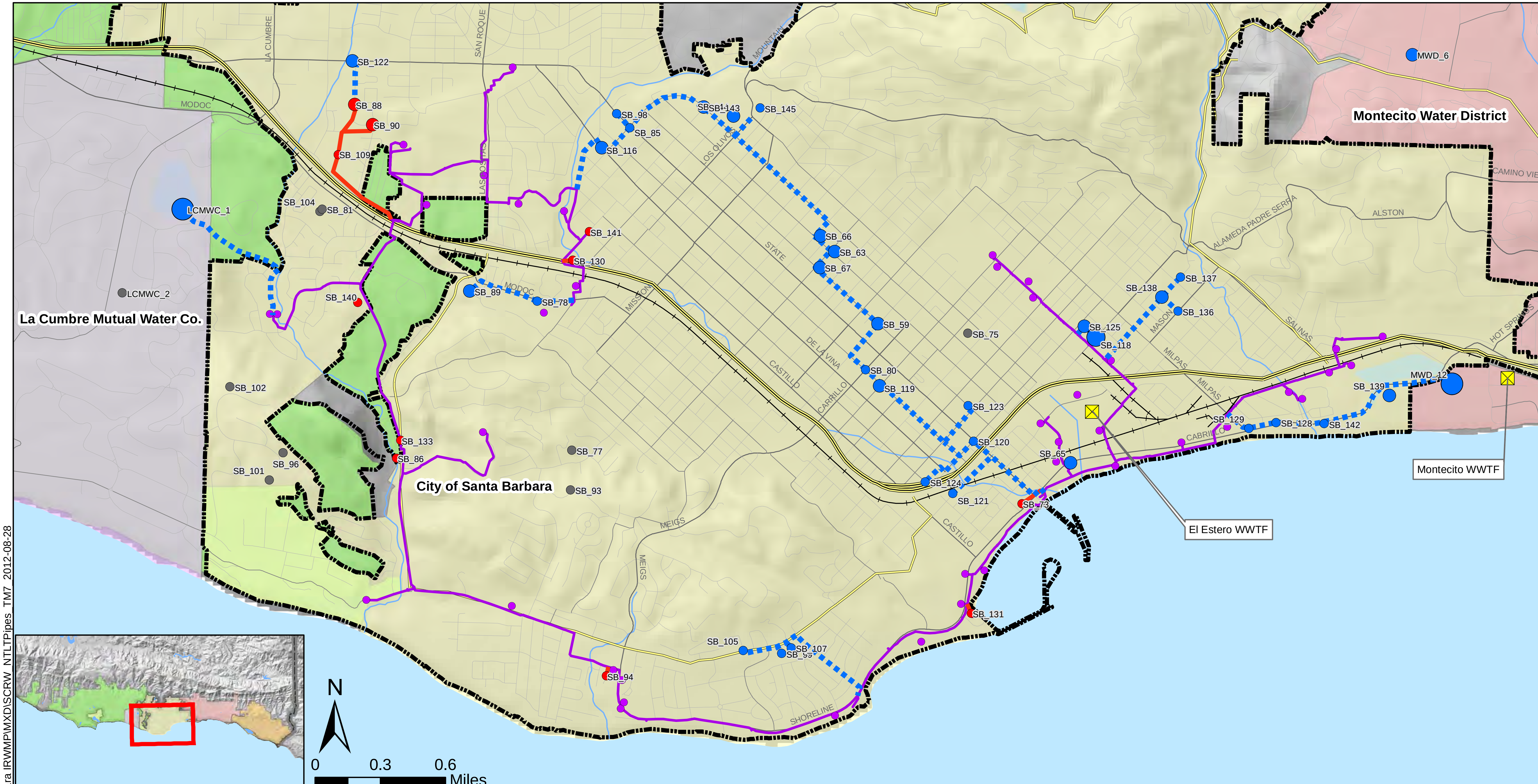
In the City's 2009 Study, the proposed projects required no additional pumping beyond the existing pump stations. However, some additional pumping may be required for the potential long-term users identified in this Study. One potential customer that may require additional pumping is Shifco (ID No. SB_105), as the elevation of this user is around 200 feet. This higher elevation appears to be above the hydraulic gradeline of the existing Phase 1 system, and therefore may require some additional pumping depending on the pressure of the main service line in this area, especially during peak demand periods. The second potential pumping need is the looped system, which has a change in elevation from about 40 feet to around 290 feet. Given the length and elevation change, it is possible that one or more booster stations will be needed as part of this loop. A more detailed hydraulic analysis would be necessary to determine the exact need for pumping for the long-term system. For purposes of this study, some pumping facility costs will be included in these projects costs.

Storage

As discussed above, no additional storage was identified in the City's 2009 Water Supply Planning study. Since the amount of system build-out is similar in this study, no additional storage was assumed to be needed under this Study.

7.2.3 Montecito Area Recycled Water System

MWD does not have any current plans to develop a recycled water system, and therefore, no near-term project has been identified. Only potential long-term options are identified. These options include serving water from Montecito WWTF and Summerland WWTP. Below is a summary of the distribution infrastructure needed for the proposed system as shown in **Figure 7-5**.



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Santa Barbara County IRWMP
South Coast Recycled Water
Development Plan

RMC
Water and Environment

Potential Long-Term Recycled Water Customer

Demand (AFY)
- Less than 5
- 5 to 20
- 20 to 50
- Greater than 50

Potential Long-Term Recycled Water System
- Customer
- Pipeline

Potential Near-Term Recycled Water System
- Customer
- Pipeline

Existing Recycled Water System
- Customer
- Pipeline

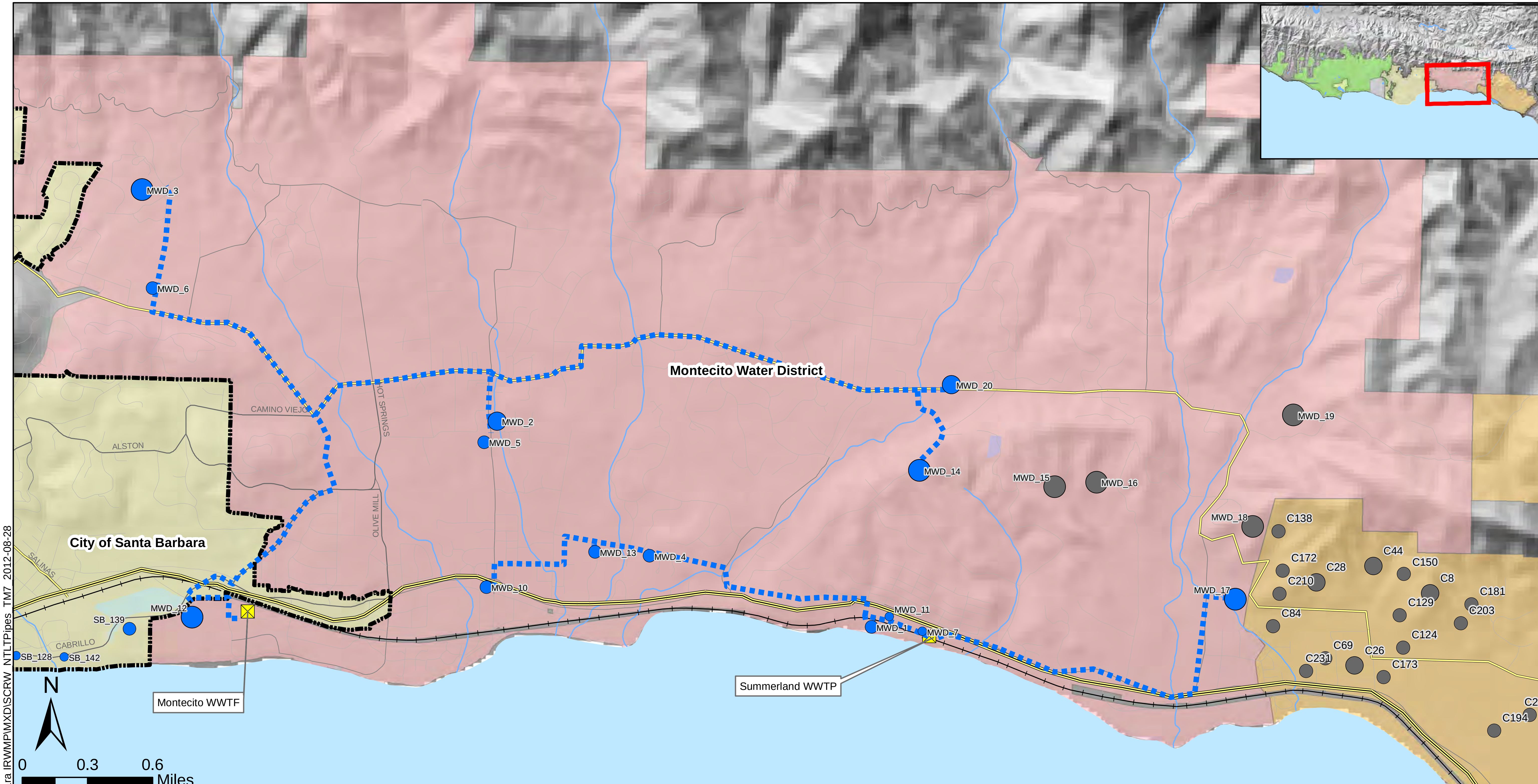
Not associated with Near- or Long-Term System
- Customer

Other Features
- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies
- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Long-Term Recycled Water System: Santa Barbara Area

Figure 7-4



Santa Barbara County IRWMP
South Coast Recycled Water
Development Plan

RMC
Water and Environment

Potential Long-Term Recycled Water Customer

Demand (AFY)
- Less than 5
- 5 to 20
- 20 to 50
- Greater than 50

Potential Long-Term Recycled Water System
- Customer
- Pipeline

Potential Near-Term Recycled Water System
- Customer
- Pipeline

Existing Recycled Water System
- Customer
- Pipeline

Not associated with Near- or Long-Term System
- Customer

Other Features
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- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies
- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Long-Term Recycled Water System: Montecito Area

Figure 7-5

Pipeline

Different options were developed for this area, including service from the Montecito WWTF to the Santa Barbara Cemetery and to several large users in the central and western portions of MWD's service area. Just over seven miles of pipeline would be required for installing service to these two potential customers

There are some potential customers near the Summerland WWTP that could use recycled water. A small pipeline extension would consist of 1,800 feet of 6-inch diameter pipe to serves these potential users. A recycled water pipeline currently exists along the main street of Summerland, Lillie Ave., and could be utilized as part of future recycled water system. There are two options to extend a recycled water system either west or east. The west expansion would consist of 11,500 feet of 6-inch diameter pipeline, and the east expansion would consist of 9,500 feet of 6-inch diameter pipeline.

Pumping

For the Montecito WWTF options, if only the Santa Barbara Cemetery were to be served, a 10-hp pump station would be needed. If the system were to be expanded to serve the agriculture customers in the northern and eastern areas as well, then a larger station would be needed at the Montecito WWTF as well as one or two booster stations.

For the Summerland WWTP options, if only the customers near Summerland WWTP are served, a 10-hp pump station would be needed. If the system were expanded to serve agriculture customers in the western or eastern areas, then an additional 10-hp pump station would be needed for either option.

Storage

If all of the Montecito WWTF options were to be implemented, an estimated 1.8-MG of storage capacity would be needed at the treatment plant or within the system to supply recycled water during peak hour conditions.

For the Summerland WWTP options, no storage is needed if recycled water is supplied only to customers near the plant. If the system were expanded either west or east, approximately 100,000 gallons of storage capacity would be needed at the WWTP or in the system itself.

7.2.4 Carpinteria Area Recycled Water System

The Carpinteria area does not have any current plans to develop a recycled water system, and therefore, no near-term project has been identified. Only potential long-term options are identified in this plan. **Figure 7-6** shows the proposed pipelines that would be needed to serve these users.

Pipeline

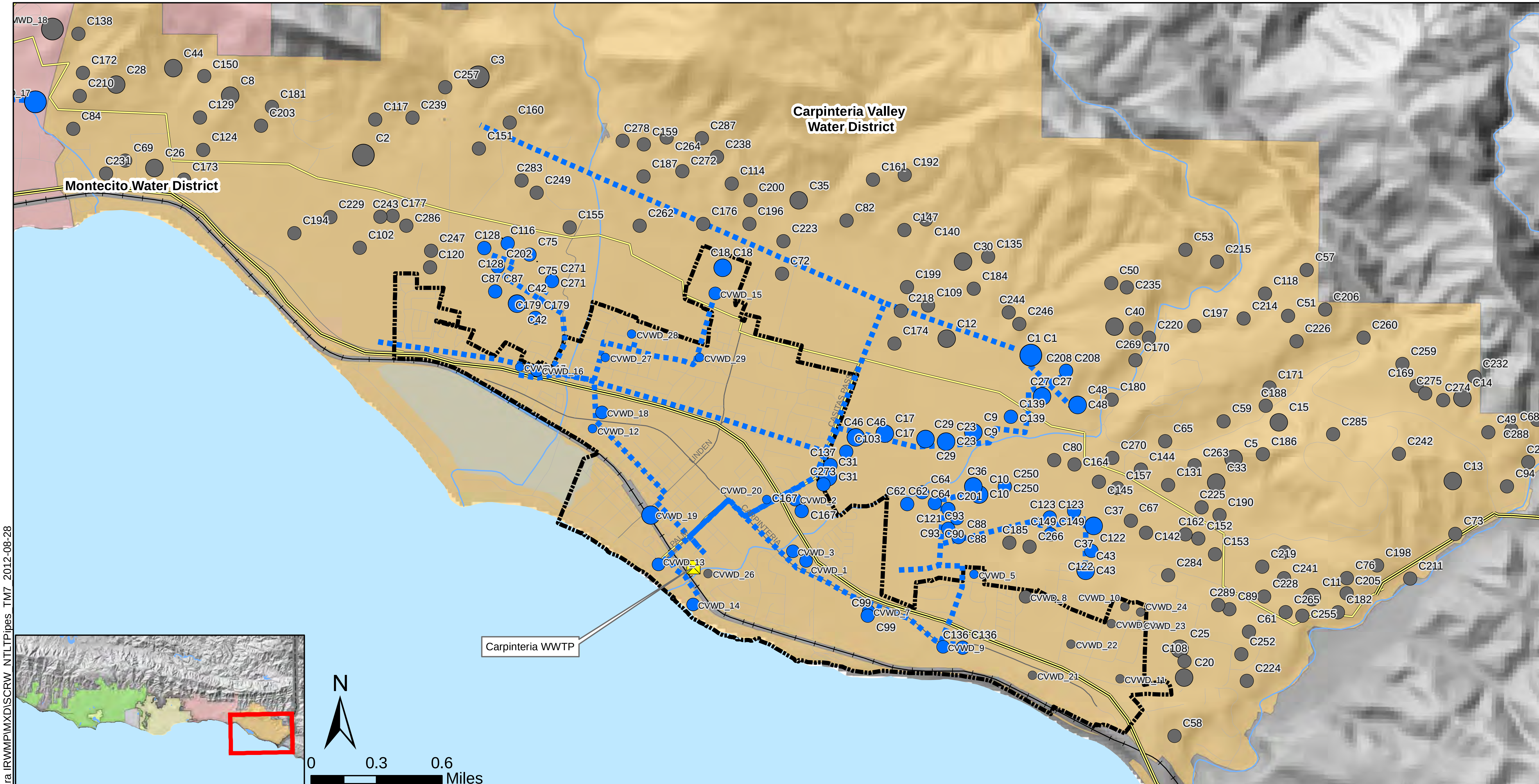
A total of 49,500 feet of pipeline would be needed to serve all selected demands as shown in **Figure 7-6**. The majority of the pipes would be 6- and 8-inches in diameter, with some 10-inch lines for the pipes stemming from the Carpinteria WWTP.

Pumping

A pump station would be needed at the Carpinteria WWTP, and the size of the pumps would vary based on the demand. If all the demands shown were included, then a 160-hp pump station would be needed. A booster station might be needed to the serve agriculture customers in the southeastern area. However, with increased pipe sizes (8" to 12") and depending on the pressure needs of the customers, this station might not be necessary. More detailed analysis would be needed to verify this, including examination of operational needs of potential customers.

Storage

An estimated 1.4 MG of storage capacity is needed at the treatment plant or within the system to supply recycled water during peak flow periods.



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Potential Long-Term Recycled Water Customer
Demand (AFY)
- Less than 5
- 5 to 20
- 20 to 50
- Greater than 50

Potential Long-Term Recycled Water System
- Customer
- Pipeline

Potential Near-Term Recycled Water System
- Customer
- Pipeline

Existing Recycled Water System
- Customer
- Pipeline

Not associated with Near- or Long-Term System
- Customer

Other Features
- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies
- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Long-Term Recycled Water System: Carpinteria Area

Figure 7-6

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Chapter 8 Potential Projects

This chapter summarizes the development and analysis of potential recycled water projects in the south coast subregion and presents the potential near- and long-term projects. A few optional projects developed for the long-term are also discussed. Preliminary facility sizing and estimated project costs are also presented in this chapter.

8.1 Analysis Approach

This section explains the development of potential recycled water projects and options in the four areas of the south coast subregion. Options are projects that are either exclusive projects due to a limited amount of available wastewater flow or are projects with extenuating circumstances such that they are not included directly in the final the long-term projects list for the south coast subregion.

As part of the south coast subregion planning effort, the participating agencies decided to formulate two time frames, near-term and long-term. Near-term potential projects could be implemented over the next ten years, and the potential long-term projects could be implemented over the next 20 to 30 years.

The following steps were conducted to develop the potential recycled water projects and options:

- Potential Customer Identification
  - Potential recycled water demands were identified for both the near- and long-term planning periods (see **Chapter 5**)
- Supply Assessment and Needs
  - Available average daily flows (see **Chapter 3)** and treatment plant improvement needs (see **Chapter 6**).were determined for each WWTP by 2030
- Planning Criteria and Distribution Needs
  - Facilities development and hydraulic criteria were established across the plan area and distribution needs to serve potential demands were identified for each area (see **Chapter 7**)

Potential recycled water projects and options were developed through a series of iterative steps that identified projects with the highest likelihood of implementation.

- Pipeline alignments were delineated from existing recycled water pipelines and from the WWTPs along major corridors to serve potential customers.
- Alignments and lengths of pipelines were computed in ArcGIS.
- Pipeline and demand information was incorporated into a hydraulic spreadsheet to define the necessary facilities, including pipeline diameters, pump station sizes, and storage capacity needs. Elevations were obtained through Google Earth, which were used to determine pump station needs and sizes.
- Cost estimates were then developed for each of the potential projects and options.

Note that actual pipeline, pump, and storage sizing would be dependent on comprehensive hydraulic analyses and customer demand scheduling on a project basis. The pipeline, pump, and storage sizing as well as pipeline lengths in the following table and figures are for conceptual purposes only.

For the Goleta and Santa Barbara areas, near- and long-term projects and options were developed from each agency’s most recent recycled water study and refined based on discussions with the individual agencies.

For the Montecito and Carpinteria areas, potential long-term projects and options were developed via a phased approach. The initial phased projects were developed to serve only potential users located near the

WWTPs. Subsequent phases were extended out from the initial phase projects until all identified demands were included or the maximum available wastewater flow was fully allocated.

8.2 Projects Summary

This section summarizes the customers and facilities for each potential recycled water project and option within the four areas: Goleta, Santa Barbara, Montecito/Summerland, and Carpinteria.

8.2.1 Goleta Area

A total of 12 potential recycled water projects were developed in the Goleta Area. Six potential projects were developed in both the near- and long-term planning period.

Summary of Projects

Figure 8-1 and **Figure 8-2** show the potential near- and long-term projects, respectively. **Table 8-1** shows a summary of the recycled water demands proposed for each potential project. **Table 8-2** shows a summary of the identified distribution system needs for each potential project. Individual projects are described following the tables.

Near-Term Projects

As shown in **Figure 8-1** six potential near-term projects were developed in the Goleta area. To implement the potential near-term projects, several system-wide improvements are first needed to maintain and upgrade GWD's current recycled water system. As discussed in Section 7.2.1, the following projects are necessary to expand the GWD system in near-term:

- Recycled Waterline Relocation Project at Goleta Beach
- Recycled Water 1-Million Gallon (MG) Reservoir
- Corrosion Protection and Pipeline Replacements
- Recycled Water Booster Station Electrical Upgrades at the Goleta WWTP

Projects G-1 through G-6

Projects G-1 through G-6 would provide recycled water to six potential customers (total of seven separate connection points) located along the existing recycled water system. These projects are planned to be implemented in conjunction with GWD's existing system improvements as previously discussed.

Long-Term Projects

As shown in **Figure 8-2**, six potential long-term projects were developed in the Goleta area. For implementation of potential long-term projects, two additional system-wide improvements are needed in the future as discussed in Section 7.2.1:

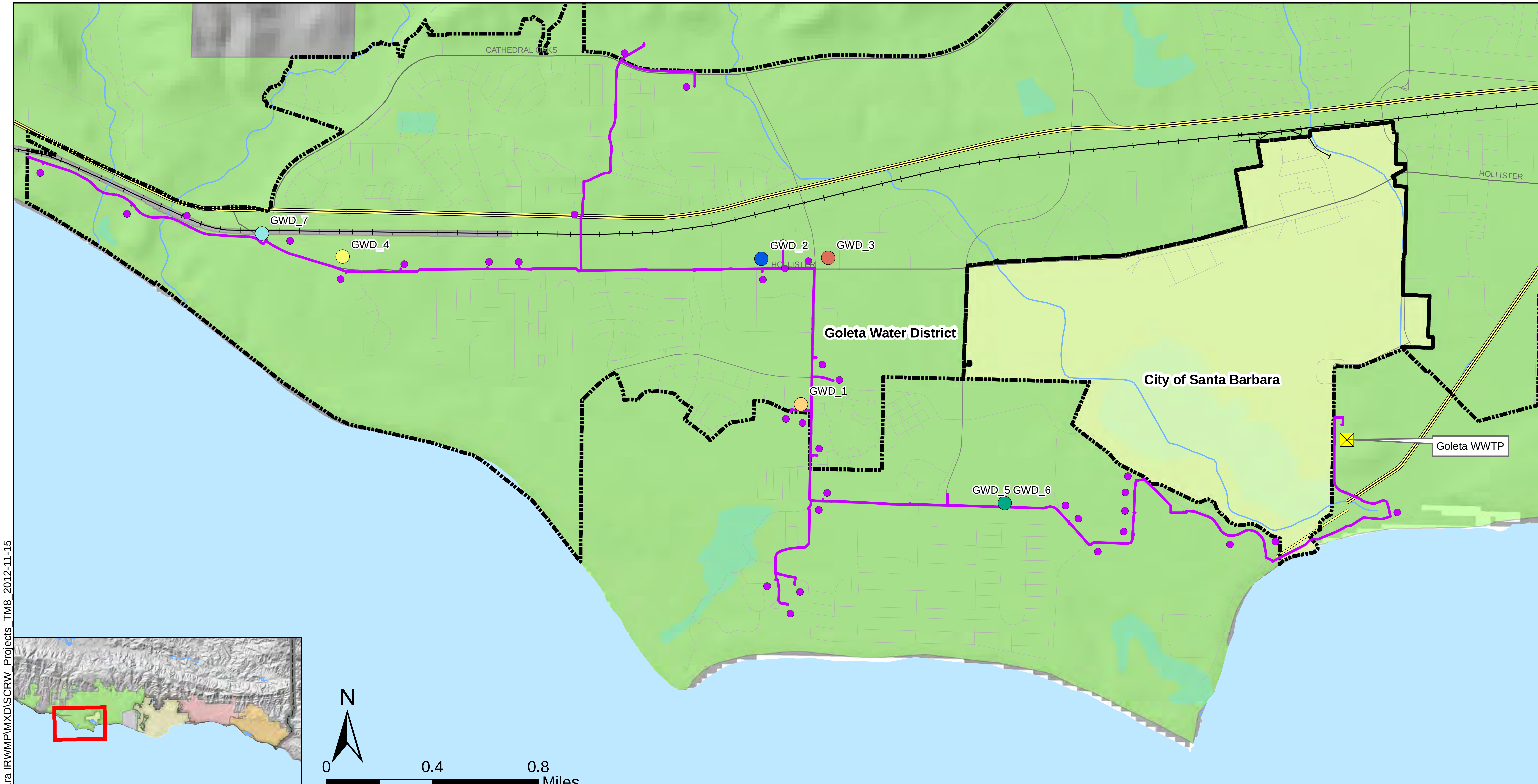
- Recycled Water Hollister Booster Station Relocation Project
- RW PR Vault Relocation at Glen Annie Golf Course

Project G-8

Project G-8 would provide recycled water to thirteen potential customers located in Isla Vista, south of the existing recycled water pipeline. The majority of these customers are small city parks.

Projects G-9 through G-12

Projects G-9 through G-12 would provide recycled water to six potential customers (seven connections) located near the existing recycled water pipeline. Individual lengths for these projects were provided by GWD as they have conducted more detailed evaluations of the conversion of these sites to recycled water.



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RMC Water and Environment

Goleta Projects
- G-1
- G-2
- G-3
- G-4
- G-5
- G-6

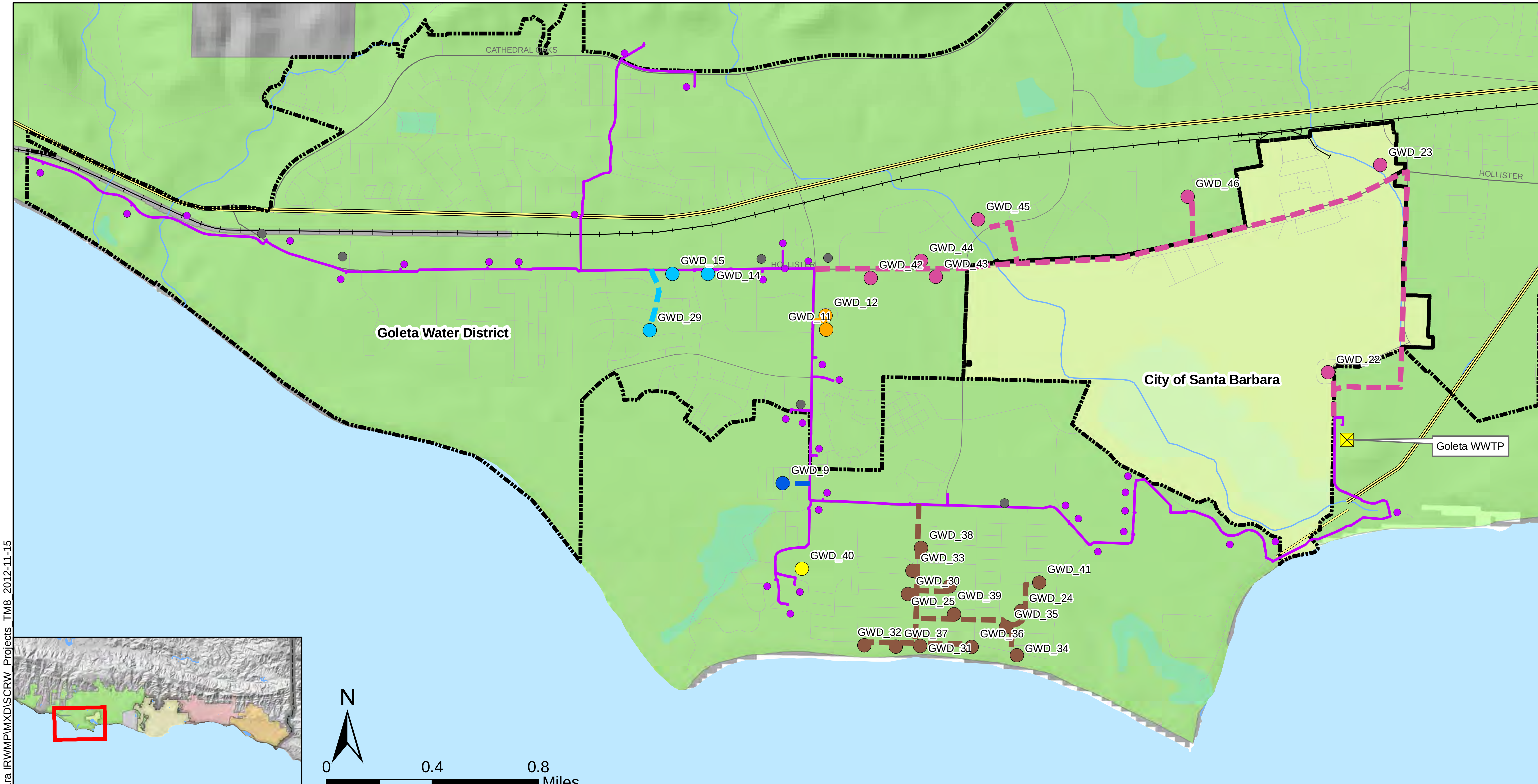
Existing Recycled Water System
- Customer
- Pipeline

Other Features
- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies
- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Near-Term Recycled Water Projects: Goleta Area

Figure 8-1



Santa Barbara County IRWMP
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RMC Water and Environment

Goleta Projects

- G-8
- G-9
- G-10
- G-11
- G-12
- G-13

Potential Near-Term Recycled Water System

- Customer
- Pipeline

Existing Recycled Water System

- Customer
- Pipeline

Other Features

- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies

- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Long-Term Recycled Water Projects: Goleta Area

Figure 8-2

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Table 8-1: Potential Demands by Project – Goleta Area

Project No.	Customer ID	Customer Name	Customer Type	Demand (AFY)	Total Demand (AFY)
Near-Term Projects					
G-1	GWD_5	El Colegio RW Medians Phase 1	Urban Irrigation	0.2	**0.4**
	GWD_6	El Colegio RW Medians Phase 2	Urban Irrigation	0.2	
G-2	GWD_1	UCSB Sierra Madre Apartments	Urban Irrigation	0.5	**0.5**
G-3	GWD_3	Rincon Palms Hotel	Urban Irrigation	0.7	**0.7**
G-4	GWD_2	Westar Associates	Urban Irrigation	10.4	**10.4**
G-5	GWD_4	Haskell's Landing	Urban Irrigation	13.5	**13.5**
G-6	GWD_7	Caltrans US101 at Cathedral Oaks Road	Urban Irrigation	1.2	**1.2**
Total Near-Term Demands (AFY)					**26.7**
Long-Term Projects					
G-8	GWD_24	Anisq Oyo Park and Peoples' Park	Urban Irrigation	3.7	**11.5**
	GWD_25	Trigo-Pasado Park	Urban Irrigation	0.4	
	GWD_30	Sueno Orchard	Urban Irrigation	0.5	
	GWD_31	Window to the Sea Park	Urban Irrigation	0.3	
	GWD_32	Sea Lookout Park	Urban Irrigation	1.2	
	GWD_33	Estero Park	Urban Irrigation	1.2	
	GWD_34	Pelican Park	Urban Irrigation	0.5	
	GWD_35	Little Acorn Park	Urban Irrigation	0.7	
	GWD_36	Camino Pescadero Park	Urban Irrigation	0.2	
	GWD_37	Walter Capps Park	Urban Irrigation	0.9	
	GWD_38	Children's Park	Urban Irrigation	1.0	
	GWD_39	Sueno Park	Urban Irrigation	0.5	
	GWD_41	Pardall Gardens	Urban Irrigation	0.4	
G-9	GWD_40	Tierra de Fortuna Park	Urban Irrigation	0.4	**0.4**
G-10	GWD_9	Married Student Housing	Urban Irrigation	2.0	**2.0**
G-11	GWD_11	East side of Storke, N. of Santa Felicia	Urban Irrigation	0.5	**1.0**
	GWD_12	East side of Storke, N. of Santa Felicia	Urban Irrigation	0.5	
G-12	GWD_14	DMV Camino Real Shopping Center	Urban Irrigation	0.6	**4.9**
	GWD_15	Pacific Oaks/Davenport Rd.	Urban Irrigation	0.8	
	GWD_29	Gol Pk/greenbelt	Urban Irrigation	3.5	

Table 8-1: Potential Demands by Project – Goleta Area

Project No.	Customer ID	Customer Name	Customer Type	Demand (AFY)	Total Demand (AFY)
G-13	GWD_22	Santa Barbara Airport	Urban Irrigation	0.5	**38.2**
	GWD_23	Twin Lakes Golf Course	Urban Irrigation	16.0	
	GWD_42	Hollister Business Park	Urban Irrigation	4.6	
	GWD_43	Cabrillo Bus. Park (includes Los Carneros and Hollister medians)	Urban Irrigation	3.0	
	GWD_44	Coromar Office Buildings	Urban Irrigation	1.5	
	GWD_45	Village at Los Carneros Housing Project	Urban Irrigation	10.0	
	GWD_46	Raytheon Offices	Urban Irrigation	2.6	
Total Long-Term Demands (AFY)					**58.0**
Total Near and Long-Term Demands (AFY)					**84.7**

Table 8-2: Identified Distribution Needs by Project - Goleta Area

Project No.	Pipeline		Pump Station		Storage Capacity Needed (MG)
	Diam. (in)	Length (ft)	No.	Size (hp)	
Near-Term Projects					
G-1 through G-6	-	-	-	-	-
Total Near-Term	**-**	**-**	**-**	**-**	**-**
Long-Term Projects					
G-8	6	9,400	-	-	-
G-9	6	570	-	-	-
G-10	6	40	-	-	-
G-11	6	150	-	-	-
G-12	6	4,000	-	-	-
G-13	12	20,600	-	-	-
Total Long-Term	**6-12**	**34,760**	**-**	**-**	**-**
Total (Near- + Long-Term)	**6-12**	**34,760**	**-**	**-**	**-**

Project G-13

Project G-13 would connect to seven potential customers and loop GWD's existing recycled water system around the Santa Barbara Airport. This would significantly improve reliability of service to GWD's customers. Project G-13 would require installing approximately 20,600 feet of a large diameter pipelines (estimated to be 12-inch for purposed of this study) from Goleta WWTP to the existing recycled water system connection at Hollister and Storke.

8.2.2 Santa Barbara

In the Santa Barbara area, seven potential near-term and eight potential long-term projects, as well as two long-term options, were developed. As discussed in Section 6.3.2, planned upgrades of the El Estero WWTF are necessary to bring the current recycled water production back on line and to provide recycled water supplies for future expansion in both the near- and long-term.

Summary of Projects

Figure 8-3 and **Figure 8-4** show the potential near- and long-term projects, respectively. **Table 8-3** shows a summary of the recycled water demands proposed for each potential project or option. **Table 8-4** shows a summary of the identified distribution system needs for each potential project or option. Individual projects are described following the tables.

Near-Term Projects

As shown in **Figure 8-3**, seven potential near-term projects were developed in the Santa Barbara area.

Projects SB-1 through SB-6

Projects SB-1 through SB-6 would provide recycled water to 11 potential customers located along the existing recycled water system. Most of these projects were developed in the City's 2009 Water Supply Planning Study and are mainly irrigation customers. No additional pipeline, pump stations, or storage is needed to serve these customers, as only onsite conversion from potable to recycled water is required at these locations.

Project SB-7

Project SB-7 would install 4,000 feet of 6-inch diameter pipeline to serve three irrigation customers. This project was also identified in the City's 2009 Water Supply Planning Study. However, connection to one user, Educated Car Wash, is included in the potential long-term Project, SB-13, as the City has concerns about being able to meet the customer's water quality needs. Once the upgrades at the El Estero WWTF are completed, the status of this potential project should be re-assessed.

Long-Term Projects

As shown in **Figure 8-4**, eight potential long-term projects were developed in the Santa Barbara area.

Project SB-8

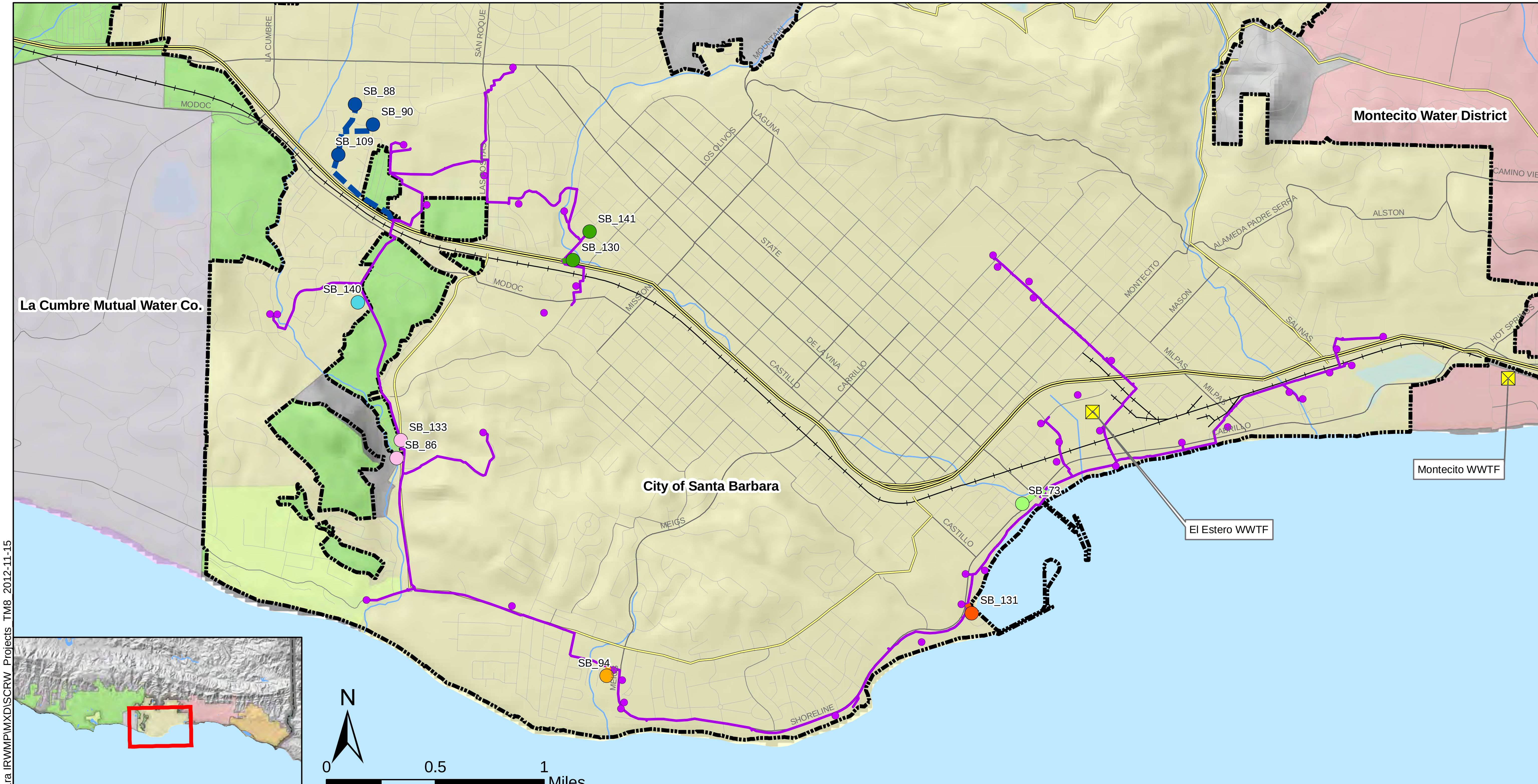
Project SB-8 would extend the City's existing system further east to connect to Clark Estate and three other customers along the beach area. The project would require installing approximately 4,300 feet of 6-inch diameter pipeline to serve the four identified irrigation customers.

Project SB-9

Project SB-9 would extend the City's existing system to connect to two parks and a school. The project would require installing approximately 3,200 feet of 6-inch diameter pipeline to serve the three identified irrigation customers.

Project SB-10

Project SB-10 would connect two commercial customers via short laterals from the existing system. Connection to industrial/commercial customers is a concern due to water quality at the El Estero WWTF. Upgrades at the plant may provide adequate water quality to meet these potential reuse customer needs. Their water quality needs should be re-assessed once the El Estero upgrades are completed.



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Santa Barbara Projects

- SB-1
- SB-2
- SB-3
- SB-4
- SB-5
- SB-6
- SB-7

Existing Recycled Water System

- Customer
- Pipeline

Other Features

- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies

- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Near-Term Recycled Water Projects: Santa Barbara Area

Figure 8-3

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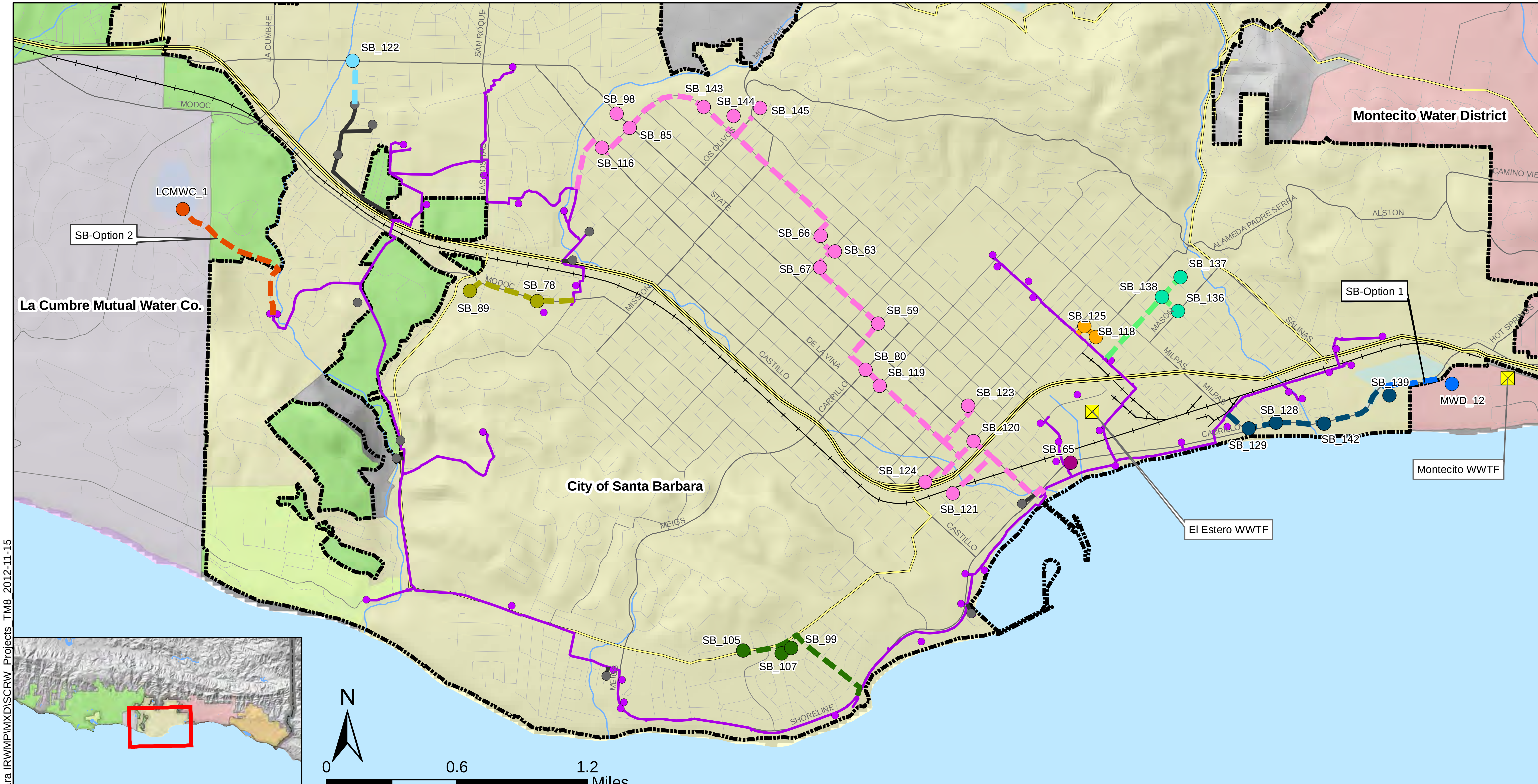

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Santa Barbara County IRWMP
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Santa Barbara Projects

- SB-8
- SB-9
- SB-10
- SB-11
- SB-12
- SB-13
- SB-14
- SB-15
- SB Option 1
- SB Option 2

Potential Near-Term Recycled Water System

- Customer
- Pipeline

Existing Recycled Water System

- Customer
- Pipeline

Other Features

- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies

- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Long-Term Recycled Water Projects: Santa Barbara Area

Figure 8-4

Table 8-3: Potential Demands by Project – Santa Barbara Area

Project No.	Customer ID	Customer Name	Customer Type	Demand (AFY)	Total Demand (AFY)
Near-Term Projects					
S-1	SB_73	Harbor View Inn	Urban Irrigation	2.2	**2.2**
S-2	SB_131	Marina Restrooms	Industrial/Commercial	1.9	**1.9**
S-3	SB_130	Elise Court Owners	Urban Irrigation	1.0	**4.0**
	SB_141	Cottage Hospital (Expansion to cooling towers)	Commercial	3.0	
S-4	SB_140	First Baptist Church	Urban Irrigation	4.0	**4.0**
S-5	SB_133	Las Positas Tennis Courts	Irrigation/Toilets	1.9	**6.4**
	SB_86	Stone Creek Owners Association[1]	Urban Irrigation	4.5	
S-6	SB_94	Reef Court Owners	Urban Irrigation	2.3	**2.3**
S-7	SB_109	Santa Barbara Auto Group	Urban Irrigation	3.4	**20.2**
	SB_88	Towbes Group Inc	Urban Irrigation	6.7	
	SB_90	Franciscan Villas Association	Urban Irrigation	10.1	
Total Near-Term Demand (AFY)					**41.0**
Long-Term Projects					
S-8	SB_128	Hotel Mar Monte	Urban Irrigation	0.8	**14.8**
	SB_129	Santa Barbara Inn	Urban Irrigation	1.5	
	SB_139	Clark Estate	Urban Irrigation	10.0	
	SB_142	East Beach	Urban Irrigation	2.5	
S-9	SB_136	Sunflower Park	Urban Irrigation	0.5	**14.7**
	SB_137	Eastside Neighborhood Park	Urban Irrigation	3.0	
	SB_138	Franklin Park & School	Urban Irrigation	11.2	
S-10	SB_118	MISSION LINEN SUPPLY	Industrial/Commercial	29.1	**41.4**
	SB_125	MISSION LINEN SUPPLY	Industrial/Commercial	12.3	

Table 8-3: Potential Demands by Project – Santa Barbara Area

Project No.	Customer ID	Customer Name	Customer Type	Demand (AFY)	Total Demand (AFY)
S-11	SB_116	LAUNDERLAND	Industrial/Commercial	17.9	**116.0**
	SB_119	S B HAND CAR WASH	Industrial/Commercial	5.6	
	SB_120	ABLITT'S FINE CLEANERS	Industrial/Commercial	4.5	
	SB_121	FIESTA CAR WASH	Industrial/Commercial	3.4	
	SB_123	DALEE CAR BATH	Industrial/Commercial	4.5	
	SB_124	ST PAUL CLEANERS	Industrial/Commercial	3.4	
	SB_143	San Roque High School	Urban Irrigation	7.0	
	SB_144	SB Old Mission	Urban Irrigation	8.0	
	SB_145	Mission Rose Gardens	Urban Irrigation	4.5	
	SB_59	County of Santa Barbara	Urban Irrigation	11.2	
	SB_63	City of Santa Barbara	Urban Irrigation	12.3	
	SB_66	City of Santa Barbara	Urban Irrigation	10.1	
	SB_67	City of Santa Barbara	Urban Irrigation	12.3	
	SB_80	Ralphs Grocery	Urban Irrigation	3.4	
	SB_85	Villa Constance South	Urban Irrigation	3.4	
	SB_98	Villa Constance North	Urban Irrigation	4.5	
S-12	SB_78	Vista Madera Owners Association	Urban Irrigation	4.5	**10.1**
	SB_89	Las Positas Meadows HOA	Urban Irrigation	5.6	
S-13	SB_122	Educated Car Wash	Industrial/Commercial	9.0	**9.0**
S-14	SB_105	Shifco	Urban Irrigation	3.4	**11.3**
	SB_107	Vista Pacifica Home	Urban Irrigation	3.4	
	SB_99	Vista Pacifica Home	Urban Irrigation	4.5	
S-15	SB_65	Chase Palm Park (Expansion)	Urban Irrigation	14.6	**14.6**
Total Long-Term Demand (AFY)					**231.9**
Total Near- and Long-Term Demand (AFY)					**272.9**
Long-Term Options					
Opt. 1	MWD_12	Santa Barbara Cemetery	Urban Irrigation	139.0	**139.0**
Opt. 2	LCMWC_1	La Cumbre Golf and Country Club	Urban Irrigation	126.6	**126.6**
Total Long-Term Option Demand (AFY)					**265.6**
Total Near- and Long-Term and Option Demand (AFY)					**538.5**

Table 8-4: Identified Distribution Needs by Project – Santa Barbara Area

Project No.	Pipeline		Pump Station		Storage Capacity Needed (MG)
	Diam. (in)	Length (ft)	No.	Size (hp)	
Near-Term Projects					
SB-1 through SB-6	-	-	-	-	-
SB-7	6	4,400	-	-	-
Total Near-Term	**6**	**4,400**	**-**	**-**	**-**
Long-Term Projects					
SB-8	6	4,300	-	-	-
SB-9	6	3,200	-	-	-
SB-10	-	-	-	-	-
SB-11	6	25,200	1	20	-
SB-12	6	2,700	-	-	-
SB-13	6	1,200	-	-	-
SB-14	6	4,000	1	10	-
SB-15	-	-	-	-	-
Total Long-Term	**6**	**40,600**	**2**	**10, 20**	**-**
Total (Near + Long-Term)	**6**	**45,000**	**2**	**10, 20**	**-**
Long-Term Options					
SB-Option 1	6	1,500	-	-	-
SB-Option 2	6	4,000	-	-	-
Total (with Options)	**6**	**50,500**	**2**	**10, 20**	**-**

Project SB-11

Project SB-11 would install approximately 25,200 feet of 6-inch diameter pipeline to loop the existing recycled water system and thus, improving the reliability of service to the City's customers. This project would loop the system by installing pipelines through the center of Santa Barbara and connect to the existing system at Castillo Street and Alamar Avenue. Santa Barbara's Old Mission and other potential recycled water customers adjacent to the new line would be connected to the recycled water system.

Project SB-12

Project SB-12 would extend the City's existing system to connect to two irrigation customers. The project would require installing approximately 2,700 feet of 6-inch diameter pipeline.

Project SB-13

Project SB-13 is a proposed expansion of the near-term project SB-7 that would connect to the Educated Car Wash. The project would require installing approximately 1,200 feet of 6-inch diameter pipeline. Customer water quality needs will need to be considered in light of the proposed upgrades at the El Estero WWTF.

Project SB-14

Project SB-14 is a proposed extension of the City's existing system and would connect to three identified irrigation customers. The project would require installing approximately 4,000 feet of 6-inch diameter pipeline.

Project SB-15

Project SB-10 would expand the amount of recycled water being used at the City's Chase Palm Park. The park is currently using recycled water for its turf areas. The park has sensitive plants and once the recycled water processes at the El Estero WWTF are upgraded, the water quality may be adequate to serve recycled water to the entire Park's irrigation systems. The actual water quality needs should be re-assessed once the El Estero upgrades are completed.

Long-Term Project Options

SB-Option 1

Project SB-Option 1 would extend 1,500 feet of 6-inch diameter pipeline from Project SB-8 to connect to the Santa Barbara Cemetery. The Santa Barbara Cemetery is a MWD customer, and therefore, an agreement between the two agencies would be needed. MWD does not currently serve recycled water.

SB-Option 2

Project SB-Option 2 would extend the existing system to supply the La Cumbre Golf and Country Club. A pump station to the La Cumbre Golf and Country Club is not needed if the Club's existing pond can serve as diurnal storage for irrigation at the Club. As discussed in Section 7.2.2, the recycled water could be stored in the Club's existing water pond and be pumped from the pond for irrigation of the course during the night. Minimum pressure would be needed to fill the pond and is likely possible with the proposed system expansions in the near- and long-term. The La Cumbre Golf and Country Club currently receives water from the La Cumbre Mutual Water District by agreement with the GWD. Therefore an agreement between the three agencies would be necessary as part of the implementation of this project. The La Cumbre Mutual Water District does not serve recycled water. This option would require an extension of 4,000 feet of 6-inch diameter pipeline from the existing system.

8.2.3 Montecito Area

Three potential long-term projects were developed in the Montecito Area, two to be supplied from the Montecito WWTF and one from the Summerland WWTP. In addition, two potential options were developed from the Summerland WWTP. As discussed in Section 7.2.3, the potential reuse projects are dependent upon upgrades at the Montecito WWTF and the Summerland WWTP to produce Title 22 quality water. The Summerland Sanitary District is interested in implementing a recycled water project and has expressed interest in working with the MWD to further explore such opportunities.

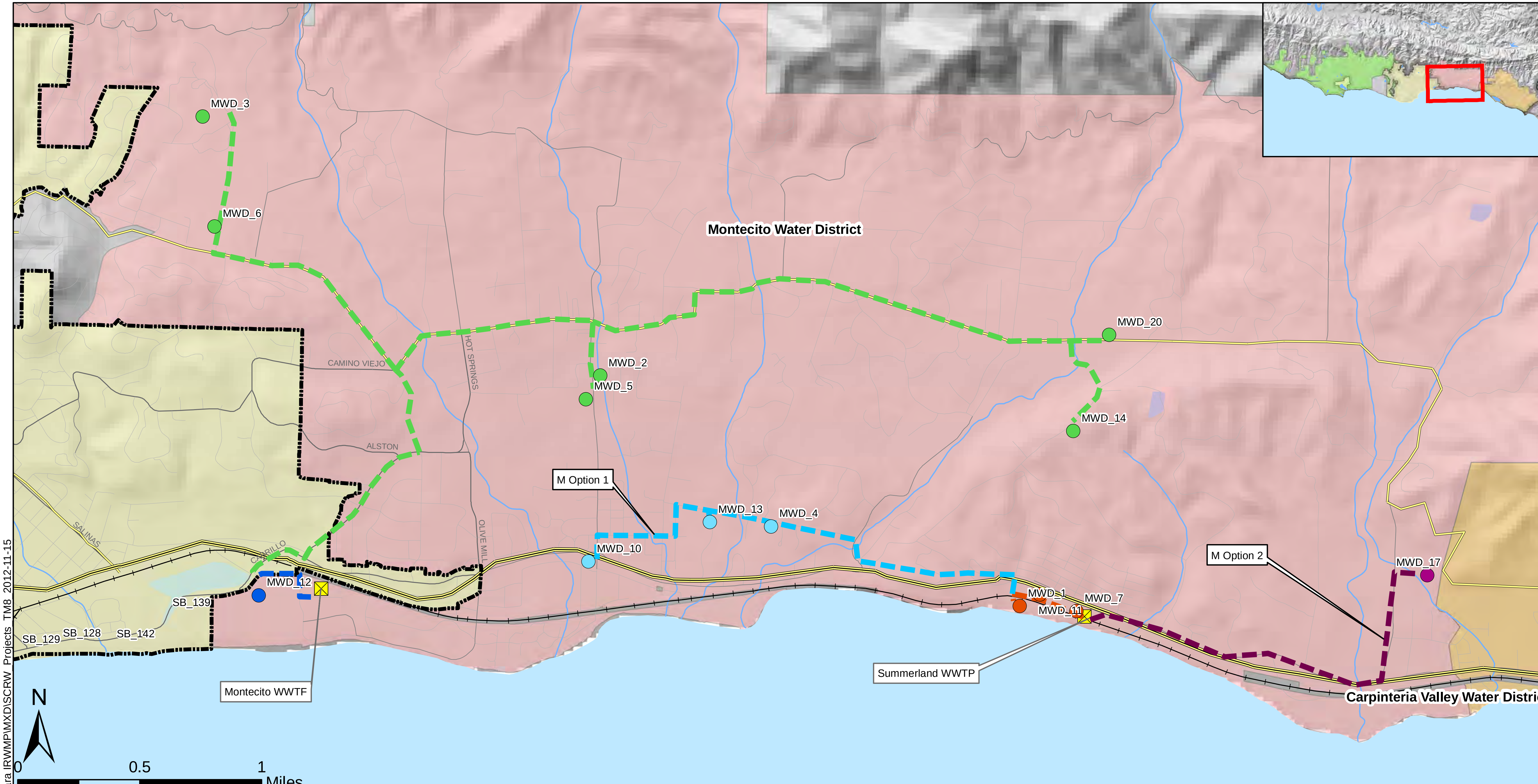
Summary of Projects

Figure 8-5 shows the potential long-term projects. **Table 8-5** shows a summary of the recycled water demands proposed for each potential project or option. **Table 8-6** shows a summary of the identified distribution system needs for each potential project or option. Individual projects are described following the tables.

Long-Term Projects

Project M-1

Project M-1 would be the first recycled water pipeline from the Montecito WWTF and would serve the Santa Barbara Cemetery with recycled water. The project would require installing approximately 1,700 feet of 8-inch diameter pipeline to serve the cemetery and a 100-hp pump station, assuming Project M-2 was implemented. If Project M-2 was not implemented, then the pipeline diameter and pump station could both be reduced in size to serve just the cemetery.



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Montecito Projects
- M-1
- M-2
- M-3
- M Option 1
- M Option 2

Existing Recycled Water System
- Customer

Other Features
- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies
- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Long-Term Recycled Water Projects: Montecito Area

Figure 8-5

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Table 8-5: Potential Demands by Project – Montecito Area

Project No.	Customer ID	Customer Name	Customer Type	Demand (AFY)	Total Demand (AFY)
Long-Term Projects					
M-1	MWD_12	Santa Barbara Cemetery	Urban Irrigation	139	**139**
M-2	MWD_14	Agricultural Land	Agriculture	261	**449**
	MWD_2	Manning Park	Urban Irrigation	30	
	MWD_20	Agricultural Land	Agriculture	40	
	MWD_3	Westmont College	Urban Irrigation	100	
	MWD_5	Montecito Union School	Urban Irrigation	8	
	MWD_6	Cold Spring Elementary School	Urban Irrigation	10	
M-3	MWD_1	Lookout Park	Urban Irrigation	8	**15**
	MWD_11	Caltrans (Summerland)	Urban Irrigation	5	
	MWD_7	Summerland School	Urban Irrigation	2	
Total Long-Term Demand (AFY)					**603**
Long-Term Options					
Opt. 1	MWD_10	Caltrans (Montecito)	Urban Irrigation	9	**35**
	MWD_13	Lemons and Avocados	Agriculture	6	
	MWD_4	Crane County Day School	Urban Irrigation	20	
Opt. 2	MWD_17	Agricultural Land	Agriculture	56	**56**

Table 8-6: Identified Distribution Needs by Project – Montecito Area

Project No.	Pipeline		Pump Station		Storage Capacity Needed (MG)
	Diam. (in)	Length (ft)	No.	Size (hp)	
Long-Term Projects from Montecito WWTF					
M-1	8	1,700	1	100	1.0
M-2	6-8	35,400	0	0	0.0
Total Long-Term from Montecito WWTF	**6-8**	**37,100**	**1**	**100**	**1.0**
Long-Term Projects from Summerland WWTP					
M-3	6	1,800	1	10	0.0
Long-Term Options from Summerland WWTP					
M-Option 1	6	11,500	1	10	0.1
M-Option 2	6	9,500	1	10	0.1
Total Long-Term from Summerland WWTP (Including M-Option 2)	**6**	**11,300**	**2**	**10, 10**	**0.1**
Total Long-Term for Montecito Area (Including M-Option 2)	**6-8**	**48,400**	**3**	**10, 10, 100**	**1.2**

Project M-2

Project M-2 would extend recycled water system from the Santa Barbara Cemetery to serve six additional customers north of Highway 101. The project would require installing approximately 35,400 feet of 6 to 8-inch diameter pipeline. Project M-2 would also require two booster pump stations along the alignment. One 20 hp pump station would serve the eastern alignment and one 30 hp pump station would serve the northern alignment.

Project M-3

Project M-3 would provide recycled water from the Summerland WWTP to three customers near the plant. The project would require installing approximately 1,800 feet of 6-inch diameter pipeline and a 10 hp pump station to serve the these customers.

M-Option 1

Montecito Option 1 would extend from the Project M-3 pipeline to serve three customers in the western area. This optional project would require installing approximately 11,500 feet of 6-inch diameter pipeline and a 10 hp pump station to serve these customers.

M-Option 2

Montecito Option 2 would extend east from the Summerland WWTP to serve an agriculture customer. The option would require installing approximately 9,500 feet of 6-inch diameter pipeline and a 10 hp pump station.

8.2.4 Carpinteria Area

Three potential long-term projects were developed in the Carpinteria area. As discussed in Section 7.2.4, the potential reuse projects are dependent upon upgrades at the Carpinteria WWTP to produce Title 22 quality water. A potential option for an indirect potable reuse and/or seawater intrusion project(s) was also identified. Such a project would require upgrade of the treatment plant advanced levels as required by the California Department of Public Health.

Summary of Projects

Figure 8-6 shows the potential long-term projects, and **Figure 8-7** shows the Indirect Potable Reuse/Seawater Intrusion Project Option. **Table 8-7** shows a summary of the recycled water demands proposed for each potential project or option. **Table 8-8** shows a summary of the identified distribution system needs for each potential project or option. Individual projects are described following the tables.

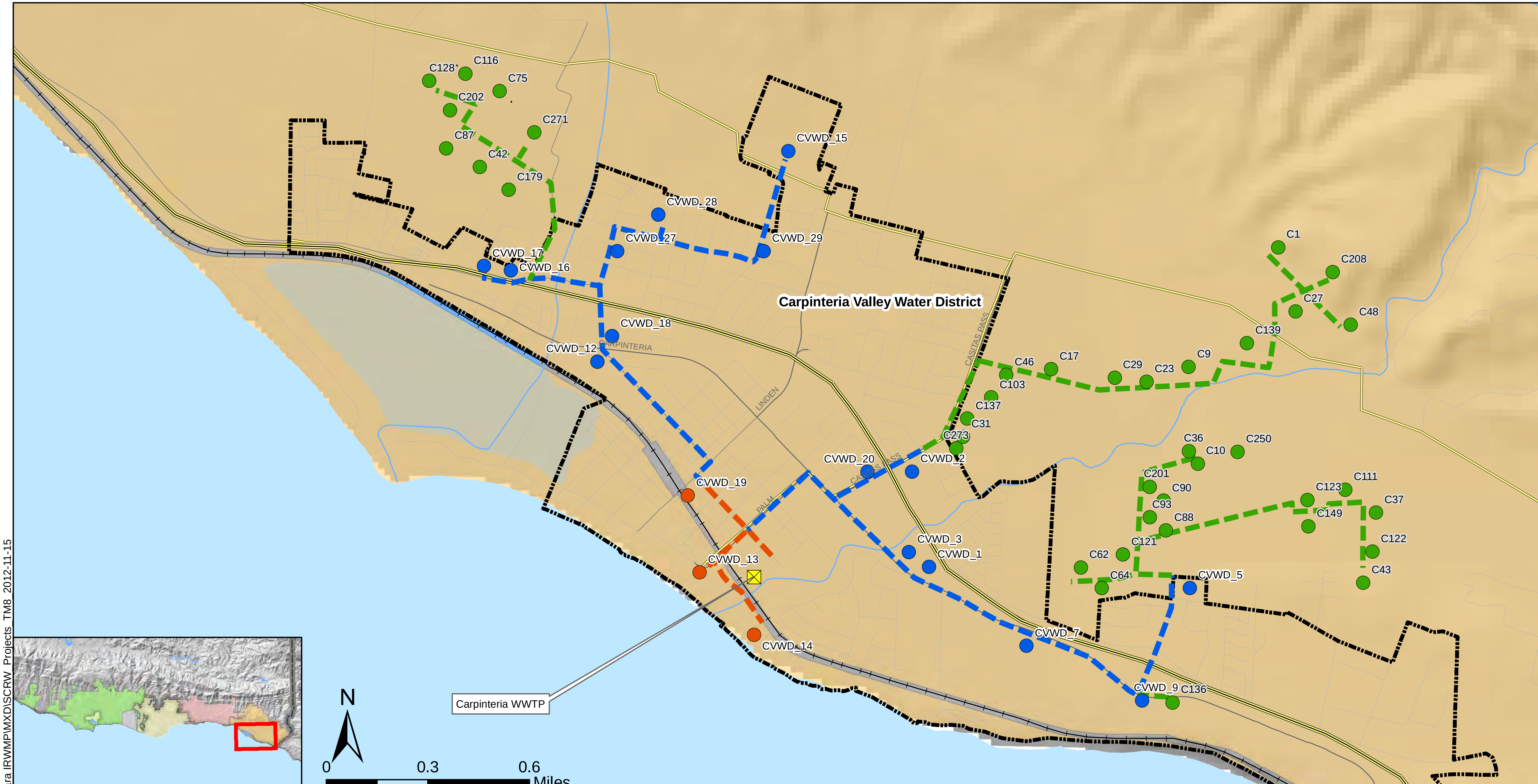
Long-Term Projects

Project C-1

Project C-1 would extend from the Carpinteria WWTP and serve three customers near the plant. The project would require installing approximately 3,600 feet of 10-inch diameter pipeline and a 150 hp pump station. These facilities are sized based on the implementation of the potential Projects C-2 and C-3. If Projects C-2 and C-3 were not implemented, then the Project C-1 facilities could be reduced in size.

Project C-2

Project C-2 would extend from Project C-1 and serve 15 customers located in the City of Carpinteria. The project would require installing approximately 21,900 feet of 6 to 8-inch diameter pipeline. Project C-2 is dependent on Project C-1 being constructed.



Santa Barbara County IRWMP
South Coast Recycled Water
Development Plan

RMC
Water and Environment

Carpinteria Projects
- C-1
- C-2
- C-3

Existing Recycled Water System
- Customer
- Pipeline

Other Features
- WWTP
- State Highway
- US Highway
- Railroad
- City Boundary

Water Agencies
- Carpinteria Valley Water District
- City of Santa Barbara
- Goleta Water District
- La Cumbre Mutual Water Co.
- Montecito Water District

Potential Long-Term Recycled Water Projects: Carpinteria Area

Figure 8-6

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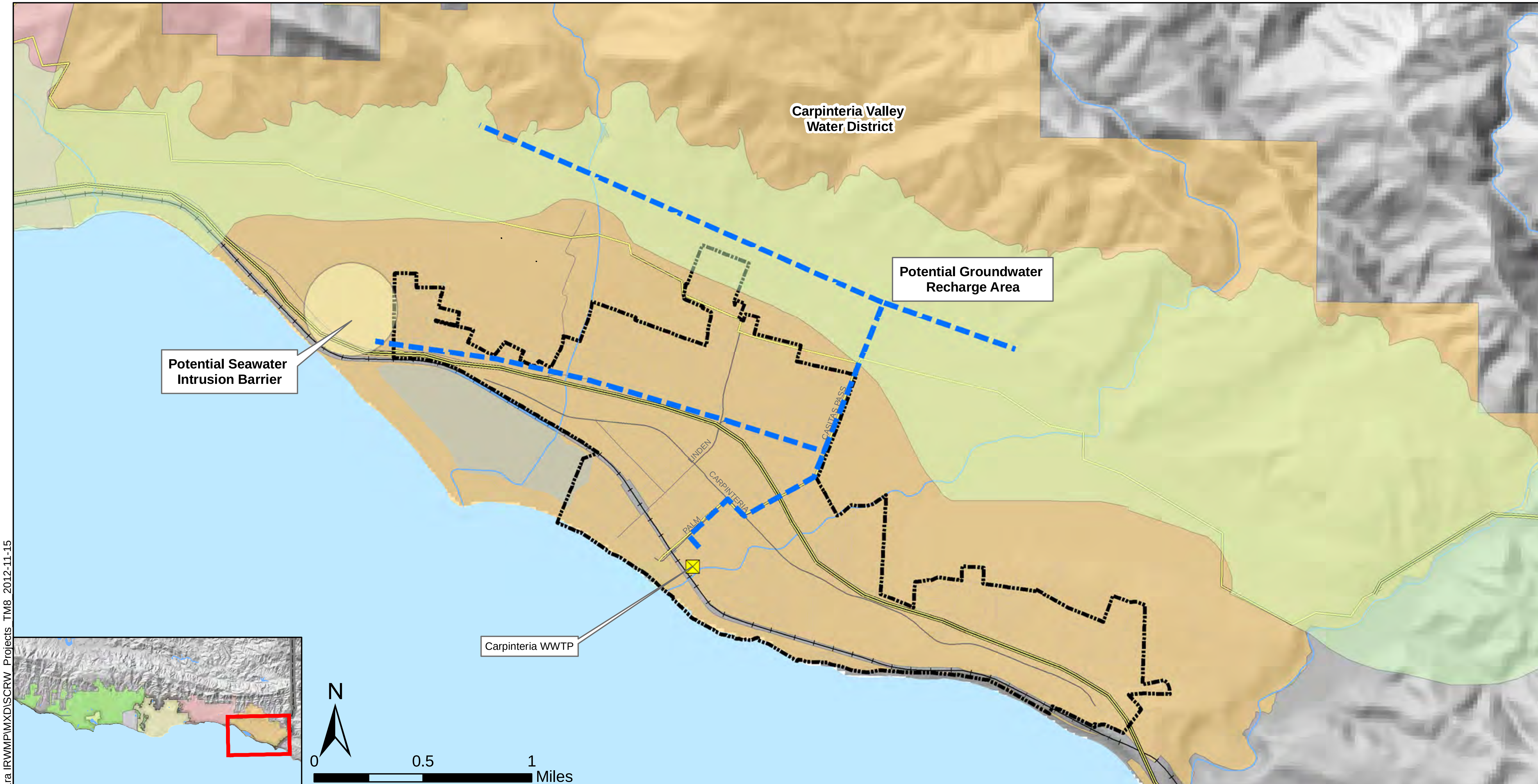

Santa Barbara County IRWMP
South Coast Recycled Water
Development Plan

RMC Water and Environment

Carpinteria Project
Indirect Potable Reuse/Seawater Intrusion

Other Features
WWTP
State Highway
US Highway
Railroad
City Boundary

Water Agencies
Carpinteria Valley Water District
City of Santa Barbara
Goleta Water District
La Cumbre Mutual Water Co.
Montecito Water District

Potential Long-Term Indirect Potable Reuse Project: Carpinteria Area

Figure 8-7

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Table 8-7: Potential Demands by Project – Carpinteria Area

Project No.	Customer ID	Customer Name	Customer Type	Demand (AFY)	Total Demand (AFY)
Long-Term Projects					
C-1	CVWD_13	Recreational Open	Urban Irrigation	8	**40**
	CVWD_14	Park	Urban Irrigation	10	
	CVWD_19	Commercial	Industrial/Commercial	22	
C-2	CVWD_1	Hotel	Industrial/Commercial	8	**80**
	CVWD_12	School	Industrial/Commercial	4	
	CVWD_15	School	Industrial/Commercial	6	
	CVWD_16	Hotel	Industrial/Commercial	6	
	CVWD_17	Hotel	Industrial/Commercial	2	
	CVWD_18	Hotel	Industrial/Commercial	7	
	CVWD_2	Orchard, Irrigated	Urban Irrigation	6	
	CVWD_20	Commercial	Industrial/Commercial	2	
	CVWD_27	Parks	Urban Irrigation	2	
	CVWD_28	Parks	Urban Irrigation	2	
	CVWD_29	Recreational Open	Urban Irrigation	2	
	CVWD_3	Hotel	Industrial/Commercial	8	
	CVWD_5	Irrigated Farm	Urban Irrigation	5	
	CVWD_7	Commercial	Industrial/Commercial	14	
	CVWD_9	Industrial	Industrial/Commercial	6	
C-3	C1	Avocado	Agriculture	76	**691**
	C10	Avocado	Agriculture	34	
	C103	Avocado	Agriculture	14	
	C111	Avocado	Agriculture	13	
	C116	Avocado	Agriculture	13	
	C121	Avocado	Agriculture	12	
	C122	Avocado	Agriculture	12	
	C123	Avocado	Agriculture	12	
	C128	Avocado	Agriculture	12	
	C136	Park / Sports Field	Agriculture	11	
	C137	Avocado	Agriculture	11	
	C139	Avocado	Agriculture	11	
	C149	Avocado	Agriculture	10	
	C17	Avocado	Agriculture	30	
	C179	Avocado	Agriculture	8	
	C201	Avocado	Agriculture	7	
	C202	Avocado	Agriculture	7	
	C208	Horse Facilities / Pasture	Agriculture	7	

Table 8-7: Potential Demands by Project – Carpinteria Area

Project No.	Customer ID	Customer Name	Customer Type	Demand (AFY)	Total Demand (AFY)
	C23	Avocado	Agriculture	26	
	C250	Avocado	Agriculture	6	
	C27	Avocado	Agriculture	25	
	C271	Avocado	Agriculture	5	
	C273	Avocado	Agriculture	5	
	C29	Avocado	Agriculture	25	
	C31	Avocado	Agriculture	24	
	C36	Avocado	Agriculture	23	
	C37	Avocado	Agriculture	23	
	C42	Avocado	Agriculture	21	
	C43	Lemons	Agriculture	21	
	C46	Avocado	Agriculture	20	
	C48	Avocado	Agriculture	20	
	C62	Avocado	Agriculture	18	
	C64	Avocado	Agriculture	18	
	C75	Avocado	Agriculture	16	
	C87	Avocado	Agriculture	15	
	C88	Avocado	Agriculture	15	
	C9	Avocado	Agriculture	35	
	C90	Avocado	Agriculture	15	
	C93	Avocado	Agriculture	15	
Total Long-Term Demand (AFY)					**811**
Long-Term Options					
C-IPR	Potential Seawater Intrusion Barrier			Unk.	**1,523**[1]
	Potential Groundwater Recharge			Unk.	

Notes:

1. Actual demands for the Indirect Potable Reuse options are not known. Total demand shown is based on maximizing reuse from the average daily flow of the Carpinteria WWTP (1.6 MGD).

Table 8-8: Identified Distribution Needs by Project – Carpinteria Area

Project No.	Pipeline		Pump Station		Storage Capacity Needed (MG)
	Diam. (in)	Length (ft)	No.	Size (hp)	
Long-Term Projects					
C-1	10	3,600	1	150	1.4
C-2	6-8	21,900	0	0	0.0
C-3	6-8	24,000	0	0	0.0
Total Long-Term	**6-10**	**49,500**	**1**	**150**	**1.4**
Long-Term Option					
C-IPR[1]	10	34,200	1	100	0.0

Notes:

1. Project C-IPR includes two injection wells under pump station.

Project C-3

Project C-1 would extend from Project C-2 and proposes to serve 39 identified agricultural customers outside the City of Carpinteria. The project would require installing approximately 21,900 feet of 6 to 8-inch diameter pipeline. Project C-3 is dependent on Projects C-1 and C-2 being constructed. If the identified agricultural customers are served recycled water, then the Carpinteria WWTP would have to upgrade to MF/ RO treatment levels to reduce salinity levels to meet the potential agricultural customer's water quality needs.

Project Option - Indirect Potable Reuse/Seawater Intrusion

The Indirect Potable Reuse/Seawater Intrusion Project is an optional project that the CVWD is currently exploring. This option would consist of advanced treatment (MF/RO) to be able to provide recycled water for either a seawater intrusion barrier and/or for groundwater recharge. Seawater intrusion is suspected at the west end of the City of Carpinteria but needs to be confirmed with additional monitoring in the area. If seawater intrusion is occurring in the area threatening groundwater supplies, then a seawater intrusion barrier using recycled water would be an effective means of mitigation.

The groundwater recharge option could be accomplished by either surface spreading or by direct injection. The CVWD has been exploring several options for further utilizing the Carpinteria Groundwater Basin, including groundwater storage and banking, in-lieu recharge in conjunction with Lake Cachuma and SWP deliveries, and aquifer storage and recovery (ASR) systems. Recycled water could also be part of any one of these groundwater strategies. Increased use of the Carpinteria Basin would involve agriculture/growers and other possible stakeholders. More modeling is needed to better quantify how much the Carpinteria Basin could be used for all the stakeholders and to test various groundwater management plans. According to its 2010 Urban Water Management Plan, the District plans to formally evaluate groundwater banking in the Carpinteria Basin in future. Additional hydrogeologic studies are necessary to determine the best options and methods, including how recycled water could be part of the District's future groundwater strategies.

As part of this plan, a conceptual project (see **Figure 8-7**) was developed that would provide advanced treated recycled water to both the potential seawater intrusion barrier and the groundwater recharge projects. Such a project would require installing approximately 34,200 feet of 6-inch diameter pipeline, injection wells for the seawater intrusion barrier, and either on-site improvement for surface spreading groundwater recharge facilities or injection wells. For this conceptual project, the entire secondary flow (1.6 MGD) from the Carpinteria WWTP was assumed to be available. Assuming a combined recovery rate of 85% for the MF/RO process, this would yield an average of 1,523 AFY of advanced treated recycled water. While producing high quality water, MF/RO processes also produce a brine-concentrate stream, which would require disposal to the ocean via the Carpinteria WWTP's existing ocean outfall. A separate or amended ocean discharge permit would be required for such a project. Additional groundwater studies and evaluations of the seawater intrusion and groundwater recharge options are needed to further advance these conceptual projects. Such studies would include determining how much recycled water could be used, the facilities required, hydrogeologic constraints, injection/spreading facility needs, and other infrastructure needs.

Streamflow Augmentation of Carpinteria Creek

As discussed in **Chapter 5**, recent concerns related to water flows and water quality impacting steelhead trout have been discussed. The option of treating and conveying recycled water from the Carpinteria WWTP has been considered at a conceptual level only. No further analysis of this conceptual project was developed under this plan as there are several challenges related to implementing such a project, including regulatory and cost/benefits that need to be further explored.

8.3 Cost Criteria

This section describes the cost estimating basis and assumptions used to develop order of magnitude cost estimates of the potential projects and options developed in the south coast subregion.

8.3.1 Cost Estimate Class

The cost estimates shown, and any resulting conclusions on project financial or economic feasibility or funding requirements, are prepared for guidance in project evaluation and implementation and used information available at the time of this plan. The final costs of the projects and resulting feasibility analyses will depend on a variety of factors, including but not limited to, actual labor and material costs, competitive market conditions, actual site conditions, final project scope, implementation schedule, continuity of personal, engineering, and construction phases. Therefore, the final project costs will vary from the estimates developed in this document. Because of these factors, project feasibility, benefit cost/ratios, alternative evaluations, project risks, and funding needs must be carefully reviewed prior to making specific financial decisions or establishing project budgets to help ensure project evaluation and adequate funding.

Unit costs presented in this plan are generally order of magnitude. Based on the American National Standards Institute Standard Z94.0, an order-of-magnitude estimate is made without detailed engineering data.

8.3.2 Cost Contingencies and Factors

Implementation Factors

Cost factors are included to try to capture all of the anticipated capital costs associated with the implementation of the project. While these costs can vary greatly from project to project and from component to component, it is most common to assume a standard factor on the estimated construction costs across all projects and project types when analyzing alternatives and project options. In addition, it is necessary to allow for many uncertainties associated with conceptual level project definitions by applying appropriate contingencies. The following defines the typical efforts and factors for these additional services and contingencies:

- Planning, environmental documentation, and permits
- Engineering services (pre-construction)
- Engineering services during construction
- Construction management and inspection
- Legal and administrative services

- Field detail allowance
- Market adjustment factors

Due to the variability in project types, a wide range of costs is likely to exist. In addition, the services may vary from project to project depending on a variety of factors, including project complexity and need. Estimation of implementation costs could vary from as low as 25 percent of the estimated project construction cost to as high as 85 percent. For this plan, a factor of 25 percent of the estimated project construction costs is used to account for these additional services.

Project Contingency

Project or program contingencies are defined as unknown or unforeseen costs. In general, higher contingencies should be applied to projects of high risk or with significant unknown or uncertain conditions. Such unknown and risk conditions for construction cost estimates could include project scope, level of project definition, occurrence of groundwater and associated dewatering uncertainties, unknown soil conditions, unknown utility conflicts, etc. For planning studies, typical project contingencies can range between 20 and 50 percent for construction cost estimates. As most of the project costs involve pipelines, which tend to have less variability in costs and uncertainties than other types of infrastructure, for this plan, an additional 30 percent for contingencies is applied to the construction and implementation cost estimates based on order of magnitude level estimates. Because of the uncertainty in need and high variability in cost from one area to another, no land acquisition costs have been included in these estimates. Land acquisition needs are typically considered in a more detailed study of specific projects.

8.3.3 Unit Costs and Assumptions

For this plan, unit costs were developed for the most common facility improvement needs for recycled water projects as shown in **Table 8-9**. Unit costs were developed based on local information provided by the involved agencies or taken from recent southern California recycled water studies completed by RMC.

Treatment

As noted previously, treatment costs for several facilities were either provided by agencies or based on previous reports. Where no specific facility information was provided or no recent information was available, unit costs for upgrading from secondary to tertiary or to advanced treatment were used.

Pipelines

The GWD provided capital costs for 6” ($150/LF) and 12” ($180/LF) recycled water pipelines, which include the cost of materials, labor, planning/implementation, and contingencies. GWD unit costs were used for all projects in the south coast subregion.

Unit construction costs for pipelines were also provided in the City of Santa Barbara’s 2009 Water Supply Study. These costs were for 2 to 8-inch diameter pipelines. GWD’s pipeline costs were also used for the Santa Barbara projects and options since GWD’s cost information was more recent and slightly more conservative than the City’s 2009 Study.

A peaking factor of 2.0 was applied to all users (except the IPR option) to account for system wide peaking flow needs.

Pump Stations

A unit cost of $6,500 per horsepower (hp) based on peak flow was used to estimate pump station costs. This is based on RMC estimates from recent recycled water facilities plans.

Storage

A unit cost of $2 per gallon based on peak flow demand was used to estimate storage costs. Storage capacity needs for new projects was estimated as being the total volume of the maximum day demand for all users in each area where no previous storage capacity information was available. This is based on RMC estimates from recent recycled water facilities plan.

Table 8-9: Capital Projects Unit Costs[1]

Item	Unit Cost	Units/Notes
Treatment		
Title 22 (Tertiary and Disinfection)	$5.40	per gallon (capacity)
Advanced (MF/RO and Disinfection)	$6.50	per gallon (capacity)
Pipelines		
6-inch diameter	$150	per LF
8-inch diameter	$160	per LF
12-inch diameter	$180	per LF
Pump Stations	$6,500	hp (based on peak flow)
Storage	$2	per gallon
Injection Well	$1 M	per well
Project Financing		
Interest Rate	6.0%	
Payback Period	30	Years

Notes:

1. Capital costs include estimated costs for construction, implementation (planning, engineering, permitting, etc.) and contingency (30%). No land acquisition costs are included in these estimates.

Injection Well Costs

A unit cost of $1 million per injection well was assumed. For recharge via surfacing spreading, $500,000 was assumed to account for potential on-site improvement needs. These costs could vary greatly depending on the type of recharge needing, actual well depths, onsite improvement needs, etc. As noted above, no land acquisitions costs were included with the injection well cost estimates.

8.4 Estimated Project Costs

Estimated costs for each potential project and option are shown in **Table 8-10** through **8-14** below. These tables illustrate the order of magnitude of effort for implementing the various projects. Capital and unit costs vary greatly due to a variety of factors including local conditions, project scale, and rehab or expansion of existing systems versus completely new recycled water systems. Therefore, each agency will need to determine the benefits and costs of the potential projects to its own water resource needs and other circumstances, as comparison of projects between areas has limited value

Table 8-10: Summary of Estimated Potential Project Costs[1] – Goleta Area

Project No.	Potential Demand (AFY)	Facility Capital Costs				Estimated Capital Costs	$/AF[2]
		Treatment	Pipeline	Pumping	Storage		
Near-Term Projects							
Existing System Improvements	785[3]	-	$775,000[4]	$474,000[5]	$2,500,000[6]	$3,749,000	N/A
G-1 through G-6	26	-	-	-	-	-	N/A
Total Near-Term	**812**	**-**	**$775,000**	**$474,000**	**$2,500,000**	**$3,749,000**	**$300**
Long-Term Projects							
Overall System Improvements	N/A	-	-	$2,925,000[7]	-	$2,925,000	N/A
G-8	11.5	-	$1,410,000	-	-	$1,410,000	$8,900
G-9	0.4	-	$86,000	-	-	$86,000	$15,600
G-10	2.0	-	$6,000	-	-	$6,000	$200
G-11	1.0	-	$23,0000	-	-	$23,000	$1,700
G-12	4.9	-	$600,000	-	-	$600,000	$8,900
G-13	38.2	-	$3,708,000	-	-	$3,708,000	$7,100
Total Long-Term	**58**	**-**	**$5,833,000**	**$2,925,000**	**-**	**$8,758,000**	**$11,000**
Total (Near + Long-Term)	**870**	**-**	**$6,608,000**	**$3,399,000**	**$2,500,000**	**$12,507,000**	**$1,000**

Notes:
1. Estimated costs include constructions costs and markups for implementation (planning, engineer, etc.) and contingencies.
2. $/AF is the capital unit costs and does not include any operations and maintenance costs.
3. Annual demand for the existing system improvements is based on GWD's current recycled water demands.
4. Includes the Recycled Waterline Relocation Project at Goleta Beach and the Corrosion Protection and Pipeline Replacement Project.
5. Includes the Recycled Water Booster Station Electrical Upgrades at the Goleta WWTP.
6. Includes the 1 Million Gallon Water Reservoir Project.
7. Includes Recycled Water Hollister Booster Station Relocation Project, Recycled Water Pressure Reducing Vault Relocation at Glen Annie Golf Course, and Cathedral Oaks Road / Highway 101 Overcrossing Project.

Table 8-11: Summary of Estimated Potential Project Costs[1] – Santa Barbara Area

Project No.	Potential Demand (AFY)	Facility Capital Costs				Estimated Capital Costs	$/AF[2]
		Treatment	Pipeline	Pumping	Storage		
Near-Term Projects							
Existing System Improvements	850[3]	$15,440,000[4]	-	-	-	$15,440,000	$1,300
SB-1 through SB-6	21	-	-	-	-	-	-
SB-7	20	-	$660,000	-	-	$660,000	$2,400
Total Near-Term	**891**	**$15,440,000**	**$660,000**	**-**	**-**	**$16,100,000**	**$1,300**
Long-Term Projects							
SB-8	15	-	$645,000	-	-	$645,000	$3,100
SB-9	15	-	$480,000	-	-	$480,000	$2,300
SB-10	41	-	-	-	-	-	-
SB-11	116	-	$3,780,000	$130,000	-	$3,910,000	$2,400
SB-12	10	-	$405,000	-	-	$405,000	$2,900
SB-13	9	-	$180,000	-	-	$180,000	$1,500
SB-14	11	-	$600,000	$65,000	-	$665,000	$4,400
SB-15	15	-	-	-	-	-	-
Total Long-Term	**232**	**-**	**$6,090,000**	**$195,000**	**-**	**$6,285,000**	**$2,000**
Total (Near + Long-Term)	**1,123**	**$15,440,000**	**$6,750,000**	**$195,000**	**-**	**$22,385,000**	**$1,400**
Long-Term Options							
SB-Option 1	139	-	$225,000	-	-	$225,000	$100
SB-Option 2	127	-	$600,000	-	-	$600,000	$300
Total Long-Term Options	**266**	**-**	**$825,000**	**-**	**-**	**$825,000**	**$200**
Total (Near + Long-Term + Options)	**1,389**	**$15,440,000**	**$7,575,000**	**$195,000**	**-**	**$23,210,000**	**$1,200**

Notes:

1. Estimated costs include constructions costs and markups for implementation (planning, engineer, etc.) and contingencies.
2. $/AF is the capital unit costs and does not include any operations and maintenance costs.
3. Annual demand includes the City's current recycled water user demands but does not include 300 AFY of internal plant process water demand.
4. Includes the process upgrades at the El Estero WWTF

Table 8-12: Summary of Estimated Potential Project Costs[1] – Montecito Area

Project No.	Potential Demand (AFY)	Facility Capital Costs				Estimated Capital Costs	$/AF[2]
		Treatment	Pipeline	Pumping	Storage		
Long-Term Projects							
M-1	139	$1,340,000[3]	$272,000	$650,000	$2,100,000	$4,362,000	$2,300
M-2	449	$4,330,000[4]	$5,583,000	$325,000	-	$10,238,000	$1,700
Total Long-Term from Montecito WWTF	**587**	**$5,670,000**	**$5,855,000**	**$975,000**	**$2,100,000**	**$14,600,000**	**$1,800**
M-3	15	$910,000[5]	$270,000	$65,000	-	$1,245,000	$6,000
Total Long-Term from Summerland WWTP	**15**	**$910,000**	**$270,000**	**$65,000**	**-**	**$1,245,000**	**$6,000**
Long-Term Options							
M-Option 1	35	-	$1,725,000	$65,000	$200,000	$1,990,000	$4,100
M-Option 2	56	-	$1,425,000	$65,000	$200,000	$1,690,000	$2,200
Total from Summerland WWTP (Long-Term + Option 2)[6]	**71**	**$910,000**	**$1,695,000**	**$130,000**	**$200,000**	**$2,935,000**	**$3,000**
Total Long-Term for Montecito Area	**659**	**$6,580,000**	**$7,550,000**	**$1,105,000**	**$2,300,000**	**$17,535,000**	**$1,900**

Notes:

1. Estimated costs include constructions costs and markups for implementation (planning, engineer, etc.) and contingencies.
2. $/AF is the capital unit costs and does not include any operations and maintenance costs.
3. Estimated cost to upgrade treatment plant to serve tertiary treated recycled water
4. Estimated cost to upgrade treatment plant to serve advanced treated recycled water
5. Estimated cost to upgrade treatment plant to serve tertiary treated recycled water for 70 AFY
6. M-Option 1 and M-Option 2 are mutually exclusive. M-Option 2 was chosen since it had a lower unit cost.

Table 8-13: Summary of Estimated Potential Project Costs[1] – Carpinteria Area

Project No.	Potential Demand (AFY)	Facility Capital Costs				Estimated Capital Costs	$/AF[2]
		Treatment	Pipeline	Pumping	Storage		
Long-Term Projects							
C-1	40	$390,000[3]	$612,000	$975,000	$2,900,000	$4,877,000	$8,900
C-2	80	$770,000[3]	$3,396,000	-	-	$4,166,000	$3,800
C-3	691	$8,250,000[4]	$3,700,000	-	-	$11,940,000	$1,300
Total Long-Term	**811**	**$9,410,000[4]**	**$7,708,000**	**$975,000**	**$2,900,000**	**$20,993,000**	**$1,900**
Long-Term Options							
C-IPR[5]	1,523	$10,400,000	$5,814,000	$650,000	-	**$18,864,000**	**$900**

Notes:

1. Estimated costs include constructions costs and markups for implementation (planning, engineer, etc.) and contingencies. These costs are intended present order of magnitude level unit costs so that some level of prioritization of costs may be utilized by future project planning efforts.
2. $/AF is the capital unit costs and does not include any operations and maintenance costs.
3. Estimated cost to upgrade treatment plant to serve tertiary treated recycled water
4. Estimated cost to upgrade treatment plant to serve advanced treated recycled water
5. Estimated cost includes two injection wells for seawater intrusion and on-site improvements for groundwater recharge facilities

Table 8-14: Summary of Estimated Potential Project Costs[1] – All Areas

Project Area	Potential Demand (AFY)	Facility Capital Costs				Estimated Capital Costs	$/AF[2]
		Treatment	Pipeline	Pumping	Storage		
Near-Term Projects							
Goleta Area[3]	812	-	$775,000	$474,000	$2,500,000	$3,749,000	$300
Santa Barbara Area[3]	891	$15,440,000	$660,000	$0	-	$16,100,000	$1,300
Total Near-Term	**1,703**	**$15,440,000**	**$1,435,000**	**$474,000**	**$2,500,000**	**$19,849,000**	**$800**
Long-Term Projects							
Goleta Area	58	-	$5,833,000	$2,925,000	-	$8,758,000	$11,000
Santa Barbara Area (Includes SB-Option 1)	371	-	$6,315,000	$195,000	-	$6,510,000	$1,300
Montecito (Includes M-Option 2)	659	$6,580,000	$7,550,000	$1,105,000	$2,300,000	$17,535,000	$1,900
Carpinteria	811	$9,410,000	$7,708,000	$975,000	$2,900,000	$20,993,000	$1,900
Total Long-Term	**1,899**	**$15,990,000**	**$27,406,000**	**$5,200,000**	**$5,200,000**	**$53,796,000**	**$2,100**
Total (Near + Long-Term)	**3,602**	**$31,430,000**	**$28,841,000**	**$5,674,000**	**$7,700,000**	**$73,645,000**	**$1,500**

Notes:

1. Estimated costs include constructions costs and markups for implementation (planning, engineer, etc.) and contingencies.
2. $/AF is the capital unit costs and does not include any operations and maintenance costs.
3. Near-term project demands also include existing system user demands but do not include 300 AFY of internal plant process water demand.

8.5 How Projects Benefit the Region (Regional Summary)

As part of the Santa Barbara Integrated Regional Water Management Plan 2013 (IRWM Plan 2013), the region has a collective goal of serving an average of 7,035 AFY by 2035. Of that total, 2,293 AFY is expected to be recycled water from the south coast subregion. To reach this goal, Goleta plans to expand to 870 AFY from its current use of 785 AFY and the City of Santa Barbara plans to expand from 1,150 AFY to 1,423 AFY, including 300 AFY of internal plant process water demand. This target could be surpassed if the Montecito or Carpinteria areas are able to move forward with implementation of their potential reuse projects.

Recycled water projects provide a variety of benefits to individual agencies, the south coast subregion of Santa Barbara County, and Santa Barbara County as a whole. Benefits can be identified by the performance measures and the objectives achieved by the projects. The Santa Barbara County IRWM Plan 2013 has identified eight regional objectives of which recycled water projects achieve five of those objectives. These benefits are identified to illustrate some of the considerations that would be part of a complete benefit-cost analysis for decision-making purposes by each agency when considering a project.

Recycled water projects benefit the region by developing and maintaining a diversified mix of water resources, augmenting supplies by using recycled water for landscaping or other non-potable uses, improving wastewater quality, utilizing technology to manage waste in an economical and environmentally sustainable manner, reducing wastewater discharges into the ocean, maintaining and enhancing water and wastewater infrastructure efficiency and reliability, planning for and developing infrastructure for disadvantaged communities, and helping the region plan and adapt to climate change. **Table 8-15** below indicates which objectives from the IRWM Plan 2013 and their applicable performance measures each project achieves.

The potential IRWMP objectives and their applicable performance measures that can be achieved by the proposed recycled water projects include the following:

- Protect, Conserve, and Augment Supplies
    - Reuse wastewater as measured by the volume of new water (acre-feet per year)
    - Create/rehabilitate facilities that augment water supply as measured by the number of facilities impacted by the project
- Protect and Improve Water Quality
    - Meet water quality objectives in Basin Plan
    - Reduce salt/nutrient loading to the basin
    - Reduce wastewater discharged to the ocean (or streams) as measured volume of water reused (acre-feet per year)
- Maintain and Enhance Water and Wastewater Infrastructure Efficiency and Reliability
    - Implement reliability improvements to customers within water and wastewater agency service areas as measured by the number of customers impacted by the improvements and the number of new infrastructure improvements
- Plan for and Adapt to Climate Change
    - Achieve previously listed objectives, along with other regional objectives such as increasing groundwater storage, conserving, preserving, protecting, and restoring habitat, conserving water, and restoring surface storage in order to address climate change.
- Equitable distribution of benefits as measured by new planning or implementation projects, the volume of water recycled, and the number of new infrastructure improvements
    - Support planning and increased recycled water use in Disadvantaged Communities (DACs)

Table 8-15: IRWM Objectives and Performance Measures by Project

Project Area and No.	IRWMP Objectives							
	Protect, Conserve, and Augment Supplies		Protect and Improve Water Quality			Maintain and Enhance Water and Wastewater Infrastructure Efficiency and Reliability	Plan for and Adapt to Climate Change	Ensure Equitable Distribution of Benefits
	Performance Measures							
	Reuse Waste-water	Create/Rehab Facilities that Augment Water Supply	Meet Water Quality Objectives in Basin Plan	Reduce Salt/Nutrient Loading to the Basin	Reduce Wastewater Discharged to the Ocean	Implement Reliability Improvements	TBD	Support Planning and Increased Recycled Water use in DACs
Goleta Area								
Near-term								
Exist. Sys. Improvements	✓	✓	✓		✓	✓	✓	
G-1	✓	✓	✓		✓	✓	✓	
G-2	✓	✓	✓		✓	✓	✓	
G-3	✓	✓	✓		✓	✓	✓	
G-4	✓	✓	✓		✓	✓	✓	
G-5	✓	✓	✓		✓	✓	✓	
G-6	✓	✓	✓		✓	✓	✓	
G-7	✓	✓	✓		✓	✓	✓	
Long-term								
G-8	✓	✓	✓		✓	✓	✓	✓
G-9	✓	✓	✓		✓	✓	✓	✓
G-10	✓	✓	✓		✓	✓	✓	
G-11	✓	✓	✓		✓	✓	✓	
G-12	✓	✓	✓		✓	✓	✓	
G-13	✓	✓	✓		✓	✓	✓	✓ (partial)

Table 8-15: IRWM Objectives and Performance Measures by Project

Project Area and No.	IRWMP Objectives							
	Protect, Conserve, and Augment Supplies		Protect and Improve Water Quality			Maintain and Enhance Water and Wastewater Infrastructure Efficiency and Reliability	Plan for and Adapt to Climate Change	Ensure Equitable Distribution of Benefits
	Performance Measures							
	Reuse Waste-water	Create/Rehab Facilities that Augment Water Supply	Meet Water Quality Objectives in Basin Plan	Reduce Salt/Nutrient Loading to the Basin	Reduce Wastewater Discharged to the Ocean	Implement Reliability Improvements	TBD	Support Planning and Increased Recycled Water use in DACs
Santa Barbara Area								
Near-term								
Exist. Sys. Improvements	✓	✓	✓	✓	✓	✓	✓	
SB-1	✓	✓	✓		✓	✓	✓	
SB-2	✓	✓	✓		✓	✓	✓	
SB-3	✓	✓	✓		✓	✓	✓	
SB-4	✓	✓	✓		✓	✓	✓	
SB-5	✓	✓	✓		✓	✓	✓	
SB-6	✓	✓	✓		✓	✓	✓	
SB-7	✓	✓	✓		✓	✓	✓	
Long-term								
SB-8	✓	✓	✓		✓	✓	✓	
SB-9	✓	✓	✓		✓	✓	✓	
SB-10	✓	✓	✓		✓	✓	✓	
SB-11	✓	✓	✓		✓	✓	✓	✓
SB-12	✓	✓	✓		✓	✓	✓	
SB-13	✓	✓	✓		✓	✓	✓	
SB-14	✓	✓	✓		✓	✓	✓	
SB-15	✓	✓	✓		✓	✓	✓	✓
SB-Option 1	✓	✓	✓		✓	✓	✓	
SB-Option 2	✓	✓	✓		✓	✓	✓	

Table 8-15: IRWM Objectives and Performance Measures by Project

Project Area and No.	IRWMP Objectives							
	Protect, Conserve, and Augment Supplies		Protect and Improve Water Quality			Maintain and Enhance Water and Wastewater Infrastructure Efficiency and Reliability	Plan for and Adapt to Climate Change	Ensure Equitable Distribution of Benefits
	Performance Measures							
	Reuse Waste-water	Create/Rehab Facilities that Augment Water Supply	Meet Water Quality Objectives in Basin Plan	Reduce Salt/Nutrient Loading to the Basin	Reduce Wastewater Discharged to the Ocean	Implement Reliability Improvements	TBD	Support Planning and Increased Recycled Water use in DACs
Montecito Area								
M-1	✓	✓	✓		✓	✓	✓	
M-2	✓	✓	✓		✓	✓	✓	
M-3	✓	✓	✓		✓	✓	✓	✓
M-Option 1	✓	✓	✓		✓	✓	✓	
M-Option 2	✓	✓	✓		✓	✓	✓	
Carpinteria Area								
C-1	✓	✓	✓		✓	✓	✓	✓
C-2	✓	✓	✓		✓	✓	✓	
C-3	✓	✓	✓		✓	✓	✓	
C-IPR	✓	✓	✓	✓	✓	✓	✓	

Chapter 9 Findings: Constraints and Next Steps

This chapter summarizes the potential constraints to implementing recycled water projects in the South Coast Region and findings or recommendations on the next steps for implementing the identified potential projects. These findings are a summary of the results of the literature review, regulatory review, potential project identification and cost estimates, and committee meetings.

9.1 Potential Constraints

Several potential projects were identified for both the near- and long-term opportunities. These projects range from ones that are expanding existing systems to projects that were developed on a more conceptual level for the long-term. The potential projects include more traditional reuse projects, such as urban irrigation uses, as well as those that could serve agricultural demands or that would involve Indirect Potable Reuse (IPR).

Several types of constraints were discussed by the workgroup. These constraints range from user specific concerns and specific project challenges to agency and regional constraints or challenges. The constraints to each project or agency can vary depending on a variety of factors. Listed below are the identified constraints to implementing the potential recycled water projects.

9.1.1 User Constraints

- **User end water quality constraints**: Irrigation and some industrial/commercial customers face water quality challenges regarding the use of recycled water. The high Total Dissolved Solids (TDS) in the region's wastewater supplies are of particular concern, as high TDS levels can impact the growth and health of grass and landscaping plants and even limit the types of plants that can utilize recycled water. In addition, the high TDS levels are a major constraint to being able to serve recycled water to many of the agricultural users in the region. Major crops in the region include avocados, citrus, and flowers, all of which require lower limits on TDS than what is in the current recycled water levels. Other water quality parameters, such as boron, can also impact crop growth. All recycled water uses need to be considered on a project-by-project basis.
    - **Golf Courses:** During the planning process, several agencies expressed concerns about the ability of golf courses to use high TDS recycled water, which can often buildup in the soil. For many golf courses, this problem is often limited to the greens but not the fairway turf. Several strategies utilized by other agencies/courses for addressing this problem include:
        - Separate the irrigation systems between the greens and fairways
        - Modify the turf type
        - Use additional water (including potable) to periodically leach the greens
        - Install a gypsum injector in-place downstream of backflow preventer or a de-ionizer system to address sodium concerns
- **Conversion Costs**: To use recycled water, customers typically must convert a portion of their potable system to recycled water. The cost of conversion can be a major challenge to some customers depending on the extent of conversion and customer financing options. Most agencies provide some level of financial support either directly or as part of the recycled water bill. In addition, the time it takes to implement and permit such conversions can be a challenge to customers who do not have adequate staff to implement such changes. Support

by agencies for conversions can vary greatly, but some level of financial and logistical support is necessary depending on the customer type and situation.

- **Long-Term Customer Viability**: One concern agencies have when planning recycled water systems is the sustainability of potential users. Industrial/commercial users can move locations or close their business with little notice. They can also change their processes, water demand, and/or time of operation. Urban irrigation users can also change their usage based on the cost of water and drought conditions. Lastly, major water users, such as agriculture and even golf courses, can be subject to future development. Such future developments may have some level of demand for recycled water, but it is often less than the current user's demand it is replacing. Planning a recycled water system must take such future changes into account, but in many cases, the risk of serving these customers falls completely on the agency. Coordinating with city planners and providing backup options for potential lost customers could mitigate such risks.

9.1.2 Project Challenges

- **Community Impacts:** Construction of recycled water projects can result in a number of potential impacts to the community. These can stem from the construction of pipelines, pump stations, storage tanks, water reclamation plants or expansions, and onsite user conversions to recycled water. Construction impacts can include closure or disruption to streets and traffic, temporary closure or access limitations to public facilities (i.e. parks, golf courses, etc.), temporary access limitations to businesses, diversion or disruption of wastewater flows and/or process at WWTPs. Some projects may also require rights-of-way or property acquisitions, which can change or limit the future use of such properties. System start up and conversion of users can also create logistical challenges that can impact the potential reuse customers. These impacts must be considered as part of the planning, design, environmental documentation, system startup, and customer conversion processes.
- **Timing/Phasing:** Implementation of recycled water projects presents many challenges, including the timing and phasing of a project. Public and political support, along with financing availability, are major concerns for implementing recycled water projects. Agencies must be prepared to move quickly when there is support for implementation of such projects. To capitalize on the timing, agencies must have already established plans for implementing their projects such that the environmental documentation and design phases can be started as soon as financing and public support are in place. Phasing of projects is one way to reduce the scope of a project so that portions of the project can be implemented quickly. However, the cost/benefits of building only part of a system must also be considered.
- **System Hydraulics:** Many of the existing and potential projects identified in the region have customers who will use water during nighttime hours. This practice requires agencies to address the problems of high peak demand that can require storage and pumping facilities. The infrastructure needs and cost of meeting peak demands is a constant challenge for many recycled water systems. Reducing peak demand use could reduce the size or even eliminate some infrastructure needs and therefore reduce the overall capital costs. Options for addressing these problems include user-end onsite storage and peak demand management measures.
- **Wastewater flows:** For many agencies in the region, the potential peak season demand exceeds the projected average daily wastewater flows. Therefore, some potential projects may be limited in their ability to expand beyond the projects identified in this plan. Although there are several communities on septic systems in the region, their small flows would

contribute minimally if added to the wastewater flows of most plants. Supplementing a recycled water system with non-potable groundwater or raw surface waters is one way to further extend recycled water systems and could utilize wastewater flows beyond the average day flow levels.

- **Regulatory:** For most of the potential projects, the regulatory statutes (Title 22) are relatively straightforward to address. However, future regulations and the potential need to utilized future technologies can present a challenge to project implementation and create uncertainty in the decision-making process. For IPR projects, the regulatory challenges can be significant and would require several years to address. As discussed in Chapter 3, this includes the State Water Resources Control Board's recent requirements for monitoring of constituents of emerging concern (CECs) as part of the permitting requirements for IPR projects.

9.1.3 Agency Challenges

- **Feasibility of Projects:** Substantial economic cost/benefit analyses should be performed when determining the feasibility of potential recycled water projects. Many recycled water projects have unique challenges, including cases with high capital costs relative to the potential demand being served or high capital costs for initial phases. Therefore, it is important when evaluating the feasibility of recycled water projects that all the direct and secondary benefits be considered in comparison to the costs. The benefits of recycled water include local water supply reliability, reduced dependence on unreliable imported water supplies, drought-proof water supplies (both at agency and customer benefit levels), and avoided wastewater discharge costs.
- **Financing of Projects:** An agency's ability to finance the capital expenditures of a recycled water project can be a major challenge. Cost-sharing arrangements with other agencies could be used to help agencies with limited financing capacity. In addition, external funding sources at State and Federal levels could assist with the financing of projects. Once potential projects have been identified and are ready for implementation, it is critical that agencies determine the financing vehicle(s) to be used and whether external funding is necessary.
- **Health Concerns over Recycled Water Quality:** Although the potential projects meet the State's current and known future regulatory requirements, there were still some concerns raised during the planning process of this study that focused on the potential occurrence of pathogens and constituents of emerging concern (CECs) in recycled water. Additional concerns were raised over the potential spread of antibiotic resistance bacteria through recycled water. Current State regulations regarding the treatment and disinfection of recycled water are designed to eliminate all bacteria as well as the smaller viruses and pathogens that occur in wastewater. While additional treatment is not likely to have any additional benefits in addressing these concerns, micro-, ultra-, or nanofiltration and/or reserve osmosis treatment processes could also be utilized to reduce the bacterial and pathogens in the recycled water prior to final disinfection.

  The State regulations are designed to meet public health safety requirements based on type of use. If State regulations were to change, then existing and potential future projects would likely be required to meet any new regulations, including any additional treatment requirements. Recycled water has been widely used in the cities of Santa Barbara (22 years) and Goleta (19 years), and both systems meet current State requirements. In general, the public in these areas have not expressed concerns over the public health and safety of the recycled water. In addition to ongoing public awareness programs, both agencies have conducted education campaigns to support the implementation of their on-going projects. Public education and awareness campaigns are an important part of the implementation process for recycled water projects and should be conducted early in the planning phases. If recycled water expands to other areas or to different use types, such as agriculture or IPR, a more regional public awareness and education program could also be considered as regional efforts may provide more collective support than individual agency efforts.

- **Customer Acceptance**: While most customers are typically willing to convert to recycled water because of economic incentives, drought-proof supply benefits, and/or the environmental benefits, some customers may resist. Reasons for such concerns include the cost of conversion (as discussed above), concern over public health, and the impacts of water quality on the applied use. As discussed elsewhere, the costs and water quality concerns can typically be mitigate by the agency. In addition, a city or agency can adopt a mandatory use policy that further defines the policies regarding the use of recycled water and potential consequences for non-compliance. This is supported by California law under the California's Porter-Cologne Water Quality Control Act (Section 13551), which states that potable water shall not be used if recycled water is made available and is considered a "reasonable beneficial use" in lieu of potable water. Many agencies have already adopted such language and will use such policies as a last resort with customers who refuse to convert or hook up to recycled water systems when they are made available.

- **Existing System Conditions and Improvements:** As discussed previously, both the Goleta Water District and the City of Santa Barbara have existing recycled water systems needing major improvements. It is essential that these improvements be made to restore their existing systems and to allow for future expansions. Recycled water systems have relatively high lifecycle costs, and similar to water and wastewater systems, agencies must plan for regular maintenance and capital improvements of their recycled water systems to ensure that they can function continuously. These improvements need to be included in future capital improvement plans as part of an agency's budget cycle process to ensure the system is functional and meeting customer needs. As more users are added to a system, it becomes more critical that such systems are well maintained and operated effectively to ensure customer satisfaction. A reliable system will also increase public acceptance to recycled water.

9.1.4 Regional Challenges

- **Institutional:** All the region's treatment plants discharge to the ocean wastewater that does not meet Title 22 recycled water treatment levels. Therefore, implementation of new recycled water projects must include treatment improvements to meet Title 22 and any customer-level water quality needs. As only water retail agencies can typically recoup these costs through the sale of recycled water, the water agencies must coordinate and establish agreements with the corresponding wastewater agency, which typically take the lead the wastewater treatment improvement needs and subsequent O&M. Such agreements must take into account the entire benefit/costs of the project to ensure that all parties' economic and financial needs are addressed. These include both capital and maintenance O&M costs. Potential projects needing advanced treatment will have higher capital and operation and maintenance costs compared to tertiary treatment levels and will produce a brine-concentrate stream that requires disposal. Brine-concentrate disposal is typically done via an ocean outfall and requires a separate or revised wastewater discharge permit by the wastewater agency. In some cases, a wastewater agency may have substantial drivers or interest in implementing a recycled water project, while the corresponding water agency remains uninterested. In these cases, the wastewater agency can take a lead role in the implementation of such a project, but agreements with the water agency must developed early in the planning process to account for revenue and other impacts to the water agency.

In addition, multiple water agencies have been identified for some potential projects, notably the City of Santa Barbara options to serve the La Cumbre County Club and the Santa Barbara Cemetery, which are both located outside the City of Santa Barbara's water service area. A variety of options can be used to address such issues, but all require that the project participants work together to identify and address the potential issues and to ensure that there is political and community support behind the effort to implement such projects. Where new agreements are necessary, agencies should address not only the short-term project, but where practical, address the long-term project as well.

- **Large Agricultural Demands:** The region has a significant agriculture sector, and as discussed earlier, there are some significant water quality constraints that need to be addressed in order to serve recycled water to these users. In addition, most of the agricultural demands use low cost groundwater or untreated surface waters (local and imported). Therefore, the financial challenges of implementing a recycled water system to serve these users would need to be ameliorated. Subsidizing the cost of a recycled water supply in agricultural areas is common for some water agencies, but the high cost to treat and deliver such water makes it especially challenging in this region. One potential benefit to serving recycled water to the agricultural users would be the value of groundwater or surface water that might be made available to a water agency in exchange for the recycled water should be considered. There is also value in drought-proof water supplies to agriculture users, the water agency, and the entire region, and this benefit should be considered when assessing the overall feasibility of such projects. In addition to most of the region's agricultural users, the two large golf courses in the Montecito area are currently using groundwater to meet over 90% of their water demands. The economic and logistical constraints of serving these customers must be addressed if recycled water is to be utilized by these customers.
- **External Funding**: The region does not currently have any external funding mechanisms in place. Implementation of many of the potential projects may require external funding, which could come from State or Federal sources.

9.2 Next Steps

The following summarizes the findings and recommended steps at both a regional and area (or agency) level and are based on the implementation needs of the identified potential projects and the constraints noted above.

- **Assessment of Regional Water Value**: To supplement local water supplies, the region relies on the State Water Project (SWP), which has become increasingly less reliable over the years due to periodic drought conditions and recent cutbacks in deliveries for environmental needs. One of the goals of the region is to not be fully dependent on the SWP and to improve the region's supply reliability. Implementation of a recycled water project by one agency does provide regional benefit in terms of supply reliability. The economic value of the identified potential reuse projects should be considered in context of the benefits it provides to the individual agency as well as the regional community. Sustained drought conditions could be greatly mitigated by maximizing the reuse potential in the region. Many agencies are required to meet the State's 20% conservation level by 2020, and recycled water can be a component towards meeting those requirements.

  To support the decision-making process, the value of recycled water to the region as a whole, along with other conservation measures, needs to be more fully assessed by the water agencies on a regional basis. The benefit-cost comparison of recycled water on a regional level should be compared with other options, including increased conservation and additional or alternative water supplies such as seawater desalination. Increased use of recycled water could allow some agencies to reduce their imported water demand during some years. Such a surplus could be banked in groundwater basins or sold to other agencies on the SWP system, which could be used to help finance recycled water, conservation, or other local water supply projects. Lastly, the value of offsetting groundwater use with recycled water for golf courses and agricultural users that use well water should be evaluated. A comprehensive analysis of water supply reliabilities along with the costs and benefits of the potential recycled water projects should be conducted to assess the full value of the potential projects to agencies and to the region.

One of the economic benefits of recycled water is the avoided costs in terms of wastewater disposal and water supplies. As part of such a regional assessment, the avoided costs from implementing recycled water projects needs to be more fully identified and evaluated. Avoided costs and benefits can be at the user, agency, and regional level.

- Avoided costs and benefits at the agency and regional level include:
  - Avoided wastewater treatment Operational and Maintenance (O&M) costs
  - Avoided wastewater ocean discharge/disposal O&M costs
  - Avoided future wastewater treatment capital improvement projects
  - Deferral or avoidance additional water supply projects to meet future demands
  - Avoided loss of water usage revenues during drought or other usage cut-back periods
  - Avoided loss of economic activity/tax on businesses impacted by drought or usage cut-back
  - Lower water system distribution treatment and O&M costs
  - Reduced water system distribution system storage needs/costs
  - Environmental benefits
  - Water quality improvement benefits
  - Meeting regulatory requirements such as Basin Plan Objectives and Salt-Nutrient Management Plans
  - Meeting future climate change conditions and supply reliability needs
- Avoided costs and benefits at the customer level include:
  - Recycled water price discounts
  - Avoided loss or cut-back of water usage during drought or other usage cut-back periods
  - Avoided economic losses to businesses, such as industrial/commercial and agriculture users
  - Water quality improvements, including potentially more consistent water quality

- **Groundwater Quality Improvements**: For recycled water projects employing reverse osmosis treatment, the reduction in salts, nutrients, and other constituents of concern could provide benefits to the region, especially to groundwater basins. Such projects should be considered as possible management strategies in the development of the Salt/Nutrient Management Plans in the individual basins in the region. These projects would include both IPR and irrigation projects where reduced TDS is required to meet basin plan objectives.
- **Meeting Customer Recycled Water Quality Needs**: This recommendation addresses both regional and project-level concerns of several water-quality related constraints identified in this plan. Recommendations include:
  - **Golf Courses:** As discussed above, there are several options for dealing with water quality concerns at golf courses. These can be addressed individually, but discussions on a regional basis could also be beneficial in sharing information and ideas. Another effective approach is to have existing recycled water customers share their positive experiences and ideas with potential new customers.

- **Industrial/Commercial Customers:** Water quality concerns by industrial and commercial customers tend to be unique to each industry. Where similar types of customers exist in the region, collaboration by agencies could be beneficial. In addition, the WateReuse Association has an Industrial Customer Committee that can provide assistance and contacts to other recycled water agencies that have similar customers and can provide information on how specific issues have been addressed in other reuse systems.
- **Agricultural Users:** As noted above, recycled water with high TDS or other constituents can be a major constraint to potential agricultural recycled water users. Potential projects involving agricultural users will need more thorough assessments of the exact needs or limits of the different agricultural products and an evaluation of how to best meet these needs. Not all agriculture customers may be suited to use recycled water, so identifying the best opportunities is significant to developing feasible projects. In addition, the long-term sustainability of the agricultural products is important to ensure that recycled water systems are not built and then abandoned because of changes in agricultural business and market conditions. Having existing customers share their positive experience and ideas is also effective in helping to addressing concerns with potential new customers.

- **External Funding**: The high capital cost of many of the potential projects may necessitate the need for external funding. Currently, the State of California has funding available via the IRMW/Proposition 84 bonds as well as up to $75,000 from the State Water Resources Control Board (SWRCB) for recycled water planning studies. At the Federal level, the most common funding source is the United States Bureau of Reclamation's (USBR) Title XVI program. To be eligible for funds under this program, an agency must first be given Congressional Authorization. Once authorized, a project(s) will then need to have funds appropriated. This can occur via a direct Congressional Act or can be secured via the USBR's current WaterSMART (Sustain and Manage America's Resources for Tomorrow) grant program, which releases funds on a regular competitive basis. Appropriations under the Title XVI program can provide up to $20 million to a project or group of projects within a region. If the South Coast agencies wish to pursue and implement potential reuse projects, it is recommended that they consider starting the lobbying and planning process to become authorized under Title XVI.
- **Institutional Issues**: Several institutional issues were identified for some potential projects. As noted above, these should be addressed early in the planning process. Specifically noted projects include:
  - **La Cumbre Golf and Country Club.** The Goleta Water District (GWD), the City of Santa Barbara, and the La Cumbre Mutual Water District would need to reach agreement on service delivery arrangements, cost-sharing, revenue, and management protocol if such a project were to move forward to consideration.
  - **Santa Barbara Cemetery.** The Santa Barbara Cemetery is a customer of the Montecito Water District (MWD), which is not currently planning to implement any recycled water projects. Optional projects include serving this user from either the City of Santa Barbara or MWD. As the City's existing recycled water system is in close proximity to the Cemetery, it may be more feasible for the City to serve this customer. However, cost and water sales revenues would need to be worked out between the two agencies.
- **Indirect Potable Reuse**: For the Carpinteria area, as well as other areas that may want to consider IPR, such projects typically take 10 or more years to fully implement from initial concept planning stages. In addition to the typical reuse project planning and design work, IPR projects also require extensive groundwater analysis, modeling, testing, treatment process pilot studies, and a program to educate and address public concerns. Finally, such projects require

lengthy negotiations with the regulatory agencies, namely the California Department of Public Health (CDPH) and the Regional Water Quality Control Board (RWQCB).

- **Environmental documentation**: Many of the projects will require environmental documentation. Depending on the timing and overlap, multiple projects could be included in one environmental documentation effort or a programmatic EIR/EIS could be developed. It is recommended that the agencies most ready to proceed in the near term consider their individual needs and assess if a common effort would be advantageous. If Federal funding is sought on a regional basis, then a regional programmatic EIS may be necessary as part of the funding requirements under Title XVI or other Federal programs.

Chapter 10 References

Carpinteria Sanitary District
- (CSD,2005) Wastewater Collection System Master Plan, April 2005

Carpinteria Valley Water District
- (CVWD, 2006) Water Reliabilities Strategies 2030, February 2006

City of Santa Barbara
- (Carollo, 2009) Water Supply Planning Study, August 2009

Goleta Water District and Goleta Sanitary District
- (CDM, 1999) Reclaimed Water Project Study, January 1999

Goleta West Sanitary District
- (GWSD, 2004) Proposed New Wastewater Treatment Plant Site and Treatment Alternatives Evaluation, July 2004

Heal the Ocean
- (Metcalf-Eddy, 2001) Cost of Tertiary Wastewater Treatment for Southern Santa Barbara County, August 2001
- (HTO, 2000) Water Reclamation Research, September 2000
- (HTP, 2010) California Ocean Wastewater Discharge Report and Inventory, March 2010

Montecito Water District and Montecito Sanitary District
- (CH2M HILL, 1991) Water Reclamation Study, January 1991

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Appendix A - Document/Data Summary

Santa Barbara South Coast Regional Reuse Study

List of Documents Received

Last Updated: 12/12/2012

Agency	Document Title (Author)	Published Date	Contents in Report
Carpinteria Sanitary District	CSD 2011 Annual Report	Jan 2011	Flow and WQ data
	NPDES Permit	Feb 2011	NPDES Permit
	Plant Diagram		Process Flow Diagram
	Final Basis of Design Report for RW Facility 1992 Tertiary Treatment Facilities	Aug 1991	Tertiary treatment design concepts
	Reclamation System Study and Implementation (RW_Feasibility)	Jul 1990	Potential customers, pipeline alignment, reservoir and cost estimates
	User Commitments	Jul 1990	Letters of commitment from customers with RW needed.
	Wastewater Collection System Master Plan	Apr 2005	Existing & Future system, projected flows
	CSD GIS	Mar 2012	Service Boundary Layer
Carpinteria Valley Water District	Water Reliabilities Strategies 2030	Feb 2006	RW as a future option but no customers identified
	CVWD GIS data	Mar 2012	Contours, Water Distribution System, District Boundary, CVWD properties, landuse, Cities boundaries
	Crop Factors	Apr 2012	water use factors for agriculture
	2010 UWMP	Jun 2011	
	Meter Records	Apr 2012	2007-2011 Meter Records for customers requested (based on landuse)
City of Santa Barbara	RW Quality	Jul 2010	Only spreadsheet format
	Background Info	Jul 2010	Two pages summary format
	Santa Barbara Water Reclamation Project - Executive Summary Report (CH2M HILL)	May 1998	Reuse Master Plan
	Water Supply Planning Study (Carollo)	Aug 2009	Shows existing and future users and facilities
	Data for Tables WSPS-Carollo Eng-Aug 2009	Aug 2009	Excel data of Table 4.16, 4.17 and Figure 5.1
	SB GIS	Mar 2012	City Limits, Existing and Potential RW Pipelines, Existing and Proposed customers, aerial
	2010 UWMP	Jun 2011	
	NPDES Permit		
County of Santa Barbara	Sanitary Agencies Boundary (CSD, SSD, MCD, GSD, GWSD)	May 2012	GIS
	SouthCoast Parcel Shapefile	May 2012	GIS

RMC Water and Environment

Santa Barbara South Coast Regional Reuse Study
List of Documents Received

Last Updated: 12/12/2012

Agency	Document Title (Author)	Published Date	Contents in Report
Goleta Sanitary District	NPDES Permit R3-2010-0012 Final Order	May 2010	NPDES Permit
	Reclaimed Water Annual Report 2011	Jan 2012	Plant Schematic, Water Quality, RW produced
	Reclaimed Water Permit	May 1996	RW Permit
Goleta Water District	Goleta Water Rec Project Map and Cost Est.	Jul 1993	Simple map with customer parcel shaded, no demands Costs broken out by plant, pipeline , PS & RO
	Reclaimed Water Project Study (CDM)	Jan 1999	Existing/Future RW facilities/users; potential users
	Goleta WRP Memo	Aug 1992	5-page memo on the Wastewater Reclamation Project (includes costs)
	MapRecycledWaterSystem_Feb2012	Feb 2012	Map of Existing RW System
	Recycled_Water_Demands_GWD_2012 updated	May 2012	Table of near-term and long-term landscape customers with demands
	UWMP-_Recycled_Water_Sections_(Ch.s_3,_4)	Feb 2012	Plant capacity, current flows delivering, ww flows projection, total projected demands
	GWD GIS	Feb 2012	GWD Boundary, RW Pipelines with hydraulic pressure zones, contours, parcel
	Seasonal Demands 2009-2011	Jan 2012	Monthly RW demands in AF
	Groundwater Management Plan	May 2010	Basin Management Objectives
	GWD Service Areas, Facilities and Mutual Water Companies	Mar 2012	Map of Facilities and Mutual Water Companies
Goleta West Sanitary District	040701 WWTP Feasibility final report	Jul 2004	Proposed New Wastewater Treatment Plant TM Site & Treatment Alternatives Evaluation; Appendix & Figures provided; Study on treatment alternatives in relation to specific sites
	GIS District Boundary	Apr 2012	Received Goleta West and Goleta Sanitary District Boundaries

Santa Barbara South Coast Regional Reuse Study

List of Documents Received

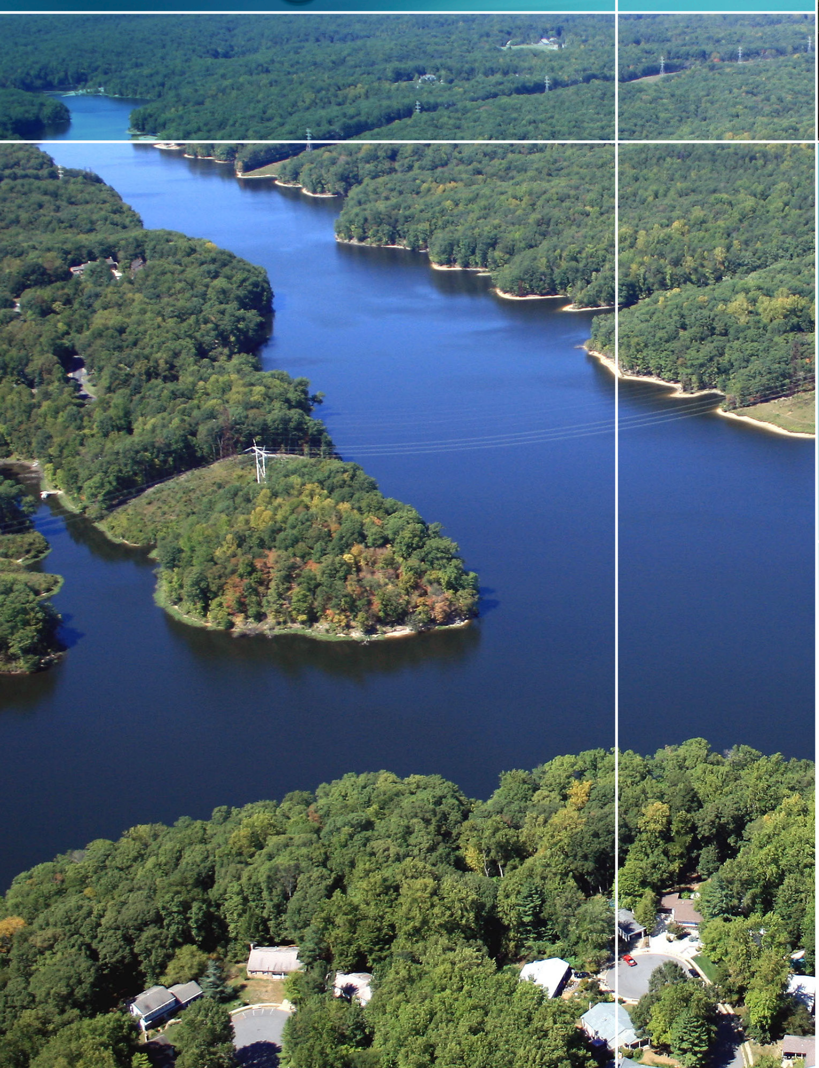
Last Updated: 12/12/2012

Agency	Document Title (Author)	Published Date	Contents in Report
Heal the Ocean	Cost of Tertiary Wastewater Treatment for Southern SB County (Metcalf-Eddy)	Aug 2001	Cost of upgrading Wastewater TP to Tertiary Treatment
	Water Reclamation Research 2000 (Bren School)	Sep 2000	WRP Research (Summary of GSD/GWD Report WRP & SB's Reclamation Efforts)
	HTO_CaOceanWastewaterDischargeInventoryJan2012	Mar 2010	A compilation and review of information by Heal the Ocean on wastewater treatment and wastewater facilities discharging into the Pacific Ocean along the coast of California.
	Wastewater Treatment Facility Google Map Info 1 -50	Mar 2012	Wastewater Treatment plant information
	Septic System Sanitary Survery Final Report	Mar 2003	Identify areas were conversion of onsite systems to sanitary sewers is warranted and feasible.
	WWTP_&_Outfall_Coords_+_Pollutant_Data_Working_Version_July_5	Mar 2012	WWTP & Outfall Pollutants Data
La Cumbre Mutual Water Company	GIS District Boundary	Apr 2012	
	Future RW Customers Demand	Apr 2012	Monthly meter data of 4 years (2008-2011) for two customers
Montecito Sanitary District	Montecito SD 2010 Annual Summary Report	Jan 2011	2010 Flow and WQ data
	GIS District Boundary	Apr 2012	
Montecito Water District	Water Reclamation Study (CH2M HILL)	Jan 1991	Reuse Market, WRP Alternatives (figures not too good/old)
Summerland Sanitary District	Board Presentation	Jan 2011	2010 Annual Report in presentation mode
	2011 Annual Report	May 2012	2011 Annual Report with data
Other	Miscellaneous Figures	Apr 2000	graph of SB's Water Supply by Source, water demand; table of SB's Water Facts; annual influent flow
	Newspaper Article	Apr 2000	Article on "Californians not yet sold on 'toilet to tap' recycling programs
	Treatment Info		Contaminants found in WW

Appendix B - EPA Guidelines for Water Reuse (2012)

EPA
United States
Environmental Protection
Agency

2012
Guidelines for Water Reuse



USAID
FROM THE AMERICAN PEOPLE

CDM Smith

EPA/600/R-12/618

September 2012

Guidelines for Water Reuse

U.S. Environmental Protection Agency

Office of Wastewater Management
Office of Water
Washington, D.C.

National Risk Management Research Laboratory
Office of Research and Development
Cincinnati, Ohio

U.S. Agency for International Development

Washington, D.C.

Notice

This document was produced by CDM Smith Inc. (CDM Smith) under a Cooperative Research and Development Agreement (CRADA) with the U.S. Environmental Protection Agency (EPA). It has been subjected to EPA's peer and administrative review and has been approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

The statutes and regulations described in this document may contain legally binding requirements. Neither the summaries of those laws provided here nor the approaches suggested in this document substitute for those statutes or regulations, nor are these guidelines themselves any kind of regulation. This document is intended to be solely informational and does not impose legally binding requirements on EPA; U.S. Agency for International Development (USAID); other U.S. federal agencies, states, local, or tribal governments; or members of the public. Any EPA decisions regarding a particular water reuse project will be made based on the applicable statutes and regulations. EPA will continue to review and update these guidelines as necessary and appropriate.

Foreword

For decades, communities have been reusing valuable reclaimed water to recharge groundwater aquifers, irrigate landscapes and agricultural fields, provide critical stream flows, and provide industries and facilities with an alternative to potable water for a range of uses. While water reuse is not new, population increases and land use changes, combined with changes in the intensity and dynamics of local climatic weather patterns, have exacerbated water supply challenges in many areas of the world. Furthermore, treated wastewater is increasingly being seen as a resource rather than simply 'waste.' In this context, water reclamation and reuse have taken on increased importance in the water supply of communities in the United States and around the world in order to achieve efficient resource use, ensure protection of environmental and human health, and improve water management. Strict effluent discharge limits have spurred effective and reliable improvements in treatment technologies. Along with a growing interest in more sustainable water supplies, these improvements have led an increasing number of communities to use reclaimed water as an alternative source to conventional water supplies for a range of applications. In some areas of the United States, water reuse and dual water systems for distribution of reclaimed water for nonpotable uses have become fully integrated into local water supplies. Alternative and efficient water supply options, including reclaimed water, are necessary components of holistic and sustainable water management.

As a collaborative effort between EPA and USAID, this document's primary purpose is to facilitate further development of water reuse by serving as an authoritative reference on water reuse practices. In the United States, water reuse regulation is primarily under the jurisdiction of states, tribal nations, and territories. This document includes an updated overview of regulations or guidelines addressing water reuse that are promulgated by these authorities. Regulations vary from state to state, and some states have yet to develop water reuse guidelines or regulations. This document meets a critical need: it informs and supplements state regulations and guidelines by providing technical information and outlining key implementation considerations. It also presents frameworks should states, tribes, or other authorities decide to develop new regulations or guidelines.

This document updates and builds on the *2004 Guidelines for Water Reuse* by incorporating information on water reuse that has been developed since the 2004 document was issued. This document includes updated discussion of regional variations of water reuse in the United States, advances in wastewater treatment technologies relevant to reuse, best practices for involving communities in planning projects, international water reuse practices, and factors that will allow expansion of safe and sustainable water reuse throughout the world. The 2012 guidelines also provide more than 100 new case studies from around the world that highlight how reuse applications can and do work in the real world.

Over 300 reuse experts, practitioners, and regulators contributed text, technical reviews, regulatory information, and case studies. This breadth of experience provides a broad and blended perspective of the scientific, technical, and programmatic principles for implementing decisions about water reuse in a safe and sustainable manner.

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Updating the Guidelines

The *Guidelines for Water Reuse* debuted in 1980 and was updated in 1992 and 2004. EPA contracted with CDM Smith through a CRADA to update the EPA guidelines for this 2012 release. Building on the work of previous versions, the CDM Smith project management team has involved a wide range of stakeholders in the development process. Beginning in 2009, EPA, USAID, and CDM Smith began facilitating workshops and informational sessions at water events and conferences around the world to solicit feedback on what information should be repeated, updated, added, or removed from the 2004 document. In addition, a committee of national and international experts in the field of water reclamation and related subjects was established to approve the document outline, develop new text and case studies, and review interim drafts of the document.

Ten stakeholder consultations were carried out in 2009 to 2011. (Unless otherwise noted, the consultations were held in the United States.) The consultations included:

- September and October 2009: Stakeholder workshops at the Annual WateReuse Symposium in Seattle, Wash., and Water Environment Federation Technical Exhibition and Conference (WEFTEC) in Orlando, Fla., were conducted to collect feedback on the format and scope of the update.
- November 2010: Brainstorming sessions at the American Water Works Association (AWWA) Water Quality Technology conference in Savannah, Ga., were held to identify major focus areas in the 2004 document and to identify potential authors and contributors.
- March, July, and September 2011: The International Water Association (IWA) Efficient 2011 conference in Jordan and the Singapore International Water Week (SIWW) in Singapore were used to collect input on international water reuse practices that encompass a range of treatment technologies, market-based mechanisms for implementation of reuse, and strategies for reducing water reuse-related health risks in developing countries. A status report was presented at the IWA International Conference on Water Reclamation and Reuse in Barcelona, Spain.
- January to October 2011: Status reports were presented at the New England Water Environment Association conference in Boston, Mass.; the WateReuse California conference in Dana Point, Calif.; the Annual WateReuse Symposium in Phoenix, Ariz.; and in a special session at the WEFTEC in Los Angeles, Calif.

The workshops held in Jordan, Singapore, and Spain provided an opportunity for input from a diverse group of international participants. Professionals from the private sector also attended these events, as did representatives from government and state agencies, universities, and nonprofit water-advocacy organizations. Non-governmental organizations, including the World Bank, World Health Organization (WHO), and International Water Management Institute (IWMI), were also represented.

The stakeholder input process identified a number of themes to update or emphasize in the updated guidelines, including:

- The role of reuse in integrated water resources management
- Energy use and sustainability associated with water reuse
- Agricultural reuse
- Wetlands polishing and stream augmentation
- Expanding opportunities for industrial reuse

- Groundwater augmentation and managed aquifer recharge
- Individual on-site and graywater reuse systems
- New information on direct and indirect potable reuse practices
- International trends in water reuse

In addition to the stakeholder input, the final document was researched, written, and reviewed by more than 300 experts in the field, including authors who contributed to case studies or chapters and reviewers. The contributors included participants from other consulting firms, state and federal agencies, local water and wastewater authorities, and academic institutions. The project management team compiled and integrated the contributions.

The formal review process included a two-stage technical review. The first stage of review was conducted by additional technical experts who were not involved in writing the document, who identified gaps or edits for further development. The project management team edited the text based on these recommendations and wrote or solicited additional text. The second stage of review was conducted by the peer review team; a group of reviewers who are experts in various areas of water reuse. The peer review team provided a written technical review and in-person comments during a meeting in June 2012. The project management team carefully evaluated and documented all technical comments/recommendations and the decision-making regarding the incorporation of the recommendations into the document.

The final draft and review record was presented to EPA and USAID for final approval in August 2012.

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Dedication

Daniel James Deely
(1944-2012)

This document is dedicated to Daniel James Deely, for his tireless dedication to a decades-long collaboration between EPA and USAID and to the *Guidelines for Water Reuse*. It is because of Dan's vision that this collaboration came about and was sustained. Dan served more than 40 years with USAID working on environmental and development projects worldwide. Dan was a walking reference for the history of the agency's water programming. His wisdom, patience, strong dedication to the human development mission of USAID, and expertise are dearly missed by his colleagues and his extended network of professional contacts.

Acknowledgements

The *Guidelines for Water Reuse* was first published in 1980 and was updated in 1992 and 2004. Since then, water reuse practices have continued to develop and evolve. This edition of the *Guidelines* offers new information and greater detail about a wide range of reuse applications and introduces new concepts and treatment technologies supporting water reuse operations. It includes an updated inventory of state reuse regulations and expanded coverage of water reuse practices in countries outside of the United States. More than 300 reuse experts contributed text and case studies to highlight how reuse applications can and do work in the real world.

The 2012 *Guidelines for Water Reuse* stands on the foundation of information generated by the substantial research and development efforts and extensive demonstration projects on water reuse practices throughout the world. Some of the most useful sources consulted in developing this update include conference proceedings, reports, and journal articles published by a range of organizations, including: the WateReuse Association (WRA), WateReuse Research Foundation (WRRF), Water Environment Federation (WEF), Water Environment Research Foundation (WERF), and AWWA. The National Research Council's *Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater* 2012 report was a timely and key contribution to the information contained in this document. This study takes a comprehensive look at the potential for reclamation and reuse of municipal wastewater to expand and enhance water supply alternatives.

The 2012 Guidelines for Water Reuse was developed by CDM Smith Inc. through a CRADA with EPA and USAID. Partial funding to support preparation of the updated document was provided by EPA and USAID. IWMI also provided technical, financial, and in-kind support for the development of Chapter 9 and the international case studies. We wish to acknowledge the direction, advice, and suggestions of the EPA Project Manager for this document, Robert K. Bastian of the Office of Wastewater Management; Dan Deely and Emilie Stander, PhD of USAID; and Jonathan Lautze, PhD and Pay Drechsel, PhD of IWMI. The CDM Smith project management team also reached out to the U.S. Department of Agriculture for input through James Dobrowolski and the U.S. Centers for Disease Control through Maxwell Zarate-Bermudez. The CDM Smith project management team was led by Project Director Robert L. Matthews, P.E., DEE and included Project Manager Katherine Y. Bell, PhD, P.E., BCEE; Technical Director Don Vandertulip, P.E., BCEE; and Technical Editors Allegra da Silva, PhD and Jillian Jack, P.E. Additional support was provided by Stacie Cohen, Alex Lumb, and Marcia Rinker of CDM Smith.

The process to create this document is outlined in **Updating the Guidelines**. We would like to express gratitude to the technical review committee who so painstakingly reviewed this document. The technical review committee included:

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Special thanks go to our colleagues who took their time to share professional experiences and technical knowledge in reuse to make these guidelines relevant and interesting. These contributors provided text or case studies; contributors who compiled and/or edited major sections of text are indicated with an asterisk (*). In addition, some members of the technical review committee contributed significant contributions of text. Please note that the listing of these contributors does not necessarily identify them as supporters of this document or represent their ideas or opinions on the subject. These persons are leaders in the field of water reuse, and their expertise has added to the depth and breadth of the document.

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Frequently Used Abbreviations and Acronyms

ANSI	American National Standards Institute
AOP	advanced oxidation processes
ASR	aquifer storage and recovery
BOD	biochemical oxygen demand
CBOD	carbonaceous biochemical oxygen demand
COD	chemical oxygen demand
CWA	Clean Water Act
DBP	disinfection by-product
DO	dissolved oxygen
DOC	dissolved organic carbon
DPR	direct potable reuse
EDC	endocrine disrupting compounds
EPA	U.S. Environmental Protection Agency
FDEP	Florida Department of Environmental Protection
GAC	granular activated carbon
HACCP	Hazard Analysis and Critical Control Points
IPR	indirect potable reuse
IRP	integrated resources plan
LEED	Leadership in Energy and Environmental Design
MBR	membrane bioreactor
MCL	maximum contaminant level
MF	microfiltration
NDMA	*N*-nitrosodimethylamine
NPDES	National Pollutant Discharge Elimination System
PPCP	pharmaceuticals and personal care product
PCR	polymerase chain reaction
POC	particulate organic carbon
RO	reverse osmosis
SAT	soil-aquifer treatment
SDWA	Safe Drinking Water Act
SRT	solids retention time
TDS	total dissolved solids
TMDL	total maximum daily load
TOC	total organic carbon
TrO	trace organic compounds
TSS	total suspended solids
TWM	total water management
UF	ultrafiltration
USACE	U.S. Army Corps of Engineers

USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
WHO	World Health Organization
WPCF	water pollution control facility
WRF	water reclamation facility
WRA	WateReuse Association
WRRF	WateReuse Research Foundation
WWTF	wastewater treatment facility
WWTP	wastewater treatment plant

CHAPTER 1
Introduction

Recognizing the need to provide national guidance on water reuse regulations and program planning, the U.S. Environmental Protection Agency (EPA) has developed comprehensive, up-to-date water reuse guidelines in support of regulations and guidelines developed by states, tribes, and other authorities. Water reclamation and reuse standards in the United States are the responsibility of state and local agencies—there are no federal regulations for reuse. The first EPA *Guidelines for Water Reuse* was developed in 1980 as a technical research report for the EPA Office of Research and Development (EPA, 1980). It was updated in 1992 to support both project planners and state regulatory officials seeking EPA guidance on appropriate water quality, uses, and regulatory requirements for development of reclaimed water systems in the various states (EPA, 1992). The primary purpose of the update issued in 2004 was to summarize water reuse guidelines, with supporting research and information, for the benefit of utilities and regulatory agencies, particularly in the United States (EPA, 2004). As of the publication of the 2012 updated document, 30 states and one U.S. territory have adopted regulations and 15 states have guidelines or design standards that govern water reuse. The updated guidelines serve as a national overview of the status of reuse regulations and clarify some of the variations in the regulatory frameworks that support reuse in different states and regions of the United States.

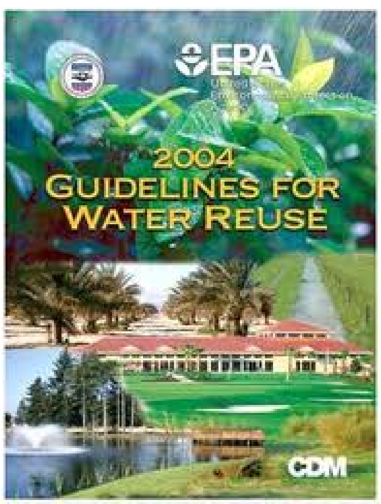

Figure 1-1
The 2004 EPA *Guidelines for Water Reuse* has had global influence.

Globally, the EPA *Guidelines for Water Reuse* has also had far-reaching influence. In fact, some countries either reference the document or adopt the guiding principles outlined in the 2004 guidelines. Many countries of the world also reference the World Health Organization (WHO) *Guidelines for the Safe Use of Wastewater, Excreta and Greywater*.

Over the last decade there has been significant growth in the application of reuse, important advances in reuse technologies, and an increase in the number of states that have implemented either rules or guidelines for reuse. In addition, growing worldwide water supply demands have forced planners to consider nontraditional water sources while maintaining environmental stewardship. In response to these changes and advances in reuse, EPA has developed the 2012 *Guidelines for Water Reuse* to incorporate this information through a Cooperative Research and Development Agreement (CRADA) with CDM Smith and an Interagency Agreement with U.S. Agency for International Development (USAID).

1.1 Objectives of the Guidelines

There were several key reasons to update the guidelines in 2012. As the field of reuse has expanded greatly over the past decade, there is a need to address new applications and advances in technologies, as well as update state regulatory information. As technologies are now advanced enough to treat wastewater to the water quality required for the intended use, the concept of "fit for purpose" is highlighted to emphasize the efficiencies realized by designing reuse for specific end applications. Second, EPA has committed to work with communities to incorporate the approach of integrated water management, where nonconventional water sources are incorporated as part of holistic water management planning, a theme that is emphasized in this update (Rodrigo et al., 2010). Third, there was interest in incorporating findings and recommendations from the National Research Council's (NRC) Water Science & Technology Board report, *Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater* (NRC, 2012).

Globally, the WHO has also updated its guidelines, which were under revision at the time of publication of the 2004 EPA guidelines document. In response to these changes and other advances in reuse technologies, EPA deemed it appropriate and necessary to revise its guidelines document to include updated information. As a result, facilitated workshops and informational sessions were initiated in 2009 at water events around the world to generate feedback about concepts that should be repeated, updated, added, or removed from the document; the current version of the *Guidelines for Water Reuse* incorporates this information.

In states and nations where standards do not exist or are being revised or expanded, the EPA guidelines can assist in developing reuse programs and appropriate regulations. The guidelines also will be useful to engineers and others involved in the evaluation, planning, design, operation, or management of water reclamation and reuse facilities. Because the number of reuse applications has expanded so significantly since publication of the 2004 document, this revision has modified the format and scope of case studies to provide readers with examples of best practices and lessons learned. Additionally, the chapter on international reuse has been expanded to include a discussion of principles for mitigating risks associated with wastewater use where treatment does not exist and enabling factors for expanding wastewater treatment to promote the increase of water reuse. The chapter also provides case studies of global experiences that can inform approaches to reuse in the United States.

1.2 Overview of the Guidelines

Stakeholder input was gathered from a wide range of contributors in order to identify key themes to emphasize in this update. The stakeholder involvement process is described in further detail in **Updating the Guidelines**. This input has been integrated throughout the document, which has been arranged by topic and devotes separate chapters to each of the key technical, financial, legal and institutional, and public involvement issues. While the document generally follows the outline of the 2004 guidelines, integration of some of the new materials resulted in expanded chapters that required minor reorganization. The document is organized into nine chapters and six appendices, as outlined in **Table 1-1**.

Throughout the text, **case studies** are introduced and referenced by a **[code name]** in brackets. In the pdf version of this document, hyperlinks will direct the reader to the case studies in the appendices. The U.S. case studies are listed and contained in Appendix D. International case studies are listed and contained in Appendix E.

1.3 Guidelines Terminology

The terminology associated with treating municipal wastewater and reusing it varies both within the United States and globally. For instance, although the terms are synonymous, some states and countries use the term *reclaimed water* while others use the term *recycled water*. Similarly, the terms *water recycling* and *water reuse* have the same meaning. In this document, the terms *reclaimed water* and *water reuse* are used. Definitions of terms used in this document, with the exception of their use in case studies, which may contain site-specific terminology, are provided below.

***De facto* reuse:** A situation where reuse of treated wastewater is, in fact, practiced but is not officially recognized (e.g., a drinking water supply intake located downstream from a wastewater treatment plant (WWTP) discharge point).

Direct potable reuse (DPR): The introduction of reclaimed water (with or without retention in an engineered storage buffer) directly into a drinking water treatment plant, either collocated or remote from the advanced wastewater treatment system.

Indirect potable reuse (IPR): Augmentation of a drinking water source (surface or groundwater) with reclaimed water followed by an environmental buffer that precedes drinking water treatment.

Nonpotable reuse: All water reuse applications that do not involve potable reuse.

Potable reuse: Planned augmentation of a drinking water supply with reclaimed water.

Table 1-1 Organization of 2012 *Guidelines for Water Reuse*

Chapter	Overview of Contents
Chapter 2–Planning and Management Considerations	EPA's TWM approach to water resources planning is described as a framework within which water reuse is integrated into a holistic water management approach. The steps that should be considered in the planning stage as part of an integrated water resources plan are then presented, followed by an overview of key considerations for managing reclaimed water supplies. These discussions cover management of supplies as well as managed aquifer recharge, which has progressed substantially since publication of the previous guidelines.
Chapter 3–Types of Reuse Applications	A discussion of reuse for agricultural, industrial, environmental, recreational, and potable supplies is presented. An expanded discussion of indirect potable reuse (IPR) and direct potable reuse (DPR) is also provided with references to new research and literature. Urban reuse practices such as fire protection, landscape irrigation, and toilet flushing were described in great detail in the 2004 guidelines and are not repeated here; however, general information regarding planning and management of reclaimed water supplies and systems that include urban reuse is provided in Chapter 2.
Chapter 4–State Regulatory Programs for Water Reuse	An overview of legal and institutional considerations for reuse is provided in this chapter. The chapter also gives an updated summary of existing state standards and regulations. At the end of this chapter are suggested minimum guidelines for water reuse in areas where such guidance or rules have not yet been established.
Chapter 5–Regional Variations in Water Reuse	This new chapter summarizes current water use in the United States and discusses expansion of water reuse nationally to meet water needs. The chapter discusses variations in regional drivers for water reuse, including population and land use, water usage by sector, water rates, and the states' regulatory contexts. Representative water reuse practices are described for each region, and U.S. water reuse case studies are introduced.
Chapter 6–Treatment Technologies for Protecting Public and Environmental Health	This chapter provides an overview of the treatment objectives for reclaimed water and discusses the major treatment processes that are fundamental to production of reclaimed water. And, while this chapter is not intended to be a design manual or provide comprehensive information about wastewater treatment, which can be found in other industry references, an overview of these processes and citations for updated industry standards is provided.
Chapter 7–Funding Water Reuse Systems	Assuring adequate funding for water reuse systems is similar to funding other water services. Because of increased interest in using reclaimed water as an alternate water source, this chapter provides a discussion of how to develop and operate a sustainable water system using sound financial decision-making processes that are tied to the system's strategic planning process.
Chapter 8–Public Outreach, Participation, and Consultation	This chapter presents an outline of strategies for informing and involving the public in water reuse system planning and reclaimed water use and reflects a significant shift in thinking toward a higher level of public engagement since publication of the last guidelines. This chapter also describes some of the new social networking tools that can be tapped to aid with this process.
Chapter 9–Global Experiences in Water Reuse	With significant input from USAID and the International Water Management Institute (IWMI), the chapter on international reuse has been expanded to include a description of the growth of advanced reuse globally. In addition, this chapter provides information on principles for mitigating risks associated with the use of untreated or partially treated wastewater, enabling factors for expanding water reuse, and new case studies that can provide informed approaches to reuse in the United States.
APPENDIX A	Federal and nonfederal agencies that fund research in water reuse
APPENDIX B	Inventory of water reuse research projects
APPENDIX C	State regulatory websites
APPENDIX D	Case studies on water reuse in the United States
APPENDIX E	Case studies on water reuse outside the United States
APPENDIX F	List of case studies that were included in the 2004 EPA guidelines
APPENDIX G	Abbreviations for Units of Measure

Reclaimed water: Municipal wastewater that has been treated to meet specific water quality criteria with the intent of being used for a range of purposes. The term *recycled water* is synonymous with *reclaimed water*.

Water reclamation: The act of treating municipal wastewater to make it acceptable for reuse.

Water reuse: The use of treated municipal wastewater (reclaimed water). Other alternate sources of water, including graywater and stormwater, are discussed in Chapter 2.

Wastewater: Used water discharged from homes, business, industry, and agricultural facilities.

In addition to the general terms defined above, the following terminology is used in this document to delineate between categories of water reuse applications (**Table 1-2**).

Table 1-2 Categories of water reuse applications

Category of reuse		Description
Urban Reuse	Unrestricted	The use of reclaimed water for nonpotable applications in municipal settings where public access is not restricted
	Restricted	The use of reclaimed water for nonpotable applications in municipal settings where public access is controlled or restricted by physical or institutional barriers, such as fencing, advisory signage, or temporal access restriction
Agricultural Reuse	Food Crops	The use of reclaimed water to irrigate food crops that are intended for human consumption
	Processed Food Crops and Non-food Crops	The use of reclaimed water to irrigate crops that are either processed before human consumption or not consumed by humans
Impoundments	Unrestricted	The use of reclaimed water in an impoundment in which no limitations are imposed on body-contact water recreation activities
	Restricted	The use of reclaimed water in an impoundment where body contact is restricted
Environmental Reuse		The use of reclaimed water to create, enhance, sustain, or augment water bodies including wetlands, aquatic habitats, or stream flow
Industrial Reuse		The use of reclaimed water in industrial applications and facilities, power production, and extraction of fossil fuels
Groundwater Recharge – Nonpotable Reuse		The use of reclaimed water to recharge aquifers that are not used as a potable water source
Potable Reuse	IPR	Augmentation of a drinking water source (surface or groundwater) with reclaimed water followed by an environmental buffer that precedes normal drinking water treatment
	DPR	The introduction of reclaimed water (with or without retention in an engineered storage buffer) directly into a water treatment plant, either collocated or remote from the advanced wastewater treatment system

1.4 Motivation for Reuse

The ability to reuse water, regardless of whether the intent is to augment water supplies or manage nutrients in treated effluent, has positive benefits that are also the key motivators for implementing reuse programs. These benefits include improved agricultural production; reduced energy consumption associated with production, treatment, and distribution of water; and significant environmental benefits, such as reduced nutrient loads to receiving waters due to reuse of the treated wastewater. As such, in 2012, the drivers for reuse are similar to those presented in the 2004 guidelines and center around three categories: 1) addressing urbanization and water supply scarcity, 2) achieving efficient resource use, and 3) environmental and public health protection.

1.4.1 Urbanization and Water Scarcity

The present world population of 7 billion is expected to reach 9.5 billion by 2050 (U.S. Census Bureau, 2011).

In addition to the increasing need to meet potable water supply demands and other urban demands (e.g., landscape irrigation, commercial, and industrial needs), increased agricultural demands due to greater incorporation of animal and dairy products into the diet also increase demands on water for food production (Pimentel and Pimentel, 2003). These increases in population and a dependency on high-water-demand agriculture are coupled with increasing urbanization; all of these factors and others are effecting land use changes that exacerbate water supply challenges. Likewise, sea level rise and increasing intensity and variability of local climate patterns are predicted to alter hydrologic and ecosystem dynamics and composition (Bates et al., 2008). For example, the western United States, including the Colorado River Basin, which provides water to 35 million people, is projected to experience seasonal and annual temperature increases, resulting in increased evaporation (Garfin et al, 2007; Cohen, 2011).

Reuse projects must factor in climate predictions, both for demand projections and for ecological impacts. Municipal wastewater generation in the United States averages approximately 75 gpcd (284 Lpcd) and is relatively constant throughout the year. Where collection systems are in poor condition, the wastewater generation rate may be considerably higher or lower due to infiltration/inflow or exfiltration, respectively. Thus, according to Schroeder et al. (2012), the potential municipal water supply offset by reuse for a community of 1 million people will be approximately 75 mgd (3,950 L/s) or 27,400 million gallons (125 MCM) per year. Given losses at various points in the overall system and potential downstream water rights, the actual available water would most likely be about 50 percent of the potential value, but the resulting impact on the available water supply would still be impressive.

As urban areas continue to grow, pressure on local water supplies will continue to increase. Already, groundwater aquifers used by over half of the world population are being overdrafted (Brown, 2011). As a result, it is no longer advisable to use water once and dispose of it; it is important to identify ways to reuse water. Reuse will continue to increase as the world's population becomes increasingly urbanized and concentrated near coastlines, where local freshwater supplies are limited or are available only with large capital expenditure (Creel, 2003).

1.4.2 Water-Energy Nexus

Energy efficiency and sustainability are key drivers of water reuse, which is why water reuse is so integral to sustainable water management. The water-energy nexus recognizes that water and energy are mutually dependent—energy production requires large volumes of water, and water infrastructure requires large amounts of energy (NCSL, 2009). Water reuse is a critical factor in slowing the compound loop of increased water and energy use witnessed in the water-energy nexus. A frequently-cited definition of sustainability comes from a 1987 report by the Bruntland Commission: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Therefore, sustainable water management can be defined as water resource management that meets the needs of present and future generations.

Water reuse is integral to sustainable water management because it allows water to remain in the environment and be preserved for future uses while meeting the water requirements of the present. Water and energy are interconnected, and sustainable management of either resource requires consideration of the other. Water reuse reduces energy use by eliminating additional potable water treatment and associated water conveyance because reclaimed water typically offsets potable water use and is used locally. For example, about 20 percent of California's electricity is consumed by water-related energy use, including potable water conveyance, storage, treatment, and distribution and wastewater collection, treatment, and discharge (California Energy Commission, 2005). Although additional energy is required to treat wastewater for reclamation, the amount of energy required for treatment and transport of potable water is generally much greater in southern California. And the estimated net energy savings could range from 0.7 to 1 TWh/yr, or 3,000 to 5,000 kWh/Mgal. At a power cost of $0.075/kWh, the savings would be on the order of $50 to $87 million per year (Schroeder et al., 2012).

Figure 1-2
Purple pipe is widely used for reclaimed water distribution systems (Photo credit: CDM Smith)

The energy required for capturing, treating, and distributing water and the water required to produce energy are inextricably linked. Water reuse can achieve two benefits: offsetting water demands and providing water for energy production. As described in Chapters 3 and 5, thermoelectric energy generation currently uses about half of the water resources consumed in the United States and is a major potential user of reclaimed water (Kenny et al., 2005). On-site energy and resource efficiency is also driving the installation of decentralized reuse applications in industrial applications and establishments seeking Leadership in Energy and Environmental Design (LEED) certification.

EPA has developed principles for an Energy-Water Future that incorporate familiar concepts of: efficiency, a water-wise energy sector as well as an energy-wise water sector, consideration of wastewater as a resource, and integrated resource planning and recognition of the societal benefits (EPA, 2012).

Understanding that reuse is one of the tools that urban water/wastewater/stormwater managers have at their disposal to improve their existing systems' energy efficiency, EPA is currently developing a handbook titled *Leveraging the Water-Energy Connection—An Integrated Resource Management Handbook for Community Planners and Decision-Makers,* envisioned to be an integrated water management-planning support document. The manual will address water conservation and efficiency (which is discussed in these guidelines with respect to its role in TWM) as well as alternative water sources (reclaimed water, graywater, harvested stormwater, etc.) as part of capacity development, building codes for improved water and energy-use efficiency, and renewable energy sources from/for both water and wastewater systems.

1.4.3 Environmental Protection

Water scarcity and water supply demands in arid and semi-arid regions drive reuse as an alternate water supply; however, there are still many water reuse programs in the United States that have been initiated in response to rigorous and costly requirements to remove nutrients (mainly nitrogen and phosphorus) from effluent discharge to surface waters. Environmental concerns over negative impacts from increasing nutrient discharges to coastal waters are resulting in mandatory reductions in the number of ocean discharges in Florida and California. By eliminating effluent discharges for all or even a portion of the year through water reuse, a municipality may be able to avoid or reduce the need for costly nutrient removal treatment processes or maintain wasteload allocations while expanding capacity. Avoiding costly advanced wastewater treatment facilities was the key driver for St. Petersburg, Fla., to initiate reclaimed water distribution to residential, municipal, commercial, and industrial demands when the state legislature enacted the Wilson-Grizzle Act in 1972, significantly restricting nutrient discharge into Tampa Bay. Today, St. Petersburg serves more than 10,250 residential connections in addition to parks, schools, golf courses, and commercial/industrial applications, including 13 cooling towers. Another current example is King County, Wash., which is implementing reuse to reduce the discharge of nutrients into Puget Sound to address the health of this marine water [US-WA-King County].

Under some National Pollutant Discharge Elimination System (NPDES) programs, water reuse may have evolved from initial land treatment system or zero discharge system concepts. The reuse program in this circumstance may serve dual objectives. First, the system could treat as much effluent on as little land as possible (thus, application rates are often greater than irrigation demands), with subsequent "disposal" of the remaining fraction. And second, the evolution of this treatment process could provide an alternate water supply when water reuse practices are implemented.

Many communities are also turning to water reuse to achieve environmental goals of maintaining flows to sensitive ecosystems, such as in Sierra Vista, Ariz.; San Antonio, Texas; and Sydney, Australia [US-AZ-Sierra Vista, US-TX-San Antonio, and Australia-Replacement Flows].

1.5 "Fit for Purpose"

While the increased use of reclaimed water typically poses greater financial, technical, and institutional challenges than traditional sources, a range of treatment options are available such that any level of water quality can be achieved depending upon the use of the reclaimed water. This is also reflective of the evolution of reclaimed water from its origins as land application and treatment for disposal of treated wastewater effluent for groundwater recharge and crop production to the advanced treatment processes that are applied today to meet potable water quality for indirect potable reuse. Indeed, the NRC's Water Science & Technology Board recently acknowledged this continuum of reuse practices in its 2012 report, *Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater (NRC, 2012)*, with the following statement:

"A portfolio of treatment options, including engineered and managed natural treatment processes, exists to mitigate microbial and chemical contaminants in reclaimed water, facilitating a multitude of process combinations that can be tailored to meet specific water quality objectives. Advanced treatment processes are also capable of addressing contemporary water quality issues related to potable reuse involving emerging pathogens or trace organic chemicals. Advances in membrane filtration have made membrane-based processes particularly attractive for water reuse applications. However, limited cost-effective concentrate disposal alternatives hinder the application of membrane technologies for water reuse in inland communities" (NRC, 2012).

This concept is represented graphically in **Figure 1-3**, which illustrates that water treatment technologies (combined with disinfection) offer a ladder of increasing water quality, and choosing the right level of treatment should be dictated by the end application of the reclaimed water for achieving economic efficiency and environmental sustainability.

There are numerous case studies that demonstrate the balance of treatment costs along with the intended use of the reclaimed water. Many of these develop reuse in the interest of replacing the use of drinking water for nonpotable applications and meeting the future water demands. As such, the treatment level required for reclaimed water production depends on the end use. A number of states, such as Washington, California, Florida, Arizona, and others, prescribe the level of treatment depending on the end use. This recognition of "Fit for Purpose" provides a framework for cost-effective treatment to be applied to a water

Figure 1-3
Treatment technologies are available to achieve any desired level of water quality

source sufficient to meet the quality appropriate for the intended use. By selecting appropriate treatment for specific applications, water supply costs can be controlled and the costs for improved wastewater treatment technologies delayed until they are balanced by the benefits. Consideration must also be balanced with the potential for future reuse of higher reclaimed water quality such that these uses are not limited.

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CHAPTER 2
Planning and Management Considerations

With increasing restrictions on conventional water resource development and wastewater discharges, reuse has become an essential tool in addressing both water supply and wastewater disposal needs in many areas. This growing dependence on reuse makes it critical to integrate reuse programs into broader planning initiatives. Since publication of the 2004 guidelines, some excellent materials on planning, developing, and managing reuse systems have been published and are referenced in this chapter. A summary of overarching management themes and discussion of some important management practices and tools are provided in this chapter.

2.1 Integrated Water Management

Beyond the need to address water supply challenges, many utility systems are under increasing pressures to save costs and demonstrate environmental stewardship. Under this scenario, weaknesses in the traditional practices of water management, which typically focus on individual resources or utilities, have become apparent. Recognizing these challenges, application of adaptive management approaches, such as integrated water management, is a means of improving water resource management and reducing waste streams (EPA, 2009). This approach is the result of a focus on broader water resources management options that encompass all of the water resource systems within a community, and reuse is a key factor in this more holistic planning method. **Figure 2-1** illustrates the difference between integrated and nonintegrated water resources management approaches.

As described in the draft document *Total Water Management* (Rodrigo et al., 2010), receiving waters (**Figure 2-1**) represent surface and groundwater resources that provide both water supply sources and points of wastewater discharge. Dry weather stormwater represents low flows that occur during non-peak events that may end up in the wastewater collection system, and wet weather stormwater represents higher flow periods that generally end up as discharge to receiving waters (Rodrigo et al., 2010). In the non-integrated approach, urban watersheds use more receiving waters for their water supplies and heavily discharge wastewater and stormwater into receiving waters.

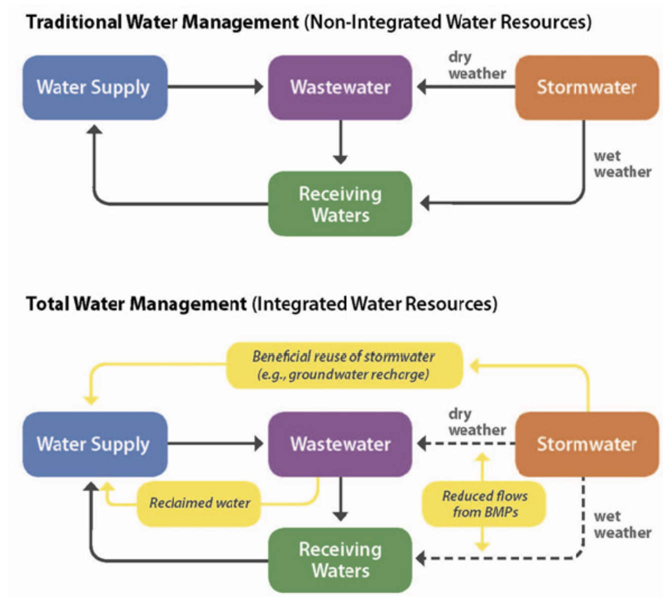

Figure 2-1
Traditional versus Integrated Water Management (adapted from O'Connor et al., 2010)

This approach can result in detrimental environmental impacts and lead to inefficiencies in the use of water. Integrated water management significantly improves the opportunities to obtain benefits from water, regardless of the stage in the water cycle. Concepts such as integrating water conservation practices to reduce the demand for freshwater are part of this comprehensive management approach. Also, rather than viewing stormwater as a nuisance, it should be considered an asset that is allowed to recharge groundwater through best management practices (BMPs), such as the use of swales, porous pavement, or cisterns. Additionally, wastewater can be reused, providing both environmental and water supply benefits.

The end result of integrated water management is reduced discharges to receiving waters and reduced reliance on surface and groundwater supplies to meet water demands. The following set of management strategies and alternative resources are typically considered in an integrated water management plan:

- Water conservation
- Reuse of wastewater
- Reuse of graywater
- Stormwater BMPs
- Rainwater harvesting
- Enhanced groundwater recharge
- Increased surface water detention
- Dry weather urban runoff treatment
- Dual plumbing for potable and nonpotable uses
- Separate distribution systems for fire protection
- Multi-purpose infrastructure
- Use of the right water quality for intended use
- Green roofs
- Low impact development (LID)

An example of this new approach to water resources planning is the Integrated Resources Plan (IRP) of Los Angeles, Calif. In 1999, Los Angeles embarked on an entirely new approach for managing its water resources. The IRP took a holistic, watershed approach by developing a partnership among different city departments that managed water supply, wastewater, and stormwater (CDM, 2005; Lopez Calva et al., 2001). The goal was to develop multi-purpose, multi-benefit strategies to address chronic droughts, achieve compliance with water quality laws (e.g., total maximum daily loads [TMDLs]), provide additional wastewater system capacity, increase open space, reduce energy consumption, manage costs, and improve quality of life for its citizens. Completed in 2006, the IRP won numerous awards and was well-supported by the city's diverse stakeholders (CH:CDM, 2006a; 2006b; and 2006c). Projects identified in the IRP will be implemented over the next 20 years. When the strategies that were evaluated as part of the IRP development were compared to traditional water management practices, integrated water management scenarios demonstrated greater benefits at lower total present value costs than the baseline traditional approach scenario.

While the results in the city of Los Angeles IRP were largely driven by the higher cost for imported water, which is very susceptible to droughts, there are other motives for integrated planning. The city of San Diego [US-CA-San Diego] is conducting an 18-month demonstration project in 2012 to demonstrate the potential of IPR. Pending the results of the demonstration project, the city would mine treated wastewater effluent from the outfall serving the Point Loma Primary Treatment Plant to provide water higher in quality than drinking water standards and augment the supply of the San Vicente Reservoir. Drivers for this project include an expanded water supply, reduction of coastal discharges, and lower energy consumption compared to importation of new supplies or ocean desalination. In other areas of the country, this integrated management approach may also produce greater benefits for water management, and not necessarily for water supply alone. Even smaller communities can benefit from examining water resources in a more interconnected and integrated manner. Franklin, Tenn. [US-TN-Franklin] has proactively adopted this management approach through the integrated water resources planning process. The city has reached beyond the typical application of this management tool to improve the overall services of the drinking water, wastewater, stormwater, and reclaimed water systems. The end result is that the city of Franklin, through a stakeholder participation process, has developed a long-term plan that will ultimately protect the Harpeth River—a source of water supply, a receiving body for treated effluent, a recreational waterway, and one of the community's most prized recreational resources.

Under the umbrella of an integrated plan, the development and management of facilities and policies for water, wastewater, stormwater, reclaimed water, and energy can be evaluated concurrently. Not only does this process bring together resources that share a common environment, it brings together the people who manage or are affected by these resources and their infrastructure, which is one of the reasons the integrated planning process is gaining in appeal. In this process, elected officials rely on the consensus backing of stakeholders, and the IRP process inherently strives to achieve goals that are common to all participating stakeholders (discussed further in Chapter 8). Specific guidance and examples of how water planners and managers can use the IRP process as an objective and balanced means of exploring the relative merits of considering reuse options alongside traditional water supply and demand management alternatives is provided in the research report titled, *Extending the Integrated Resource Planning Process to Include Water Reuse and Other Nontraditional Water Sources* (WRRF, 2007a). The report provides an extensive description of each of the elements of the IRP process, the issues and opportunities related to incorporating reuse into integrated plans, and the tools and models that can be used for facilitating appropriate reuse applications into an integrated management plan. Additional information is also provided in the draft document, *Total Water Management* (Rodrigo et al., 2010).

Integral to the successful implementation of integrated water management is a regulatory framework that facilitates rather than obstructs this approach. The various managed components of an integrated water resources plan, which may include water, wastewater, stormwater, reclaimed water, and energy, may be regulated by different state agencies and, in some cases, one component may be regulated by more than one state agency. Some state agencies, particularly those that have been delegated Clean Water Act (CWA), NPDES, and Safe Drinking Water Act (SDWA) federal programs, have deliberately elected to establish clear boundaries to avoid any potential for redundancy and confusion for the public. In the case of an IPR proposal, however, aspects of the project might require involvement and possibly permitting by multiple agencies. The degree of coordination and cooperation that can be achieved may vary from project to project and from state to state. Therefore, states committed to achieving integrated water resources planning goals may choose to adopt laws that consolidate regulatory programs to the extent possible or improve the coordination and cooperation among programs of different state agencies for the purpose of facilitating this planning framework. Subsequently, regulatory programs developed on the basis of these laws should provide greater focus and details on implementation of more integrated solutions.

2.2 Planning Municipal Reclaimed Water Systems

Regardless of the size and type of a reclaimed water system, there are planning steps that should be considered (although an industrial process recycle system may have different process control drivers). Planning should be consistent with the overall water resources management objectives, which should be defined through an integrated planning process (Section 2.1). As part of an integrated water resources plan, a reclaimed water master plan can identify acceptable community uses for reclaimed water, potential customers and their demands, and the quality of water required. Planners must also determine the volume of reclaimed water available for distribution, paying attention to the diurnal discharge curve at the community WWTP. This is an important consideration that can drive many other planning decisions as water conservation practices often require evening or early morning irrigation when low flows to the WWTP occur. If irrigation will occur during low influent wastewater periods, the supply of reclaimed water may not be adequate to meet the instantaneous demands, unless the reclaimed water demand rate is low compared to current treatment plant capacity. Storage is one option to resolve this supply/demand imbalance.

As part of the initial viability assessment, it is critical to examine federal and state laws, regulations, rules, and policies. Frameworks of state regulations are described in Chapter 4. In addition to the state regulatory context, certain overarching federal and state natural resource and environmental impact laws apply at the planning stage. The National Environmental Policy Act (NEPA) requires an assessment of environmental impacts for all projects receiving federal funds and subsequent mitigation of all significant impacts. Many states also have equivalent rules that mandate environmental impact assessment and mitigation planning for all projects prior to construction. These requirements often stipulate terms of public review. Even in cases where it is not legally required, stakeholder involvement in the planning of a water-reuse system is important and can help to achieve a successful outcome, as described in Chapter 8.

Other laws protect biological, scenic, and cultural resources. These laws can result in a *de facto* moratorium on the construction of large-scale water diversions (by dams) that flood the habitat of protected species or inundate pristine canyons or areas of historical significance. These laws are of particular relevance where new water supply is under consideration. In some cases these laws make reuse more attractive than new source development, but they may impact seasonal storage options for reclaimed water.

To further examine project viability, the following project-planning steps taken from the *WateReuse Association Manual of Practice* serve as a guide (WRA, 2009):

A. Identify quantity of reclaimed water available
B. Screen all existing and potential future uses and users
C. Identify potential users
D. Determine if users will accept reclaimed water
E. Compare supply to potential demand
F. Prepare distribution system layout
G. Finalize customer list
H. Determine economic feasibility
I. Compile final user list and distribution
J. Prepare point-of-sale facilities
K. Obtain regulatory approval
L. Perform on-site retrofits
M. Perform cross-connection test
N. Begin delivering water

While the *WateReuse Association Manual of Practice* provides details on each of these steps, a number of considerations are worth further exploration.

2.2.1 Identifying Users and Types of Reuse Demands

Because permitted uses vary greatly between states, a review of individual state regulations is important so the utility has a thorough understanding of how reclaimed water is regulated and what uses are allowed. Once regulations and allowed uses are fully understood, a utility may review water usage records to identify and locate some of its largest users. Focusing first on the largest water users helps the utility get the best possible return on investment, as well as maximize its benefits to the potable water system. In addition to water records, aerial photographs can be useful in identifying users who could utilize reclaimed water for irrigation purposes (such as golf courses and other recreational facilities).

Variables such as an area's climate, state regulations, and common industries will determine the best potential reclaimed water customers. Irrigation of golf courses and recreational facilities may be the most well-known application of reclaimed water, but there are a number of less-traditional applications that can provide a utility with significant potable water savings:

- Irrigation and toilet flushing in large government facilities, such as capital complexes, schools, hospitals, colleges, and prisons
- Irrigation and toilet flushing in sports franchises, large arenas, and planned community centers
- Brownfield redevelopment
- Various uses in commercial and manufacturing processes
- Industrial fire protection
- Stream restoration/augmentation (where regulations allow)

The most reliable customers will be those who can utilize nonpotable water daily and throughout the year, such as in boilers and chillers or in a manufacturing process. These potential customers with a consistent usage rate will provide the utility with a baseline usage and will not be affected by wet or dry weather. A utility can count on these customers to provide turnover in pipelines during cool and/or wet periods and to provide a certain amount of consistent revenue. Additionally, within an integrated management approach, a utility may want to consider where the application of reuse provides the most value to the overall water supply system. Providing reclaimed water to commercial or industrial customers using a potable system nearing its capacity or to any users competing for the same limited resources as the utility may be more advantageous than supplying irrigation water to the local golf course, even if the latter is provided at a higher cost. Similarly, supplying reclaimed water to hydrate an impacted wetland or to control saline water movement within a critical aquifer system may allow continued or expanded use of a limited conventional water resource. Once initial potential users are identified, information should be gathered about the best way to get reclaimed water to them.

2.2.2 Land Use and Local Reuse Policy

Most communities in the United States engage in some type of structured planning process whereby the local jurisdiction regulates land use development according to a general plan, sometimes reinforced with zoning regulations and similar restrictions. Developers of approved areas for new development may be required to prepare specific plans that demonstrate sufficient water supply or wastewater treatment capacity. In these contexts, dual-piped systems may be developed at the outset of development. It is important that any reuse project conforms to requirements under the general plan to ensure the project does not face legal challenges on a land use basis. Local planning processes often include public notice and hearings. As the public may have many misconceptions about reclaimed water, it is important for planners to address public concerns or opposition, as described in depth in Chapter 8.

Chapter 5 of the 2004 guidelines identified land use and environmental regulation controls used by local government entities to implement and manage reclaimed water systems; this chapter also identified mandatory use requirements in California. Since publication of the 2004 guidelines, many communities and states have implemented more formal water planning processes to meet public health needs for adequate water, wastewater, and reclaimed water services. There are several reasons a utility might create a local policy to require connection to a reclaimed water system, with parallel logic used in many communities to require connection to municipal utilities when reasonably available. The most common reason to require connection is to assure use of the new system, adequate to shift some of the water demand and to pay for the new system or defer new potable main construction. In an integrated water management program, potable water supplies may be limited and require construction of a reclaimed water/dual water system to meet the total demand. Even if reclaimed water is priced lower than the potable supply, the public may not have been adequately informed to understand the benefits of a diversified water system and may resist conversion to reclaimed water.

Mandatory connection to reclaimed water systems is becoming more common. Planning for future use of reclaimed water allows communities to require certain uses to utilize reclaimed water if reasonably available. Because construction cost for retrofit with a dual water system is higher and disruption of other infrastructure is unavoidable, dual water piping can be installed initially with the nonpotable distribution system dedicated to irrigation, cooling towers, or industrial processes. When reclaimed water is available to the development area, a connection to the supply is the only local construction required.

Utilities may also need to secure bonds used for construction with an ordinance requiring connection to a reclaimed water system, thus providing a guarantee of future cash flow to meet bond payments. In addition to state legislative action in California (identified in Chapter 5 of the previous guidelines), many utilities have included mandatory connection language. Water Recycling Funding Program Guidelines initially issued in 2004 and amended in July 2008 require loan/grant applicants to include a draft mandatory use ordinance in their application packet (CA SWRCB, 2009). Text in the Marina Coast Water District Ordinance, Title 4, 4.28.030 Recycled water service availability, includes:

A. When recycled water is available to a particular property, as described in Section 1.04.010, the owner must connect to the recycled water system. The owner must bear the cost of completing this connection to the recycled water system.

B. New water users who are not required to connect to recycled water because the distance to the nearest recycled water line is greater than the distance provided in Section 1.04.010, shall be required to construct isolated plumbing infrastructure for landscape irrigation or other anticipated nonpotable uses, with a temporary connection to the potable water supply.

C. All new private or public irrigation water systems, whether currently anticipating connection to the recycled system or that shall be connected to the potable water system temporarily while awaiting availability of recycled water, shall be constructed of purple polyvinyl chloride (PVC) pipe to the existing district standard specification" (Marina Coast Water District, 2002).

Examples of other California utilities with mandatory connection requirements include Dublin San Ramon Services District (DSRSD); Inland Empire Utility Agency; San Luis Obispo Rowland Heights; Cucamonga Valley Water District; and Elsinore Valley Municipal Water District. Florida is another state with mandatory connection requirements; 78 counties, cities, and private utilities responded on their 2011 annual reuse reports that they either require construction of reclaimed water piping in new residential or other developments or require connection to reuse systems when they become available. The Florida communities of Altamonte Springs; Boca Raton; Brevard, Charlotte, Polk, Colombia, Palm Beach, and Seminole Counties; Marco Island; and Tampa are examples. There are no communities in Texas with mandatory connections, but requirements were also found in Yelm, Wash.; Cary, N.C.; and Westminster, Md.

Along with the mandatory connection requirement, there are also ordinances that promote use of reclaimed water through incentives. The St. Johns River Water Management District, Fla., provides a model water conservation ordinance to cities within the district to promote more water efficient landscape irrigation. The model ordinance includes time-of-day/ day-of-week restrictions based on odd-even street address as well as daily irrigation limits of 0.75 in/day (1.9 cm/d). Exemptions may be granted to these limitations. Possible exemptions include using a micro-spray, micro-jet, drip, or bubbler irrigation system; establishing new landscape; or watering in lawn treatment chemicals. The use of water from a reclaimed water system is allowed anytime.

The capacity of a reclaimed water system can be strained if customers continue to use reclaimed water beyond the utility capacity to supply it. In Cape Coral, Fla., the city council is considering an ordinance to re-establish an emergency water conservation plan due to a persistent drought since 2007 (Ballaro, 2012). The dry-season water demand—and the abuse of reclaimed water—has increased. As much as 42 million gallons (160,000 m^3) of reclaimed water are being used each scheduled watering day, and 19 million gallons (72,000 m^3) were being used on a day when no watering is allowed. The council is taking a proactive approach to protect the city's water resources, including reclaimed water.

2.2.3 Distribution System Considerations

It is important to keep in mind that reclaimed water distribution systems require many of the same planning and design considerations as potable water systems. And, because public water utilities are ultimately responsible for protecting the integrity of their water systems, safety programs addressing the potential for cross-connections must involve the public water authorities from inception. If a dual water system is being considered, planning for a new potable water system may be concurrent. Retrofits into existing developed areas, however, may require more effort as designers must identify all existing utilities to meet separation distances and avoid impacts to other utilities during construction. In any case, design of a reclaimed water distribution system should follow design standards required in the state where the project is implemented.

Where reclaimed water criteria are not available, designers should apply the general engineering design standards applicable to potable water or irrigation systems, as appropriate. General guidelines will be provided in this section, and users of these guidelines are referred to other current design documents that can provide guidance for reclaimed water systems. The *WateReuse Association Manual of Practice* identifies the basic steps in developing a water reuse program, including system engineering criteria (WRA, 2009). American Water Works Association (AWWA) published the third edition of its *Manual of Water Supply Practices M-24*, which discusses planning, design, construction, operation, regulatory framework, and management of community dual water systems (AWWA, 2009). AWWA also is preparing a new Reclaimed Water Management Standard that will be the first in a planned series of management standards. Additional information on cross-connection control is also provided in the

To develop a robust reclaimed water distribution system, it is important to provide an initial "backbone," or primary transmission main, of sufficient size to allow the system to carry reclaimed water away from the source. The primary transmission main should be constructed in a location that will allow for connections to future lines as well as easy connection to previously identified large potable water users. Several items should be considered when evaluating potential routes for the primary transmission main of a reclaimed water distribution system, including:

- The location of previously identified potential users
- The total amount of potable water to be saved by connecting these potential users to the reclaimed water distribution system

- The amount of potable water to be saved that is not dependent on weather or climate conditions
- Other potential future users along each alternate route
- Other utility or roadway projects that may be taking place around the same time as construction of the primary transmission main, which may help reduce initial capital costs

Coordination with other potential projects can help save a large amount of money in capital investment, and acquiring additional users (or positioning the utility to acquire additional users in the future) will help offset the capital investment and provide future revenue.

With a new reclaimed water distribution system, especially in a state or region where reclaimed water is not yet common, customer and public education are critical components for making the project successful. Potential customers must be informed of the benefits of using reclaimed water instead of potable water for their nonpotable water needs. There may be a financial incentive for the first customers in a new system. In addition, any myths or misconceptions about reclaimed water need to be dispelled immediately and replaced with accurate information about the safety and quality of reclaimed water. Providing water quality data on reclaimed water may help ease customer concerns. As the distribution system grows, new users will be identified more easily. During periods of dry weather or drought, potential users will often identify themselves and help expand the system.

Reuse systems often have different peak hours than potable water systems. Peak usage of a reclaimed water distribution system often occurs at night when large users are irrigating. To help shave the peaks from the system, a utility can set an irrigation schedule for large irrigation users. This will prevent too many large irrigation users from irrigating simultaneously and taxing the system. Requiring large users to maintain their own on-site storage can also control peak delivery rates and equalize flow within the system.

2.2.3.1 Distribution System Pumping and Piping

To meet initial and projected demands, a hydraulic model using real data from potable water records can provide a realistic view of how much reclaimed water could be used at both average and peak times. This will help determine the size of the primary transmission main, as well as initial or future storage. Hydraulic modeling can also identify optimum pipe diameters and routing for initial and expanded distribution systems. Integral to the choice of pipe diameters based on anticipated flow rates are decisions on utility and customer storage, time-of-day watering restrictions, and rate of delivery to the customer. Large irrigation customers, especially golf courses, may already have water features that are filled daily from existing water sources and that serve as storage for on-site irrigation systems. Automated irrigation systems are quite common at golf courses and are typically programmed to apply controlled amounts of water to meet course demands based on weather conditions and evapotranspiration data. A component of the user agreement may include limits on rate of delivery to fill an existing storage feature at a flat rate during a 24-hour period to maximize delivery capacity for the utility. The blend of large customers that have available storage and small customers that simply are willing to replace potable water at line pressure with reclaimed water at line pressure will influence system storage, pumping, and delivery main sizing.

Most states require reclaimed water distribution piping to be purple, with the color integral to the pipe; Pantone 512 or 522 is often specified for this purpose (**Figure 2-2**). Reclaimed water piping should be identified in a manner consistent with state design criteria, which may include labeling or tags as well as signage along the piping alignment. Pipe material is often PVC, as color is readily incorporated into the pipe during manufacturing. For larger systems that use concrete steel cylinder pipe for transmission mains, purple dye can be added to the mortar during manufacture of the pipe, as is the practice for most of the large diameter pipes in the transmission lines in the San Antonio Water System (SAWS).

Figure 2-2
36-inch CSC 301 purple mortar pipe, San Antonio Water System (Photo credit: Don Vandertulip)

Where utility preference or construction conditions dictate the use of other pipe material, such as ductile iron pipe, purple plastic sleeves can be used to provide corrosion control and identify the water main as a reclaimed water main. Likewise, steel pipe can be painted and high density polyethylene (HDPE) pipe can be ordered with purple stripes integral to the pipe.

Separation distances are required between reclaimed water pipes and water and sewer pipes, typically identified as 9 or 10 ft (3 m) pipe-to-pipe horizontal separation between reclaimed water and potable water piping. The same provision typically applies to separation distance between a reclaimed water pipe and a sanitary sewer main. Where a crossing occurs, the pipe with the highest quality product should be located above the other two, with 1 ft (0.3 m) vertical separation between any two pipes. Specifically, potable pipe should be above reclaimed water pipe, and reclaimed water pipe should be above the sanitary sewer main, as shown in **Figure 2-3**.

2.2.3.2 Reclaimed Water Appurtenances

Reclaimed water distribution systems will have all of the appurtenances typical of a potable water system. Most of the typical system components are now available in purple to support increased installation of purple color-coded reclaimed water systems. Valve riser covers are often triangular or square to distinguish them from potable water covers; reclaimed water system valves can be ordered as plant valves with opposite open and close positions from potable valves. Backflow prevention devices, air relief valves, meter boxes, and sprinkler heads are all available in purple. All components and appurtenances of a nonpotable system should be clearly and consistently identified throughout the system. Identification should be through color coding and marking so that the nonpotable system (i.e., pipes, pumps, outlets, and valve boxes) is distinctly set apart from the potable system. The methods most commonly used are unique colorings, labeling, and markings.

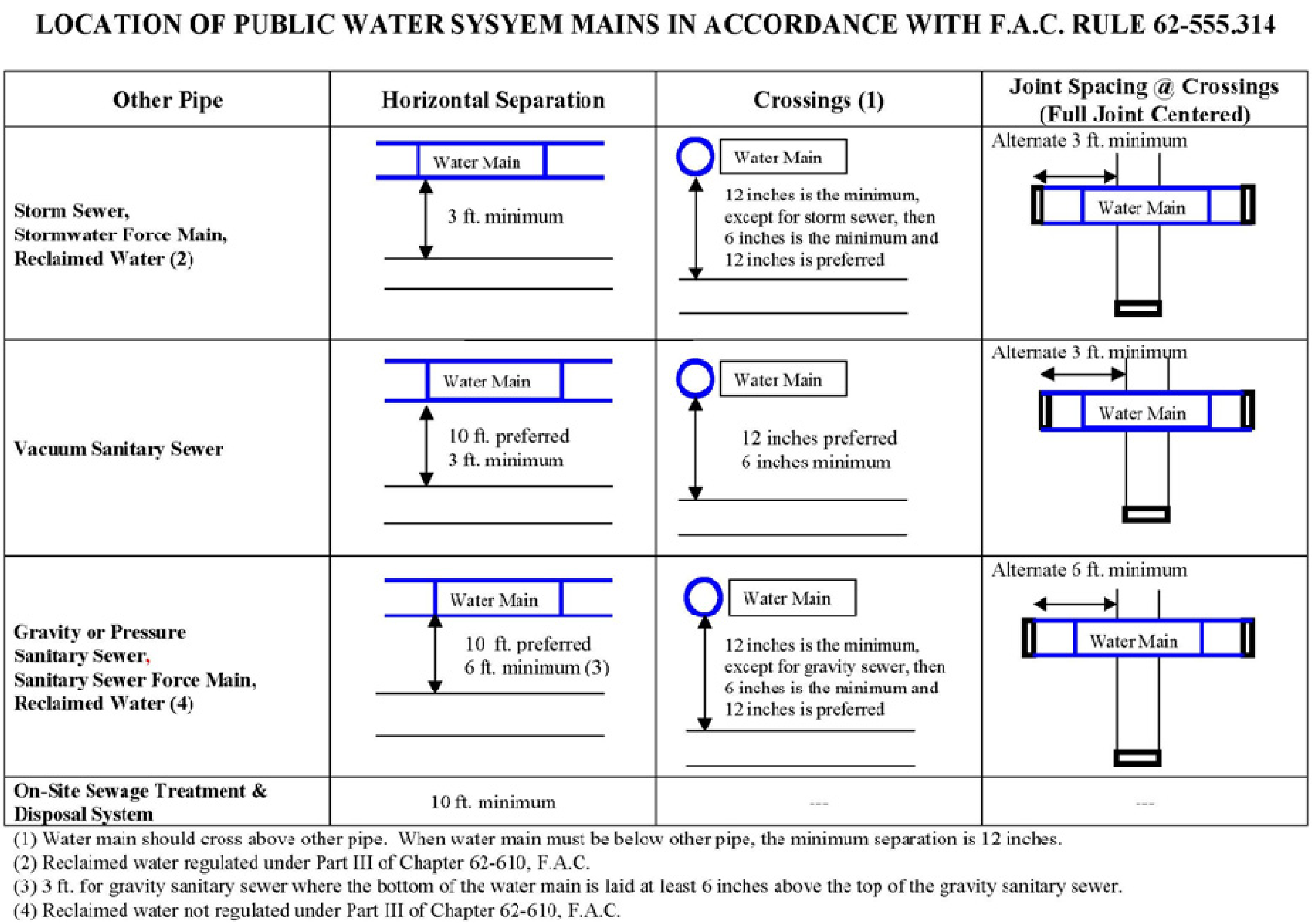

Figure 2-3
Appropriate separation of potable, reclaimed water, and sanitary sewer pipes (FDEP, n.d.)

A reclaimed water distribution system typically requires signage at facilities (e.g., pump stations, storage, etc.), and some states require marking of utility pipelines along the alignment. For irrigation components that incorporate hose bibs, most state regulations require a locking hose vault or quick connection assembly to preclude unauthorized connection and use of the reclaimed water. Purple asset identification tags can be attached to valve box lids, valve handles, backflow preventers, and other appurtenances to readily identify these system components. All major irrigation system suppliers have snap-on components (rings) in purple that can be added to existing sprinkler heads, as shown in **Figure 2-4**. Purple Mylar pre-printed stickers are also popular and can be wrapped around pop-up sprinkler heads to identify the system as providing reclaimed water.

2.2.3.3 On-site Construction Considerations

Many reclaimed water providers provide guidance and instructions to property owners connecting to the reclaimed water system. This can include user manuals and training classes for on-site supervisors of commercial properties. These manuals and instructions typically cover state and local regulations related to reclaimed water, proper use, cross-connection control, and on-site construction standards and materials. Good examples of user manuals are those provided by SAWS and DSRSD (SAWS, 2006 and DSRSD, 2005). Tucson has developed an extensive cross-connection control program and a manual for its cross-connection control specialist; more information on the Tucson Site Inspection Program is available in a case study [US-AZ-Tucson].

Typically, utility design criteria apply within the public right-of-way, and locally-adopted plumbing code controls, construction practices, permits, and construction inspections apply for work on private property. There are two plumbing codes in general use within the United States: the Uniform Plumbing Code produced by the International Association of Plumbing and Mechanical Officials (IAPMO) and the International Plumbing Code produced by the International Code Council (ICC). Beginning in 2008, several professional organizations (WateReuse Association [WRA], Water Environment Federation [WEF], AWWA) serving reclaimed water utilities began a dialogue with IAPMO, and eventually also with ICC, attempting to change plumbing code pipe color requirements adopted in 2009. The proposal requires all pipe conveying alternate waters to be purple; alternate waters includes reclaimed water provided by the off-site municipal utility provider but also would include any other nonpotable water generated on the private property. The issue for many utilities is the significant water quality difference between municipally produced, tested, and distributed reclaimed water and other on-site water, including graywater, which is by definition "wastewater." The second issue that surfaced was the plumbing code's use of green pipe to designate potable water. In the municipal utility business, blue is the color used to designate potable water piping while green is used to designate wastewater. This identified a potential cross-connection problem that, to date, is unresolved.

Figure 2-4
Purple snap-on reclaimed water identification cap
(Photo credit: Rain Bird)

Color coding of utility piping systems has been practiced for decades, and the roots of the current American National Standard Institute (ANSI) Standard Z-535 color standard in the United States can be traced back to the July 16, 1945 American Standard Association (ASA) approval of safety color standards at the request of the War Department (ANSI, 2007).

The American Public Works Association (APWA) Uniform Color Standard was initially adopted in 1980 (Precaution Blue for water systems and Safety Green for sewer systems), and an updated policy that added purple for reclaimed water pipes was adopted in 2003. The use of purple pipe to designate reclaimed or recycled water was first adopted by the AWWA California-Nevada Section in 1997. The California Department of Health Services and Nevada Division of

Environmental Protection reviewed and accepted the guidelines (AWWA, 1997). More recently, the Common Ground Alliance (CGA) was formed by the Department of Transportation in 1998, and in 2009 the CGA adopted the APWA Uniform Color Standard. The CGA Uniform Color Code and Marking Guideline, Appendix B (CGA, 2011) is the basis of color-code marking for the national One-Call System used to locate and mark underground utilities prior to construction (Vandertulip, 2011a).

Three states have addressed the issue of on-site purple pipe application for conveyance of alternative waters. California adopted final rules for graywater systems that became effective January 27, 2010, as Title 5, Part 24, Chapter 16A Nonpotable Water Reuse Systems. Purple pipe requirements in California's state code for recycled water (Title 22) were maintained for reclaimed water piping in a building, and Universal Product Code (UPC) 1610.2 state adoption of the plumbing code excludes reference to pipe color for alternate waters. In similar fashion, Florida adopted

the International Plumbing Code (IPC) without adopting the pipe color code sections, while maintaining Section 602 requirements that reclaimed water be distributed in purple pipe. Washington state modified the base UPC in WAC 51-56-1600 Chapter 16—Gray water systems 1617.2.2 Other Nonpotable Reused Water to maintain yellow pipe with black text designating the type of nonpotable water while 1617.2.1 maintained purple pipe for reclaimed water (Vandertulip, 2011b).

2.2.4 Institutional Considerations

The rules and regulations governing design, construction, and implementation of reuse systems are described in Section 2.2.3, and the practical implications of these rules can be found in Chapter 4. In addition to rules specifically aimed at water reuse projects, regulations governing utility construction in general also apply. The details of such rules are beyond the scope of this document but can be promulgated by state agencies (including health departments) and local jurisdictions or can be established by federal grant or loan programs.

Once facilities have been constructed, state and local regulations often require monitoring and reporting of performance, as described in Chapter 4. To provide production, distribution, and delivery of reclaimed water, as well as payment for it, a range of institutional arrangements can be utilized, as listed in **Table 2-1**.

It is necessary to conduct an institutional inventory to develop a thorough understanding of the institutions with jurisdiction over various aspects of a proposed reuse system. On occasion there is an overlap of agency jurisdiction, which may cause conflict unless steps are taken early in the planning stages to obtain support and delineate roles. The following institutions should be involved or, at a minimum, contacted: federal and state regulatory agencies, administrative and operating organizations, and general units of local (city, town, and county) government.

In developing a viable arrangement, it is critical that both public and private organizations be considered. As access to public funds decrease, the potential for private capital investment increases. It is vital that the agency or entity responsible for financing the project be able to assume bonded or collateralized indebtedness, if such financing is likely, and have accounting and fiscal management structures to facilitate financing (see Chapter 7). Likewise, the arrangement must designate an agency or entity with contracting power so that agreements can be authorized with other entities in the overall service structure. Additional responsibilities may be assigned to different groups depending on their historical roles and technical and managerial expertise. Close internal coordination between departments and branches of

Table 2-1 Common institutional arrangements for water reuse

Type of Institutional Arrangement	Production	Wholesale Distribution	Retail Distribution
Separate Authorities	Wastewater Treatment Agency	Wholesale Water Agency	Retail Water Entity
Wholesaler/Retailer System	Wastewater Treatment Agency	Wastewater Treatment Agency	Retail Water Entity
Joint Powers Authority (for Production and Distribution only)	Joint Powers Authority	Joint Powers Authority	Retail Water Entity
Integrated Production and Distribution	Water/Wastewater Authority	Water/Wastewater Authority	Water/Wastewater Authority

local government, along with a range of legal agreements, will be required to ensure a successful reuse program. Examples of institutional agreements developed for water reuse projects are provided in the 2004 guidelines in Chapter 5 and in a case study [US-CA-San Ramon].

Finally, the relationship between the water purveyor and the water customer must be established, with requirements on both sides to ensure reclaimed water is used safely. Agreements on rates, terms of service, financing for new or retrofitted systems, educational requirements, system reliability or scheduling (for demand management), and other conditions of supply and use reflect the specific circumstances of the individual projects and the customers served. (See Chapter 7 for a discussion of the development of the financial aspects of water reuse fees and rates.) In addition, state laws, agency guidelines, and local ordinances may require customers to meet certain standards of performance, operation, and inspection as a condition of receiving reclaimed water. However, where a system supplies a limited number of users, development of a reclaimed water ordinance may be unnecessary; instead, a negotiated reclaimed water user agreement would suffice. It is worth noting that in some cases, where reclaimed water is still statutorily considered effluent, the agency's permit to discharge wastewater—along with the concomitant responsibilities—may be delegated by the agency to customers whose reuse sites are legally considered to be distributed outfalls of the reclaimed water.

2.3 Managing Reclaimed Water Supplies

Managing and allocating reclaimed water supplies may be significantly different from the management of traditional water sources. Traditionally, a water utility drawing from groundwater or surface impoundments uses the resource as both a source and a storage facility. If the entire yield of the source is not required, the water is simply left for use at a later date. Yet in the case of reuse, reclaimed water is continuously generated, and what cannot be used immediately must be stored or disposed of in some manner. As a traditional reclaimed water system expands, an increasing volume of water may need to be stored. Depending on the volume and pattern of projected reuse demands, in addition to operational storage considerations, seasonal storage requirements may become a significant design consideration and have a substantial impact on the capital cost of the system. While some systems continue to rely on conventional disposal alternatives, the increasing value of reclaimed water is also resulting in more research into practices that provide for increased storage volumes, supplemental water supplies that allow an increased customer base, and improved seasonal management, which together reduce the need for discharges to streams or ocean outfalls.

Where water reuse is being implemented to reduce or eliminate wastewater discharges to surface waters, state or local regulations usually require that adequate seasonal storage be provided to retain excess wastewater under a specific return period of low demand. In some cold climate states, storage volumes may be specified according to projected nonapplication days due to freezing temperatures. Failure to retain reclaimed water under the prescribed weather conditions may constitute a violation of an NPDES permit and result in penalties. A method for preparing storage calculations under low-demand conditions is provided in the *EPA Process Design Manual: Land Treatment of Municipal Wastewater* (EPA, 2006). In many cases, state regulations will also include a discussion about the methods to be used for calculating the storage required to retain water under a given rainfall or low demand return interval. In almost all cases, these methods will be aimed at demonstrating sites with hydrogeologic storage capacity to receive treated effluent for the purposes of disposal. In this regard, significant attention is paid to subsurface conditions as they apply to the percolation of effluent into the groundwater with specific concerns as to how the groundwater mound will respond to effluent loading. Because seasonal storage is such an important factor in maximizing use of reclaimed water, this section provides a discussion of considerations for seasonal storage systems, including surface water storage as well as managed aquifer recharge practices.

Another option to maximize the use of reclaimed water is to supplement reclaimed water flows with another water source, such as groundwater or surface water. Supplemental sources, where permitted, can bridge the gap during periods when reclaimed water flows are not sufficient to meet the demands. This practice allows connection of additional users and increases reuse versus disposing of excess reclaimed water. Additionally, operational strategies can be implemented to meet peak demands while maximizing the use of reclaimed water during other times of the year. One such strategy is the use of curtailable customers. Brevard County, Fla., has a group of reclaimed water users referred to as "curtailable customers"—customers that maintain an alternative water source (e.g., golf courses that still have irrigation wells as back-up supplies) that can be used during peak demand periods to release reclaimed water demand to meet seasonal peak demands in other areas of their reuse system.

2.3.1 Operational Storage

In many cases, a reclaimed water distribution system will provide reclaimed water to a diverse customer base. Urban reuse customers typically include golf courses and parks and may also include commercial and industrial customers. Such is the case in the city of St. Petersburg, Fla., and Irvine Ranch Water District, Calif. These reuse programs, which were previously described in the 2004 guidelines, provide water for cooling, wash-down, toilet flushing, and irrigation (EPA, 2004). Each water use has a distinctive demand pattern and, thereby, impacts the need for storage. While there are systems that operate without seasonal storage, thus limiting their ability to maximize beneficial reuse of the available reclaimed water, the increasing value of reclaimed water is driving better use of operational storage facilities. As a supplement to engineered storage systems, as discussed in Section 2.3.2.4, aquifer storage and recovery (ASR) has tremendous potential to better align reclaimed water availability and with demand, particularly for long periods of time. The potential storage volumes for ASR and the land requirements may be much greater than for conventional engineered systems such as above-ground storage tanks and surface reservoirs.

Planners are referred to text in the 2004 guidelines for additional discussion on planning seasonal system storage (EPA, 2004). When considering reclaimed water distribution system storage, planners and engineers should consider the types of users, potential peak demands (daily and seasonal), potential for concurrent peaks, time-of-day restrictions for irrigation, and whether the reclaimed water system will be designed to meet fire protection requirements. Retrofitted dual water systems usually do not include fire protection as the existing potable water system has usually been designed to meet domestic requirements, irrigation demands, and concurrent fire flow requirements. By transferring the irrigation demands from the potable water system to the reclaimed water system, the capability of the existing potable water system is extended, and system components for the reclaimed water system can focus on the irrigation and industrial demands. Because there are different peaking factors and time-of-day demands on industrial demands compared to irrigation demands, extended-period simulation models can be used to assist designers in selecting appropriate storage volumes. As discussed in Section 2.2.3, large system users may be required to provide their own on-site storage, allowing multiple large users to be supplied at a constant flow rate over the full 24-hour day. This can decrease pumping and system storage requirements. Some utilities, such as the Loxahatchee River District in Florida, have the ability to curtail deliveries of reclaimed water to large users through telemetry-controlled valves once contractual volumes are met or during periods of extremely high demand.

From an operational perspective, maintaining a chlorine residual in the reclaimed water system is as important as maintaining a residual in the potable water system. Public health decisions should control design decisions; maintaining good bacteriological quality in a reclaimed water system where occasional contact with the public is likely dictates monitoring and control measures. This could include chlorine residual analyzers at system storage and booster pump stations to confirm adequate chlorine residuals and systems to add incremental amounts of disinfectant to maintain high water quality. Operational practices that decrease water age by keeping the reclaimed water moving through the system can also improve the quality of the delivered water and decrease system maintenance efforts. Maintaining positive water movement during low-flow/low-demand periods of the year can be accomplished by operating tanks at lower elevations or by having a discharge point at the far ends of the reclaimed water distribution system. In an ideal design, a large customer with continuous demands would be located at the end of the system, ensuring continuous flow through the piping. If there is an opportunity to include discharge to a creek or other water feature near the end of the distribution system, this environmental augmentation can provide a base flow that will assist in maintaining reclaimed water quality in the distribution system. Another alternative is to install air-gap discharges to a sanitary sewer that will provide a continuous flow in the reclaimed water transmission main even during periods of low demand.

Tank material selection should be based on the material selection criteria applied to the local water system. This guidance is based on the delivery of reclaimed water that is stabilized and meeting state-defined water quality goals. For advanced purification systems that include reverse osmosis (RO), reclaimed water product should be stabilized prior to pumping into the distribution system and storage.

Reclaimed water storage tanks are likely to encounter the same public scrutiny as potable storage tanks. When retrofitting an existing system, consider the tank locations already controlled by the utility, and determine if these sites can accommodate a reclaimed water tank. If the potable water tank is located on a high tract of land to minimize tank elevation or pumping head, that same advantage would apply to the reclaimed water system. Tank color may be another common issue to consider. Many states will have labeling requirements, but color choices for the tank structure may not be specified. Maintaining one tank bowl color can provide for a consistent appearance and reduce maintenance cost while reducing customer questions. As with potable storage systems, tank sites should be secure and often are connected into the utility supervisory control and data acquisition (SCADA) system, with water system operators monitoring and controlling the two parallel systems.

2.3.2 Surface Water Storage and Augmentation

The reuse of water after discharge into surface water often results in augmentation of potable water supplies where surface water is used for potable water supply. While there are other uses that benefit from surface water storage and augmentation, this section focuses on surface discharge as it relates to unplanned or planned indirect potable reuse, which are also discussed in greater detail in Section 3.7. Unplanned or incidental indirect potable reuse has occurred for decades as utilities pursued the most plentiful, appropriate, and cost-effective options for water supplies. The recent National Academy of Science report, *Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater* described *de facto* reuse (discussed further in Chapter 3), which is the unplanned reuse of treated wastewater that has been discharged to the environment as source water (NRC, 2012). In most cases, the decision to intentionally use or not use a surface water source that included some water that originated as treated wastewater was based on availability and yield of the source water, cost, public acceptance, and public confidence in water treatment processes. The balance of these factors is different for each utility and the communities it serves. In most cases, discharges upstream of surface water sources are designed to meet permit limits and corresponding water quality standards that are protective of beneficial uses downstream of the discharge, including withdrawals for public water supply.

In some cases, the incremental addition of various advanced treatment processes to a reclaimed water treatment process will allow the reclaimed water to meet surface water quality standards, thereby making it a viable option to augment water supplies, e.g., the SDWA. The incentive to provide this additional treatment for surface water augmentation may be driven by regulations intended to protect water supplies, but in most cases it is linked to the benefits derived by the discharger or a downstream community seeking to increase the yield of water supplies on which they depend either directly or indirectly.

While satisfying the decision factors noted above may be necessary to pursue indirect potable reuse, there are two additional factors that typically control viability of implementation. First, although existing water supplies may be of limited availability and yield, there still must be a means to reap the benefits of withdrawing the additional yield of the augmented water supply via water rights, permits, storage contracts, etc. In other words, a utility can rarely be expected to expend funds in excess of what is required by regulation or law unless there is a recognized benefit to its ratepayers. Second, the public acceptance of indirect potable reuse is of paramount importance but must be based on the specifics of the project and the local community. The following examples illustrate how these key components can play out in project planning and implementation.

An often-cited example of surface water augmentation is the Upper Occoquan Service Authority's (UOSA) discharge into the Occoquan Reservoir in northern Virginia [US-VA-Occoquan]. In this particular case, serious water quality issues were caused by multiple small effluent discharges into the reservoir. The Fairfax County Water Authority withdraws water from the Occoquan Reservoir to meet the water supply needs of a large portion of northern Virginia. UOSA was formed in 1971 to address the water quality problem by the same local government entities that relied on the reservoir for their water supply. Therefore, these local governments, and by proxy their residents, received the benefits of the investments in additional wastewater treatment, satisfying the first key component that their water supply was now both protected and augmented. Regarding the second key component, the improvements made a dramatic improvement in the water quality of the reservoir that was readily visible to the general public. Algae blooms, foul odors, low dissolved oxygen (DO) for fish, and other factors were addressed by the regionalization and additional treatment processes, which provided the public with a tangible example of a system that resulted in improved water quality over past practices.

Another example is the Forsyth County, Ga., discharge to Lake Lanier [US-GA-Forsyth County]. Lake Lanier is formed by Buford Dam, which is operated by the U.S. Army Corps of Engineers (USACE) on the Chattahoochee River north of Atlanta. Forsyth County withdraws all of its water from Lake Lanier, as do several other communities around the lake. Given the linkage between water withdrawal from the lake and the desire to return reclaimed water to the lake, the first key component was satisfied by the issuance of a revised state withdrawal permit and amended USACE storage contract that provided credit for the water returned. In this case, the key issues were permitting the discharge and the multiple administrative and legal challenges raised by stakeholders with interests in the lake. Because the focus of these stakeholders was primarily lake quality, discharge limits were made significantly more stringent using anti-degradation regulations as the rationale. In a federal court decision in September 2011, it was determined that Georgia could not use the lake for water supply. Georgia's neighbors, Alabama and Florida, have argued that Congress never gave Georgia permission to use the federal reservoir as a water source (Henry, 2011 and Section 5.2.3.5).

2.3.3 Managed Aquifer Recharge

As our population continues to grow and the associated demand for water increases, alternative water resources may play a greater role in meeting water demands. Reclaimed water is a safe and reliable source of supply for replenishing groundwater basins, creating salt water intrusion barriers, and mitigating the negative impacts of subsidence caused by over withdrawal of groundwater. Aquifer recharge has a long history, and there are abundant examples of successfully managed programs. Managed aquifer recharge (MAR) has been successfully applied in California for almost 50 years; the Montebello Forebay Groundwater Recharge Project uses recycled water to recharge the Central Groundwater Basin and provides 40 percent of the total water supply for the metropolitan area of Los Angeles County, Calif. [US-CA-Los Angeles County].

Other MAR projects have been implemented to aid in maintaining a salt balance in water supply aquifers, as demonstrated in a case study on the Santa Ana River Basin [US-CA-Santa Ana River]. In Arizona, the Groundwater Management Act allows users to store recharged water and sell the associated water rights. This led to the first-ever auction of reclaimed water rights in Prescott Valley. The ability to bank recharged reclaimed water provided the versatility necessary for the auction [US-AZ-Prescott Valley]. In Mexico City, reclaimed water is being used to recharge the local aquifer, which is overdrawn by 120 percent, leading to the subsidence of the soil in some places at a rate of up to 16 in/yr (40 cm/yr) [Mexico-Mexico City]. (National Water Commission of Mexico, 2010).

MAR systems may be described in terms of their five major components: a source of reclaimed water, a method to recharge, sub-surface storage, recovery of the water, and the final use of the water. One of the key considerations in MAR is managing the travel time of reclaimed water before it is recovered for use. As a result, the identification, selection, and testing of environmentally-acceptable tracers for measuring travel times of reclaimed water and its constituents in recharge systems has been the subject of recent research. In the research report *Selection and Testing of Tracers for Measuring Travel Times in Natural Systems Augmented with Treated Wastewater Effluent* (WRRF, 2009), a summary of literature related to conservative and surrogate tracers for reclaimed water constituent transport in the subsurface is provided along with the materials and results from tracer experiments on three common recharge systems augmented with reclaimed water, information on the process for regulatory approval of the use of tracers for reclaimed water recharge systems, and field methods for conducting tracer tests. Reclaimed water can be directly or indirectly used after sub-surface storage. Some systems both directly and indirectly use reclaimed water when demand for irrigation is high and recharge water for future indirect use when demand for irrigation is low.

The two primary types of groundwater recharge are surface spreading and direct injection. Vadose zone injection wells have been increasing in use as this technology has become established in recent years. **Figure 2-5** illustrates these recharge methods. Direct injection wells may also be used as dual-purpose ASR wells for both recharging and recovering stored water. The recharge method will depend on the aquifer type and depth and on the aquifer characteristics, which impact the ability to recharge water into the storage zone and later recover that water. The use of recharge basins and vadose zone injection wells is restricted to unconfined aquifers, while direct injection systems may be used in both unconfined and deeper confined aquifer systems.

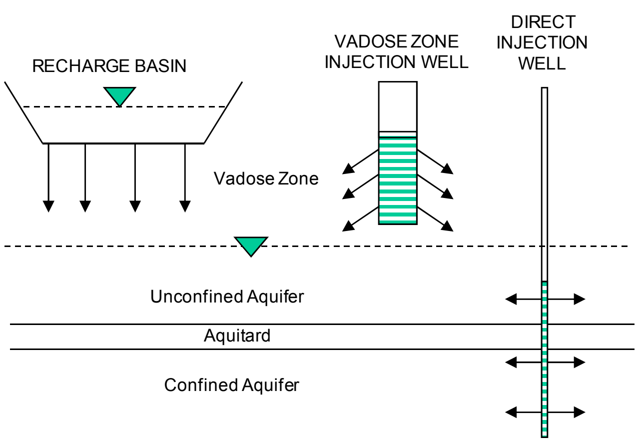

Figure 2-5
Commonly used methods in managed aquifer recharge

There are many site-specific variables that affect the design and selection of the most appropriate MAR system for a specific application. As shown in **Figure 2-6**, the first critical question is "what aquifer is being considered for use in the MAR system?" If a confined aquifer is being considered, then direct injection is the only feasible alternative; direct injection may include either single-use injection wells or the dual-purpose wells used in ASR systems. If the goal of a groundwater recharge project is to provide short-term storage and the water must be recovered quickly, then ASR systems might be the only feasible alternative. If an existing distribution and well system may be utilized as part of an ASR system, then dual-purpose direct injection wells might be the best choice. If an unconfined aquifer is being considered, there are no constraints on the choice of recharge method.

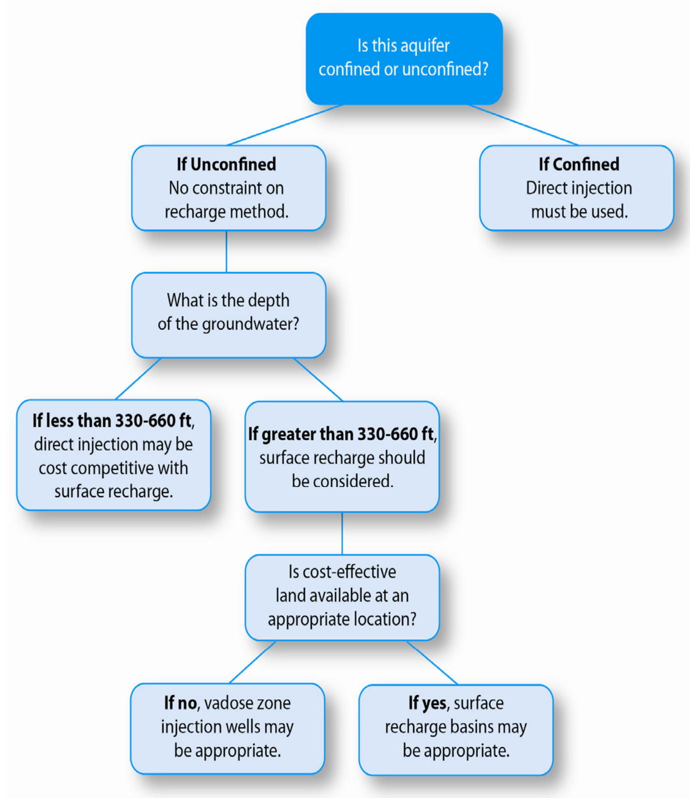

Figure 2-6
Sample decision tree for selection of groundwater recharge method

For unconfined aquifers, as the depth to groundwater increases, the cost of direct injection wells increases; therefore, the effect of depth should be evaluated for each situation. Land price, location, and availability are also key considerations. Potential negative impacts from rising groundwater levels, including groundwater mounding, must also be considered.

2.3.3.1 Water Quality Considerations

Depending on the method and purpose of groundwater recharge, most states require either a minimum of secondary treatment with or without additional filtration for groundwater recharge. State Underground Injection Control programs and Sole Source Aquifer Protection are included under Sections 1422 of the SDWA, which provides safeguards so that aquifer recharge and ASR wells do not endanger current and future underground sources of drinking water. There is currently no specific requirement for nutrient removal, but lower effluent nutrient concentrations required for point-source discharges could meet strict nutrient groundwater recharge requirements, such as the 0.5 mg/L ammonia limit in Miami-Dade County for the South District Water Reclamation Plant (SDWRP), without additional treatment. Additionally, the California *Draft Regulations for Groundwater Replenishment with Recycled Water* proposes a 10 mg/L total nitrogen limit for recycled water (California Department of Public Health [CDPH], 2011). Nutrient removal at the wastewater plant is also thought to remove *N*-nitrosodimethylamine (NDMA) precursors, reducing the potential formation of NDMA. Generally, direct injection requires water of higher quality than is required for surface spreading because of the absence of a vadose zone and/or shallow soil matrix treatment afforded by surface spreading, as discussed in Chapter 6. In addition, higher-quality water is needed to maintain the hydraulic capacity of the injection wells, which can be affected by physical, biological, and chemical clogging. Water quality parameters are typically measured at the end of the treatment plant, but some agencies, such as Florida's Miami-Dade Department of Environmental Resources Management (DERM), allow projects to meet the requirements at the nearest ecological receptor.

In many cases, wells used for injection and recovery of reclaimed water are classified by EPA as Class V injection wells, and some states, including California and Florida, require that the injected water must meet drinking water standards prior to injection, depending on the native quality of water in the aquifer being recharged. Typical water quality parameters used for regulating recharge include total nitrogen, nitrate, nitrite, total organic carbon (TOC), pH, iron, total coliform bacteria, and others, depending on the use of the aquifer. Other water quality parameters can be used to estimate potential well corrosion or fouling, including calculated values such as the Langelier Saturation Index (LSI), the Silt Density Index (SDI), and the Membrane Fouling Index (MFI). Information and global case studies on specific treatment technologies to address microbial and chemical contaminants for MAR applications are available in *Water Reclamation Technologies for Safe Managed Aquifer Recharge* (Kazner et al., 2012).

Other criteria specific to the quality of the reclaimed water, groundwater, and aquifer matrix must also be taken into consideration. These include possible undesirable chemical reactions between the injected reclaimed water and groundwater, iron precipitation, arsenic leaching, ionic reactions, biochemical changes, temperature differences, and viscosity changes. Most clogging problems are avoided by proper pretreatment, well construction, and operation (Stuyfzand, 1998). Hydrogeochemical modeling should be performed to confirm compatibility of the recharge water and the aquifer matrix. In some areas, such as South Florida and Southern California, naturally-occurring arsenic-containing minerals in the aquifer matrix may leach into the groundwater due to changes in oxidation-reduction potential (ORP) during injection, storage, and recovery. Arsenic in recovered water has been detected or is a significant concern based on area ASR projects. Approaches to minimizing arsenic levels and other trace inorganic leaching/transport can include controlling the pH and matching the ORP of the recharge water with the ORP of the ambient groundwater. For direct injection to a highly permeable aquifer, such as the Biscayne Aquifer in South Florida, additional nutrient limits that are stricter than those required for typical direct injection may be set. The nutrient requirements address the potential impacts to nearby surface waters, such as rivers, lakes, canals, and wetlands that are hydrologically connected and supported by the aquifer. For the SDWRP, DERM has a very low ammonia requirement (0.5 mg/L) and includes phosphorus removal in its antidegradation water quality requirements.

2.3.3.2 Surface Spreading

Surface spreading is the most widely-used method of groundwater recharge due to its high loading rates with relatively low maintenance requirements. At the spreading basin, the reclaimed water percolates into the soil, consisting of layers of loam, sand, gravel, silt, and clay. As the reclaimed water filters through the soil, these layers allow it to undergo further physical, biological, and chemical purification through a process called Soil Aquifer Treatment (SAT); ultimately, this water becomes part of the groundwater supply. SAT systems require unconfined aquifers, vadose zones free of restricting layers, and soils that are coarse enough to allow for sufficient infiltration rates but fine enough to provide adequate filtration. A summary and discussion of the removal mechanisms for pathogens, organic carbon, contaminants of concern, and nitrogen during SAT are provided in Chapter 6. These mechanisms are important when spreading basins and analogous systems, such as bank filtration, are used; this treatment also occurs to a varying extent during ASR, vadose zone injection, and direct injection. Though management techniques are site-specific and vary accordingly, some common principles are practiced in most spreading systems. The three main engineering factors that can affect the performance of surface spreading systems are reclaimed water pretreatment, site characteristics, and operating conditions (Fox, 2002).

Reclaimed Water Pretreatment. Municipal wastewater typically receives a minimum of conventional secondary treatment, but may also receive filtration followed by disinfection (e.g., chlorination) prior to groundwater recharge. Some utilities are beginning to further treat the reclaimed water with microfiltration, RO, and ultraviolet (UV) disinfection prior to recharge into potable water aquifers. For reclaimed water that is spread in groundwater basins, the soil itself provides additional treatment to purify the water through SAT. Reclaimed water pretreatment directly impacts the performance of a SAT system. While RO processes provide high reclaimed water quality, the reject brine waste streams from this process may be difficult to dispose.

Site Characteristics. Local geology and hydrogeology determine the site characteristics for a surface-spreading operation. Site selection is dependent on a number of factors, including suitability for percolation, proximity to conveyance channels and/or water reclamation facilities, and land availability. Design options for spreading grounds are limited to the size and depth of the basins and the location of production wells. The subsurface flow travel time is affected by the well locations.

System Operation. For surface spreading to be effective, the wetted surfaces of the soil must remain unclogged to maximize infiltration, and the quality of the reclaimed water should not inhibit infiltration. Spreading basins are typically operated under a wetting/drying cycle designed to optimize inflow and percolation and discourage the presence of vectors. Spreading basins can be subdivided into an organized system of smaller basins that can be filled or dried alternately to allow maintenance in some basins while others are being used.

Spreading basins should be managed to avoid nuisance conditions, such as algae growth and insect breeding in the basins. This is typically accomplished by rotating a number of basins through wetting, draining, and drying cycles. Cycle length is dependent on soil conditions, the development of a clogging layer, and the distance to the groundwater table. Algae can clog the bottom of basins and reduce infiltration rates. Algal growth can be minimized by upstream nutrient removal or by reducing the detention time of the reclaimed water within the basins, particularly during summer periods when algal growth rates increase due to solar intensity and increased temperature.

Periodic maintenance, which involves cleaning the basin bottom by scraping the top layer of soil, is used to prevent clogging. Disking of the basin to break up surface clogging is generally not used as it forces finer clay particles deeper into the soil column. When a clogging layer develops during a wetting cycle, infiltration rates can decrease to unacceptable levels. The drying cycle allows for the aeration and drying of the clogging layer and the recovery of infiltration rates during the next wetting cycle.

2.3.3.3 Injection Wells

Methods for recharging groundwater using injection wells can include injection either into the vadose zone or directly into the aquifer. Each injection method has its own unique applicability and requirements, which vary with location, quantity and quality of source water, and hydrogeology of the vadose zone and target aquifers. While direct injection wells are more expensive than vadose zone wells, the control of where the water is injected minimizes risks associated with lost water. Direct injection wells can also be cleaned and redeveloped, which reduces fouling and lengthens the life of the wells. A summary of vadose zone and direct-injection well construction and operation is presented in **Table 2-2**, including the main advantages and disadvantages for each of the recharge methods. Vadose zone wells are the least expensive injection method, but they have a limited life and must be replaced periodically. Direct injection wells are more costly, can be maintained for a longer life, and allow water to be directly and quickly recharged into the targeted aquifer.

Table 2-2 Comparison of vadose zone and direct injection recharge wells

Recharge Method	Main Advantages	Main Disadvantages
Vadose Zone Wells	– Suitable for unconfined aquifers – Bypass low permeability layers – Decreased travel time to aquifers versus surface spreading – Lower cost – SAT benefits to water quality – May allow smaller setback from extraction wells	– Inability to rehabilitate clogged wells – Decreased certainty of migration pathways – Requires operation to avoid air entrainment – Deeper wells needed to penetrate deep clay layers – New wells required periodically – Greater risk of water loss
Groundwater Injection Wells	– Can target specific aquifers and locations – Benefits groundwater levels immediately – Wells can be cleaned and redeveloped – Can be maintained for a longer life	– Wells can be costly to install and maintain – Periodic pumping required to maintain capacity – Foot valves may be required to minimize air entrainment

Vadose Zone Injection. Vadose zone injection wells for groundwater recharge with reclaimed water were developed in the 1900s and have been used primarily where aquifers are very deep and construction of a direct-injection well is difficult and expensive. A vadose zone well is essentially a dry well, installed in the unsaturated zone above the permanent water table. These wells typically consist of a large-diameter borehole, sometimes with a casing or screen assembly, installed with a filter pack. The well is used to transmit recharge water into the ground, allowing water to enter the vadose zone through the well screen and filter pack and percolate into the underlying water table. Creating this conduit into the ground can be advantageous where surficial soils or the shallow subsurface contain clay layers or other low-permeability soils that impede percolation deep into the ground. Vadose zone wells allow recharge water to bypass these layers, reaching the water table faster and along more direct pathways. Typical vadose zone injection wells vary in width from about 2 ft (0.5 m) up to 6 ft (2 m) in diameter and are drilled 100 to 150 ft (30 to 46 m) deep. A vadose zone injection well is backfilled with porous media, and a riser pipe is used to allow water to enter at the bottom of the wells to prevent air entrainment. An advantage of vadose zone injection wells is significant cost savings when compared to direct-injection wells.

Although the infiltration rates of vadose zone wells are often similar or slightly better as compared to direct-injection wells, they cannot be backwashed, and a severely clogged well may be permanently destroyed. Therefore, reliable pretreatment is considered essential to maintaining performance of a vadose zone injection well. Maintenance of a disinfection residual is critical if the water has not been treated by RO. Because of the considerable cost savings associated with vadose wells as compared to direct injection wells, the estimated 5-year life cycle for a vadose injection well can still make it an economical choice. And, because vadose zone injection wells allow for percolation of water through the vadose zone and flow into the saturated zone, it should be expected that some water quality improvements similar to soil aquifer treatment would be achieved (see Chapter 6 for further discussion).

The number of vadose zone injection wells is dependent on the recharge capacity of the soil matrix. Recharge capacities can be estimated from test wells and infiltration tests. The head required to drive the water into the ground is influenced by the lithology and hydraulic conductivity (permeability) of the soil in the vadose zone. Because the movement of the water is highly dependent on localized features, such as clay layers or low-permeability lenses, movement is difficult to predict. Capture of the recharge water within the aquifer for extraction is also less certain than with direct injection, and vadose zone projects are at greater risk of water loss.

Vadose zone injection facilities were constructed as part of the city of Scottsdale's Water Campus project northeast of downtown Phoenix, Ariz. The project has 35 active injection wells (with 27 back-up wells) with a capacity of about 400 gpm each. The wells were constructed to a depth of 180 to 200 ft with the aquifer water level approximately 1,200 ft below ground surface (bgs). Vadose zone injection wells of similar design are also used by the cities of Gilbert and Chandler, Ariz. Reuse projects in other areas, such as the Seaside Basin in the Monterrey Bay area of California, have also considered the use of vadose zone wells because of the depth to groundwater (300+ ft bgs). According to groundwater modeling estimates, it would take almost 300 days for the water recharged in the vadose zone to reach the top of the aquifer. Because of clay layers and other low- permeability soil lenses, there is minimal control of where the recharged water enters the underlying aquifer and at what rate.

Rapid Infiltration Trenches. Rapid infiltration trenches (RITs) are not vadose zone wells, but are similar in that recharge water is discharged into a media-filled "hole" or trench. Unlike the vertically-constructed vadose zone well, however, RITs are long, horizontal trenches excavated into the soil and filled with media. A horizontal, perforated pipe conveys the water into the RIT where it percolates into the underlying soil. RITs can be excavated into the vadose zone where the groundwater is deep, or into the aquifer where groundwater levels are close to the surface. Because RITs are not true wells, specialty contractors are not required, and the costs can be less than either vadose zone or direct-injection wells.

Direct Injection. Direct-injection systems involve pumping recharge water directly into either a confined or unconfined aquifer. Direct injection is used where space or hydrogeological conditions are not conducive to surface spreading; such conditions might include unsuitable surface/near-surface soils of low permeability, unfavorable topography for construction of basins, the desire to recharge confined aquifers, or scarcity of land. Direct injection is also an effective method for creating barriers against saltwater intrusion in coastal areas and for development of ASR systems using dual-purpose wells. In designing a direct-injection well system, it is critical to fully characterize the target aquifer and surrounding confinement hydraulics that will affect migration of the reclaimed water. Additionally, water quality within the reuse system and the target aquifer must be balanced along with the needs of the end user in development of a direct-injection system.

A direct-injection well is drilled into the targeted aquifer, discharging recharge water at a specific depth within the aquifer. Direct-injection wells are similar to extraction wells in that they have a borehole and casing and may have screens, granular media around the well, and a drop pipe into the well. The diameter of the well depends on required flow and the ability of the aquifer to move the water. Screened wells are required in unconsolidated formations whereas open-hole construction is typically used in rock formations. The injection well can be designed to target specific aquifers or specific portions of an aquifer that are most suitable for injection. Typical direct-injection wells vary in diameter from about 12 to 30 in (30 to 76 cm), and depths vary from less than 100 ft to more than 1,500 ft (30 to 470 m) in certain applications. Ideally, an injection well will recharge water at the same rate as it can pump yield water; however, conditions are rarely ideal. Injection/withdrawal rates tend to decrease over time, and although clogging can easily be remedied in a surface spreading system by scraping, drying, and other methods, remediation in a direct-injection system can be costly and time consuming, depending on the nature and severity of clogging. The most frequent causes of clogging are accumulation of organic and inorganic solids, biological and chemical precipitates, and dissolved air and gases from turbulence. Low concentrations of suspended solids (1 mg/L) can clog an injection well. Even low concentrations of organic contaminants can cause clogging due to bacteriological growth near the point of injection. Typical remediation of a clogged well is by mechanical means or chemical injection of acids and/or disinfectants.

Treatment of organics can occur in the groundwater system with time, especially in aerobic or anoxic conditions (Gordon et al., 2002; Toze and Hanna, 2002). Therefore, the location of the direct injection wells in relation to the extraction well is critical to determining the flow-path length and residence time in the aquifer, as well as the mixing of recharge water with native groundwater. When recharge water has been treated by RO, improvements in water quality are not expected. There have been several cases where direct-injection systems with wells providing significant travel time have allowed for the passage of NDMA and 1,4-dioxane into recovery wells, even though treatment processes included RO. Additional treatment of reclaimed water is now required to control these contaminants. These trace organic compounds (TrOCs) have not been observed in soil aquifer treatment systems using spreading basins where microbial activity in the subsurface is stimulated. It is uncertain whether RO water discharged into a vadose zone well will support biological activity and additional treatment; at the Scottsdale Water Campus, attenuation of NDMA during sub-surface transport has been limited with RO-treated water and vadose zone injection wells.

Direct-injection wells have been used for Orange County Water District's (OCWD) Talbert Gap Barrier with water supplied by the Groundwater Replenishment System (GWRS), for the Dominguez Gap Barrier with water supplied by the West Basin Municipal Water District's El Segundo facilities, and for the Alamitos Barrier with water supplied in part by the Water Replenishment District's Leo J. Vander Lans Water Treatment Facility (LVLWTF) [US-CA-Vander Lans]. Direct-injection wells were also proposed for Miami-Dade Water and Sewer Department's SDWRP [US-FL-Miami So District Plant].

2.3.3.4 Recovery of Reclaimed Water through ASR

ASR allows direct recovery of reclaimed water that has been injected into a subsurface formation for storage. ASR can be an effective management tool to provide reclaimed water storage, minimizing seasonal fluctuations in supply and demand, by allowing storage during the wet season when demand is low and recovery of water during dry periods when demand is high. Because the potential storage volume of an ASR system is essentially unlimited, it is expected that these systems will offer a solution to the shortcomings of the traditional, engineered storage techniques. ASR was considered as part of the Monterey County, Calif., reuse program to overcome seasonal storage issues associated with an irrigation-based project. In the United States, reclaimed water ASR projects are currently operating in Arizona, Florida, and Texas (Pyne, 2005; Shrier 2010). Internationally, the only operating ASR systems identified in literature are located in Australia.

While ASR is gaining interest, there are considerations for operation of these systems. Federal Underground Injection Control (UIC) rules do not allow the injection of any fluid other than water meeting drinking water standards into an underground source of drinking water (USDW), which is defined as having a total dissolved solids concentration of less than 10,000 mg/L (EPA, 2001). Section 1453 of the 1996 amendments to the SDWA outlines a Source Water Quality Assessment to achieve maximum public health protection. This could require reclaimed water to be treated with advanced treatment and disinfection processes, such as RO and UV light with ozone or peroxide, to not only meet drinking water standards but also to address state-specific regulations for trace organics and pathogens. Therefore, many existing reclaimed water ASR projects inject into portions of aquifers beneath the USDW (i.e., into brackish water aquifers). However, there still must be good vertical confinement between the injection zone and the base of the USDW to prevent upward vertical migration of the injected reclaimed water into the USDW. For reclaimed water ASR projects injecting into nonpotable aquifers (total dissolved solids [TDS] >10,000 mg/L), the recovery efficiencies are usually less than for other ASR projects injecting into the USDW.

In addition, potentially undesirable geochemical reactions between the injected fluid and the aquifer matrix must be considered. Unlike other MAR systems, there is a buffer zone where reclaimed water and native groundwater blend in a manner that is distinctly different from other systems. Pathogens and organic contaminants in reclaimed water complicate the use of ASR for reclaimed water storage and recovery, and high levels of treatment and disinfection are needed to implement reclaimed water ASR.

ASR Water Quality Considerations. The primary contaminants in reclaimed water that affect ASR projects include nutrients and metals, pesticides, endocrine disruptor compounds, pharmaceuticals and personal care products, and microbes (WRRF, 2007b). SDWA describes the essential steps for every community to inventory known and potential sources of contamination within their drinking water sources. Nutrients and most bacteria are usually removed in advanced biological wastewater treatment processes. While most large pathogens are not a concern in most MAR systems, the reversal of flow in ASR systems can release materials that are normally removed. These same treatment processes are also typically used to remove the other recalcitrant groups of contaminants listed above. If the TOC concentrations are elevated and chlorine is used for disinfection, disinfection by-products (DBPs) such as trihalomethanes, haloacetic acids, and NDMA can be of concern. A more in-depth discussion of these source water quality concerns is presented in *Prospects for Managed Underground Storage of Recoverable Water* and *Reclaimed Water Aquifer*

Storage and Recovery: Potential Changes in Water Quality (NRC, 2008 and WRRF, 2007b).

According to the 2007 WateReuse Research Foundation (WRRF) study referenced above, 13 U.S.-based reclaimed water ASR projects and three international reclaimed water ASR projects were identified in various phases of development and implementation **(Table 2-3)**. Two additional projects in Florida were being tested as of 2012; the Collier County and Naples projects are also shown in **Table 2-3**. The reclaimed water source for all 18 ASR projects will meet advanced wastewater treatment levels with disinfection. Additionally, two of the facilities in the United States (Fountain Hills and Scottsdale, Ariz.) and one project in Kuwait (Sulaibiya) are/will be using advanced filtration technologies, such as microfiltration (MF) or MF/RO, to improve water quality prior to injection.

While there are specific water quality requirements for ASR, regulatory agencies also may limit the quantity of reclaimed water used for a groundwater recharge project, also referred to as the reclaimed water contribution (RWC). The RWC is calculated by dividing the volume of reclaimed water recharge by the total volume of water recharge. Other sources of water recharge, which serve to dilute the reclaimed water, must not be of wastewater origin and can include imported water, local water supply, and, potentially, subsurface flow. The inclusion of subsurface flow in the basin recharged by the Inland Empire Utilities Agency, in Chino, Calif. has virtually eliminated the need for other sources of water recharge. The RWC may be set by the regulatory agency and can vary depending on the level of effluent treatment, the type of recharge, and project history.

Monitoring. Recharge projects are strictly regulated and subject to complex water quality monitoring and compliance programs that assess all the waters used for recharge of the groundwater system to ensure the protection of human health and the environment. Additionally, water reclamation plant performance reliability is ensured through various in-plant control parameters, redundancy capabilities, and emergency operation plans. This is discussed in greater detail in Section 2.3.4.

The use of recycled water to recharge groundwater via surface spreading or direct injection has been successfully applied in California for almost 50 years [US-CA-Los Angeles County]. As the future supply of surface water continues to diminish and our population continues to grow, alternative water resources must increase to meet water demands.

Subsurface Geochemical Processes. Adverse geochemical reactions can occur in the storage zone due to differences in water quality between the injected fluid and native water quality (Mirecki, 2004; NRC, 2008). Although relatively uncommon in ASR projects, geochemical reactions can occur that result in dissolution and clogging of the aquifer matrix in the storage zone. The most notable reaction is the oxidation of arsenopyrite, a naturally-occurring mineral in aquifers. When this mineral is oxidized, arsenic is released into the stored water (at concentration in excess of the drinking water maximum contaminant level (MCL) of 10 µg/L) due to differences in ORP between the injected fluid and native groundwater.

Many source waters (potable, surface, and reclaimed water) have an elevated ORP (+millivolts) and DO (>2 to 3 mg/L) concentrations relative to confined aquifers and deep portions of unconfined aquifers (-millivolts and <0.5 mg/L). The oxidized source waters can react with the aquifer matrix, which is in equilibrium under reduced conditions, changing the hydrogeochemistry of the stored and recovered water. Different technologies that can adjust the ORP and DO of the recharge waters closer to that of the native water before injection into confined aquifers have been developed (Bell et al., 2009; Entrix, 2010). Recent research by USACE suggests that treated surface water initially causes arsenic in the aquifer matrix to leach into the stored and recovered water, but it is later readsorbed in the presence of naturally high iron and TOC concentrations in the source water (Mirecki, 2010). The conclusions in this study suggest that similar water quality conditions that can lead to the precipitation of arsenic occur in reclaimed water. Additional information on the state of the practice of ASR using reclaimed water is provided in the WRRF report, *Reclaimed Water Aquifer Storage and Recovery: Potential Changes in Water Quality* (WRRF, 2007b).

Table 2-3 Operational status and source water treatment for reclaimed water ASR projects

State or Country	City or County	Operation Status	Reclaimed Water Treatment Level
Arizona	Chandler	Full Operation	Advanced treatment with UV disinfection
Arizona	Fountain Hills	Full Operation	Conventional secondary treatment /microfiltration/unknown method of disinfection
Arizona	Scottsdale	Full Operation	Advanced treatment/microfiltration/RO/Cl_2 disinfection
Florida	Cocoa	Testing	Advanced treatment with Cl_2 disinfection
Florida	Englewood	Full Operation	Advanced treatment with Cl_2 disinfection
Florida	Hillsborough County	Terminated	NA
Florida	Clearwater	Terminated	NA
Florida	Lehigh Acres	Testing	Advanced treatment with Cl_2 disinfection
Florida	Manatee County	Testing	Advanced treatment with Cl_2 disinfection
Florida	Collier County	Testing	Advanced treatment with Cl_2 disinfection
Florida	Naples	Testing	Advanced treatment with Cl_2 disinfection
Florida	Oldsmar	Permitting	Advanced treatment with Cl_2 disinfection
Florida	Pinellas County	Feasibility/Planning	Advanced treatment with Cl_2 disinfection
Florida	St. Petersburg	Testing	Advanced treatment with Cl_2 disinfection
Florida	Tarpon Springs	Feasibility/Planning	Advanced treatment with Cl_2 disinfection
Florida	Sarasota County	Construction	Advanced treatment with Cl_2 disinfection
Texas	El Paso	Full Operation	Advanced treatment/ozone disinfection
Australia	Adelaide (Bolivar)	Full Operation	Advanced treatment with Cl_2 disinfection
Australia	Willunga	Testing	Advanced treatment with Cl_2 disinfection
Kuwait	Sulaibiya	Feasibility/Planning	Advanced treatment/RO/unknown method of disinfection

(Source: Updated data from WRRF, 2007b)
Cl_2 means chlorine
NA means not applicable

2.3.3.5 Supplementing Reclaimed Water Supplies

Another option to maximize the use of reclaimed water for irrigation is to supplement reclaimed water flows with other sources, such as groundwater or surface water. Supplemental sources, where permitted, can bridge the gap during periods when reclaimed water flows are not sufficient to meet the demands, Supplementing reclaimed water flows allows connection of additional users and increases reuse overall versus disposing of excess reclaimed water. Incremental use of supplemental supplies can result in a significant return in terms of reclaimed water usage versus supplemental volumes.

An example of a utility that developed supplemental supplies is the city of Cape Coral, Fla. There are approximately 400 mi of canal systems within the city. Of these, approximately 295 mi are considered freshwater and about 105 mi are brackish water. In addition, within these canals, approximately 27 water-control structures (weirs) have been designed and placed to control canal flows. Supplemental water from this canal system has been used since the early 1990s to bridge the gap between reclaimed water supply and demands. Today, Cape Coral's reclaimed water program ("Water Independence for Cape Coral" or WICC) provides supplemented reclaimed water to almost 38,000 residences for irrigation. The city has implemented a major initiative over the last decade to install automated flow controls on all existing weirs, allowing the city to control freshwater canal levels and optimize the hydro period to mimic more natural flow patterns. These upgrades allow the city to store considerably more water in the existing canals. ASR is also planned to store excess surface water. Upon completion of the project, the city will be able to store an additional 1 billion gallons (3.8 MCM) of freshwater in the canals during dry periods and in ASR wells during wet periods.

In addition to supplementing reclaimed water supplies, alternative source waters can be used to replace the demands for reclaimed water. Discussion of alternative water sources as part of an integrated water management approach is provided in Section 2.4

2.3.4 Operating a Reclaimed Water System

In order to protect public health and enhance customer satisfaction and confidence, water of a quality that is safe and suitable for the intended end uses must be reliably produced and distributed, regardless of the source water. AWWA published the third edition of its *Manual of Water Supply Practices M-24*, which discusses planning, design, construction, operation, regulatory framework, and management of community dual-water systems (AWWA, 2009). In addition to the materials discussion in that manual, a brief discussion of the importance and considerations for well-designed quality assurance/quality control (QA/QC) and monitoring programs is provided here.

2.3.4.1 Quality Control in Production of Reclaimed Water

A high standard of reliability, similar to water treatment plants, is required at wastewater reclamation plants. An array of design features and non-design provisions can be employed to improve the reliability of the separate elements of a water reclamation system and the system as a whole. Backup systems are important in maintaining reliability in the event of failure of vital components, including the power supply, individual treatment units, mechanical equipment, the maintenance program, and the operating personnel. Federal guidelines identify the following factors that are appropriate to consider for treatment operations (EPA, 1974):

Design Factors:

- Duplicate dual feed sources of electric power
- Standby on-site power for essential plant elements
- Multiple process units and equipment
- Holding tanks or basins to provide for emergency storage of overflow and adequate pump-back facilities
- Flexibility of piping and pumping facilities to permit rerouting of flows under emergency conditions
- Dual chlorination systems
- Automatic residual control
- Instrumentation and control systems for online monitoring of treatment process performance and alarms for process malfunctions
- Supplemental storage and/or water supply to ensure that the supply can match user demands

Other Factors:

- Preliminary project planning and engineering report to indicate reliability compliance
- Effective monitoring program
- Effective maintenance and process control program
- Operator certification to ensure that qualified personnel operate the water reclamation and reclaimed water distribution systems
- A comprehensive QA program to ensure accurate sampling and laboratory analysis protocol
- A comprehensive operating protocol that defines the responsibilities and duties of the operations staff to ensure reliable production and delivery of reclaimed water
- A strict industrial pretreatment program and strong enforcement of sewer-use ordinances to prevent illicit dumping of hazardous materials—or other materials that may interfere with the intended use of the reclaimed water—into the collection system

Additional discussion of many of these reliability features is discussed in Section 3.4.3 of the 2004 EPA *Guidelines for Water Reuse*. Many states have incorporated procedures and practices into their reuse rules and guidelines to enhance the reliability of reclaimed water systems, including inline automatic diversion valves when reclaimed water quality does not meet monitoring requirements for chlorine residual and turbidity.

2.3.4.2 Distribution System Safeguards for Public Health Protection in Nonpotable Reuse

As described in Chapters 3 and 4, the level of treatment required for reclaimed water depends on the intended use. Where water reuse applications are designed for indirect or direct potable reuse, treatment is designed to achieve the level of purity required for potable reuse. Where reclaimed water is to be used in nonpotable applications, water quality must be protective of public health, but need not be treated to the quality required for potable reuse. In addition to appropriate water quality requirements, other safeguards must be employed to protect public health in nonpotable reuse.

Where reclaimed water is intended for nonpotable reuse, the major priority in design, construction, and operation of a reclaimed water distribution system is the prevention of cross-connections. A cross-connection is a physical connection between a potable water system used to supply water for drinking purposes and any source containing nonpotable water through which potable water could be contaminated. Another major objective is to prevent improper or inadvertent use of reclaimed water as potable water. To protect public health from the outset, a reclaimed water distribution system should be accompanied by the following protection measures:

- Establish that public health is the overriding concern
- Devise procedures and regulations to prevent cross-connections and misuse, including design and construction standards, inspections, and operation and maintenance staffing
- Ensure the physical separation of the potable water, reclaimed water, sewer lines, and appurtenances in design and construction
- Develop a uniform system to mark all nonpotable components of the system
- Devise procedures for approval (and disconnection) of service
- Establish and train special staff members to be responsible for operations, maintenance, inspection, and approval of reuse connections
- Provide for routine monitoring and surveillance of the nonpotable system
- Prevent improper or unintended use of nonpotable water through a proactive public information program

Some states specify the type of identification required. For example, the Florida Department of Environmental Protection (FDEP) requires all components to be tagged or labeled (bearing the words “Do not drink” in English and “No beber” in Spanish, together with the equivalent standard international symbol) to warn the public and employees that the water is not intended for drinking (FDEP, 2009). **Figure 2-7** shows a typical reclaimed water advisory sign and pipe coloring.

Figure 2-7
Typical sign complying with FDEP signage requirements (Photo credit: Lisa Prieto)

The type of messaging on advisory signs must comply with state guidelines and regulations and be chosen carefully to support public awareness. Chapter 8 discusses some of the issues surrounding messaging about water reuse. One specific issue for signage that includes the message “do not drink” is the potential long-term public perception that reclaimed water *cannot* be safe for drinking. If a city may want to introduce potable reuse in the future, the choice of messaging for signage of nonpotable reuse applications is all the more critical.

In addition to advisory signs and coloring, the valve covers for nonpotable transmission lines should not be interchangeable with potable water covers. For example, the city of Altamonte Springs, Fla., uses square valve covers for reclaimed water and round valve covers for potable water. Blow-off valves should be painted and carry markings similar to other system piping. Irrigation and other control devices should be marked both inside and outside. Any constraints or special instructions should be clearly noted and placed in a suitable cabinet. If fire hydrants are part of the system, they should be painted or marked, and the stem should require a special wrench for opening.

All piping, pipelines, valves, and outlets must be color-coded, or otherwise marked, to differentiate reclaimed water from domestic or other water (FDEP, 2009). FDEP requires color coding with Pantone Purple 522C using different methods, depending on the size of the pipe (FDEP, 2009). Pipe coloring can be integrated into the material or added externally with a polyethylene vinyl wrap, vinyl adhesive tape, plastic marking tape (with or without metallic tracer), or stenciling, as shown in **Figure 2-8**. The IAPMO publishes the *Uniform Plumbing Code*, a document that many state and local governments use as a model when they approve their own plumbing codes. An alternate code is the IPC distributed by the ICC.

Figure 2-8
Reclaimed water pumping station, San Antonio, Texas (Photo credit: Don Vandertulip)

Permitting and Inspection. The process to permit water reclamation and reuse projects differs from state to state; however, the basic procedures generally include plan and field reviews followed by periodic inspections of facilities. This oversight includes inspection of reclaimed water generators, distributors and, in some cases, end users. Additional guidance on permitting and inspection is provided in the *Manual of Water Supply Practices M-24* (AWWA, 2009). Piping at the site of reclaimed water use may be controlled by local plumbing code, and advance coordination between utility and local plumbing departments is advised.

2.3.4.3 Preventing Improper Use and Backflow

Several methods can be used to prevent inadvertent or unauthorized connection to a reclaimed water system. The Irvine Ranch Water District, Calif., mandates the use of special quick-coupling valves with an Acme thread key for on-site irrigation connections. This type of valve is not used in potable water systems, and the cover on the reclaimed water coupler is different in color and material from that used on the potable system. Hose bibs are generally not permitted on nonpotable systems because of the potential for incidental use and possible human contact with the reclaimed water. Florida regulations (FDEP, 2009) allow below-ground bibs that are either placed in a locking box or require a special tool to operate.

Where the possibility of cross-connection between potable and reclaimed water lines exists, backflow prevention devices should be installed on-site when both potable and reclaimed water services are provided to a user. The backflow prevention device is placed on the potable water service line to prevent potential backflow from the reclaimed water system into the potable water system if the two systems are illegally interconnected. Accepted methods of backflow prevention vary by state, but may include:

- Air gap
- Reduced-pressure principal backflow prevention assembly
- Double-check valve assembly
- Pressure vacuum breaker
- Atmospheric vacuum breaker

In addition to discussion of backflow prevention in Section 3.6.1 of the 2004 EPA *Guidelines for Water Reuse,* additional guidance is provided in the 2003 EPA *Cross-Connection Control Manual* which has been designed as a tool for health officials, waterworks personnel, plumbers, and any others involved directly or indirectly in water supply distribution systems, with more recent information in the AWWA *Manual of Water Supply Practices M-24* (AWWA, 2009).

2.3.4.4 Maintenance

Maintenance requirements for nonpotable components of the reclaimed water distribution system should be the same as for potable systems. From the outset, items such as isolation valves, which allow for repair to parts of the system without affecting a large area, should be designed into the system. Flushing the line after construction should be mandatory to prevent sediment from accumulating, hardening, and becoming a serious future maintenance problem. New systems should confirm whether discharge of reclaimed water from the initial construction activity is allowed or considered an unauthorized discharge. The flush water may need to be returned to a sanitary sewer, or use of potable water may be considered for initial flushing. A reclaimed water supplier should

reserve the right to withdraw service for any offending condition, subject to correction of the problem. Such rights are often established as part of a user agreement or reuse ordinance.

2.3.4.5 Quality Assurance: Monitoring Programs

The purpose of monitoring is to demonstrate that the management system and treatment train are functioning according to design and operating expectations. Expectations should be specified in management systems, such as a Hazard Analysis and Critical Control Points (HACCP) or water safety plan (WSP). While the monitoring program will be based on the regulatory and permit requirements established for the system, the program not only must address those elements needed to verify the product water but also must support overall production efficiency and effectiveness. Having performance standards and metrics along with policies describing organizational goals and responsibilities for the execution of a water quality management program will reinforce a strong public perception of the overall water quality being produced. See Chapter 8 for additional discussion of public education and communication tools.

Monitoring programs must establish goals for reclaimed water treatment performance and distribution system water quality, provide monitoring to verify conformance with the goals, and establish appropriate actions if goals are not achieved. An example of water quality monitoring requirements for Texas is provided in **Table 2-4**.

The Texas Commission on Environmental Quality (TCEQ) regulates wastewater reclamation and reuse in Texas. Under Chapter 210 of Texas Administrative Code, Volume 30, TCEQ prescribes the quality and use requirements as well as the responsibilities of producers and users. In addition to regulatory requirements, specific uses of reclaimed water, such as some industrial uses or even irrigation when it is for particular golf courses, may require additional testing and/or increased monitoring frequency. Monitoring requirements for reclaimed water are based on the intended use and not on the treatment process utilized to produce reclaimed water (TCEQ, 1997). Two reclaimed water use types are recognized by the TCEQ: Type I use is where contact with humans is likely, such as irrigation, recreational water impoundments, firefighting, and toilet flush water, and Type II use is where contact with humans is unlikely, such as in restricted or remote areas [US-TX-San Antonio].

Three to four parameters must be monitored in accordance with the intended use of the reclaimed water in Texas: *E. coli* or fecal coliform (cfu/100 mL), 5-day biochemical oxygen demand (BOD_5) or 5-day

Table 2-4 Quality monitoring requirements in Texas

Texas Category	Is human contact likely?	Examples	Monitoring frequency	*Enterococci* (MPN/100mL)	Fecal Coliforms or *E. coli* (MPN/100mL)	$CBOD_5$ or BOD_5 (mg/L)	Turbidity (NTU)
Type I	Yes	Irrigation, recreational impoundments, firefighting, toilet flush water	Twice weekly	9/4[1]	75/20[1]	5	3
Type II	No	Restricted or remote reuse	Once weekly	35	800/200[1]	15 or 20[2]	N/A

[1] The first value represents a single sample maximum value and the next value refers to a 30-day average (BOD5 and Turbidity) or 30-day geometric mean (fecal coliform or *E. coli*).

[2] In Type II uses, the CBOD5 maximum 30-day average value is 15 mg/L while the BOD5 value is 20 mg/l for the same period.

carbonaceous biochemical oxygen demand ($CBOD_5$) (mg/L), Turbidity (NTU) and *Enterococci* (cfu/100mL) (**Table 2-4**). Use type also affects monitoring frequency. Type I uses require a twice-weekly monitoring protocol while Type II uses require weekly monitoring.

The first element of a system monitoring program is choosing appropriate, quantifiable measurement parameters that relate to operational and regulatory decision-making. At a minimum, state-required regulatory parameters should be included for analysis. Parameters such as flow rates, distribution system water quality (measured by chlorine residual and bacteriological quality), and TDS are commonly included, but the final choice will depend on the individual system. Detailed monitoring lists may not be necessary once relationships between types of chemicals, treatment train performance, and surrogate measures have been established with definitive data generated from statistically robust experiments. For example, the city of San Diego's water purification demonstration project monitors several water quality parameters, including contaminants regulated by the SDWA [US-CA-San Diego]. Online monitoring methods are preferred because they provide real-time data on system performance. Further, well-defined criteria must be set for each measurement parameter to support the facility's water quality and productivity goals. These may be established by regulatory drivers or self-imposed as part of the overall quality or operational goals.

As noted, in many instances the use of real-time remote measuring devices is required to maintain process and product quality control. Well-defined procedures for the care, calibration, calibration verification, and data collection for any remote or inline measurement devices should be established.

For parameters that cannot be measured online, a routine sampling plan must be developed to select representative sampling sites that adequately cover all key elements (Critical Control Points [CCP]) in the process at a frequency sufficient to anticipate potential problems and respond before problems become critical. In addition to daily, weekly, or monthly analyses, periodic (quarterly or annually) analyses that are more comprehensive can further validate that the routine process performance indicators are adequate to detect potential problems. Locations where high failures are occurring may require more frequent sampling as part of the corrective action.

Sampling methods should focus on obtaining data where the resulting accuracy is adequate for the intended purpose. Samples that are not immediately analyzed must be handled in a way that maintains sample integrity. The validity of the sampling process can significantly impact the validity and usability of the data from those samples. Sampling procedures for required regulatory reporting should following well-accepted practices, such as Standard Methods for the Examination of Water and Wastewater.

Because regulatory and public perception of the monitoring program will rely heavily on the confidence in the quality and validity of the data collected, certifications or accreditations for laboratories doing analytical work supporting the water industries may be required. These can include state programs, such as Arizona Department of Health Services (ADHS), or national accreditation programs, such as The National Environmental Laboratory Accreditation Conference (NELAC) Institute (TNI, n.d.), which is used by states like Texas and Florida. The NELAC Institute (TNI) was formed in 2006 by combining the boards of the NELAC and the Institute for National Environmental Laboratory Accreditation. Accreditation may be required for both internal and commercial laboratories. These programs require laboratories that produce data to support water quality programs to have established basic quality requirements incorporated into their data collection processes. These requirements should include the analytical procedures, instrument calibration requirements, quality control practices and documentation, and reporting protocol sufficient to document the traceability and quality of the result.

The city of Tucson, Ariz., has a well-established Reclaimed Water Site Inspection Program that accomplishes many of these goals [US-AZ-Tucson]. The program provides for periodic inspection of all sites having reclaimed water service, along with training and certification of reclaimed water site testers.

2.3.4.6 Response to Failures

The final and probably most important element is a well-defined and rigorously-enforced procedure for responding to system failures within the defined criteria. Obviously, this will include procedures for returning to normal operation as quickly as reasonably possible, but it should also include root-cause analysis or other investigative techniques to determine if systematic problems exist. In addition to water quality monitoring, the system as a whole requires monitoring and maintenance. A number of best practices to monitor the system include:

- Contractor training requirements on the regulations governing reclaimed water installations
- Requirements to submit all modifications to approved facilities to the responsible agencies
- Detection and documentation of any breaks in the transmission main
- Random inspections of user sites to detect any faulty equipment or unauthorized use
- Installation of monitoring stations throughout the system to test pressure, chlorine residual, and other water quality parameters
- Accurate recording of system flow to confirm total system use and spatial distribution of water supplied

2.3.5 Lessons Learned from Large, Medium, and Small Systems

Regardless of the size of a reclaimed water system, there are lessons learned that can be applied to other systems, and several case study examples are highlighted below by system size. Large reclaimed water systems (large systems) are defined as systems with a capacity larger than 10 mgd (440 L/s). In general, large systems have matured from smaller, initial start-up or backbone facilities that were implemented to meet smaller demands in prior years. As illustrated by several current large systems in the United States, however, this may not always be the case. Medium reclaimed water systems (medium systems) are defined as systems with a capacity ranging from 1 to 10 mgd (44 to 440 L/s). And small systems are defined as facilities treating flows ranging between 1,500 and 100,000 gpd (5.6 to 380 m^3/d), while small community systems may treat flows of up to 1 mgd (44 L/s) (Crites and Tchobanoglous, 1998).

Large Systems. The scale of the delivery system for the case study examples varies from gravity plant discharge to delivery through 130 mi (210 km) of pipeline. Three of these systems started at near their current capacities by providing alternative water sources to mature markets with significant drivers to meet water supply needs under time constraints. The UOSA, for example, developed from regional concerns over water quality issues from small and individual systems draining to the Occoquan Reservoir [US-VA-Occoquan]. What emerged from regional planning are key examples of planned IPR as a means of augmenting the raw water reservoir with high-quality source water, as depicted in **Figure 2-9**. Common themes throughout all of these large system case studies are the importance of public education and public information programs to educate staff, elected officials, the business community, and customers, which is discussed further in Chapter 8.

These large projects include significant design challenges that have led to state-of-the-science technical applications to meet the project constraints. However, the successful application of technology for projects such as the Occoquan Reservoir has been documented in research by Rose et al. (2001). Application of the lessons learned from these large reclaimed water projects provides valuable information for all systems in technology application and proven results for public acceptance.

Further, large reclaimed water system projects will typically involve more than one agency. In the case of OCWD and Orange County Sanitation District (OCSD), two boards worked together over many years to collectively solve problems and serve their individual system needs [US-CA-Orange County]. In the case of the Upper Occoquan project [US-VA-Occoquan], the UOSA was created by the state of Virginia and took over service obligations from numerous small providers. Supply to the Palo Verde Nuclear Generating Station (PVNGS) and USACE wetlands project in Arizona required public involvement and public hearings through state and two federal agencies [US-AZ-Phoenix]. San Antonio's project [US-TX-San Antonio] was driven by endangered species lawsuits limiting future water withdrawals, which required multiple local, state, and federal agencies to work together.

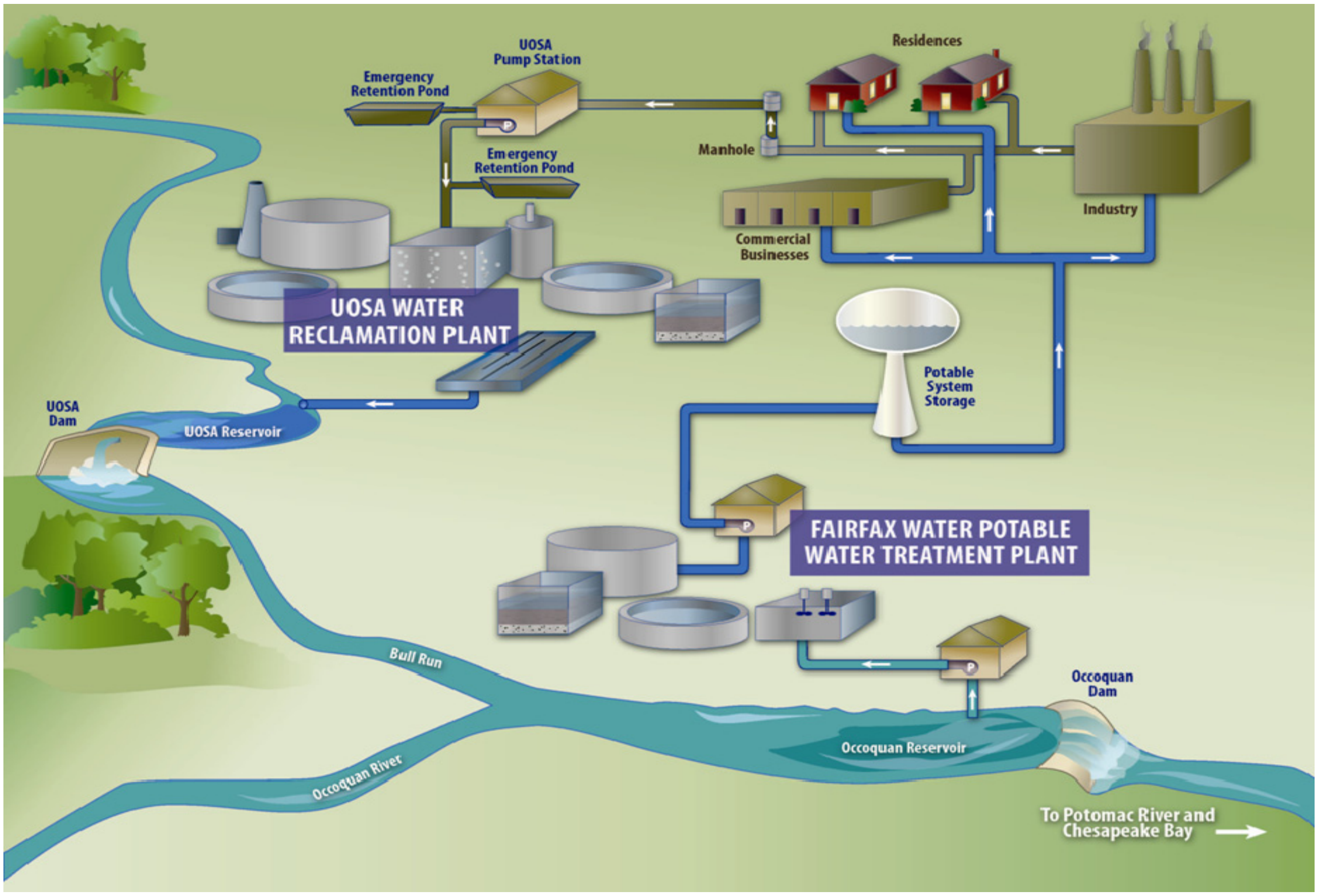

Figure 2-9
Upper Occoquan schematic

Each of these projects is an example of leaders and planners recognizing the importance of providing timely and accurate information to decision-makers and the public. These projects also provide valuable resource recovery and reuse to support the local water supply. In doing so, various permits required for the projects were issued because of community support.

Medium Systems. Existing medium-sized facilities can benefit from the experience of larger systems as well as from the development of their existing systems. Medium-sized systems have typically worked through many of the same operational considerations and, in most cases, the community is aware of the benefits of reusing local resources. For medium systems in particular, identifying potential reclaimed water customers is one of the most important phases of planning the reuse system and ensuring that the system can be sustained. Unlike large systems with capacities of greater than 10 mgd (438 L/s), which generally have a set reclaimed water user baseline, and smaller systems, which generally rely on a pre-identified (and consistent) source of reclaimed water, medium systems are largely dependent on the needs of their customer bases. This need can greatly vary depending on the type of reclaimed water customer, the end use for the reclaimed water, and the time of year (i.e., decreased demands in wet weather months). Identifying potential customers will help evaluate the financial viability of a reuse system as well as provide an estimate of how much potable water can be saved by connecting customers to a new reclaimed water system. A more accurate estimate may be provided by contacting identified potential customers to determine their willingness to participate in converting a portion of their demands to reclaimed water.

An excellent case study example of a medium system expanding its customer base is the city of Pompano Beach, Fla. [US-FL-Pompano Beach]. The city's OASIS (Our Alternative Supply Irrigation System) program is taking a systematic approach to increase existing and future reuse capacity to achieve the region's reuse requirements. Current plant capacity is 7.5 mgd (329 L/s), of which only 1.8 mgd (79 L/s) are produced because of a lack of demand. The city's greatest reuse challenge has been convincing single-family residential customers to hook up to the system. While connection is mandatory for commercial and multi-family customers, the city did not mandate connection for single-family residences. Even though construction of the reuse mains required working in existing neighborhoods and placing a reuse meter box at each home, and even though each home pays a monthly available charge, single-family residential customers have been slow to connect to the system. Reasons range from connection cost to permitting issues. Residents also complained about the annual backflow preventer assembly certifications and the resulting payback time.

In 2010, the city manager and the city commissioner approved a connection program to target single-family residential customers. The new program allows the city, working through a contractor, to perform the necessary plumbing on the customer's property to connect to the reuse system and eliminates the annual certification requirement for the customer. Installation cost is covered by the city's utilities department, which also retains ownership of the dual-check valve and meter. These costs are recovered through reclaimed water use rate ($0.85/1,000 gallons [$0.22/m^3] for the smallest meter size) that is slightly higher than existing reclaimed water use rates ($0.61/1,000 gallons [$0.16/m^3]). The program includes a public outreach campaign "I Can Water," which launched in July 2011 with meetings, media outreach, mailers, cable TV, a Web page, and a hotline. To reward the existing 73 customers, the city will replace and take over their backflow devices and keep them at the current lower rate. Customer response to this campaign has been positive.

Small Systems and Small Community Systems. Small systems and small community systems differ in both size and scope. Small systems typically serve a small development or project, while small community systems serve an entire community. Small systems can generally be classified according to the following categories:

- Point-of-use systems for a specific user
- A satellite facility within a medium or large system that is remote from the main WWTP or reclaimed water source
- A decentralized system in an area without community collection and treatment
- An internal industrial process reuse system
- A start-up system in initial phases of development that is intended to progress to a medium or large system
- A community reclaimed water system for a community generating less than 1 mgd (44 L/s) of plant flow

The scale of effort required in planning a small system is proportional to the system size. For example, the planning area for a small town may not be as large as a system for a population of 4 million, but small communities typically have fewer resources, so the effort can still be significant. Most of the systems will have similar regulatory hurdles, and all of the users in the categories above will need to address potential plant improvements to provide a water quality that will be acceptable to potential customers (sometimes in excess of the regulatory quality).

There is often an overlap in the above categories. For example, in order to conserve water and money, a small community with an existing WWTP decides to start a reclaimed water system by providing reclaimed water to its golf course. In this case, the planning process may initially be truncated by having one customer that can use a large volume of water. During the summer in the arid south, an 18-hole golf course can use 2 ac-ft (2,500 MCM) of reclaimed water per night. For many small communities, this may exceed their capacity, and as a result during peak summer use the reclaimed water may only supplement the previous source water. If a small community is a little larger, success with the first customer may lead to another planning process to identify other customers and explore the possibility of extending the small reclaimed water system.

An excellent case study example of this evolution is in Yelm, Wash. [US-WA-Yelm], where the community embraced reclaimed water as the best solution to safeguard public health, protect the Nisqually River, and provide an alternate water supply. While the city faced challenges, an intensive community outreach program helped the city successfully expanded its system into one of the first Class “A” Reclaimed Water Facilities in the state of Washington. Yelm constructed a wetlands park to have a highly visible and attractive focal point promoting reclaimed water use, and a local reclaimed water ordinance was adopted, establishing the conditions of reclaimed water use. The ordinance includes a “mandatory use” clause allowing Yelm to require construction of reclaimed water distribution facilities as a condition of development approval. Yelm continues to plan expansion of storage, distribution, and reuse facilities, and in 2002 the city received the Washington State Department of Ecology’s Environmental Excellence Award for successfully implementing Class “A” reclaimed water into its community.

Additional information on low-cost treatment technologies for small-scale water reuse projects is provided in a recent WRRF report on *Low-Cost Treatment Technologies for Small-Scale Water Reclamation Plants*, which identifies and evaluates established and innovative technologies that provide treatment of flows of less than 1 mgd (44 L/s) (WRRF, 2012). A range of conventional treatment processes, innovative treatment processes, and package systems was evaluated with the primary value of this work including an extensive cost database in which cost and operation data from existing small-scale water reclamation facilities have been gathered and synthesized.

2.4 Water Supply Conservation and Alternative Water Resources

Water scarcity is one of the key drivers for developing reclaimed water supplies and systems. As part of the overall management of water resources, it is critical to evaluate alternative management strategies for making the most of the existing supplies. Water conservation is an important management consideration for managing the water demand side. On the supply side, the use of alternative water resources, such as reuse of graywater, rainwater harvesting (where applicable), produced water, and other reuse practices, should also be considered as part of an overall plan.

2.4.1 Water Conservation

Integrating water conservation goals and programs into utility water planning is emerging as a priority for communities outside of the traditional water-short regions of the United States. Catalysts for implementing water conservation programs include growing competition for limited supplies, increasing costs and difficulties with developing new supplies, increasing demands that stress existing infrastructure, and growing public support for resource protection and environmental stewardship. As a result of the growing interest in water conservation, one of EPA's most successful partnership programs is WaterSense®, which supports water efficiency by developing specifications for water-efficient products and services (EPA, 2012). The program also provides resources for utilities to help promote their water conservation programs.

In addition to using conservation as a means to utilities to help meet growing water demands, many utilities are also beginning to understand the value of water conservation as a way of saving on costs for both the utility and its customers. Throughout the United States, utilities have experienced quantifiable benefits associated with long-term water conservation programs, including:

- Reduction in operation and maintenance costs resulting from lower use of energy for pumping and less chemical use in treatment and disposal
- Less expensive than developing new sources
- Reduced purchases from wholesalers
- Reduce, defer, or eliminate need for capacity expansions and capital facilities projects

Selecting the appropriate conservation program components includes understanding water use habits of customers, service area demographics, and the water efficiency goals of the utility; some of the most effective practices that encourage conservation include:

- Customer education
- Metering
- Rate structures with a volumetric component with rate increases with increased use (tiered rate structure)
- Irrigation efficiency measures

- Time-of-day and day-of-week water limitations
- Seasonal limitations and/or rate structures
- High-efficiency device distribution and rebates

Since 1991, for example, the Los Angeles Department of Water and Power has installed more than one million ultra-low-flush toilets and hundreds of thousands of low-flow showerheads and has provided rebates for high-efficiency washing machines and smart irrigation devices. The city used less water in 2010 than it did in 1990, despite adding more than 700,000 new residents to its service area (Rodrigo et al., 2010).

While it is clear that potable water resources should be conserved for the reasons above, reclaimed water in some regions of the country is not considered a resource; rather, it is sometimes viewed as a waste that must be disposed of. With this mindset, customers are sometimes encouraged to use as much reclaimed water as they want, whenever they want. In areas where there are fresh water supply shortfalls or where reclaimed water has become valued as a commodity, however, conservation has also become an important element of reclaimed water management. As a result, reclaimed water is recognized by many states as a resource too valuable to be wasted. The 1995 Substitute Senate Bill 5605 Reclaimed Water Act, passed in the state of Washington, stated that reclaimed water is no longer considered wastewater (Van Riper et al., 1998). The California legislature has declared, “Recycled water is a valuable resource and significant component of California’s water supply” (California State Water Resources Control Board, 2009). These recent declarations are part of broad statewide objectives to achieve sustainable water resource management. Chapter 8 describes how water conservation and water reuse public outreach can be synergistic.

Efficient and effective use can be critical to ensure that the reclaimed water supply is available when there is a demand for it. In addition, storage of reclaimed water can focus on periods of low demand for later use during high-demand periods, thereby stretching available supplies of reclaimed water and maximizing its use. While this practice is sometimes a challenge, it is gaining interest because of recent advances in management practices, such as ASR, which is discussed in Section 2.3.

Several conservation methods that are used in potable water supply systems are applicable to reclaimed water systems, including volume-based rate structures, limiting irrigation to specific days and hours, incorporation of soil moisture sensors or other controllers that apply reclaimed water when conditions dictate irrigation, and metering. Examples of reclaimed water conservation are prevalent in Florida. Many utilities’ reclaimed water availability is limited by seasonal demands that can exceed supply, making conservation and management strategies a necessity. To promote conservation, several utilities have implemented conservation rate structures to encourage efficient use of reclaimed water. In addition, utilities that provide reclaimed water for landscape irrigation, including irrigation for residential lots, medians, parks, and other green space, are promoting efficient use of reclaimed water by limiting the days and hours that users can irrigate. The Loxahatchee River District in Palm Beach County, Fla., has designated irrigation days for residential landscape irrigation reuse customers and can shut off portions of its system on designated non-irrigation days. Port Orange, Fla., retrofitted its entire reuse system with meters so that customers could be charged according to a tiered volumetric rate rather than a flat rate that encouraged excessive use. And the Southwest Florida Water Management District has recognized the importance of conserving reclaimed water to ensure more customers can be served by providing grant funding for reuse programs where efficient use is a criterion for receiving funds.

2.4.2 Alternative Water Resources

While these guidelines are intended to highlight the reuse of reclaimed water derived from treated municipal effluent, there are a number of other alternative water sources that are often considered and managed in a manner similar to reclaimed water. Some of the most important alternative water resources include individual and on-site graywater and stormwater.

2.4.2.1 Individual On-site Reuse Systems and Graywater Reuse

Graywater is untreated wastewater, excluding toilet and—in most cases—dishwasher and kitchen sink wastewaters. Wastewater from the toilet and bidet is "blackwater," and while the exclusion of toilet waste is a key design factor in on-site and graywater systems, this does not necessarily prevent fecal matter and other human waste from entering the graywater system—albeit in small quantities. Examples of routes for such contamination include shower water and bathwater and washing machine discharge after cleaning of soiled underwear and/or diapers (Sheikh, 2010). In fact, California's latest graywater standards define graywater as untreated wastewater that has not been contaminated by any toilet discharge; has not been affected by infectious, contaminated, or unhealthy bodily wastes; and does not present a threat from contamination by unhealthful processing, manufacturing, or operating wastes. Graywater does include wastewater from bathtubs, showers, bathroom washbasins, clothes washing machines, and laundry tubs, but does not include wastewater from kitchen sinks or dishwashers (California Building Standards Commission, 2009). Thus, for a graywater system, it is assumed that a building or homeowner would take extraordinary care in source control of contaminants and ensure pathogen-free graywater, an assumption that could be questionable in a certain percentage of cases.

For these reasons, use of graywater has been a controversial practice. While viewed by some as the panacea for water shortages, groundwater depletion, surface water contamination, and climate change, use of graywater can also be seen as a threat to the health and safety of the users and their neighbors. While the reality of graywater lies somewhere between these two perceptions, the installation of a graywater system may save a significant amount of potable water (and its costs) for the homeowner or business, even though the payback period for the more complex systems may exceed the useful life of the system. Graywater use does not always reduce total water use, as shown in a study in Southern Nevada (Rimer, 2009). Because all wastewater in the region is collected, treated, and returned to Lake Mead, all water is already reused. Using untreated or partially treated graywater had higher public health risk than continued use of reclaimed water, and graywater users felt less constrained in using potable water, actually increasing total metered water use. There are no documented cases in the United States of any disease that has been caused by exposure to graywater—although systematic research on this public health issue is virtually nonexistent. And, while the absence of documentation does not prove that there has never been such a case, graywater is, in fact, wastewater with microbial concentrations far in excess of levels established in drinking, bathing, and irrigation water standards for reclaimed water (Sheikh, 2010).

Graywater Policy and Permitting. Key to the viability of small or on-site graywater systems is an effective policy, permitting, and regulatory process to provide adequate treatment of graywater for the intended end use. In many states the regulatory system is still designed for large-scale systems; the permitting process for small systems is complex because small systems cross into the purview of various regulatory agencies, which can cause hurdles in the approval process. There are a number of states and local agencies that provide specific regulations or guidance for graywater use, including Arizona, California, Connecticut, Colorado, Georgia, Montana, Nevada, New Mexico, New York, Massachusetts, Oregon, Texas, Utah, Washington, and Wyoming. In addition to the states that have specific policies on graywater use, there are other institutional policies, such as the UPC and the IPC, that are applicable to the implementation of graywater systems. A comprehensive compilation of graywater laws, suggested improvements to graywater regulations, legality and graywater policy, sample permits, public health considerations, studies, and other considerations has been assembled by Oasis Design, a firm with vested interest in promoting use of graywater. Links to numerous resources targeted at regulators, inspectors, elected officials, building departments, health departments, builders, and homeowners have been posted by Oasis Design (Oasis Design, 2012).

Graywater Quality Criteria. For any size and type of system, proper consideration for public health begins with risk management, which puts in place mechanisms to minimize or eliminate the risk of contaminated water entering the water supply. Thus, from a policy perspective, the first step in risk management is establishing transparent criteria for water quality; the NSF Standard 350 establishes water quality criteria for on-site systems.

In 2011, NSF/ANSI Standard 350 *Onsite Residential and Commercial Water Reuse Treatment Systems* and NSF/ANSI Standard 350-1 *Onsite Residential and Commercial Graywater Treatment Systems for Subsurface Discharge* were adopted (NSF, 2011a and 2011b). The standards provide detailed methods of evaluation; product specifications; and criteria related to materials, design and construction, product literature, wastewater treatment performance, and effluent quality for on-site treatment systems. Graywater treatment to NSF 350 levels also requires certified operators, reliability, and public water supply protection. The NSF/ANSI Standard 350 is for graywater treatment systems with flows up to 1,500 gpd (5.7 m^3/d) or larger. The standards apply to graywater treatment systems having a rated treatment capacity of up to 1,500 gpd (5.7 m^3/d), residential wastewater treatment systems with treatment capacities up to 1,500 gpd (5.7 m^3/d), and commercial treatment systems with capacities exceeding 1,500 gpd (5.7 m^3/d) for commercial wastewater and commercial laundry facilities. End uses appropriate for reclaimed water from these systems include indoor restricted urban water use, such as toilet flushing, and outdoor unrestricted urban use, such as surface irrigation.

The Standard 350 effluent criteria (**Table 2-5)** are applied consistently to all treatment systems regardless of size, application, or influent quality. Effluent criteria in **Table 2-5** must be met for a system to be classified as either a residential treatment system for restricted indoor and unrestricted outdoor use (Class R) or a multi-family and commercial facility water treatment system for restricted indoor and unrestricted outdoor use (Class C).

The NSF/ANSI Standard 350-1 is for graywater treatment systems with flows up to 1,500 gpd (5.7 m^3/d). For systems above 1,500 gpd (5.7 m^3/d), a multiple-component system should be performance tested for at least 6 months at the proposed site of use following the field evaluation protocol in Annex A of NSF-350. Annex A prescribes testing sequence, frequency of sampling and testing, and test protocol acceptance and review procedures. End uses appropriate for these systems include only subsurface discharges to the environment. The effluent requirements of graywater systems seeking certification through the ANSI/NSF Standard 350-1 for subsurface discharge are provided in **Table 2-6**.

Table 2-6 Summary of ANSI/NSF Standard 350-1 for subsurface discharges

Parameter	Test Average
$CBOD_5$ (mg/L)	25 mg/L
TSS (mg/L)	30 mg/L
pH (SU)	6.0 – 9.0
Color	MR[1]
Odor	Non-offensive
Oily film and foam	Non-detectable
Energy consumption	MR

[1] MR: Measured reported only.

It is important to note that while the NSF/ANSI Standards provide detailed information for graywater use, individual state statutes and regulations and local building codes, which generally take precedence, may not allow graywater use in a given locale.

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Table 2-5 Summary of NSF Standard 350 Effluent Criteria for individual classifications

Parameter	Class R		Class C	
	Test Average	Single Sample Maximum	Test Average	Single Sample Maximum
$CBOD_5$ (mg/L)	10	25	10	25
TSS (mg/L)	10	30	10	30
Turbidity (NTU)	5	10	2	5
E. coli [2] (MPN/100 mL)	14	240	2.2	200
pH (SU)	6.0 – 9.0	NA[1]	6.0 – 9.0	NA
Storage vessel disinfection (mg/L)[3]	≥ 0.5 – ≤ 2.5	NA	≥ 0.5 – ≤ 2.5	NA
Color	MR[4]	NA	MR	NA
Odor	Nonoffensive	NA	Nonoffensive	NA
Oily film and foam	Nondetectable	Nondetectable	Nondetectable	Nondetectable
Energy consumption	MR	NA	MR	NA

[1] NA: not applicable
[2] Calculated as geometric mean
[3] As total chlorine; other disinfectants can be used
[4] MR: Measured reported only

include suspended media treatment, fixed media treatment systems, and constructed wetland systems. All of these technologies must be followed by advanced filtration and disinfection. On-site applications of membrane bioreactor (MBR) technology have also been utilized effectively in commercial and residential properties for outdoor irrigation and indoor nonpotable uses. Design standards for treatment systems are enforced through local health and environmental agencies, and permits to operate on-site treatment systems often include requirements for increased levels of monitoring.

Because increased monitoring can be burdensome for small systems, operational monitoring can be used to determine if the system is performing as expected. By using instrumentation and remote monitoring technologies, small schemes can produce real-time data to ensure the system is functioning according to water quality objectives. This operational monitoring strategy is a risk management methodology borrowed from the food and beverage industry; the HACCP is a preventive approach that identifies points of risk throughout the treatment process and assigns corrective actions should data reveal heightened risk (Natural Resource Management Ministerial Council, Environment Protection and Heritage Council and Australian Health Ministers' Conference, 2006). Water quality parameters are set at different CCPs and monitored in real-time online; if data reveal water quality is outside the set parameters, a corrective action will be triggered automatically in real time. With an operational monitoring model in place, ongoing sampling serves only as confirmation of the operational data, and frequency of regulatory sampling could be reduced. In the case where indoor uses are allowed, turbidity meters are often employed as a measure of system performance.

While the quantitative impact of increased graywater use is expected to be modest, even under the most aggressive growth assumptions, much of the growth in graywater use is expected to take place in areas where municipal water reuse will likely not be practiced—unsewered urban areas and rural and remote areas, as exemplified in several case studies Australia-Sydney]. Further, there are growing possibilities for increased on-site treatment systems in urban buildings that are LEED certified.

2.4.2.2 LEED-Driven On-site Treatment

A recent development in on-site treatment systems in urban development has been driven largely by the private sector's desire to create more highly sustainable developments through the LEED program. This program area remains small compared to the municipal reuse market. However, it has a growing role for improving water efficiency in new buildings and developments and also for major modifications to existing facilities. A primary driver that compels land developers to consider the implementation of on-site treatment systems is the sustainability accreditation that is promoted and earned through the LEED program. The LEED program was developed by the U.S. Green Building Council (USGBC) in 2000 and represents an internationally-recognized green building certification system. At the time of preparation of this document, the current version of the Rating System Selection Guidance was LEED 2009, originally released in January 2010 and updated in September 2011. The guidance is currently under revision with the new LEED v4 focusing on increasing technical stringency from past versions and developing new requirements for project types such as data centers, warehouses and distribution centers, hotels/motels, existing schools, existing retail, and mid-rise residential buildings. More information is available on the USGBC website (USGBC, n.d.).

LEED provides building owners/operators with a framework for the selection and implementation of practical, measurable, and sustainable green building design, construction, and operations and maintenance solutions. LEED promotes sustainable building and site development practices through a tiered certification rating system that recognizes projects that implement green strategies for better overall environmental and health performance. The LEED system evaluates new developments, as well as significant modifications to existing buildings, based on a certification point system where applicants may earn up to a maximum of 110 points. LEED promotes a whole-building approach to energy and water sustainability by observance of these seven key areas of the LEED evaluation criteria: 1) sustainable sites, 2) water efficiency, 3) energy and atmosphere, 4) materials and resources, 5) indoor air quality, 6) innovation and design process, and 7) regional-specific priority credits. Developments may qualify for LEED certification designation and points, according to the following qualified certification categories:

- LEED Certified – 40 to 49 points
- LEED Silver – 50 to 59 points
- LEED Gold – 60 to 79 points
- LEED Platinum - 80+ points

On-site treatment systems can comprise a substantial fraction of the certification points with these systems qualifying for up to a maximum number of 11 points through the water efficiency and innovation and design processes in combination with water conservation practices. On-site water treatment systems may qualify for up to 10 points in the water efficiency category through water efficient design, construction, and long-term operation and maintenance features that promote water conservation and efficiency as follows:

- Water Efficient Landscaping, 2 to 4 points
- Innovative Wastewater Technologies, 2 points
- Water Use Reduction, 2 to 4 points

The on-site treatment system must provide water use reductions in conjunction with an associated water conservation program to secure a maximum number of LEED water efficiency points. An on-site treatment system may also help qualify for an Innovation in Design Process maximum credit of one point.

A major sub-category under the Water Efficiency section of the LEED criteria is water use reduction. The water use reduction subcategory determines how much water use can be reduced in and around a LEED-certified development. One item that can receive a score under water reuse is a rainwater (rooftop) harvesting system. The harvested rainwater resource may then be combined with an on-site graywater treatment system, a high-quality wastewater treatment system, or with the use of a municipal reclaimed water system source. The combination of the rainwater harvesting system with either a graywater treatment system, an on-site wastewater treatment system, or a municipal reuse system can together account for a total of up to seven LEED points. While this practice is contrary to the conventional practice of avoiding dilution of biologically degradable material in the sewage that is used by municipal wastewater treatment processes, the on-site treatment system allows multiple objectives of reducing effluent discharges and reducing stormwater runoff while providing water that can be used for nonpotable purposes. The Fay School, located in Southborough, Mass., achieved LEED Gold Certification from the USGBC. The Fay School students now monitor building energy and building water consumption from a digital readout in each new dormitory building. The entire project was developed from the Fay School's interest in sustainable design principles and educates the students on the importance of water efficiency [US-MA-Southborough].

Battery Park City in lower Manhattan, New York City, is a collection of eight high-rise structures with 10 million ft^2 of floor area that serves 10,000 residents plus 35,000 daily transient workers. Water for toilet flushing, cooling, laundry, and irrigation comes from six on-site treatment systems. On-site systems use MBR technology for biological treatment and UV and ozone for disinfection. Potable water is supplied by New York City and the on-site treatment systems overflow to a combined wastewater/stormwater outfall. All buildings in Battery Park City are LEED certified Gold or Platinum (WERF, n.d.).

In an industrial setting, the Frito-Lay manufacturing facility in Casa Grande, Ariz., received a LEED Gold EB (Existing Building) certification with modification to the manufacturing process to incorporate an on-site process water treatment system and addition of 5 MW of on-site photovoltaic power generation [US-AZ-Frito Lay].

Reclaimed water, along with other major alternative water sources, such as harvested rainwater and collected stormwater runoff, offer the opportunity to maximize landscape irrigation and reduce potable water use at many industrial and commercial institutions and at multi-family residential developments. In the south and southwest United States, air conditioning condensate collection and reuse may represent another significant alternate water resource. On-site treatment systems can be designed to treat municipal wastewater, graywater, harvested rainwater, and stormwater. Regardless of water source selected for use, care must be taken to differentiate pipes on the private side of the municipal utility boxes, appropriately color code on-site pipes, and adopt a cross-connection control program for the different water sources.

2.4.2.3 Stormwater Harvesting and Use

Comprehensive and sustainable integrated water management programs should also consider multiple goals, including those that are related to stormwater, such as cost-effectively controlling flooding and erosion; improving water quality; conserving, sustaining, and recharging water supply; and preserving and restoring the health of wetlands and aquatic ecosystems. Because rainfall is generally the most significant factor in managing stormwater, capture and harvesting of rainfall and associated runoff present opportunities for stormwater use benefits. These include direct use of runoff for urban and agricultural irrigation, alternative water supply, aquifer recharge and saltwater intrusion barriers, wetlands enhancement, low (minimum) flow augmentation, feed lot cleaning, heating ventilation and air conditioning (HVAC) and power plant cooling, firefighting, and toilet flushing. However, stormwater harvesting requires an effective means of stormwater capture and retention that also supports the concurrent need for flood control. A good example of this practice is Cape Coral, Fla., which has maintained a very effective stormwater harvesting program since the 1980s primarily because of its extensive network of canals throughout the city. Within Cape Coral's integrated water management system, stormwater makes up as much as 75 percent of the irrigation water demand in the city, which allows for 100 percent reuse of the city's wastewater flows. Another case study that highlights these benefits is from the Water Purification Eco-Center (WPEC) at the Rodale Institute in Kutztown, Pa. [US-PA-Kutztown]; the WPEC project captures rainwater for public septic use and treats the septic water to be returned to the surrounding environment.

While the benefits of stormwater harvesting are clear, there are currently no federal regulations governing rainwater harvesting for nonpotable use, and the policies and regulations enacted at the state and local levels vary widely from one location to another. Regulations are particularly fragmented with regard to water conservation, as the permissible uses for harvested water tend to vary depending on the climate and reliability of the water supply. There are local plumbing codes, and some states, including Georgia, have published *Rainwater Harvesting Guidelines*, but not all states have formally defined rainwater harvesting as a practice distinct from water recycling (Georgia Department of Community Affairs, 2009). In recent years, cities and counties looking to promote water conservation have begun issuing policies that better define harvested water and its acceptable uses. The city of Portland, Ore., for example, provides explicit guidance on the accepted uses of harvested water both indoors and outdoors. In January 2010, Los Angeles County issued a policy providing a clear, regulatory definition of "rainfall/nonpotable cistern water" and drawing a specific distinction between harvested water and graywater or recycled water.

In 2010, IAPMO published the *Green Plumbing and Mechanical Code Supplement (GPMCS).* The supplement is a separate document from the Uniform Plumbing and Mechanical Codes and establishes requirements for green building and water efficiency applicable to plumbing and mechanical systems. The purpose of the GPMCS is to "provide a set of technically sound provisions that encourage sustainable practices and works towards enhancing the design and construction of plumbing and mechanical systems that result in a positive long-term environmental impact" (IAPMO, 2010). In addressing "Non-potable Rainwater Catchment Systems," the GPMCS specifically identifies provisions for collection surfaces, storage structures, drainage, pipe labeling, use of potable water as a back-up supply (provided by air-gap only), and a wide array of other design and construction criteria. It also refers to and incorporates information from the *ARCSA/ASPE Rainwater Catchment Design and Installation Standard* (2008), a joint effort by the American Rainwater Catchment Systems Association (ARCSA) and the American Association of Plumbing Engineers (ASPE) (ARCSA/ASPE, 2008).

2.5 Environmental Considerations

Increasing water withdrawals, coupled with effluent discharges from WWTPs and agricultural runoff, can dramatically alter the hydrological cycles and nutrient cycling capacity of aquatic ecosystems. Water reuse can have both positive and adverse impacts on surrounding and downstream ecosystems. Elimination or reduction of a surface water discharge by reclamation and reuse generally reduces adverse water quality impacts to the receiving water. However, development of water reuse systems may have unintended environmental impacts related to land use, stream flow, and groundwater quality.

An environmental assessment may be required to meet state regulations or local ordinances and is required whenever federal funds are used. Formal guidelines for the development of an environmental impact statement (EIS) have been established by EPA. Such studies are generally associated with projects receiving federal funding or new NPDES permits and are not specifically associated with reuse programs. Where an investigation of environmental impacts is required, it may be subject to state policies. The following conditions could induce an EIS in a federally-funded project:

- The project may significantly alter land use.
- The project is in conflict with land use plans or policies.
- Wetlands will be adversely impacted.
- Endangered species or their habitat will be affected.
- The project is expected to displace populations or alter existing residential areas.
- The project may adversely affect a floodplain or important farmlands.
- The project may adversely affect parklands, preserves, or other public lands designated to be of scenic, recreational, archaeological, or historical value.
- The project may have a significant adverse impact upon ambient air quality, noise levels, or surface or groundwater quality or quantity.
- The project may have adverse impacts on water supply, fish, shellfish, wildlife, and their actual habitats.

These types of activities associated with federal EIS requirements are described below. Many of the same requirements are incorporated into environmental assessments required under state laws.

2.5.1 Land Use Impacts

Water reuse can induce significant land use changes, either directly or indirectly. Direct changes include shifts in vegetation or ecosystem characteristics induced by alterations in water balance in an area, such as wetland restoration or creation. Indirect changes include land use alterations associated with industrial, residential, or other development made possible by the added supply of water from reuse. Other examples of changes in land use as a result of available reclaimed water include the potential for urban or industrial development in areas where natural water availability limits the potential for growth. For example, if the supply of potable water can be increased through recharge using reclaimed water, then restrictions to development might be reduced or eliminated. Even nonpotable supplies, made available for uses such as residential irrigation, can affect the character and desirability of developed land in an area. Similar effects can also happen on a larger scale, as municipalities in areas where development options are constrained by water supply might find that nonpotable reuse enables the development of parks or other amenities that were previously considered to be too costly or difficult to implement. Commercial users, such as golf courses, garden parks, or plant nurseries, have similar potential for development given the presence of reclaimed water supplies.

2.5.2 Water Quantity Impacts

Instream flows and levels in lakes and reservoirs can either increase or decrease as a consequence of reuse projects. In each situation where reuse is considered, there is the potential to shift water balances and effectively alter the prevailing hydrologic regime in an area, with the potential to damage or improve impacted ecosystems. Where wastewater discharges have occurred over an extended period of time, the flora and fauna can adapt and even become dependent on that water. A new or altered ecosystem can arise, and a reuse program implemented without consideration of this fact could have an adverse impact on such a community. Examples of how flows can increase as a result of a reuse project include:

- In streams where dry weather base flows are groundwater dependent, land application of reclaimed water for irrigation or other purposes can cause an increase in base flows, if the prevailing groundwater elevation is raised.
- Increases in stream flows during wet periods can result from pervasive use of recharge on the land surface during dry periods. In such a case, antecedent conditions are wetter, and less water moves into the ground, thereby increasing

runoff during a rainstorm. The instream system bears the consequences of this change.

- Instream flow reduction is also possible and can impact actual or perceived water rights. For example, the Trinity River in Texas, near the Dallas-Fort Worth Metroplex, maintains a continuous flow of several hundred cubic feet per second during dry periods due to return flows (discharges) from multiple WWTPs. If extensive reuse programs were to be implemented at the upstream facilities, dry weather flows in the Trinity River would be reduced, and plans for urban development downstream could potentially be impacted due to water restriction. Houston-area interest near the downstream end of the Trinity River stalled TCEQ issuance of Metroplex discharge and bed and banks transfer permits for several years until agreements were reached with individual large discharges in the Metroplex to maintain minimum flow to Lake Livingston, a primary source of drinking water for Houston.

In southern Arizona, the San Pedro River is distinct as the last free-flowing undammed river in Arizona, which supports a unique desert riparian ecosystem. Population growth around Sierra Vista has caused a significant drop in the groundwater table, which in turn reduces the stream flow in the river. Ecological considerations, including the protection of endangered species, prompted the decision to recharge the underlying aquifer with reclaimed water. Environmental Operations Park (EOP) in Sierra Vista includes a reclamation facility that polishes reclaimed water in constructed wetlands. The reclaimed water is then used to recharge the local aquifer in order to mitigate the adverse impacts of continued groundwater pumping in the San Pedro River system. The Sierra Vista EOP was established as a multi-use center, combining recharge basins, constructed wetlands, native grasslands, and a wildlife viewing facility [US-AZ-Sierra Vista].

An example from Sydney, Australia provides a rather unusual case where water reclamation was designed explicitly for environmental flows. Drinking water supplies in Sydney's main storage reservoir (Warragamba Dam) were rapidly declining between 2000 and 2006 due to severe drought. By law, Warragamba Dam was also required to continue to provide satisfactory environmental flows (4.8 billion gallons [18 MCM] released annually) in the downstream Hawkesbury Nepean River system. A massive water reclamation project was implemented [Australia-Replacement Flows] to replace the Warragamba Dam's discharge with an alternative high-quality water source that met the required downstream environmental flows.

The SAWS in Texas defined the historic spring flow at the San Antonio River headwaters during development of its reclaimed water system. In cooperation with downstream users and the San Antonio River Authority, SAWS agreed to maintain release of 55,000 ac-ft/yr (68 MCM/yr) from its water reclamation facilities. This policy protects and enhances downstream water quality and provides 35,000 ac-ft/yr (43 MCM/yr) of reclaimed water for local use [US-TX-San Antonio].The implication of these examples is that a careful analysis of the entire hydrologic system is an appropriate consideration in a reuse project, particularly where reuse flows are large, relative to the hydrologic system that will be directly impacted. Likewise, analysis of the effects from the chemical, physical, and biological constituents in discharges of reclaimed water must be considered where the end use is environmental flows; this is the same or similar to what is required for discharges of wastewater effluent.

2.5.3 Water Quality Impacts

There are potential water quality impacts from introducing reclaimed water back into the environment. The ecological risks associated with environmental reuse applications can be assessed relative to existing wastewater discharge practices (NRC, 2012); additional discussion on this topic is provided in Chapter 3. The report concludes that the ecological risks in reuse projects for ecological enhancement are not expected to exceed those encountered with the normal surface water discharge of treated municipal wastewater. Indeed, risks from reuse could be lower if additional levels of treatment are applied. The report cautions that current limited knowledge about the ecological effects of trace chemical constituents requires research to link population-level effects in natural aquatic systems to initial concerning laboratory observations. In reuse applications targeted for ecological enhancement of sensitive aquatic systems, careful assessment of risks from these constituents is warranted because aquatic organisms can be more sensitive to certain constituents than humans (NRC, 2012).

In addition to potential impacts on surface water quality, groundwater quality can be significantly impacted by recharge with reclaimed water. Recharging groundwater with reclaimed water may change the water quality in the receiving aquifer. Conditions must be evaluated on a case-by-case basis, depending on potential constituents present in reclaimed water and the underlying site hydrogeology; additional discussion is provided in Section 2.3.3.

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CHAPTER 3
Types of Reuse Applications

The United States has achieved numerous accomplishments toward expanding the use of reclaimed water and extending water resources for many communities. Yet, there is room for improvement in terms of the total amount of water reused, distribution of reclaimed water use throughout the country, and the adoption of new, higher quality uses. A report by the NRC Water Science & Technology Board titled *Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater* estimates that as much as 12 bgd (45 MCM/d) of the 32 bgd (121 MCM/d) produced in the United States can be beneficially reclaimed and reused (NRC, 2012). Recent estimates indicate that approximately 7 to 8 percent of wastewater is reused in the United States (Miller, 2006 and Global Water Intelligence [GWI], 2010b) (**Figure 3-1**). Therefore, there is tremendous potential for expanding the use of reclaimed water in the future.

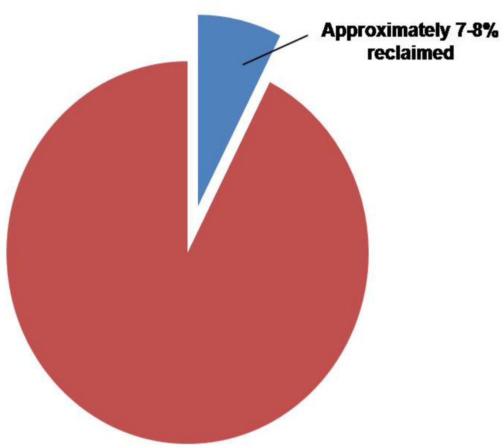

Figure 3-1
Reclaimed water use in the United States

Outside of the United States, there are examples of countries with different water resource demands that greatly exceed this percentage. Several countries, including Australia and Singapore, have established goals for reuse, expressed in terms of the percentage of municipal wastewater effluent that is treated to a higher quality and beneficially reused. Australia currently reuses approximately 8 percent of its treated wastewater with a goal of reusing 30 percent by 2015. Saudi Arabia currently reuses 16 percent with a goal to increase reuse to 65 percent by 2016. Singapore reuses 30 percent and has long-term planning in place to diversify its raw water supplies and reduce dependence on supplies from outside sources (i.e., Malaysia). Israel has attained the highest national percentage by beneficially reusing 70 percent of the generated domestic wastewater.

The last comprehensive survey of water reuse in the United States was conducted in 1995 by the U.S. Geological Survey (USGS); more recently, the USGS compiled water use data from 2005 (Solley et al., 1998). Estimates of wastewater reuse were compiled by some states for the industrial, thermoelectric, and irrigation categories but were not reported because of the small volumes of water compared to the totals (Kenny et al., 2009). The study revealed that 95 percent of water reuse occurred in just four states: Arizona, California, Florida, and Texas. This is now estimated to be less than 90 percent due to increased water reuse in several other states, especially Nevada, Colorado, New Mexico, Virginia, Washington, and Oregon. In addition, reuse is now practiced in the Mid-Atlantic and Northeast regions of the United States, with a number of water reuse facilities in New Jersey, Pennsylvania, New York, and Massachusetts. Production and distribution of reclaimed water varies regionally by categories of use and depends on historical and emerging drivers, as described in Chapter 5.

Table 3-1 shows the distribution of reclaimed water use for California and Florida—the two largest users of reclaimed water in the United States. Although California reused 669,000 ac-ft (825 MCM) of water in 2009, coastal communities were an untapped source of reclaimed water by discharging 3.5 million ac-ft (4,300 MCM) of highly-treated wastewater to the Pacific Ocean. The challenge for coastal communities then shifts from adequate supply to an ability to distribute the new source water from the coast through a highly-developed urbanized area to points of use.

Table 3-1 Distribution of reclaimed water in California (Baydal, 2009) and Florida (FDEP, 2011)

Reuse Category		California (% Use in 2009)	Florida (% Use in 2010)
Irrigation	Agricultural	29	11
	Urban reuse (landscape irrigation, golf courses)	19	55
Groundwater Recharge		5	14
Seawater Intrusion Barrier		8	-
Industrial Reuse		7	13
Natural Systems and Other Uses		23	9
Recreational Impoundments		7	-
Geothermal Energy		2	-

The distribution of reclaimed water use in the United States is a reflection of regional characteristics, and these differences are explored in greater detail in Chapter 5. Understanding the planning considerations and requirements for reuse types is critical to developing a successful program. Thus, this chapter highlights major types of reuse, including agricultural, industrial, environmental, recreational, and potable reuse; examples of these applications across the United States and internationally are provided for these applications.

3.1 Urban Reuse

While there are several major categories of reuse, in the United States urban reuse is one of the highest volume uses. Applications such as recreational field and golf course irrigation, landscape irrigation, and other applications, including fire protection and toilet flushing, are important components of the reclaimed water portfolio of many urban reuse programs. Urban reuse is often divided into applications that are either accessible to the public or have restricted access, in settings where public access is controlled or restricted by physical or institutional barriers, such as fences or temporal access restriction. Additional information on the treatment and monitoring requirements for both types of urban reuse is provided in Chapter 6. Additionally, because urban reuse comprises such a large fraction of the total reclaimed water use, detailed information regarding planning and management of reclaimed water supplies and systems that include urban reuse is provided in Chapter 2.

3.1.1 Golf Courses and Recreational Field Irrigation

In order to maximize the use of potable water in resource-limited systems, communities are working to identify alternatives for minimizing nonpotable consumption by supplying reclaimed water for reuse. When used to irrigate residential areas, golf courses, public school yards, and parks, reclaimed water receives treatment and high-level disinfection and is not considered a threat to public health. However, the water quality of reclaimed water differs from that of drinking quality water or rainfall and should be considered when used for irrigation and other industrial reuse applications. Of particular importance are the salts and nutrients in reclaimed water, and special management practices for both end uses may be required depending on the concentrations in the reclaimed water. For example, in some areas where landscaping is irrigated, the salt sensitivity of the irrigated plants should be considered.

The 2004 *Guidelines for Water Reuse* (EPA, 2004) identified irrigation of golf courses as one of several typical urban water reuse practices. While this was and still is an attractive use for reclaimed water as large quantities can be beneficially used by one user, there are operational practices and cautions that planners should consider. Between September 2000 and December 2004, AWWA conducted a survey of reclaimed water use practices on golf courses (Grinnell, 2004). Results of this survey were compiled from 180 responses from seven states, Canada, and Mexico. Two-thirds of the responses were from Florida, California, and Arizona. Combined with data from the Golf Course Superintendents Association of America (GCSAA), AWWA estimated in 2004 that 2,900 of the 18,100 golf courses surveyed were using reclaimed water, a 600 percent increase from 1994 data. Although most comments were positive, some respondents expressed concern regarding algal problems in ponds, changes in course treatment, and increased turf management.

A more recent survey in 2006 by the GCSAA and the Environmental Institute for Golf (EIFG) requested input from superintendents at 16,797 courses and received response from 2,548 (GCSSA and EIFG, 2009). Based on this survey, an estimated 12 percent of golf courses in the United States use reclaimed water, with more courses in the southwest (37 percent) and southeast (24 percent) practicing reuse. In fact, the most recent state survey for Florida in 2010 (FDEP, 2011) listed 525 golf courses using nearly 118 mgd (5170 L/s) of reclaimed water, representing about 17.9 percent of the daily reuse within the state. This continued application of reuse to golf courses is exemplified in the following case studies:

- US-FL-Pompano Beach
- US-FL-Marco Island
- US-TX-Landscape Study
- Australia-Victoria

The most common reason identified by golf courses for not using reclaimed water for irrigation was the lack of a source for reclaimed water (53 percent of respondents) (FDEP, 2011). It was also not a surprise that the poorest water quality identified by respondents was in the southwest where there was typically higher TDS and salinity concerns. With lower water quality, systems in the southwest and southeast were most likely to use wetting agents and fertigation systems. To address some of the water quality concerns, turfgrass research has been conducted to determine the most salt-tolerant species for a geographic area and soil type.

In San Antonio, SAWS and Texas A&M University conducted a 2-year test (2003 to 2004) that compared the application rates of potable (control) water and reclaimed water on 18 plots of Tifway Bermuda grass and Jamur zoysia grass (Thomas et al., 2006). The study evaluated leachate quality, soil ion retention, and grass quality. Of particular concern was the potential transport through the root zone of nitrate, which could potentially percolate in the local karst geology to the sole source Edwards Aquifer. Results indicated both grasses were well adapted to using the SAWS reclaimed water; the grasses maintained high quality but did not uptake all of the nitrogen applied during the December to February dormant period. Soil ions concentrations increased, indicating a need for long-term monitoring, scheduled leaching, and/or supplemental treatment to maintain good soil conditions. During the dormant season for the two grasses, the study recommended applications of reclaimed water at no more than the evapotranspiration rate to preclude nitrate transport below the root zone.

Golf course turf studies have been conducted for over 30 years and there are several publications that have been developed for the USGA and GCSAA related to use of reclaimed water for golf course irrigation. Reclaimed water for this purpose has been referred to as "purple gold," especially in the southwestern United States where golf course turf depends on irrigation (Harivandi, 2011). Recommendations for use of reclaimed water for turfgrass irrigation focus on quality limits of reclaimed water and monitoring. For reclaimed water that exceeds the recommended criteria presented in **Table 3-2**, slight to moderate use restrictions would apply (Harivandi, 2011).

Even though the poorest quality reclaimed water with respect to TDS is produced in the southwest, it is there where the greatest golf course reuse occurs. In addition to selecting salt-tolerant grasses such as Alkali, Bermuda, Fineleaf, St. Augustine, Zoysia, Saltgrass, Seashore, or Paspalum, many facilities have implemented solutions to mitigate adverse impacts of challenging water quality. Some of these practices include:

- Applying extra water to leach excess salts below the turfgrass root zone
- Providing adequate drainage

Table 3-2 Interpretation of reclaimed water quality

Parameter	Units	Degree of Restriction on Use		
		None	Slight to Moderate	Severe
Salinity				
Ecw	dS m^{-1}	< 0.7	0.7 - 3.0	> 3.0
TDS	mg/L	< 450	450 - 2,000	> 2,000
Ion Toxicity	SAR	< 3	3-9	> 9
Sodium (Na)	meq/L	< 3	> 3	
Root Absorption	mg/L	< 70	> 70	
Foliar Absorption	meq/L	< 2	2 - 10	> 10
Chloride (Cl)	mg/L	< 70	70 - 355	> 355
Root Absorption	meq/L	< 3	> 3	
Foliar Absorption	mg/L	< 100	> 100	
Boron	mg/L	< 1.0	1.0 - 2.0	> 2.0
pH			6.5 - 8.4	

- Modifying turf management practices
- Modifying the root zone mixture
- Blending irrigation waters
- Using amendments

A study by Virginia Polytechnic Institute and State University investigated nutrient management practices and application rates of nitrogen to turf and crops in Virginia (Hall et al., 2009). This study found that 50 percent of responding golf course superintendents were applying nitrogen to greens at rates in excess of turfgrass needs (> 5.1 lbs of water soluble nitrogen per 1,000 ft^2). With only 16 percent of respondents providing supplemental irrigation, no significant problems were detected, but the study did suggest education programs to reduce nitrogen application rates in several turf management areas to minimize potential for transport of nutrients off-site.

In addition to managing water quality, many facilities are required to implement special management practices where reuse is implemented to minimize the potential of cross-connection of water sources. For example, golf courses in San Antonio are required to include a double-check valve on the reclaimed water supply to the property to prevent backflow of reclaimed water into the SAWS potable water distribution system. Golf courses are also required to include a reduced pressure principal backflow preventer on the potable water supply to the property.

Irrigation of public parks and recreation centers, athletic fields, school yards and playing fields, and landscaped areas surrounding public buildings and facilities plays an important role in reuse. The considerations for irrigating these areas are much like those for golf courses. However, as discussed in Chapter 4, many states have regulations that specifically address urban use of reclaimed water.

3.2 Agricultural Reuse

Water availability is central to the success of agricultural enterprises domestically and globally and cuts across multiple disciplines related to human health, food safety, economics, sociology, behavioral studies, and environmental sciences (O'Neill and Dobrowolski, 2011). As such, almost 60 percent of all the world's freshwater withdrawals go towards irrigation uses. Farming could not provide food for the world's current populations without adequate irrigation (Kenny et al., 2009). By 2050, rising population and incomes are expected to demand 70 percent more production, compared to 2009 levels. Increased production is projected to come primarily from intensification on existing cultivated land, with irrigation playing an important role (FAO, 2011).

In the United States, agricultural irrigation totals about 128,000 mgd (5.6 M L/s) (Kenny et al., 2009), which represents approximately 37 percent of all freshwater withdrawals. Confounding the agricultural water supply issue are the recent increases in midwestern and southeastern inter-annual climate variability that has led to more severe droughts, making issues of agricultural water reliability a greater national challenge. In many regions of the United States, expanding urban populations and rising demands for water from municipal and industrial sectors now compete for water supplies traditionally reserved for irrigated agriculture. In other areas, irrigation water supplies are being depleted by agricultural use. These shifts in the availability and quality of traditional water resources could have dramatic impacts on the long-term supply of food and fiber in the United States (Dobrowolski et al., 2004, 2008).

Agricultural use of reclaimed water has a long history and currently represents a significant percentage of the reclaimed water used in the United States. Therefore, the U.S. Department of Agriculture/National Institute of Food and Agriculture (USDA/NIFA) has made funding for water reuse one of its key priorities; additional discussion of the USDA/NIFA research is provided in Appendix A. Reclaimed water from municipal and agricultural sources provides many advantages, including:

- The supply of reclaimed water is highly reliable and typically increases with population growth.
- The cost of treating wastewater to secondary (and sometimes even higher) standards is generally lower than the cost of potable water from unconventional water sources (e.g., desalination).
- The option of allocating reclaimed water to irrigation is often the preferred and least expensive management alternative for municipalities.

- Reclaimed water is an alternative to supplement and extend freshwater sources for irrigation.
- In many locales, reclaimed water might be the highest quality water available to farmers, and could represent an inexpensive source of fertilizer. However, this advantage is conditional on proper quantities and timing of water and nutrients. Depending on the stage of growth, excess nutrients can negatively affect yields (Dobrowolski et al., 2008).

Use of reclaimed water for agriculture has been widely supported by regulatory and institutional policies. In 2009, for example, California adopted both the *Recycled Water Policy* and "Water Recycling Criteria." Both policies promote the use of recycled water in agriculture (SWRCB, 2009 and CDPH, 2009). In response to an unprecedented water crisis brought about by the collapse of the Bay-Delta ecosystem, climate change, continuing population growth, and a severe drought on the Colorado River, the California State Water Resources Control Board (SWRCB) was prompted to "exercise the authority granted to them by the Legislature to the fullest extent possible to encourage the use of recycled water, consistent with state and federal water quality laws." As a result, future recycled water use in California is estimated to reach 2 million ac-ft/yr (2,500 MCM/yr) by 2020, and 3 million ac-ft/yr (3,700 MCM/yr) by 2030 (SWRCB, 2009). As a result, California presently recycles about 650,000 ac-ft/yr (800 MCM/yr), an amount that has doubled in the last 20 years (SWRCB, 2010) with agriculture as the top recycled water user. Other reclaimed water uses are shown in **Figure 3-2**.

In Florida, promotion of reclaimed water began in 1966; currently, 63 of 67 counties have utilities with reclaimed water systems. One of the largest and most visible reclaimed water projects is known as WATER CONSERV II in Orange County, Fla., where farmers have used reclaimed water for citrus irrigation since 1986. Another long-serving example of reclaimed water use in the United States is the city of Lubbock, Texas, where reclaimed water has been used to irrigate cotton, grain sorghum, and wheat since 1938. In addition, reclaimed water is a significant part of the agricultural water sustainability portfolio in Arizona, Colorado, and Nevada (**Table 3-3**).

Table 3-3. Nationwide reuse summaries of reclaimed water use in agricultural irrigation (adapted from Bryk et al., 2011)

	Annual Agricultural Reuse Volume	
State	**mgd**	**1000 ac-ft/yr**
Arizona	23	26
California	270	303
Colorado	2.97	3
Florida	256	287
Idaho	0.27	0.3
North Carolina	1.0	1
Nevada	13.4	15
Texas	19.4	22
Utah	0.81	1
Washington	0.02	0.03
Wyoming	0.89	1

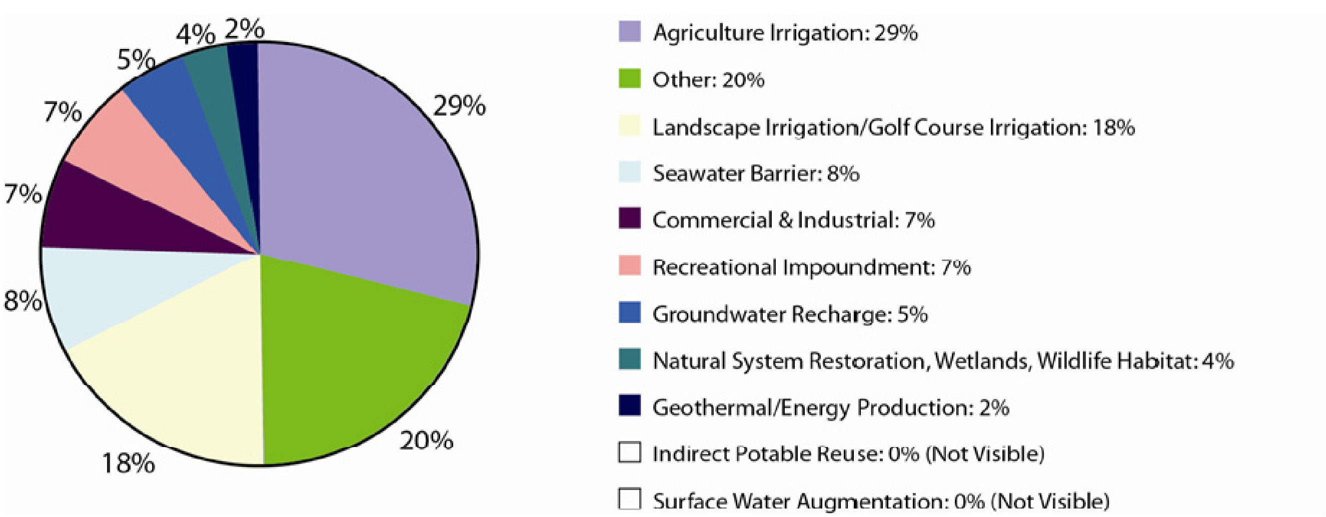

Figure 3-2
Nationwide reuse summaries of reclaimed water use in agricultural irrigation (adapted from Bryk, et al., 2011)

3.2.1 Agricultural Reuse Standards

Different regions and governmental agencies, both in the United States and globally, have adopted a variety of standards for use of reclaimed water for irrigation of crops. These rules and regulations have been developed primarily to protect public health and water resources; specific crop water quality requirements must be developed with the end users. The standards that have been adopted in the United States have proven protective of public health in spite of the vast differences in their stringency.

The WHO guidelines (WHO, 2006) for irrigation with reclaimed water, widely adopted in Europe and other regions, is a science-based standard that has been successfully applied to irrigation reuse applications throughout the world. And, the California Water Recycling Criteria (Title 22 of the state Code of Regulations) require the most stringent water quality standards with respect to microbial inactivation (total coliform < 2.2 cfu/100 mL). California Water Recycling Criteria requires a specific treatment process train for production of recycled water for unrestricted food crop irrigation that includes, at a minimum, filtration and disinfection that meets the state process requirements.

Irrigation of crops (both food and non-food) with untreated wastewater is widely practiced in many parts of the developing world with accompanying adverse public health outcomes. Nonetheless, this practice represents an economic necessity for many farming communities and for the rapidly expanding population at large, much of which is dependent on locally grown crops. Various international aid organizations have mobilized to improve upon these irrigation practices and provide barriers against transmission of disease-carrying agents (Scott et al., 2004). Regulated and well-managed irrigation under WHO guidelines (or similar standards) can be protective of public health and the health of farm workers. More restrictive regulations, such as those in California and Italy, while amply protective, are potentially prohibitively expensive in some economic contexts without necessarily improving the public health outcome. Additional discussion of the implications of stringent regulations in economically challenged contexts is provided in Chapter 9. The regulations, guidelines, and standards that are relevant to agricultural reuse applications in the United States, as well as a summary of standards by reuse type, are provided in Chapter 4.

3.2.2 Agricultural Reuse Water Quality

Because agricultural reuse is one of the most significant uses of reclaimed water globally, it is critical to understand the factors that determine success or failure of a farming operation dependent upon reclaimed water for irrigation. The same concerns for chemical constituents are applicable to all sources of irrigation water, and reclaimed water is no exception. Several factors, including soil-plant-water interactions (irrigation water quality, plant sensitivity and tolerance, soil characteristics, irrigation management practices, and drainage) are important in crop production. For example, under poor drainage conditions, even the most generally suitable water quality used for irrigation may lead to crop failure. On the other hand, well-drained soils, combined with a proper leaching fraction in the irrigation regime, can tolerate relatively high salinity in the irrigation water, whether it is reclaimed water or brackish groundwater.

Thus, when considering the use of reclaimed water in agriculture, it is important to identify the key constituents of concern for agricultural irrigation. Plant sensitivity is generally a function of a plant's tolerance to constituents encountered in the root zone or deposited on the foliage, and reclaimed water tends to have higher concentrations of some of these constituents than the groundwater or surface water sources from which the water supply is drawn. The types and concentrations of constituents in reclaimed water depend on the municipal water supply, the influent waste streams (i.e., domestic and industrial contributions), the amount and composition of infiltration in the wastewater collection system, the treatment processes, and the type of storage facilities. Determining the suitability of a given reclaimed water supply for use as a supply of agricultural irrigation is, in part, site-specific, and agronomic investigations are recommended before implementing an agricultural reuse program.

To assess quality of reclaimed water with respect to salinity, the Food and Agriculture Organization (FAO) (1985) has published recommendations for agricultural irrigation with degraded water; this information provides a guide to making an initial assessment for application of reclaimed water in an agricultural setting. A summary of these recommendations is provided in **Table 3-4**. There are a number of assumptions in these guidelines, which are intended to cover the wide range of conditions that may be encountered in irrigated agriculture practices; where sufficient experience, field trials, research, or observations are available, the guidelines may be modified to address local conditions more closely.

- **Yield Potential**: Full production capability of all crops, without the use of special practices, is assumed when the guidelines indicate no restrictions on use. A "restriction on use" indicates that choice of crop may be limited or that special management may be needed to maintain full production capability; it does not indicate that the water is unsuitable for use.

- **Site Conditions**: Soil texture ranges from sandy-loam to clay-loam with good internal drainage; the climate is semi-arid to arid, and rainfall is low. Rainfall does not play a significant role in meeting crop water demand or leaching requirement. Drainage is assumed to be good, with no uncontrolled shallow water table present within 6 ft (2 m) of the surface.

- **Method of Irrigation:** Normal surface or sprinkler irrigation methods are used; water is applied infrequently, as needed; and the crop utilizes a considerable portion of the available stored soil-water (50 percent or more) before the next irrigation. At least 15 percent of the applied water percolates below the root zone. The guidelines are too restrictive for specialized irrigation methods, such as localized drip irrigation, which results in near daily or frequent irrigations, but are applicable for subsurface irrigation if surface-applied leaching satisfies the leaching requirements.

Table 3-4 Guidelines for interpretation of water quality for irrigation[1]

Potential Irrigation Problem		Units	Degree of Restriction on Irrigation		
			None	Slight to Moderate	Severe
Salinity *(affects crop water availability)*[2]					
	EC_w	dS/m	< 0.7	0.7 – 3.0	> 3.0
	TDS	mg/L	< 450	450 – 2000	> 2000
Infiltration *(affects infiltration rate of water into the soil; evaluate using EC_w and SAR together)*[3]					
SAR	0 – 3	**and EC_w =**	> 0.7	0.7 – 0.2	< 0.2
	3 – 6		> 1.2	1.2 – 0.3	< 0.3
	6 – 12		> 1.9	1.9 – 0.5	< 0.5
	12 – 20		> 2.9	2.9 – 1.3	< 1.3
	20 – 40		> 5.0	5.0 – 2.9	< 2.9
Specific Ion Toxicity *(affects sensitive crops)*					
	Sodium (Na)[4]				
	surface irrigation	SAR	< 3	3 – 9	> 9
	sprinkler irrigation	meq/l	< 3	> 3	
	Chloride (Cl)[4]				
	surface irrigation	meq/l	< 4	4 – 10	> 10
	sprinkler irrigation	meq/l	< 3	> 3	
	Boron (B)	mg/L	< 0.7	0.7 – 3.0	> 3.0
Miscellaneous Effects *(affects susceptible crops)*					
	Nitrate (NO_3-N)	mg/L	< 5	5 – 30	> 30
	Bicarbonate (HCO_3)	meq/L	< 1.5	1.5 – 8.5	> 8.5
	pH		**Normal Range 6.5 – 8.4**		

[1] Adapted from FAO (1985)
[2] EC_w means electrical conductivity, a measure of the water salinity, reported in deciSiemens per meter at 25°C (dS/m) or in millimhos per centimeter (mmho/cm); both are equivalent.
[3] SAR is the sodium adsorption ratio; at a given SAR, infiltration rate increases as water salinity increases.
[4] For surface irrigation, most tree crops and woody plants are sensitive to sodium and chloride; most annual crops are not sensitive. With overhead sprinkler irrigation and low humidity (< 30 percent), sodium and chloride may be absorbed through the leaves of sensitive crops.

- **Restriction on Use:** The "Restriction on Use" shown in **Table 3-4** is divided into three degrees of severity: none, slight to moderate, and severe. The divisions are somewhat arbitrary because changes occur gradually, and there is no clear-cut breaking point. A change of 10 to 20 percent above or below a guideline value has little significance if considered in proper perspective with other factors affecting yield. Field studies, research trials, and observations have led to these divisions, but management skill of the water user can alter the way in which the divisions are interpreted for a particular application. Values shown are applicable under normal field conditions prevailing in most irrigated areas in the arid and semi-arid regions of the world.

3.2.2.1 Salinity and Chlorine Residual

As noted in **Table 3-4**, salinity is a key parameter in determining the suitability of the water to be used for irrigation, and the wide variability of salinity tolerance in plants can confound the issue of establishing salinity criteria. All waters used for irrigation contain salt to some degree; therefore, salts (both cations and anions) will build up without proper drainage. *Agricultural Salinity Assessment and Management*, which is the second edition of ASCE MOP 71 (American Society of Civil Engineers [ASCE], 2012) provides additional information on worldwide salinity and trace element management in irrigated agriculture and water supplies. This updated edition provides a reference to help sustain irrigated agriculture and integrates contemporary concepts and management practices. It covers technical and scientific aspects of agricultural salinity management as well as environmental, economic, and legal concerns. However, because salinity management is such an important consideration in agricultural reuse, a brief discussion of the topic is provided here.

Salinity is determined by measuring the electrical conductivity (EC) and/or the TDS in the water; however, for most agricultural measurements, TDS is reported as EC. The use of high TDS water for irrigation will tend to increase the salinity of the groundwater if not properly managed. The extent of salt accumulation in the soil depends on the concentration of salts in the irrigation water and the rate at which salts are removed by leaching. Using TDS as a measure of salinity, no detrimental effects are usually noticed below 500 mg/L. Between 500 and 1,000 mg/L, TDS in irrigation water can affect sensitive plants; at concentrations above 1,000 to 2,000 mg/L, TDS levels can affect many crops, so careful management practices should be followed. Several case study examples demonstrate the importance and implementation of TDS management for use of reclaimed water for irrigation [US-TX-Landscape Study; US-CO-Denver Soil; US-CA-Monterey; and Israel/Jordan-AWT Crop Irrigation]. At TDS concentrations greater than 2,000 mg/L, water can be used regularly only for salt-tolerant plants on highly permeable soils. A study was conducted in Israel to address the impact of reclaimed water containing high levels of salts, including ions specifically toxic to plants, such as sodium (Na) and boron (B); results are provided in a case study summary from Israel and Jordan [Israel and Jordan - Brackish Irrigation].

With respect to chlorine residuals, which may be present as a disinfection residual, free chlorine at concentrations less than 1 mg/L usually poses no problem to plants; chlorine at concentrations greater than 5 mg/L can cause severe damage to most plants. However, some sensitive crops may be damaged at levels as low as 0.05 mg/L. For example, some woody crops may accumulate chlorine in the tissue up to toxic levels; further, excessive chlorine residuals can have a similar leaf-burning effect that is caused by sodium and chloride when reclaimed water is sprayed directly onto foliage. Low-angle spray heads or surface irrigation options can reduce the leaf-burning impact.

3.2.2.2 Trace Elements and Nutrients

Thirteen mineral nutrients are required for plant growth, and fertilizers are added to soils with inadequate concentrations of these nutrients. Mineral nutrients are divided into two groups: macronutrients (primary and secondary) and micronutrients. Primary macronutrients, which include nitrogen, phosphorus, and potassium, are often lacking from the soil because plants use large amounts for growth and survival. The secondary macronutrients include calcium, magnesium, and sulfur. Micronutrients—boron, copper, iron, chloride, manganese, molybdenum, and zinc—are elements essential for plant growth in small quantities and are often referred to as trace elements. While these trace elements are necessary for plant growth, excessive concentrations can be toxic.

The recommended maximum concentrations of constituents in reclaimed water for "long-term continuous use on all soils" are set conservatively based on application to sandy soils that have adsorption capacity. These values have been established below the concentrations that produce toxicity when the most sensitive plants are grown in nutrient solutions or sand cultures to which the constituent has been added. Thus, if the suggested limit is exceeded, phytotoxicity will not necessarily occur; however, most of the elements are readily fixed or tied up in soil and accumulate with time such that repeated application in excess of suggested levels is likely to induce phytotoxicity. The trace element and nutrients criteria recommended for fine-textured neutral and alkaline soils with high capacities to remove the different pollutant elements are provided in **Table 3-5.** These criteria, were previously presented in 2004, however, based on maintaining sustainable application of reclaimed water for irrigation, recommendations have included removal of increased concentrations for short-term use, which is also consistent with recommendations of the FAO in *Water Quality for Agriculture* (FAO, 1985). There are also related effects of pH on plant growth, which are primarily related to its influence on metal toxicity, as shown in **Table 3-5**; as a result, a pH range of 6-8 is recommended for reclaimed water used for irrigation.

Of the macronutrients, nitrogen is the most widely applied as a fertilizer. Nitrogen is important in helping plants with rapid growth, increasing seed and fruit production, and improving the quality of leaf and forage crops. Like nitrogen, phosphorus effects rapid

Table 3-5 Recommended water quality criteria for irrigation

Constituent	Maximum Concentrations for Irrigation (mg/L)	Remarks
Aluminum	5.0	Can cause nonproductiveness in acid soils, but soils at pH 5.5 to 8.0 will precipitate the ion and eliminate toxicity
Arsenic	0.10	Toxicity to plants varies widely, ranging from 12 mg/L for Sudan grass to less than 0.05 mg/L for rice
Beryllium	0.10	Toxicity to plants varies widely, ranging from 5 mg/L for kale to 0.5 mg/L for bush beans
Boron	0.75	Essential to plant growth; sufficient quantities in reclaimed water to correct soil deficiencies. Optimum yields obtained at few-tenths mg/L; toxic to sensitive plants (e.g., citrus) at 1 mg/L. Most grasses are tolerant at 2.0 - 10 mg/L
Cadmium	0.01	Toxic to beans, beets, and turnips at concentrations as low as 0.1 mg/L; conservative limits are recommended
Chromium	0.1	Not generally recognized as an essential element; due to lack of toxicity data, conservative limits are recommended
Cobalt	0.05	Toxic to tomatoes at 0.1 mg/L; tends to be inactivated by neutral and alkaline soils
Copper	0.2	Toxic to a number of plants at 0.1 to 1.0 mg/L
Fluoride	1.0	Inactivated by neutral and alkaline soils
Iron	5.0	Not toxic in aerated soils, but can contribute to soil acidification and loss of phosphorus and molybdenum
Lead	5.0	Can inhibit plant cell growth at very high concentrations
Lithium	2.5	Tolerated by most crops up to 5 mg/L; mobile in soil. Toxic to citrus at low doses—recommended limit is 0.075 mg/L
Manganese	0.2	Toxic to a number of crops at few-tenths to few mg/L in acidic soils
Molybdenum	0.01	Nontoxic to plants; can be toxic to livestock if forage is grown in soils with high molybdenum
Nickel	0.2	Toxic to a number of plants at 0.5 to 1.0 mg/L; reduced toxicity at neutral or alkaline pH
Selenium	0.02	Toxic to plants at low concentrations and to livestock if forage is grown in soils with low levels of selenium
Tin, Tungsten, and Titanium	-	Excluded by plants; specific tolerance levels unknown
Vanadium	0.1	Toxic to many plants at relatively low concentrations
Zinc	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at increased pH (6 or above) and in fine-textured or organic soils

growth of plants and is important for blooming and root growth. Potassium is absorbed by plants in larger amounts than any other mineral element except nitrogen and, in some cases, calcium; the role of this nutrient is key in fruit quality and reduction of diseases. All of these nutrients can be obtained from application of reclaimed water, so there is added value in using reclaimed water. However, in light of ever-increasing regulatory requirements for nutrient removal to address loads to receiving streams, nitrogen and/or phosphorus are often removed in municipal WWTPs.

As a result of nutrient removal, even if reclaimed water is applied in adequate quantities to provide trace nutrients, fertilizer application may still be required. Where appropriate for crop use, increased supply of reclaimed water for irrigation could provide needed nutrients for crops while concurrently reducing nutrient load to the receiving stream.

Nutrients, such as nitrogen and phosphorus, may contain beneficial qualities for irrigation. In a Canadian case study, the authors provided insight into cost-effective advantages of diverting these nutrients from Lake Simcoe [Canada-Nutrient Transfer].

3.2.2.3 Operational Considerations for Agricultural Reuse

A municipal wastewater treatment facility and an agricultural operation have little in common, except that one entity supplies the water and the other uses it. Understanding how these two enterprises function is critical to developing a successful agricultural reuse system. First, operators of the municipal facility must understand that the demand for irrigation water will vary throughout the year as a function of rainfall and normal seasonal agricultural operations. Experience has shown that attempts to deliver a fixed volume of water for agricultural applications, independent of the actual need for irrigation water, rarely survive the first rainy season. Experience also suggests that asking the municipal or agricultural entity to take on the duties of the other party can cause problems. For example, farmers are typically not well suited to navigate the regulatory requirements to obtain a permit for use of reclaimed water. Likewise, a municipality is not set up to respond to changes in the agricultural market.

There are many differences between municipal and agricultural operations that may not be apparent until the water reclamation system goes into operation. Consideration of these differences is needed at the preliminary design stage of a project to ensure the proposed water reclamation system is feasible. A recommended list of considerations for agricultural reuse projects is provided below:

- Compatibility of agricultural operations with reclaimed water may warrant site-specific investigations to reveal compatibility issues that may arise when switching from traditional water supplies to reclaimed water. For example, reclaimed water treated to secondary standards may not be suitable for use in drip irrigation systems as the suspended solids in the reclaimed water can increase clogging.
- There are differences in agricultural and municipal system reliability requirements. For example, distribution pipe pressure ratings for agriculture are close to that of the expected working pressure. Additionally, pump capacity redundancy in municipal systems is installed in the event of a failure; however, this is not common practice in agricultural operations.
- Because reclaimed water quality is directly linked to crops that may be produced with that water, there may be additional regulatory controls that dictate when irrigation is applied and who is allowed on the property being irrigated. Examples of regulatory controls include modifications to irrigation systems to prevent contact with edible crops as required in Florida, Texas, and other states.
- It also may be undesirable to use secondary quality reclaimed water where irrigation equipment results in aerosols, particularly where the area under irrigation is adjacent to the property boundary.
- Regular communication between the end user and reclaimed water supplier is critical to a successful program, as it allows issues to be addressed as they arise.

3.2.3 Irrigation of Food Crops

Irrigation of food crops with reclaimed water is common both in the United States and globally. However, there are “resource constrained” regions where untreated wastewater and inadequately-treated reclaimed water, sometimes mixed with river water, is used for irrigation of food crops—with devastating gastrointestinal disease consequences for consumers of the crops. As a result, the WHO guidelines provide specific procedures for minimizing these risks in most regions of the world (WHO, 2006). These regulations for food crop irrigation with reclaimed water are intended to minimize risks of microbial contamination of the crops, especially those grown for raw consumption, such as lettuce, cucumbers, and various fruits. The regulations specify treatment processes, water quality standards, and monitoring regimes that minimize risks for use of reclaimed water for irrigation of crops that are ingested by humans. Further discussion on global water reuse is provided in Chapter 9. Additional discussion of state regulatory guidelines and requirements for irrigation of food crops with reclaimed water is also provided in Section 4.5.2.3.

An example of large-scale recycled water irrigation for raw-eaten food crops is in Monterey County, Calif. [US-CA-Monterey]. More than 5,000 ha of lettuce, broccoli, cauliflower, fennel, celery, strawberries, and artichokes have been irrigated with recycled water for more than a decade (**Figure 3-3**). This large-scale use of recycled water was preceded by an intensive, 11-year pilot study to determine whether or not the use of disinfected filtered recycled water for irrigation of raw-eaten food crops would be safe for the consumer, the farmer, and the environment (Sheikh et al., 1990). Results of this project have shown that food crops are protected against pathogenic organisms, such as *Giardia* and *Cryptosporidium* (Sheikh et al., 1999).

Marketing of produce from farms in northern Monterey County has been successful and profitable, although the local farmers initially feared customer backlash and rejection of produce irrigated with "sewer water." As a result, farmers insisted that the produce not be labeled as having been irrigated with recycled water. The Monterey Regional Water Pollution Control Agency—producer/supplier of the recycled water—works closely with the farming community and has a contingency plan in place to address claims arising from an epidemic that might be traced to or associated with the fields using recycled water. Over the 13 years of irrigation (as of December 2011), there have been no such associations.

The success of this exemplary and pioneering project in Monterey County—from both technical and public acceptance points of view—has encouraged similar projects in other parts of the United States. and throughout the world [US-CA-Temecula, US-WA-King County, Argentina-Mendoza, Israel/Palestinian Territories/Jordan-Olive Irrigation, Senegal-Dakar, Vietnam-Hanoi]. In eastern Sicily (Italy), Cirelli et al. (2012) showed that reclaimed water treated at constructed wetlands could be used for edible food crops in Mediterranean countries and other arid and semi-arid regions that are confronting increasing water shortages. In addition to demonstrating that food crops were safe for human consumption, some crops showed higher yields (by approximately 20 percent) using reclaimed water when compared with controls supplied with freshwater.

3.2.4 Irrigation of Processed Food Crops and Non-Food Crops

Irrigation of non-food crops (seed crops, industrial crops, processed food crops, fodder crops, orchard crops, etc.) with reclaimed water is far less complicated and more readily accepted by the agricultural community. Many countries use the WHO guidelines, which are risk-based and designed to provide a reasonable level of safety, assuming conservative levels of exposure by the public, the consumer, and farm workers. An example of reclaimed water use for non-food production is in Jordan, where reclaimed water is used on alfalfa plants, as shown in **Figure 3-4** [Jordan-Irrigation].

In the United States, various states have adopted regulations for use of reclaimed water for non-food crop irrigation that are generally more relaxed than for food crops, allowing disinfected secondary effluent to be used in many cases. In any case, these are generally far more restrictive than the WHO guidelines. For example, California Water Recycling Criteria (Title 22) requires total coliform bacteria to be less than 23 MPN/100 mL for irrigation of non-food crops. This standard can be related to the concern for exposure of farm workers to the recycled water, although this level of water quality can be reliably achieved with well-operated secondary treatment processes with disinfection.

Figure 3-3
Monterey County vegetable fields irrigated with disinfected tertiary recycled water

Figure 3-4
Alfalfa irrigated with secondary effluent, Wadi Mousa (near Petra), Jordan

Between the standards of California and WHO, there is a wide range of treatment standards throughout the world, as shown in **Table 3-6**. Additional discussion of state regulatory guidelines and requirements for irrigation of food crops with reclaimed water in the United States is also provided in Section 4.5.2.3.

Table 3-6 Examples of global water quality standards for non-food crop irrigation

Microbial Standards or Guidelines by State, Country, Region	Total Coliform per 100 mL	Fecal Coliform or *E. coli* per 100 mL
Puglia (S. Italia)	≤ 10	
California, Italy	≤ 23	
Australia		≤ 10
Germany	≤ 100	≤ 10
Washington State	≤ 240	
Florida, Utah, Texas, EPA (Guidelines)		≤ 200
Arizona, New Mexico, Australia, Victoria, Mexico		≤ 1,000
Austria		≤ 2,000
Sicily	≤ 3,000	≤ 1,000
Cyprus		≤ 3,000
WHO, Greece, Spain		≤ 10,000

3.2.5 Reclaimed Water for Livestock Watering

Generally in the United States, reclaimed water is not utilized for direct consumption by livestock; however, *de facto* reuse often occurs. In this case, **Table 3-7** is provided as a guide to acceptable water quality for livestock consumption. It should be noted that the information in **Table 3-7** was developed from FAO 29 Water Quality in Agriculture, with more recent updates from Raisbeck et al. (2011) for molybdenum, sodium, and sulfate (FAO, 1985). These values are based on amounts of constituents normally found in surface and groundwater and are not necessarily the limits of animal tolerance. Additional sources of these substances may need to be considered along with drinking water, such as additional animal intake of these substances through feedstuffs. If concerns persist about safety for livestock, the local land-grant university should be consulted for additional information.

3.3 Impoundments

Uses of reclaimed water for maintenance of impoundments range from water hazards on golf courses to full-scale development of water-based recreational impoundments involving incidental contact (fishing and boating) and full body contact (swimming and wading). With respect to water quality for recreational reuse that involves body contact, EPA has had recreational water quality criteria since 1986 for surface water that receives treated effluent regulated through the NPDES program. The criteria were developed to protect swimmers from illnesses from exposure to pathogens in recreational waters, as described in Section 6.3.1. EPA has also recently proposed new draft recreational water quality criteria in response to research findings in the fields of molecular biology, virology, and analytical chemistry (EPA, 2011).

Table 3-7 Guidelines for concentrations of substances in livestock drinking water[1]

Constituent (Symbol)	Concentration (mg/L)
Aluminium (Al)	5.0
Arsenic (As)	0.2
Beryllium (Be)[2]	0.1
Boron (B)	5.0
Cadmium (Cd)	0.05
Chromium (Cr)	1.0
Cobalt (Co)	1.0
Copper (Cu)	0.5
Fluoride (F)	2.0
Iron (Fe)	not needed
Lead (Pb)[3]	0.1
Manganese (Mn)[4]	0.05
Mercury (Hg)	0.01
Molybdenum (Mo)	0.3
Nitrate + Nitrite (NO_3-N + NO_2-N)	100
Nitrite (NO_2-N)	10.0
Selenium (Se)	0.05
Sodium (Na)	1000[5]
Sulfate (as SO_4)	1000[6]
Vanadium (V)	0.10
Zinc (Zn)	24.0

1 Adapted from FAO (1985) with updates for Mo, Na, and SO4 from Raisbeck et al. (2011).
2 Insufficient data for livestock; value for marine aquatic life is used.
3 Lead is accumulative, and problems may begin at a threshold value of 0.05 mg/L.
4 Insufficient data for livestock; value for human drinking water used.
5 Short-term exposure (days/weeks) can be up to 4000 mg/L, assuming normal feedstuff Na concentrations.
6 Short-term exposure (days/weeks) can be up to 1.8 mg/L, assuming normal feedstuff SO4 concentrations.

3.3.1 Recreational and Landscape Impoundments

One example of reclaimed water use for recreational impoundments is the Santee Lakes Recreation Preserve (Park), which is a recreational facility owned and operated by Padre Dam Municipal Water District. It is located strategically within San Diego County, Calif. Its seven lakes, which contain approximately 82 ac (33 ha) of water, were formed by sand and gravel mining in the dry stream bed of Sycamore Canyon as part of the district's original water reclamation program. In the early 1960s, the district converted the lakes to recreational use to demonstrate the concept of water reuse. Its purpose was also to gain public acceptance of reclaimed water for recreational, agricultural, irrigation, and industrial applications.

As with any form of reuse, the development of water reuse projects that include impoundments will be a function of water demand coupled with a cost-effective source of suitable quality reclaimed water. Regulation of impoundments that are maintained using reclaimed water typically is according to the potential for contact for that use. For example, in Arizona, reclaimed water that is used for recreational impoundments where boating or fishing is an intended use of the impoundment must meet Class A requirements, which includes secondary treatment, filtration, and disinfection so that no detectable fecal coliform organisms are present in four of the last seven daily reclaimed water samples taken, and no single sample maximum concentration of fecal coliform organisms exceeds 23/100 mL. Even though NPDES permits may allow discharge of treated effluent into a water body with higher bacterial concentrations, swimming and other full-body recreation activities are prohibited where reclaimed water is used to maintain the "recreational" impoundment. This is consistent with goals to protect public health, particularly in light of evidence provided by Wade et al. (2010) who have shown a relationship between gastrointestinal illness and estimates of fecal indicator organisms and that children less than 11 years old are at greater risk from exposure (Wade et al., 2008).

In impoundments where body contact is prohibited, such as a manmade facility that is created for storage, landscaping, or for aesthetic purposes only, less stringent requirements may apply.

3.3.2 Snowmaking

The benefits of installing a reclaimed water distribution system to help meet peak irrigation demands during growing season has to be weighed carefully with the costs associated with managing the reclaimed water in the winter months when temperature and climate conditions render the system useless for irrigation. When water demands from customers that require consistent flow (such as industrial or cooling system customers) cannot be secured as part of a reclaimed water customer base in winter months, one option to manage reclaimed water in the winter months may be to make snow. While snowmaking is sometimes regulated as an urban reuse, some states consider snowmaking for recreational purposes to have body contact that requires water quality similar to that used in recreational impoundments, which is why this reuse application is discussed in this section.

Making snow from reclaimed water for the purpose of prolonging and avoiding interruption of the recreation season of sledding and skiing areas is becoming more popular, particularly in water-scarce areas. However, given the difficulty of otherwise making use of reclaimed water during the winter months, it is hard to ignore the resource as a water supply for snowmaking. This is particularly the case in areas where the temperatures are low enough to maintain water in the form of snow but natural precipitation will not otherwise support a longer recreation season. In most states, use of reclaimed water for snowmaking is either regulated or managed as a winter-time disposal option or as a reuse option, but seldom both.

Snowmaking with reclaimed water is being done in the United States, Canada, and Australia (e.g., Victoria's Mount Buller Alpine Resort installed in 2008 and Mount Hotham Resort installed in 2009). Snowmaking using reclaimed water in the United States is occurring in Maine, Pennsylvania, and California. The details of these facilities are shown in a case study [US-ME-Snow]. Some states have rules or regulations pertaining to snowmaking with reclaimed water. There do not appear to be any human health effects studies associated with exposure to snow made with reclaimed water. The highlights of the regulations from a few select states are provided to exemplify how different states implement snowmaking with reclaimed water.

Storing or stockpiling reclaimed water in the form of snow avoids the cost of building large surface water reservoirs or additional lagoon treatment modules. Depending on the quality of the originating reclaimed water, precautions may need to be taken regarding the fate of snowmelt. It may be necessary to prevent snowmelt from frozen reclaimed water with a relatively high content of phosphorus from entering a sensitive water body. Conversely, if reclaimed water can be sprayed onto a seasonally dormant agricultural field, the phosphorus may be a benefit to the farmer who will plant the field in the spring.

Care must also be taken to quantify the volume of snowmelt runoff that will occur according to a range of spring thaw scenarios to manage the runoff. Planners should consider downstream and groundwater rights to the water diverted for snowmaking and to the snowmelt. An ac-ft (1,200 m^3) of medium-density snow (1 ac with 1 ft of snow on it) has an equivalent water volume of approximately 146,000 gallons (550 m^3). It is necessary to consider the density of the accumulated snow and its depth to avoid overfilling the reservoir with snowmelt. Note also that snow will sublimate (convert from the solid phase of water to the gaseous phase without going through the liquid phase) during storage.

Captured snowmelt from snow made from reclaimed water of a particular quality may not reflect the original water quality. Snowmelt may pick up contaminants from the soil, including microbiological and chemical constituents; further, sublimation has the effect of concentrating whatever constituents are present into higher concentrations. In addition, some constituents that were present in the original reclaimed water may degrade over time, or be "lost" (as in the case of nutrients) to the soil when the snow melts. Therefore, if snowmelt is to be introduced into the reclaimed water distribution system, it may be necessary to treat it to achieve the same level of quality as the reclaimed water produced by the reclamation facility.

Arizona

The Arizona Department of Environmental Quality (ADEQ) regulates reclaimed water quality for prescribed uses allowing for snowmaking with Class A reclaimed water, which is wastewater that has undergone secondary treatment, filtration, and disinfection to achieve a 24-hour average turbidity of 2 NTU or less (instantaneous turbidity of 5 NTU or less) and no detectable fecal coliform organism in four of the last seven daily reclaimed water samples (single sample maximum of 23 fecal coliform organism per 100 mL). As of 2012, there were no ADEQ-permitted uses of reclaimed water for snowmaking in Arizona. However, the Sunrise Park Resort, owned and operated by the White Mountain Apache Tribe (WMAT), makes use of WWTP effluent blended with another source of water for snowmaking. ADEQ does not regulate the WMAT, as they are a sovereign nation; thus, it is not known what water quality is used, to what extent, or with what frequency.

A service agreement between the city of Flagstaff and owners of the Snowbowl Ski Resort allowed Flagstaff to sell reclaimed water for snowmaking. Planning started in 2000, and approval from the U.S. Forest Service was granted in 2004 (Snowbowl operates on federal land). In 2004, opponents to snowmaking with reclaimed water, led by the Navajo Nation, filed suit against Snowbowl and the city of Flagstaff. Following several court cases, in 2009 the full U.S. 9th Circuit Court refused to reject lower court decisions supporting the Snowbowl/Flagstaff agreement, and the U.S. Supreme Court refused to hear the case. In September 2009 a new suit was filed by Save the Peaks Coalition, and on February 9, 2012, a three-judge panel of the 9th U.S. Circuit Court of Appeals rejected the current suit as it was "virtually identical" to the previous suit (Associated Press, 2012).

California

CDPH regulates recycled water use and allows for snowmaking with disinfected filtered reclaimed water meeting specific turbidity criteria. However, it is noted that in some cases (such as for the Donner Summit Public Utilities District), snowmaking may also be permitted under an NPDES permit.

Colorado

The Colorado Department of Public Health and Environment's Regulation No. 84—Reclaimed Water Control Regulation does not mention snowmaking. Regulators in Colorado view snowmaking with reclaimed water as inevitable discharge to surface waters during snowmelt and runoff. Therefore, use of reclaimed water to make snow would be permitted under the NPDES discharge framework rather than under Regulation No. 84. Further, because water rights regulations in Colorado limit the amount of water that can be reused to the volume imported from west of the Continental Divide, reclaimed water is first applied to highest use at lowest cost.

Maine

The Maine Department of Environmental Protection (MDEP) does not have reclaimed water quality or water reuse rules, let alone regulations for snowmaking. However, the MDEP issues wastewater discharge permits for making snow with reclaimed water under the Maine Pollution Discharge Elimination System program. Snowmaking is used to reduce the volume of water in lagoons or to otherwise manage treatment plant effluent. There are currently systems in operation in three Maine communities (town of Rangeley; Carrabassett Valley Sanitary District, which serves Sugarloaf Mountain Ski Resort; and Mapleton Sewer District).

New Hampshire

New Hampshire's rules regarding snowmaking provide more discussion about snowmaking than any other state. Snow can be made using disinfected, filtered secondary effluent, depending on the end use of the manufactured snow. It can be used to recharge aquifers or for recreation purposes, such as skiing. Snow made from reclaimed water is referenced as "E-Snow" (for Effluent Snow) in New Hampshire's *Land Treatment and Disposal of Reclaimed Wastewater: Guidance for Groundwater Discharge Permitting* revised July 30, 2010.

Before reclaimed water is considered for recreational snowmaking, it must first be filtered with site-specific nutrient removal depending on snowmelt and runoff to surface streams. Treatment beyond secondary quality is commonly achieved using a variety of biological nutrient removal technologies, and the processed wastewater is filtered using advanced (ultra) filtration to achieve 4-log reduction of viral pathogens; disinfection is also included as the final treatment process. It is noteworthy that higher quality reclaimed water is required for golf course irrigation than for snowmaking.

Pennsylvania

Although the Pennsylvania Department of Environmental Protection does not have water reuse regulations, it does have guidelines that allow water reuse through the issuance of a Water Quality Management permit from the agency. The guidelines, titled *Reuse of Treated Wastewater Guidance Manual 362-0300-009* sets forth minimum treatment goals for snowmaking. Snowmaking is allowed with Class B water, which is water that has undergone secondary treatment, filtration, and disinfection. Where chlorine is utilized for disinfection, a total chlorine residual of at least 1.0 mg/L should be maintained for a minimum contact time of 30 minutes at design average flow, and there should be a detectable chlorine residual (>0.02 mg/L) at the point of reuse application.

Where UV light is used for disinfection, a design dose of 100 mJ/cm^2 under maximum daily flow should be used. The design dose may be reduced to 80 mJ/cm^2 for porous membrane filtration and 50 mJ/cm^2 for semi-permeable membrane filtration. This dose should also be based on continuous monitoring of lamp intensity, UV transmittance, and flow rate. Reclaimed water is being used for snowmaking at Seven Springs Mountain Resort, and planning for use at Bear Creek Mountain Resort is underway.

3.4 Environmental Reuse

Environmental reuse primarily includes the use of reclaimed water to support wetlands and to supplemental stream and river flows. Aquifer recharge also may be considered environmental reuse, but because this practice is integral to management of many reuse systems, an expanded discussion of this topic is provided in Section 2.3. A more detailed discussion of using wetlands and other natural systems for treatment to enhance water quality is provided in Chapter 6 with regulatory requirements for this reuse type described in Section 4.5.2.7.

3.4.1 Wetlands

Over the past 200 years, substantial acreage of wetlands in the continental United States have been destroyed for such diverse uses as agriculture, mining, forestry, and urbanization. Wetlands provide many important functions, including flood attenuation, wildlife and waterfowl habitat, food chain support, aquifer recharge, and water quality enhancement. In addition, maintenance of wetlands in the landscape mosaic is important for regional hydrologic balance. Wetlands naturally provide water conservation by regulating the rate of evapotranspiration and, in some cases, by providing aquifer recharge. Wetlands are also natural systems that can be used to treat a wide range of pollution sources, and they are particularly attractive for rural areas in developed countries and for general use in developing countries.

Development has altered the landscape, including changing the timing and quantities of stormwater and surface water flows and lowering of the groundwater tables, which affect environmental systems that have adapted and depend on these for their existence. Reclaimed water could be used to mitigate some of these impacts. Application of reclaimed water serves to restore and enhance wetlands that have been hydrologically altered. New wetlands can be created through application of reclaimed water, resulting in a net gain in wetland acreage and function. In addition, constructed and restored wetlands can be designed and managed to maximize habitat diversity within the landscape.

While the focus of this section is to highlight applications of wetlands, it is worth noting that some states, including Florida, South Dakota, and Washington, do provide regulations to specifically address use of reclaimed water in wetlands systems. In addition to state requirements, natural wetlands, which are considered waters of the United States, are protected under EPA's NPDES Permit and Water Quality Standards programs. The quality of reclaimed water entering natural wetlands is regulated by federal, state, and local agencies and must be treated to secondary treatment levels or greater. On the other hand, constructed wetlands, which are built and operated for the purpose of treatment, are not considered waters of the United States. Several case studies focused on wetlands are highlighted in this document and briefly summarized below:

- **US-AZ-Phoenix:** The 91st Avenue WWTP reuses approximately 60 percent of the current plant production (by a nuclear generating station for cooling tower makeup water, new constructed wetlands, and an irrigation company for agricultural reuse), with the remaining effluent discharged to the dry Salt River riverbed that bisects the nearby communities.

- **US-GA-Clayton County:** The Clayton County Water Authority (CCWA) began water reuse in the 1970s when a land application system (LAS) was selected as a way to increase water supplies for its growing population while minimizing the stream impact of wastewater discharges. Over the past decade, the LAS was converted into a series of treatment wetlands, and the existing treatment plant was upgraded to an advanced biological treatment plant. This system, along with additional constructed wetlands, provides some aquifer infiltration, but the vast majority flows into two of CCWA's water supply reservoirs—Shoal Creek and Blalock reservoirs. Water typically takes 2 years under normal conditions to filter through wetlands and reservoirs before being reused and takes less than a year under drought conditions. The Panhandle Road Constructed Wetlands and the E.L. Huie Constructed Wetlands have treatment capacities of 4.4 mgd (193 L/s) and 17.4 mgd (762 L/s), respectively. The transition from LAS to wetlands has saved energy costs through reduced pumping. The wetlands system is less expensive to maintain and operate and has allowed CCWA to reduce maintenance staff, equipment, and materials. The wetlands treatment system and indirect reuse program have lowered CCWA's need for additional reservoir storage and water withdrawals.

- **US-FL-Orlando Wetlands:** The Orlando Easterly Wetlands enhances the environment with highly-treated reclaimed water. The project began in the mid-1980s when the city, faced with the need to expand its permitted treatment capacity, was unable to increase the amount of nutrients being discharged into sensitive area waterways. The constituents of concern in the effluent consist primarily of nitrogen and phosphorus, which can promote algae blooms that deplete oxygen in a water body and result in fish kills and other undesirable conditions. Florida water bodies are particularly susceptible to these problems due to periods of very low flows that occur in the summer. This project has seen great success throughout its two decades of performance. The Orlando Wetlands Park consists of 1,650 ac (670 ha) of hardwood hammocks, marshes, and lakes, and is a great location for bird-watching, nature photography, jogging, and bicycling.

- **Israel-Vertical Wetlands:** Compact vertical-flow constructed wetlands are being used in Israel for decentralized treatment of domestic wastewater. When treated with the UV disinfection unit, the effluent of the recirculating vertical flow constructed wetland (RVFCW) consistently met the stringent Israeli *E. coli* standards for reclaimed water irrigation of less than 10 cfu/100 mL (Inbar, 2007). The treated wastewater will be used for unrestricted landscape and, possibly, fodder irrigation.

3.4.1.1 Wildlife Habitat and Fisheries

Diverse species of mammals, plants, insects, amphibians, reptiles, birds, and fish rely on wetlands for food, habitat, and/or shelter. Wetlands are some of the most biologically productive natural ecosystems in the world, comparable to tropical rain forests or coral reefs in the number and variety of species they support. Migrating waterfowl rely on wetlands for resting, eating, and breeding, leading to increased populations. Wetlands are also vital to fish health and, thus, to the multibillion dollar fishing industry in the United States. Wetlands also provide an essential link in the life cycle of 75 percent of the commercially-harvested fish and shellfish in the United States, and up to 90 percent of the recreational fish catch. Wetlands provide a consistent food supply, shelter, and nursery grounds for both marine and freshwater species. The city of Sequim, Wash., constructed its water reclamation facility and upland reuse system to protect shellfish beds and conserve freshwater supplies. Due to the location of Sequim, it was vital for the community to make conservation and marine protection a priority [US-WA-Sequim].

Another case study, the Sierra Vista EOP, Ariz. [US-AZ-Sierra Vista] spans 640 ac (260 ha) and includes 30 open basins that recharge nearly 2,000 ac-ft/yr (2.5 MCM/yr) of reclaimed water to the aquifer, 50 ac (20 ha) of constructed wetlands, nearly 200 ac of native grasslands, and 1,800 ft^2 (170 m^2) of wildlife viewing facility. The constructed wetlands provide numerous beneficial services, including filtering and improving water quality as plants take up available nutrients. In the EOP wetlands, secondary treated effluent is filtered naturally. The primary purpose of EOP is to offset the effects of continued groundwater pumping that negatively impacts the river and to protect the habitat for native and endangered species.

3.4.1.2 Flood Attenuation and Hydrologic Balance

Flood damages in the United States average $2 billion each year, causing significant loss of life and property (EPA, 2006a). One of the most valuable benefits of wetlands is their ability to store flood waters; maintaining only 15 percent of the land area of a watershed in wetlands can reduce flooding peaks by as much as 60 percent. In addition to reducing the frequency and intensity of floods by acting as natural buffers that soak up and store a significant amount of flood water, coastal wetlands serve as storm-surge protectors when hurricanes or tropical storms come ashore. And, according to Hey et al. (2004), the damage sustained by the Gulf Coast during Hurricane Katrina could have been less severe if more wetlands had been in place along the coast and Mississippi delta. As a result, with the encouragement of the Louisiana Department of Environmental Quality and a $400,000 grant from the Delta Regional Authority, the Sewerage and Water Board of New Orleans identified a plan to use highly-treated reclaimed water from the WWTP to restore the damaged marsh lands. The multi-disciplinary project also includes proof of a new technology, ferrate (discussed further in Chapter 6), that is intended to scrub treated effluent of emerging pollutants of concern and set new standards for use of biosolids in wetlands assimilation (AWWA, 2010).

3.4.1.3 Recreation and Educational Benefits

Wetlands such as the Orlando Wetlands Park [US-FL-Orlando Wetlands] are also inviting places for popular recreational activities, including hiking, fishing, bird-watching, photography, and hunting. In addition to the many ways wetlands provide recreational benefits, they also offer numerous less-tangible benefits. These include providing aesthetic value to residential communities, reducing streambank erosion, and providing educational opportunities as an ideal "outdoor classroom," as demonstrated at the Sidwell Friends School case study [US-DC-Sidwell Friends]. The school, in Washington, D.C., incorporated a constructed wetland into its middle school building renovation. This water reuse system was part of an overall transformation of a 50-year-old facility into an exterior and interior teaching landscape that seeks to foster an ethic of social and environmental responsibility in each student. With a focus on smart water management, a central courtyard was developed with a rain garden, pond, and constructed wetland that uses stormwater and wastewater for both ecological and educational purposes. More than 50 plant species, all native to the Chesapeake Bay region, were included in the landscape.

3.4.2 River or Stream Flow Augmentation

Among the numerous water industry challenges are high demand and inadequate supplies. Water conservation and reuse can reduce the demand on aquifers, as can river or stream flow augmentation. River and stream augmentation differs from a surface water discharge in several ways. Augmentation seeks to accomplish a benefit, such as aesthetic purposes or enhancement of aquatic or riparian habitat, whereas discharge is primarily for disposal. River or stream flow augmentation may provide an economical method of ensuring water quality, as well as having other benefits. It can minimize the challenge of locating a reservoir site, the additional water can improve the overall water quality of the receiving water body, and it can ameliorate the effect of low flow drought conditions, providing high quality water at the time of test need. River and stream augmentation may also reduce or eliminate water quality impairment and may be desirable to maintain stream flows and to enhance the aquatic and wildlife habitat, as well as to maintain the aesthetic value of the water courses. This may be necessary in locations where a significant volume of water is drawn for potable or other uses, largely reducing the downstream volume of water in the river or stream.

As with impoundments, water quality requirements for river or stream augmentation will be based on the designated use of the water course and the aim to enhance an acceptable appearance. In addition, there should be an emphasis on creating a product that can promote native aquatic life. The quality of the reclaimed water discharged to the receiving water body is critical to evaluating its benefits to the stream. Currently, there are limited data available to assess such water augmentation schemes a priori, and detailed, site-specific evaluations are needed (WRRF, 2011a). Water reclamation for stream augmentation applications requires consideration of a complex set of benefits and risks. For example, wastewater is known to contain microbiological contaminants as well as other trace levels of organic contaminants, some of which may be carcinogens, toxins, or endocrine disruptors (Lazorchak and Smith, 2004). These contaminants may be present in the reclaimed water at varying concentrations, depending upon the treatment process used (Barber et al., 2012), and the presence of these types of compounds in a receiving water body may have ecotoxicological consequences.

While some states have guidelines or regulations that provide requirements for reclaimed water quality and monitoring to protect wetlands (Section 4.5.2.7), which may even be considered part of the treatment system, requirements for reclaimed water quality for augmenting rivers or streams are often covered under a discharge permit. And, while the whole effluent toxicity (WET) testing and biomonitoring required in some NPDES permits may provide an indication of the overall ecological effect of the reclaimed water, this approach still presents a regulatory challenge because the current science on compounds of emerging concern is not fully defined (Section 6.2.2.3). Thus, evaluation and design for river or stream flow augmentation must address the site-specific water quality and habitat needs of the water course and any downstream use of the reclaimed water. And, in an appropriately designed river or stream augmentation project where treatment is provided to be protective of the end use of the receiving water, there are opportunities for public education regarding the value of reclaimed water as a resource and its potential to provide environmental benefits.

One case study example illustrates the potential for positive impacts of water reuse on downstream ecosystems. In the city of Sequim, Wash., in addition to municipal uses, reaerated reclaimed water is discharged into Bell Creek to improve stream flows for fisheries and habitat restoration, keeping the benthic layer wet for small species that live in the streambed [US-WA-Sequim].

3.4.3 Ecological Impacts of Environmental Reuse

The NRC report describes how ecological risks in environmental reuse applications should be assessed relative to existing wastewater discharge practices (NRC, 2012). The report concludes that the ecological risks in reuse projects for ecological enhancement are not expected to exceed those encountered with the normal surface water discharge of reclaimed water, although risks from reuse could be lower if additional levels of treatment are applied. The report cautions that current limited knowledge about the ecological effects of trace chemical constituents requires research to link population level effects in natural aquatic systems to initial concerning laboratory observations. In reuse applications targeted for ecological enhancement of sensitive aquatic systems, careful assessment of risks from these constituents is warranted, because aquatic organisms can be more sensitive to certain constituents than humans (NRC, 2012).

Lake Elsinore, southern California's largest natural lake, is fed only by rain and natural runoff, with an annual evaporation rate of 4.5 ft. Because of these characteristics, the lake has been plagued for decades by low water levels and high concentrations of nutrients. The Elsinore Valley Municipal Water District (EVMWD) implemented a project to transfer 5 million gallons of reclaimed water per day to the lake to help with the low water levels [US-CA-Elsinore Valley].

3.5 Industrial Reuse

Traditionally, pulp and paper facilities, textile facilities, and other facilities using reclaimed water for cooling tower purposes, have been the primary industrial users of reclaimed water. Since the publication of the 2004 *Guidelines for Water Reuse*, the industrial use of reclaimed water has grown in a variety of industries ranging from electronics to food processing, as well as a broader adoption by the power-generation industry. Over the past few years, these industries have embraced the use of reclaimed water for purposes ranging from process water, boiler feed water, and cooling tower use to flushing toilets and site irrigation. Additionally, industries and commercial establishments seeking LEED certification are driven to reclaimed water to enhance their green profile. In addition, these facilities recognize that reclaimed water is a resource that can replace more expensive potable water with no degradation in performance for the intended uses.

When reclaimed water was first used for industrial purposes (dating back to the first pulp and paper industries), it was generally treated and reused on-site. As water resources in the arid states have become increasingly stressed (Arizona, California, and Texas) and availability of groundwater sources are becoming extremely limited (Florida), municipal facilities have started to produce reclaimed water for irrigation, industrial, and power company users. This section examines water reuse in traditional industrial settings (cooling towers and boiler water feed) and discusses emerging industries, such as electronics and produced waters from natural gas operations. Additional discussion on state guidelines and regulations for industrial reuse is provided in Section 4.5.2.8.

Case study examples of industrial water reuse to address energy and sustainability goals include reuse projects by companies such as Coca-Cola, Frito-Lay, and Intel [US-AZ-Frito Lay]. Coca-Cola has installed recycle-and-reclaim loops in 12 of its water treatment systems in North America and Europe, with goals of equipping up to 30 facilities with these systems by the end of 2012. These loops allow facilities to reuse processed water in cooling towers, boilers, or cleaning, saving an average of 57 million gallons (220 million liters) of water per system annually.

3.5.1 Cooling Towers

Cooling towers are recirculating evaporative cooling systems that use the reclaimed water to absorb process heat and then transfer the heat by evaporation. As the cooling water is recirculated, makeup water (reclaimed water) is required to replace water lost though evaporation. Water must also be periodically removed from the cooling water system to prevent a buildup of dissolved solids in the cooling water. There are two common types of evaporative cooling water systems—cooling towers and spray ponds. Spray ponds are not widely used and generally do not utilize reclaimed water. Cooling towers have become very efficient, with only 1.5 to 1.75 percent of the recirculated water being evaporated for every 10°F (6°C) drop in process water temperature, reducing the need to supplement the system flow with makeup water. Because water is evaporated, dissolved solids and minerals remain in the recirculated water, and these solids must be removed or treated to prevent accumulation on equipment. Removal of these solids is accomplished by discharging a portion of the cooling water, referred to as blow-down water, which is usually treated by a chemical process and/or a filtration/softening/clarification process before disposal to a local WWTP. Cooling tower designs vary widely. Large hyperbolic concrete structures can range from 250 to 400 ft (76 to 122 m) tall and 150 to 200 ft (46 to 61 m) in diameter and are common at utility power plants, as shown in **Figure 3-5.**

These cooling towers can recirculate (cool) approximately 200,000 to 500,000 gpm (12,600 to 31,500 L/s) and evaporate approximately 6,000 to 15,000 gpm (380 to 950 L/s) of water. Smaller cooling towers, which may be used at a variety of industries, can be rectangular boxes constructed of wood, concrete, plastic, and/or fiberglass-reinforced plastic with circular fan housings for each cell. Each cell can

Figure 3-5
Large hyperbolic cooling towers (Photo Courtesy of International Cooling Towers)

recirculate (cool) approximately 3,000 to 5,000 gpm (190 to 315 L/s). Commercial air conditioning cooling tower systems can recirculate as little as 100 gpm (6 L/s) to as much as 40,000 gpm (2,500 L/s).

Any contamination of the cooling water through process in-leakage, atmospheric deposition, or treatment chemicals will also impact the water quality. While reclaimed water generally has very low concentrations of microorganisms due to the high level of treatment, one of the major issues with reclaimed water use in cooling towers relates to occurrence of biological growth when nutrients are present. Biological growth can produce undesirable biofilm deposits, which can interfere with heat transfer and cause microbiologically-induced corrosion from acid or corrosive by-products and may shield metal surfaces from water treatment corrosion inhibitors and establish under-deposit corrosion. Biological films can grow rapidly and plug heat exchangers, create film on the cooling tower media, or plug cooling tower water distribution nozzles/sprays.

Scaling can also be a problem in cooling towers. The primary constituents resulting in scale potential from reclaimed water are calcium, magnesium, sulfate, alkalinity, phosphate, silica, and fluoride. Minerals that form scale in concentrated cooling water generally include calcium phosphate (most common), silica (fairly common), and calcium sulfate (fairly common); other minerals that are less commonly found include calcium carbonate, calcium fluoride, and magnesium silicate. Constituents with the potential to form scale must be evaluated and controlled by chemical treatment and/or by adjusting the cycles of concentration. Therefore, reclaimed water quality must be evaluated, along with the scaling potential to establish the use of specific scale inhibitors, as demonstrated by the Southwest Florida Water Management District through its Regional Reclaimed Water Partnership Initiative [US-FL-SWFWMD Partnership] illustrating the use of reclaimed water for cooling water at a major utility in Florida. Another power plant, located in Colorado, [US-CO-Denver Energy] utilizes reclaimed water for cooling towers.

3.5.2 Boiler Water Makeup

The use of reclaimed water for boiler make-up water differs little from the use of conventional potable water—both require extensive pretreatment. Water quality requirements for boiler make-up water depend on the pressure at which the boiler is operated; in general, higher pressures require higher-quality water. The primary concern is scale buildup and corrosion of equipment. Control or removal of hardness from either potable water or reclaimed water is required for use as boiler make-up; additionally, control of insoluble scales of calcium and magnesium, and control of silica and alumina, are also required. Alkalinity of the reclaimed water, as determined by its bicarbonate, carbonate, and hydroxyl content, is also of concern because excessive alkalinity concentrations in boiler feed water may contribute to foaming and other forms of carryover, resulting in deposits in superheater, reheater, and turbine units. Bicarbonate alkalinity in feed water breaks down under the influence of boiler heat to release carbon dioxide, a major source of localized corrosion in steam-using equipment and condensate-return systems. Organics in reclaimed water can also cause foaming in boilers, which can be controlled by carbon adsorption or ion exchange. The American Boiler Manufacturers Association (ABMA) maximum recommended concentration limits for water quality parameters for boiler operations is presented in **Table 3-8**. For steam generation, TDS levels are recommended to be less than 0.2 part per million (ppm) and less than 0.05 ppm for once through steam generation (OTSG).

Since 2000, several refineries in southern Los Angeles, Calif., have turned to using recycled water as their primary source of boiler make-up water. Using clarification, filtration, and RO, high-quality boiler make-up water is produced that provides water supply, chemical, and energy savings. The West Basin Municipal Water District (WBMWD) supplies recycled water for both low-pressure and high- pressure boiler feed water; because high-quality water is required for high-pressure boiler feed, some of the water (after the

Table 3-8 Recommended boiler water limits

Drum Operating Pressure (psig)	0-300	301-450	451-600	601-750	751-900	901-1000	1001-1500	1501-2000	OTSG
Steam									
TDS max (ppm)	0.2-1.0	0.2-1.0	0.2-1.0	0.1-0.5	0.1-0.5	0.1-0.5	0.1	0.1	0.05
Boiler Water									
TDS max (ppm)	700-3500	600-3000	500-2500	200-1000	150-750	125-625	100	50	0.05
Alkalinity max (ppm)	350	300	250	200	150	100	n/a	n/a	n/a
TSS Max (ppm)	15	10	8	3	2	1	1	n/a	n/a
Conductivity max (μmho/cm)	1100-5400	900-4600	800-3800	300-1500	200-1200	200-1000	150	80	0.15-0.25
Silica max (ppm SiO_2)	150	90	40	30	20	8	2	1	0.02
Feed Water (Condensate and Makeup, After Deaerator)									
Dissolved Oxygen (ppm O_2)	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	n/a
Total Iron (ppm Fe)	0.1	0.05	0.03	0.025	0.02	0.02	0.01	0.01	0.01
Total Copper (ppm Cu)	0.05	0.025	0.02	0.02	0.015	0.01	0.01	0.01	0.002
Total Hardness (ppm $CaCO_3$)	0.3	0.3	0.2	0.2	0.1	0.05	ND	ND	ND
pH @ 25° C	8.3-10.0	8.3-10.0	8.3-10.0	8.3-10.0	8.3-10.0	8.8-9.6	8.8-9.6	8.8-9.6	n/a
Nonvolatile TOC (ppm C)	1	1	0.5	0.5	0.5	0.2	0.2	0.2	ND
Oily Matter (ppm)	1	1	0.5	0.5	0.5	0.2	0.2	0.2	ND

Source: Boiler Water Quality Requirements and Associated Steam Quality for Industrial/Commercial and Institutional Boilers (American Boiler Manufacturers Association, 2005) first-pass RO treatment and disinfection) passes through RO a second time (second pass) to remove additional dissolved solids from the water. For water fed to the Chevron refinery in El Segundo, Calif., about 5.8 mgd (254.1 L/s) receives single-pass RO treatment low-pressure boiler feed, while an additional 2.4 mgd (105 L/s) receives second-pass RO treatment for high-pressure boiler feed. The product water is pumped to a storage tank at the nearby Chevron refinery. Boiler water is also produced at the WBMWD's satellite MF/RO plant in Torrance, Calif.; the 2,200 gpm (3,500 ac-ft/yr or 4.3 MCM/yr) satellite treatment plant located on-site at the Exxon Mobil refinery produces water for their boiler feed operations. Another WBMWD facility in Carson also provides recycled water to the BP refinery.

3.5.3 Produced Water from Oil and Natural Gas Production

While not specifically reuse of treated municipal effluent, the reuse of produced water that is generated as a by-product resulting from the extraction of crude oil or natural gas from the subsurface warrants discussion. Produced water, for the purposes of this discussion, is defined as any water present in a reservoir with a hydrocarbon resource that is produced to the surface with the crude oil or natural gas. There are three types of water associated with subsurface hydrocarbon reservoirs and production operations:

- Formation water is water that flows from the hydrocarbon zone or from production activities when injected fluids and additives are introduced to the formation.
- Produced water is generated when the hydrocarbon reservoir is produced and formation water is brought to the surface.
- Flowback is water that returns to the surface within a few days or weeks following hydraulic fracturing performed on a natural hydrocarbon reservoir; this practice involves injection of large volumes of fracturing fluid into the hydrocarbon reservoir.

Recent advances in drilling techniques have led to an increase in production water from unconventional gas formations, including coal seams, tight sand, and shale deposits. These new techniques result in approximately eight barrels of water brought to the surface for every barrel of oil. This produced water is often highly saline and contaminated by hydrocarbons; it is a waste that requires treatment, disposal, and, potentially, recycling. Handling this produced water is an integral part of the oil and gas industry, and according to estimates by Clark and Veil (2009), the United States generates around 20.7 bbl/yr out of a worldwide total 69.8 bbl/yr (or 2.4 mgd of 8 mgd total; 9 ML/d of 30 ML/d total). The breakdown by state of produced water is shown in **Figure 3-6.** As might be expected, the quality of produced waters varies widely, ranging from water that meets state and federal drinking water standards to water having very high TDS concentrations. The properties can vary considerably depending on geographic location, the source geological formation, and the type of hydrocarbon being extracted. When produced water contains certain constituents at high concentrations, it can threaten aquatic life if discharged to streams or other water bodies or used as irrigation water without treatment. As a result, produced water management is subject to applicable federal and state regulatory requirements, which are further described by the U.S. Department of Energy in an online resource, The Produced Water Management System (DOE, n.d.).

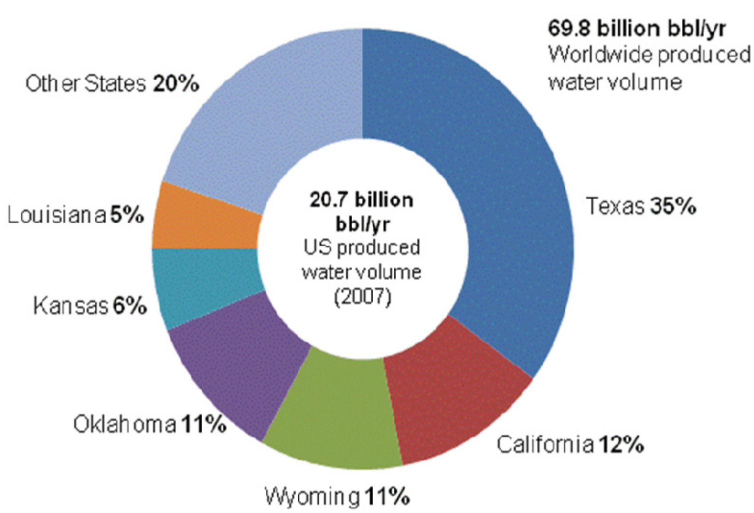

Figure 3-6
Estimates of produced water by state

It is of interest to note that under current regulations, produced water can only be utilized west of the 99 meridian and the practice is most contentious. Where produced water can be used, as with reclaimed water produced from treated municipal effluent, there are a variety of uses depending on the produced water quality and the level of treatment provided. Low TDS water sources, such as those common with coalbed methane production, may be reused with very little treatment (NRC, 2010). Higher TDS sources usually require a much higher level of treatment and may be limited in their end uses. End uses of treated, produced water include surface water flow augmentation, aquifer recharge, storage and recovery, crop irrigation, and livestock watering. Produced water may also be used for a variety of industrial purposes, especially in areas where freshwater resources are scarce. It is important to note that produced waters associated with hydraulic fracturing operations cannot be used as reclaimed water for alternative uses without extensive and expensive treatment operations, and reuse is limited to development of additional wells, with appropriate treatment.

Treatment of produced water is often required before the water can be put to beneficial reuse. The degree of treatment and the type of treatment technology used is based on a number of factors, including the produced water quality, volume, treated water quality objectives, options available for disposal of residual waste (such as concentrated brine), and cost. In oil and gas operations, it is sometimes necessary to use modular technologies that can be mobilized for localized treatment in the field versus building a fixed-based treatment facility in a central location. The overall objective is to develop a simple, cost-effective treatment solution capable of consistently meeting effluent treatment objectives. Because of the wide variation in produced water quality and treatment objectives in oil and gas fields across the United States, development of the best solution is challenging and often requires a combination of treatment technologies to meet the individual needs of each operator. Treatment technologies commonly used for produced water prior to reuse include oil-water separators, dissolved gas flotation or coalescing media separators, adsorption, and filtration targeted for removal of specific constituents from the produced water. As a result, the best approach must balance produced water quality, simplicity of operations, treatment objectives, and cost.

3.5.4 High-Technology Water Reuse

The use of reclaimed water in high-technology manufacturing, such as the semiconductor industry, is a relatively new practice. Within the semiconductor industry, there are two major processes that use water: microchip manufacturing, which has rarely utilized reclaimed water, and the manufacture of circuit boards. In circuit board manufacturing, water is used primarily for rinse operations; similar to production of boiler feed water, reclaimed water for circuit board manufacturing requires extensive treatment. While only circuit board manufacturing uses reclaimed water in the actual production process, both semiconductor and circuit board manufacturing facilities do use reclaimed water for cooling water and site irrigation.

Examples of reuse in high-technology industries include projects by companies such as Intel, that improved the efficiency of the process used to create the ultra-pure water (UPW) required to clean silicon wafers during fabrication. Previously, almost 2 gallons of water were needed to make 1 gallon of UPW. Today, Intel generates 1 gallon of UPW from between 1.25 and 1.5 gallons. After using UPW to clean wafers, the water is suitable for industrial purposes, irrigation, and many other needs. Intel's factories are equipped with complex rinse-water collection systems with separate drains for collecting lightly contaminated wastewater for reuse. This reuse strategy enables Intel to harvest as much water from its manufacturing processes as possible and then direct it to equipment such as cooling towers and scrubbers. In addition, several of Intel's locations take back graywater from local municipal water treatment operations for municipal use. In 2010, Intel internally recycled approximately 2 billion gallons (7.6 MCM) of water, equivalent to 25 percent of its total water withdrawals for the year.

3.5.5 Prepared Food Manufacturing

The food and beverage manufacturing industry was initially reluctant to use—and publicize the use of—reclaimed water because of public perception concerns. As knowledge of water reuse principles has increased, so has the reuse of highly-treated process waters that meet water quality criteria and address public health concerns. In many cases, not only is reuse of water at a manufacturing site "green," but it also can reduce operating costs and an industry's water footprint and, in some cases, provide better water quality than the public water supply.

Because of the interest in reuse for the food and beverage industry, the International Life Sciences Institute Research Foundation (ILSIRF) was requested to develop guidelines for water recovery for multiple uses in beverage production facilities. Many beverage producers and food processors are experiencing multiple pressures to find ways to minimize the total volume of water they use in the production of product. Producers need to secure adequate, predictable, and sustainable supplies of water for all uses at reasonable costs, and with efficient usage to maximize product output. Reducing the "water footprint" of a facility that is feeling these pressures allows for greater production of product and less waste, as well as realizing possible economic advantages, and possibly better relations with local citizens and governments. Companies such as Coca-Cola and PepsiCo are implementing practices to improve their water use in their operations as further described in case study examples of water recovery practices at beverage processing facilities [US-GA-Coca-Cola and US-NY-PepsiCo].

In response to this request, ILSIRF convened an international expert committee to carry out the guideline development process that has been underway since the summer of 2011; the expected completion and release date is the end of 2012. Beverage production processes covered by these guidelines include sodas, beer, juices, milk, and still or carbonated waters. The technologies being considered are typically used in current bottling or public drinking water and applicable water reclamation (ILSIRF, 2012).

An award-winning example of integrated water reuse and sustainable practices is represented in the 2011 WateReuse Association Project of the Year award to PepsiCo/Frito-Lay Corporation Casa Grande, Ariz., facility [US-AZ-Frito Lay]. A new process water recovery treatment plant eliminated the previous land application system and currently recycles 75 percent of plant process water, saving 100 million gallons of water per year. Elimination of the land application site allowed for the installation of 5 MW of solar photovoltaic and Sterling dish technology, reducing impact on the local power grid.

There are numerous water-demanding processes in the food and beverage industry, in addition to the potable water that may be incorporated into the product. These include cleaning and sanitation, steam and hot water generation for processing, transport and cleaning of food products, equipment cleaning, container (bottles, cans, cartons, etc.) cleaning, can and bottle conveyor belt lubrication, can and bottle warming, and cooling. Water use for cleaning varies by industry segment from 22 percent of water use in jam production to 70 percent in the bakery segment (East Bay Municipal Utility Division, 2008).

The transport of some food products, such as potatoes and other canned goods, through the processing facility may be accomplished via water flumes. While conveyor systems with water sprays or counter-flow wash systems are gaining in use as a water conservation measure, flume water and spray water from these processes are often collected and reused following filtration and disinfection, if appropriate. Conserving water through the use of dry cleaning methods is often integrated with other water reuse practices such as using internally recycled water from equipment cleaning for other uses or for irrigation. These practices can reduce operating costs and flows to the wastewater treatment process.

Container cleaning (bottles, cans, kettles, other containers) is performed both before and after the filling process, as some overfill or spillage typically occurs. Wash water can be filtered through nanofiltration to recover both the sugars and product for use as animal feed or for growing yeast, while the cleaned water is available for additional reuse, such as crate or pallet cleaning or conveyor lubrication. Water, including reclaimed water, can be used for both heating and cooling, with water as the heat transfer medium. In canning, heating of cold ingredients after can filling prevents formation of condensation on the can and allows shorter drying cycles.

The Coca-Cola Company has developed and is implementing its Rainmaker® beverage process water recovery system for clean-in-place and bottle washing. Following conventional treatment, the recovered water is further treated using MBR ultrafiltration, RO, ozonation, and UV disinfection. This process was bench tested then implemented in facilities in Ahmedabad, India, and Hermosillo, Mexico, with reduction in water use up to 35 percent. Based on the full-scale application, the Hermosillo facility has approval to continue use of the Rainmaker® system, and approval is anticipated in 2012 for Ahmedabad (Gadson, 2012).

Reuse and waste load reduction combined in a new facility in Spartanburg, S.C., with expansion of New United Resource Recovery Corporation, LLC. (NURRC), a joint venture formed in 2007 between Coca-Cola Company and United Resource Recovery Corporation (URRC). NURRC recycles discarded plastic beverage bottles and other food product containers into NSF-certified reclaimed plastic for the bottling and beverage industry. When proposing a ten-fold expansion of its facility, NURRC realized that this would also increase the wastewater load to the Spartanburg Sanitary Sewer District (SSSD), with a population equivalent load of 30,000 people and concurrent increase in water use. A high-strength treatment process relying on ultrafiltration and RO was installed to produce reclaimed water with BOD less than 1 mg/L and TDS less than 100 mg/L; the reclaimed water is now used in multiple nonpotable processes throughout the facility. On-site pre-treatment of waste streams from the UF/RO process has resulted in a reduction of the waste load to SSSD to only 20 percent of the pre-expansion loads (Cooper, 2012).

3.6 Groundwater Recharge – Nonpotable Reuse

Groundwater recharge to aquifers not used for potable water has been practiced for many years, but has often been viewed as a disposal method for treated wastewater effluent. In addition to providing a method of treated effluent disposal, groundwater recharge of reclaimed water can provide a number of other benefits including

- Recovery of treated water for subsequent reuse or discharge
- Recharge of adjacent surface streams
- Seasonal storage of treated water beneath the site with seasonal recovery for agriculture

In many cases, groundwater can be recharged in a manner that also utilizes the soil or aquifer system where reclaimed water is applied as an additional treatment step to improve the reclaimed water quality. SAT, further discussed in Chapter 2, is particularly attractive in dry areas in arid regions and studies in Arizona, California, and Israel (Idelovich, 1981) have demonstrated that the recovery of the treated water may be suitable for unrestricted irrigation on many types of crops. Additional discussion on groundwater recharge using land treatment and SAT are provided in the 2006 *Process Design Manual - Land Treatment of Municipal Wastewater Effluents* (EPA, 2006b) and Chapter 2 of this document.

The Talking Water Gardens project in Oregon is a case study example of a public-private partnership that has helped Albany and Millersburg meet the newly established temperature total maximum daily limits (TMDL) for the Willamette River along with providing ecological services including groundwater recharge. The objective of the TMDL is to enhance the fish passage through that area, protecting a threatened salmonid species. The Talking Water Gardens serve as the final treatment step for wastewater effluent through natural hydrological processes in the wetlands. The project includes 37 ac (15 ha) of constructed wetlands that serve as an environmentally beneficial alternative to more traditional wastewater treatment methods. Project developers estimate that the wetlands treatment alternative will provide approximately 2.5 times more value in ecological services than a conventional treatment alternative when project attributes such as habitat disturbance, groundwater recharge, and habitat diversity are considered (EPA, n.d.).

3.7 Potable Reuse

In 1980, EPA sponsored a workshop on "Protocol Development: Criteria and Standards for Potable Reuse and Feasible Alternatives" (EPA, 1982). In the Executive Summary of that document, the chairman of the planning committee noted that "*A repeated thesis for the last 10 to 20 years has been that advanced wastewater treatment provides a water of such high quality that it should not be discharged but put to further use. This thesis when joined to increasing problems of water shortage, provides a realistic atmosphere for considering the reuse of wastewater. However, at this time, there is no way to determine the acceptability of renovated wastewater for potable purposes*." This demonstrates that more than 30 years ago there was recognition of the importance of reuse for potable purposes as well as acknowledgement that what was known about the quality of the treated wastewater was a limitation to this practice.

Since that time, a great deal has changed with respect to our understanding of this concept. The 2012 NRC report presents a brief summary of the nation's recent history in water use and shows that although reuse is not a panacea, the amount of wastewater discharged to the environment is of such quantity that it could play a significant role in the overall water resource picture and complement other strategies, such as water conservation (NRC, 2012). One of the most important themes throughout the report is water reuse for potable reuse applications, including a discussion of both DPR and IPR and unplanned or *de facto* reuse.

Water reclamation for nonpotable applications is well established, as discussed in the previous sections of this chapter, with system designs and treatment technologies that are generally well accepted by communities, practitioners, and regulatory authorities. The use of reclaimed water to augment potable water supplies has significant potential for helping to meet future needs, but planned potable water reuse only accounts for a small fraction of the volume of water currently being reused. However, if *de facto* (or unplanned) water reuse is considered, potable reuse is certainly significant to the nation’s current water supply portfolio. The unplanned reuse of wastewater effluent as a water supply is common, with some drinking water treatment plants using waters from which a large fraction originated as wastewater effluent from upstream communities, especially under low-flow conditions. Thus, the term *de facto* reuse will be used to describe unplanned IPR, which has been identified in the NRC report (2012), and is becoming recognized by professionals and the general public. Examples of *de facto* potable reuse abound, including such large cities as Philadelphia, Nashville, Cincinnati, and New Orleans, which draw their drinking water from the Delaware, Cumberland, Ohio, and Mississippi Rivers, respectively. These communities, and most others using unplanned IPR sources, do provide their customers with potable water from these rivers that meet current drinking water regulations by virtue of the drinking water treatment technologies used.

This practice of discharging treated wastewater effluent to a natural environmental buffer, such as a stream or aquifer, has historically been deemed as an appropriate practice for IPR. However, research during the past decade on the performance of several full-scale advanced water treatment operations indicates that some engineered systems can perform equally well or better than some existing environmental buffers in attenuating contaminants, and the proper use of indicators and surrogates in the design of reuse systems offers the potential to address many concerns regarding quality assurance. A number of these planned IPR projects have been in use for many years, demonstrating successful operation and treatment.

Several examples of IPR and DPR projects are summarized in **Table 3-9** to illustrate that this practice occurs worldwide at both very small and very large scales. And there are countless other planned IPR applications, where treated wastewater is deliberately recharged to a groundwater aquifer using rapid infiltration basins or injection wells, or to a drinking water reservoir. Additional information for the examples described in **Table 3-9** are provided in case studies; in addition to the case studies provided in the table, more information on specific IPR projects in the United States is available in case studies for successful IPR projects [US-CA-Los Angeles County, US-CA-San Diego, US-AZ-Prescott Valley, US-CA-Vander Lans].

Implementation of technologies for increasingly higher levels of treatment for many of these IPR projects has led to questions about why reclaimed water would be treated to produce water with higher quality than drinking water standards, and then discharged to an aquifer or lake. This realization has led to new interest in DPR, utilizing the various multiple-barrier treatment technologies. However, even with the numerous successful IPR projects, such as cited in **Table 3-9**, and technology advances, Windhoek, Namibia, was the first city to implement long-term DPR without use of an environmental buffer. This is an example of the distinction between IPR and DPR: a reuse practice in which purified municipal wastewater is introduced into a water treatment plant intake (after treatment to at least near drinking water quality) for the purposes of this document, or directly into the water distribution system after meeting drinking water standards which has been proposed by others (Tchobanoglous et al., 2011).

Table 3-9 Overview of selected planned indirect and direct potable reuse installations worldwide (not intended to be a complete survey)

Country	City	Project Capacity (mgd)	Description of Advanced System for Potable Reuse	Case Study
Belgium	Wulpen	1.9	Reclaimed water is returned to the aquifer before being reused as a potable water source	[Belgium-Recharge]
India	Bangalore (planned)	36	Reclaimed water will be blended in the reservoir, which is a major drinking water source	[India-Bangalore]
Namibia	Windhoek	5.5	Reclaimed water is blended with conventionally-treated surface water for potable reuse	(NAS, 2012)
United States	Big Spring, Texas	3	Reclaimed water is blended with raw surface water for potable reuse	[US-TX-Big Spring]
United States	Upper Occoquan, Virginia	54	Reclaimed water is blended in the reservoir, which is a major drinking water source	[US-VA-Occoquan]
United States	Orange County, California	40	Reclaimed water is returned to the aquifer before being reused as a potable water source	[US-CA-OrangeCounty]
United Kingdom	Langford	10.5	Reclaimed water is returned upstream to a river, which is the potable water source	[United Kingdom-Langford]
Singapore	Singapore	122	Reclaimed water is blended in the reservoir, which is a major drinking water source	[Singapore-NEWater]
South Africa	Malahleni	4.2	Reclaimed water from a mine is supplied as drinking water to the municipality	[South Africa-eMalahleni Mine]

Source: Adapted from Von Sperling and Chernicharo (2002)

The rationale for DPR is based on the technical ability to reliably produce purified water that meets all drinking water standards and the need to secure dependable water supplies in areas that have, or are expected to have, limited and/or highly variable sources. A unique DPR project has been successful aboard the International Space Station [US-TX-NASA]. However, although reclaimed water can be treated to meet all applicable standards, DPR still raises a number of issues and requires a careful examination of regulatory requirements, health concerns, project management and operation, and public perception. Many of these issues have been discussed in greater detail with respect to how regulatory agencies and utilities in California would pursue DPR as a viable option in the future (Crook, 2010).

3.7.1 Planned Indirect Potable Reuse (IPR)

Planned IPR involves a proactive decision by a utility to discharge or encourage discharge of reclaimed water into surface water or groundwater supplies for the specific purpose of augmenting the yield of the supply. For the purposes of the discussion related to planned IPR, it is useful to examine **Figure 3-7,** which provides a graphical representation of IPR with specific examples. There are specific regulatory programs that may be referenced for this practice, and additional discussion on regulatory approaches to planned IPR is provided in Section 4.5.2.10.

In either case, the decision to pursue planned IPR typically involves the following factors.

- Limited availability and yield of alternate sources
- High cost of developing alternate water sources
- Conscious or unconscious public acceptance
- Confidence in, and some level of control over, both advanced reclaimed water treatment processes and water treatment processes

In some cases, the level of reclaimed water treatment required to meet water quality standards is considerable. The incentive to provide additional treatment may be driven by regulations intent on protecting water supplies but in most cases is also

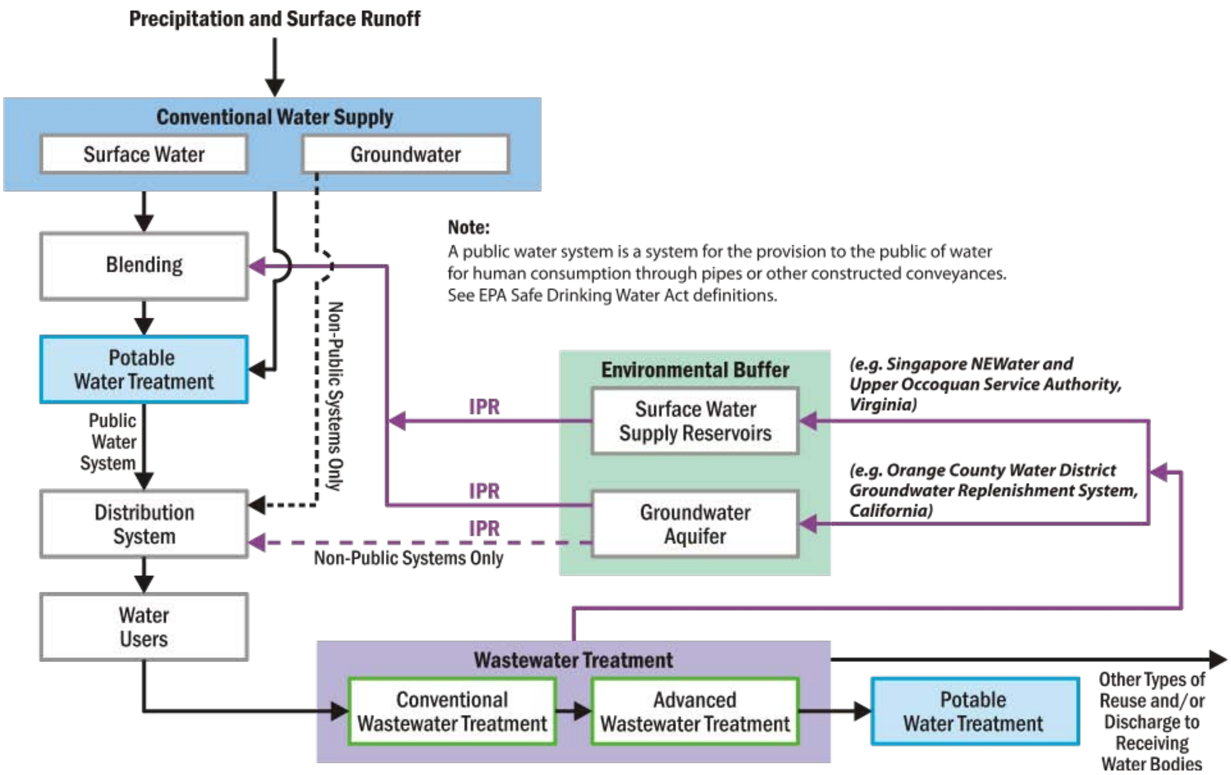

Figure 3-7
Planned IPR scenarios and examples

linked to benefits to the discharger or community in increasing the yield of water supplies that they depend on either directly or indirectly. While satisfying these four factors may be necessary to pursue IPR, they are not sufficient. Two specific components of these factors typically control the viability of implementation. First, even though existing water supplies may be of limited availability and yield, the means via water rights, permits, and storage contracts must exist to reap the benefits of withdrawing the additional yield of the augmented water supply. Second, public acceptance of IPR is of paramount importance but sometimes takes counterintuitive turns based on the specifics of the project and the local community. The following examples illustrate how these key components can play out in project planning and implementation.

An often-cited example of IPR is the UOSA discharge into Occoquan Reservoir in Northern Virginia. In this particular case, serious water quality issues were caused by multiple small effluent discharges into the reservoir. The Fairfax County Water Authority withdraws water from the reservoir to meet the water supply needs of a large portion of Northern Virginia. In 1971, the UOSA was formed to address the water quality problem by the same local government entities that relied on the reservoir for their water supply. Therefore, these local governments, and by proxy their residents, received the benefits of the investments of additional wastewater treatment, satisfying the first key component that their water supply was now both protected and augmented. Regarding the second key component, the improvements made a dramatic improvement in the water quality of the reservoir that was readily visible to the general public. Algae blooms, foul odors, low DO for fish, etc., were addressed by the regionalization and advanced treatment and provided the public with a tangible example showing improved water quality over past practices. See [US-VA-Occoquan] for further information.

Another example is the Gwinnett County, Ga., where treated effluent is discharged to Lake Lanier. Operated by the USACE, Lake Lanier is formed by Buford Dam on the Chattahoochee River north of Atlanta. Gwinnett County, along with several other communities around the lake, withdraws all of its water for potable supply from Lake Lanier. Given the linkage between the water withdrawal from the lake and the desire to return reclaimed water to the lake, the first key component was satisfied by the issuance of a revised state withdrawal permit and amended USACE storage contract that provided credit for the water returned. In this case, the key issue focused on permitting the discharge and on the multiple administrative and legal challenges identified by stakeholders with interest in the lake. Because the focus of the stakeholders was primarily lake quality, discharge limits were significantly reduced from already-low proposed levels. For example, the proposed 0.13 mg/L total phosphorus limit based on detailed lake modeling was eventually reduced through the legal and permitting process to 0.08 mg/L using anti-degradation regulations as the rationale. Interestingly, plaintiffs also successfully pushed for the outfall to be closer to the county's raw water intake to ensure that the reclaimed water discharge would be as reliable as possible.

In other example IPR projects, including San Diego and Tampa, the issue of supply and demand was not a significant concern, as the ability of the dischargers to utilize the reclaimed water to augment their yields was confirmed early in the planning process. However, unlike Gwinnett County, the primary opposition to IPR was related to the perceived health risks to the public from drinking the treated drinking water from the blended source. Public opposition of this type has significantly delayed or tabled many IPR plans. In many cases the opposition appears to be rooted, in part, to the public's perception of the quality of the existing water source and that it will be degraded by the addition of reclaimed water. San Diego was able to provide new educational communication materials to the public and interest groups and is operating an IPR demonstration facility to provide specific data for permitting to augment the San Vicente Reservoir with recycled water [US-CA-San Diego]. Additional information on public information campaigns is provided in Chapter 8.

3.7.2 Direct Potable Reuse (DPR)

To date, no regulations or criteria have been developed or proposed specifically for DPR in the United States. Past regulatory evaluations of this practice generally have been deemed unacceptable due to a lack of definitive information related to public health protection. Still, the *de facto* reuse of treated wastewater effluent as a water supply is common in many of the nation's water systems, with some drinking water treatment plants using water with a large fraction originating as wastewater effluent from upstream communities, especially under low-flow conditions (NRC, 2012). Considering that unplanned reuse is already widely practiced, DPR may be a reasonable option based on significant advances in treatment technology and monitoring methodology in the last decade and health effects data from IPR projects and DPR demonstration facilities. For example, the water quality and treatment performance data generated at operational IPR projects such as Montebello Forebay [US-CA-Los Angeles County] (WRRF, 2011b), Water Factory 21/Orange County Groundwater Replenishment Project [US-CA-Orange County], Occoquan Reservoir [US-VA-Occoquan], Scottsdale Water Campus, and El Paso Water Utility Hueco Bolson augmentation indicate that the advanced wastewater treatment processes in place in these projects can meet the required purification level. In addition to addressing the technical challenges of potable reuse, these projects, as well as San Diego, Calif., CA IPR Demonstration Project [US-CA-San Diego] and Big Spring, Texas, direct blending project [US-TX-Big Spring], demonstrate recent public acceptance of these kinds of water supply projects.

3.7.2.1 Planning for DPR

A number of recent publications have focused on identifying the role that DPR will have in the management of water resources in the future (Tchobanoglous et al., 2011; NRC, 2012; Crook, 2010; Leverenz et al., 2011; Schroeder et al., 2012). For the purposes of the discussion related to planned DPR in this section, it is useful to examine **Figure 3-8**, which provides a graphical representation of DPR, according to the definitions provided in this document, with specific examples.

As defined herein, DPR refers to the introduction of purified water, derived from municipal wastewater after extensive treatment and monitoring to assure that strict water quality requirements are met at all times, directly into a municipal water supply system. The resultant purified water could be blended with source water for further water treatment or could be used in direct pipe-to-pipe blending, providing a significant advantage of utilizing existing water distribution infrastructure. Tchobanoglous et al. (2011) proposed a general process flow for alternative potable reuse strategies, which is the basis for **Figure 3-8** and in which two DPR options are available.

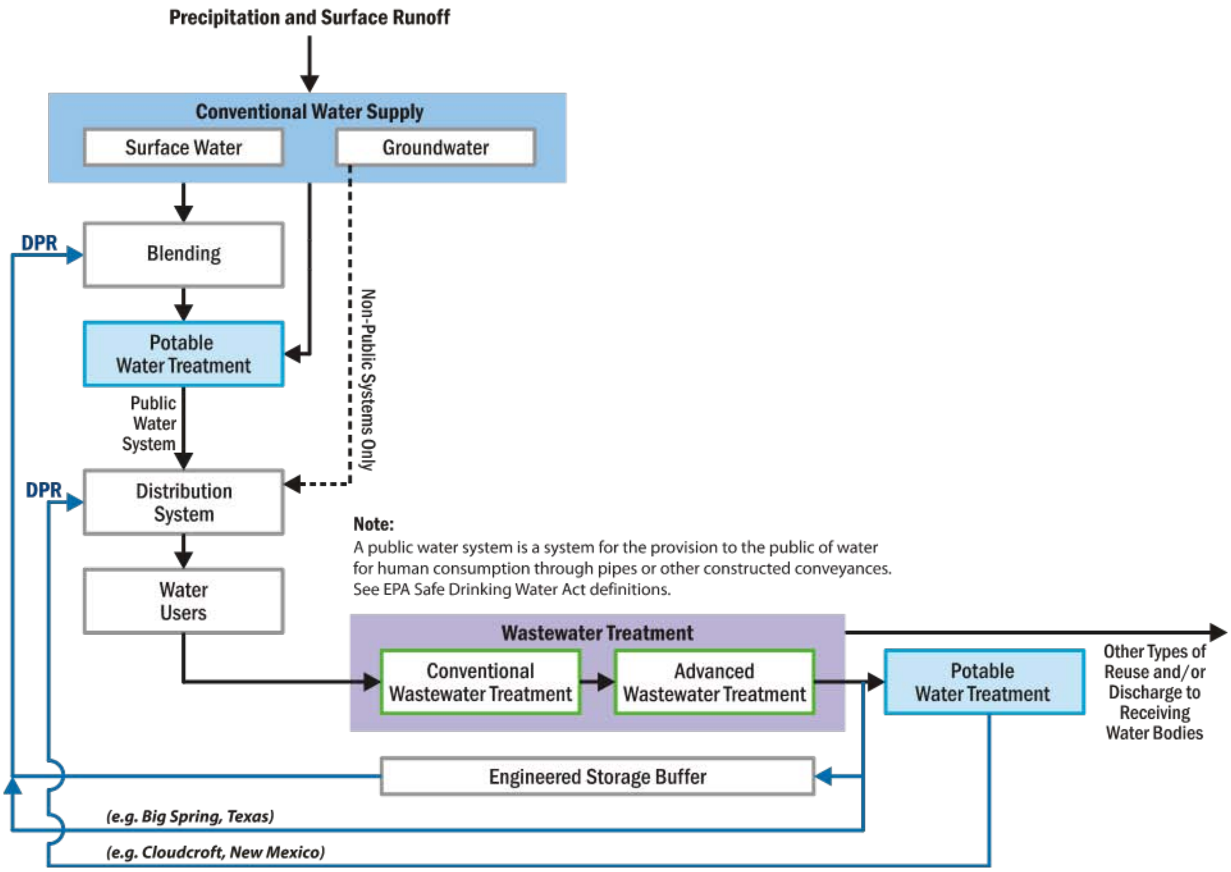

Figure 3-8
Planned DPR and specific examples of implementation

In the first option, purified water is first placed in an engineered storage buffer; from there, purified water is blended with the water supply prior to water treatment. In the second option, purified water, without the use of an engineered storage buffer, can be blended back into the distribution system for delivery to water users. An in-depth discussion of implementation of these options is provided by Tchobanoglous et al. (2011) and Leverenz et al. (2011), along with the concept and role of the engineered storage buffer, which is a mechanism for detention to provide response time for any off-specification product water.

Multiple additional process configurations may be available, such as the configuration in Big Spring, Texas, where direct blending of highly-treated reclaimed water with quality higher than drinking water standards is provided in a raw, surface water transmission main supplying six different community surface water treatment plants. In this particular project, the low TDS DPR water blends in the transmission main with significantly higher TDS lake water, improving the blended source water quality [US-TX-Big Spring].

In many parts of the world, DPR may be the most economical and reliable method of meeting future water supply needs. While DPR is still an emerging practice, it should be evaluated in water management planning, particularly for alternative solutions to meet urban water supply requirements that are energy intensive and ecologically unfavorable. This is consistent with the established engineering practice of selecting the highest quality source water available for drinking water production. Specific examples of energy-intensive or ecologically-challenging projects include interbasin water transfer systems, which can limit availability of local water sources for food production, and source area ecosystems, which are often impacted by reduced stream flow and downstream water rights holders who could exercise legal recourse to regain lost water. In some circumstances, in addition to the high energy cost related to long-distance transmission of water, long transmission systems could be subject to damage from earthquakes, floods, and other natural and human-made disasters. Desalination is another practice for which DPR could serve as an alternative, because energy requirements are comparatively large, and brine disposal is a serious environmental issue. By comparison, DPR using similar technology will have relatively modest energy requirements and provide a stable local source of water. It is important to note, however, that DPR will not be a stand-alone water supply. Therefore, in managing water supplies, other local sources will need to be combined with DPR to create reliable, robust, sustainable water supplies.

While the technical issues of DPR can be easily addressed through advanced treatment, there lies the significant task of developing public education and outreach programs to achieve public acceptance of this practice. The San Diego Phase II demonstration project is a key example of the level of effort that is required to achieve support for DPR, with nearly half of the project funding being dedicated to the purpose of education and outreach [US-CA-San Diego]. Successful operation of the Orange County Groundwater Replenishment Project for more than 3 years has accommodated innumerable tours and hosted many national reporters with positive education and feedback from most participants [US-CA-Orange County].

3.7.2.2 Future Research Needs

There are several existing potable reuse projects in the United States and abroad. Past research and operational data from existing IPR facilities indicate that available technology can reduce chemical and microbial contaminants to levels comparable to or lower than those present in many current drinking water supplies. Notwithstanding the demonstrated safety of using highly-treated reclaimed water for IPR, there are areas of research that could further advance the safety, reliability, and cost-effectiveness of IPR and more clearly determine the acceptability of DPR as it relates to public health protection. Other future research needs may be related to new or alternative treatment unit processes or treatment trains that are proposed, regulatory requirements (e.g., constituent limits, monitoring, and analytical techniques), public acceptance, and other factors.

The NRC report identified several key research needs related to both nonpotable and potable reuse, which are summarized below (NRC, 2012):

- Quantify the extent of *de facto* (unplanned) potable reuse in the United States
- Address critical gaps in the understanding of health impacts of human exposure to constituents in reclaimed water
- Enhance methods for assessing the human health effects of chemical mixtures and unknowns
- Strengthen waterborne disease surveillance, investigation methods, governmental response infrastructure, and epidemiological research tools and capacity
- Quantify the nonmonetized costs and benefits of potable and nonpotable water reuse compared with other water supply sources to enhance water management decision-making
- Examine the public acceptability of engineered multiple barriers compared with environmental buffers for potable reuse
- Develop a better understanding of contaminant attenuation in environmental buffers and wetlands
- Develop a better understanding of the formation of hazardous transformation products during water treatment for reuse and ways to minimize or remove them
- Develop a better understanding of pathogen removal efficiencies and the variability of performance in various unit processes and multi-barrier treatment, and develop ways to optimize these processes
- Quantify the relationship between polymerase chain reaction detections and infectious organisms in samples at intermediate and final stages
- Develop improved techniques and data to consider hazardous events or system failure in risk assessment of water reuse

- Identify better indicators and surrogates that can be used to monitor process performance in reuse scenarios and develop online real-time or near real-time monitoring techniques for their measurement
- Analyze the need for new reuse approaches and technology in future water management

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CHAPTER 4
State Regulatory Programs for Water Reuse

This chapter presents an overview of the overarching approach to developing a reuse program at the state level, a regulatory framework outlining fundamental components for states considering developing or revising regulations, and a summary of which states have regulations and guidelines governing reuse. This chapter also provides a listing of the existing state water reuse regulations or guidelines in 10 sample states (Arizona, California, Florida, Hawaii, Nevada, New Jersey, North Carolina, Texas, Virginia, and Washington) for a comparison of approaches governing different types of reuse applications. Finally, the chapter provides suggested regulatory guidelines for water reuse.

4.1 Reuse Program Framework

Since publication of the 2004 guidelines, several states have developed state water reuse programs, building on the examples of other states with well-established water reuse programs, such as Florida, California, Texas, and Arizona. Establishing an effective state water reuse program involves a number of complex factors beyond establishing guidelines or regulations. There are 15 key elements to an effective state water reuse program, as presented in **Table 4-1**.

4.2 Regulatory Framework

Reuse programs operate within a framework of regulations that must be addressed in the earliest stages of planning. A thorough understanding of all applicable regulations is required to plan the most effective design and operation of a water reuse program and to streamline implementation. Currently, there are no federal regulations directly governing water reuse practices in the United States. In the absence of federal standards and regulations, each state may choose to adopt rules and develop programs for water reuse to meet its specific resource needs, and to ensure that water reuse projects are designed, constructed, and operated in a manner protective of the environment, other beneficial uses, and human health. Water reuse regulations and guidelines have been developed by many states, as described in Section 4.5. Regulations refer to actual rules that have been enacted and are enforceable by governmental agencies. Guidelines, on the other hand, are generally not enforceable, but can be used in the development of a reuse program. In some states, however, guidelines are, by reference, included in the regulations, and thus are enforceable. In addition to providing treatment and water quality requirements, comprehensive rules or guidelines also promote reuse by providing the playing field for which projects must comply. They provide the certainty that if a project meets the requirements, it will be permitted.

Table 4-2 provides fundamental components of a regulatory framework that states may want to consider when developing or amending rules or regulations for water reuse.

4.3 Relationship of State Regulatory Programs for Water Reuse to Other Regulatory Programs

States' regulatory programs for water reuse must be consistent with and, in some cases, function within the limitations imposed by other federal and state laws, regulations, rules, and policies. The following subsections describe some of the more common laws and regulations that can affect states' regulatory programs for water reuse. Laws, policies, rules, and regulations that affect state water reuse regulatory programs include water rights laws, water use, and wastewater discharge regulations, as well as laws that restrict land use and protect the environment.

Table 4-1 Key elements of a water reuse program (Adapted from WateReuse Association, 2009)

	Factor	Description
1	Establish the objectives	Objectives that encourage and promote reuse should be clear and concise.
2	Commit to the long run	A water reuse program should be considered a permanent, high-priority program within the state.
3	Identify the lead agency or agencies	The lead agencies should be able to issue permits for the production, distribution, and use of the reclaimed water. These permits are issued under state authority and are separate from the federal requirements for wastewater discharges to surface waters under the NPDES permit program. Preference to the lead agency determination should be given to the public health agency since the intent of the use of reclaimed water is for public contact and/or consumption following adequate and reliable treatment.
4	Identify water reuse leader	A knowledgeable and dedicated leader of the water reuse program who develops and maintains relationships with all water programs and other agencies should be designated.
5	Enact needed legislation	Initial legislation generally should be limited to a clear statement of the state objectives, a clear statement of authorization for the program, and other authorizations needed for implementation of specific program components. States also will want to review and evaluate existing state water law to determine what constraints, if any, it will impose on water reuse and what statutory refinements may be needed.
6	Adopt and implement rules or guidelines governing water reuse	With stakeholder involvement, a comprehensive and detailed set of reuse regulations or guidelines that are fully protective of environmental quality and public health should be developed and adopted in one location of the regulations. Formal regulations are not a necessity—they may be difficult and costly to develop and change and therefore overly rigid. Frameworks that have an ability to adapt to industry changes are most effective.
7	Be proactive	The water reuse program leader should be visible within the state and water reuse community while permitting staff of the lead agency must have a positive attitude in reviewing and permitting quality water reuse projects.
8	Develop and cultivate needed partnerships	Partnerships between the agency responsible for permitting the reclaimed water facilities (usually the lead agency) and the agency(ies) responsible for permitting water resources as well as the agency responsible for protection of public health are critical. Other agency partnerships, such as with potential major users of reclaimed water such as the department of transportation, are also helpful in fostering state-wide coordination and promotion of water reclamation.
9	Ensure the safety of water reuse	Ensuring the protection of public health and safety can be accomplished by placing reliance on production of high-quality reclaimed water with minimal end use controls, or allowing lower levels of treatment with additional controls on the use of reclaimed water (setback distances, time of day restrictions, limits on types of use, etc.), or by a combination of both types of regulations. A formal reliability assessment to assure a minimum level or redundancy and reliability to review and detail operating standards, maintainability, critical operating conditions, spare parts requirements and availability, and other issues that affect the ability of the plant to continuously produce reclaimed water. A critical component to ensuring the safety of reclaimed water for public access and contact-type reuse is defining requirements for achieving a high level of disinfection and the monitoring program necessary to ensure compliance (this is described further in Chapter 6).
10	Develop specific program components	Program components are going to differ from state to state and maturity of the reuse program.
11	Focus on quality, integrity, and service	Not only should the reclaimed water utilities implement high-quality reuse systems that are operated effectively, but the lead agency should also model this commitment to quality and prompt service to the regulated and general public regarding reuse inquiries and permitting issues. In effect, the lead agency should focus on building same level of trust public potable water systems develop and re-establish daily.
12	Be consistent	A comprehensive and detailed set of state regulations, as well as having a lead reuse role, help keep the permitting of reuse systems consistent. If there are multiple branches around the state involved in permitting, training and other measures of retaining consistency must be taken.
13	Promote a water reuse community	The lead agency should be proactive in developing and maintaining the state's water reuse community—reuse utilities, consulting engineers, state agencies, water managers, health departments, universities, researchers, users of reclaimed water, and others—in an effort to disseminate information and obtain feedback related to possible impediments, issues, and future needs. Active participation in the national and local reuse organizations is valuable.
14	Maintain a reuse inventory	Maintenance of a periodical (e.g., annual) reuse inventory is essential in tracking success of a state's water reuse program. Facilities in Florida that provide reclaimed water are required by their permits to submit an annual reuse report form every year. That data not only is used in the states annual reuse inventory report and reuse statistics but is also shared with the WateReuse Association's National Reuse Database.
15	Address cross-connection control issues	Coordination and joint activity between agencies and within agencies (drinking water program, wastewater program, water reuse program, etc.) must be taken to address cross-connection control issues (this is described further in Chapter 2).

Table 4-2 Fundamental components of a water reuse regulatory framework for states

Category	Comment
Purpose and/or goal statement	▪ Frame the state's purpose for developing the rule or regulation (e.g., to satisfy a need or fulfill a statutory requirement), and describe the ultimate vision for the water reuse program. The process to authorize, develop, and implement rules or *changes* to rules is time consuming and costly. After adoption, rules are difficult to change, which limits the ability to accommodate new technologies and information.
Definitions	▪ Define type of use and other water reuse-related terms used within the body of the rule or regulation.
Scope, and Applicability	▪ Define the scope and applicability of the rules or regulations that delineates what facilities, systems, and activities are subject to the requirements of the rules or regulations. ▪ Include grandfathering or transitioning provisions for existing facilities, systems, or activities not regulated prior to the adoption of the rules or regulations.
Exclusions and prohibitions	▪ Describe facilities, systems and activities that are 1) not subject to the requirements of the rules or regulations, and 2) specifically prohibited by the rules or regulations.
Variances	▪ Describe procedures for variances to design, construction, operation, and/or maintenance requirements of the regulation for hardships that outweigh the benefit of a project, and the variance, if granted, would not adversely impact human health, other beneficial uses, or the environment. These variance procedures give regulators flexibility to consider projects that may deviate only minimally from the requirements with no significant adverse impact or opportunities that are not anticipated during initial development of a regulation. Since variances need to be based on sound, justifiable reasons for change, regulatory programs should develop guidance on how to develop adequate justification that can be relied upon as precedence setting for future regulatory decisions and actions.
Permitting requirements	▪ Describe the permitting framework for water reuse. Indicate whether the water reuse rule or regulation will serve as the permitting mechanism for water reuse projects or identify other regulations through which the water reuse rule or regulation will be implemented and projects permitted. ▪ Describe if or how end users of reclaimed water will be permitted, and rights of end user to refuse reclaimed water if not demanded. ▪ Describe permit application requirements and procedures. Specify all information that the applicant must provide in order to appropriately evaluate and permit the water reuse projects.
Define or refine control and access to reclaimed water	▪ Determine the rights to and limits of access and control over reclaimed water for subsequent use and the relationship between the underlying water right, wastewater collection system ownership, reclamation plant ownership, and downstream water users who have demonstrated good-faith reliance on the return of the wastewater effluent into a receiving stream within the limits and requirements of the state's water rights statutory and regulatory requirements.
Relationship to other rules	▪ Describe relationship between water reuse rule or regulation and, for example, water and wastewater regulations, environmental flow requirements, solid waste or hazardous waste rules, groundwater protection, required water management plans, and relevant health and safety codes for housing, plumbing, and building.
Relationship to stakeholders	▪ Identify regulatory or non-regulatory stakeholders from various sectors (e.g., water, wastewater, housing, planning, irrigation, parks, ecology, public health, etc.) that have a role or duty in the statewide reuse program.
Relationship to regulations or guidelines for uses of other non-conventional water sources	▪ Describe other rules or regulations that exist for graywater recycle and stormwater or rainwater harvesting and use. ▪ Some states may choose to develop a more comprehensive approach that encompasses rules or regulations for all non-conventional water sources, including water reuse, within one set of rules or regulations.
Reclaimed water standards	▪ See Tables 4-6 to 4-15 for standards that are either defined by end use or by degree of human contact. ▪ Include a provision to evaluate and allow standards to be developed on a case-by-case basis for less common uses of reclaimed water that are not listed. ▪ Require points of compliance to be established to verify compliance with standards. ▪ Describe response and corrective action for occurrence of substandard reclaimed water (a component of the Contingency Plan, below).
Treatment technology requirements	▪ In addition to reclaimed water standards, some states specify treatment technologies for specific reuse applications.
Monitoring requirements	▪ Describe methods and frequency for monitoring all standards listed in the rules or regulations.
Criteria or standards for design, siting and construction	▪ Describe criteria or standards of engineering design, siting, and construction for water reuse facilities and systems that typically include, but are not limited to, facilities or systems to treat/reclaim, distribute, and store water for reuse. ▪ Develop requirements for dual plumbed distributions systems (separate distribution of potable and nonpotable water) that are co-located. ▪ Describe requirements for the transfer of reclaimed water and its alternative disposal if unsuitable or not required by target user (e.g., during wet seasons).

Table 4-2 Fundamental components of a water reuse regulatory framework for states (cont.)

Category	Comment
Construction requirements	▪ Describe requirements for engineering reports, pilot studies, and certificates required to construct and to operate.
Operations and maintenance (O&M)	▪ Describe minimum requirements for the submission and content of O&M manual. The scope and content of an O&M manual will be determined by the type and complexity of the system(s) described by the manual.
Management of pollutants from significant industrial users as source water protection	▪ Where facilities or systems with inputs from significant industrial users are proposing to generate reclaimed water suitable for human contact or potable reuse, describe programs that must be implemented to manage pollutant of concern from significant industrial users. ▪ Pretreatment programs of combined publicly owned treatment works and reclamation systems may satisfy program requirements. ▪ Develop program requirements for satellite reclamation systems also affected by inputs from significant industrial users. ▪ Such pretreatment programs should develop discharge limits that are intended to protect source water, rather than wastewater treatment and sewer system integrity.
Access control and use area requirements	▪ Describe requirements to control access to sites where reclaimed water will be generated, or in some cases, stored or utilized. ▪ Describe requirements for advisory sign placement, message, and size. ▪ Describe requirements for proper use of reclaimed water by end users to ensure protection of the environment and human health (.e.g., setbacks, physical barriers or practices to prevent reclaimed water from leaving the site of use, etc.).
Education and notification	▪ Include requirements for generators or providers of reclaimed water to educate end users of appropriate handling and use of the water, and to provide notification to end users regarding the discharges of substandard water to reuse and loss of service for planned or unplanned cause.
Operational flow requirements	▪ Requirements for maintaining flow within design capacity of treatment system or planning for additional treatment capacity as needed.
Contingency plan	▪ Include a requirement for a contingency plan that describes how system failures, unauthorized discharges, or upsets will be remedied or addressed.
Recordkeeping	▪ Describe what operating records must be maintained, the location where they are retained, and the minimum period of retention.
Reporting	▪ Describe what items must be reported, the frequency of reporting, and to whom they are reported.
Stakeholder participation	▪ Requirements on public notice, involvement, and decision-making. This will apply where the water reuse rule or regulation is used as the vehicle to permit water reuse projects.
Financial assistance	▪ Describe state, local, or federal funding or financing sources.

4.3.1 Water Rights

Water reuse regulatory programs must work within the prevailing water rights laws of the state. Each state in the United States was granted ownership and control over all waters within their boundaries at statehood. "Water rights" provide the legal right for an entity to divert, capture, and use water within the boundaries of each individual state. In the United States, there are two main approaches to water rights law—appropriative doctrines (common in historically water-scarce areas) and riparian doctrines (common in historically water-abundant areas). Appropriative water rights are assigned or delegated to consumers, generally based on seniority of which users laid first claim to that water and not from the property's proximity to the water source. In contrast, riparian water rights are based on the proximity to water and are acquired by the purchase of the land. In the West, reuse can be the target of legal challenges, depending on how the local system of water rights regards the use and return of reclaimed water.

Access to or control over reclaimed water, like formal water rights, is unique to each individual state. Some states manage access to and use of reclaimed water under their water rights permitting program; others, like the state of Washington, incorporate this management directly with the reclaimed water permit. In this instance, the use of reclaimed water is not granted a separate and new water rights certificate or license, although the use of the reclaimed water cannot harm or impair existing rights that can demonstrate dependence on the return flows.

While most owners of water reclamation facilities generally have first rights to the use of the reclaimed water, there are scenarios where the facility is obligated to discharge effluents to receiving water bodies rather than using the reclaimed water for other beneficial uses. These scenarios include: 1) where reduction in effluent discharge flows could be challenged by downstream users, 2) where laws require that place-of-use be located within the watershed from which the water was originally drawn (in the case that reclaimed water might be distributed outside the watershed), 3) where "beneficial uses" of higher priority can make a claim for the reclaimed water (over, for example, industrial reuse), or 4) where reductions in water withdrawals from water supply because of reclamation might change customer rights or allocations in future periods of shortage (where rights or allocations are based on historic usage).

The most significant constraint affecting use of reclaimed water is the need to assure minimum instream flows sufficient to protect aquatic habitat. This is especially necessary in locations where instream flows are necessary to protect the habitat of threatened and endangered fisheries. There are also cases where federal water laws may affect or supersede state regulatory programs for water reuse, particularly where water reuse would impact international boundaries (e.g., the Great Lakes, the Tijuana River, the Colorado River), Native American water rights, multiple states with a claim on limited water supplies, water rights on federal property (or on non-reserved lands), instream flow requirements to support threatened and endangered fisheries under the Endangered Species Act (ESA), and other federal reserved water rights. Additional information is available in the 2004 EPA *Guidelines for Water Reuse* Chapter 5 and *Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater* Chapter 10 (EPA, 2004 and NRC, 2012).

4.3.2 Water Supply and Use Regulations

Federal, state, and local entities may set standards for how water may be used as a condition for supply, and these standards can include water use restrictions, water efficiency goals, or water supply reductions. Some of these include criteria for substitution and offset credits associated with use of reclaimed water, and the resulting benefit to the utility provider.

Water use restrictions may serve to promote reuse when water users are required to use potable or reclaimed water for only certain uses under specific conditions. Penalties or consequences for non-compliance may include disconnection of service, fees, fines, or jail time for major infractions. However, other regulations designed to protect water customers from service termination may mitigate or neutralize such penalties. There are generally provisions to allow prohibited or "unreasonable" uses of potable water when reclaimed water is unavailable, unsuitable for a specific use, uneconomical, or would cause negative environmental impacts. An example of California's statutory mandate to utilize reclaimed water is provided in Chapter 5 of the 2004 guidelines.

Mandatory or voluntary water efficiency goals may be promulgated as part of a holistic water management program, often stimulated by public outreach campaigns and incentives. Mandatory goals may carry penalties as described above for water use restrictions. State-wide efficiency requirements may include incentives for localities to meet targets as a prerequisite for grants, loans, allocations, or other benefits. Water reuse may qualify or be required as water efficiency measures such as allowed under Washington State Department of Health's Water Use Efficiency program. Water efficiency is discussed further in Chapter 2.

Water supply reductions are most often imposed during periods of drought and can trigger the invocation of seniority-based water allocations that can result in reduced allocations for those with more junior rights. Water agencies may adopt tiered pricing and allocation strategies. Water shortages often provide an opportunity to increase public awareness of the costs associated with water supply and may provide a powerful basis to develop a state regulatory program for water reuse, particularly where other methods to augment supply are more costly or have been exhausted.

4.3.3 Wastewater Regulations and Related Environmental Regulations

Both the federal government and state agencies exercise jurisdiction over the quality and quantity of wastewater discharge into public waterways of the United States. The primary authority for the regulation of wastewater is the Federal Water Pollution Control Act, commonly referred to as the Clean Water Act (Public Law 92-500). The 1972 CWA assigned the federal government and states specific responsibilities for water quality management designed to make all surface waters "fishable and swimmable." The CWA requires states to set water quality standards, thus establishing the right to control pollution from WWTPs, as long as such regulations are at least as stringent as federal rules. Major objectives of the CWA are to eliminate all pollutant discharges into navigable waters, stop discharges of toxic pollutants in toxic amounts, develop waste treatment management plans to control sources of pollutants, and to encourage (but not require) water reclamation and reuse through delegation agreements. Primary jurisdiction under the CWA is with EPA, but in most states many provisions of the CWA are administered and enforced by the state water pollution control agencies.

Wastewater discharge regulations mostly address treated effluent quality, but can indirectly restrict the quantity of effluent discharged to a receiving body by limiting the pollutant loads resulting from the discharge. Treated wastewater discharge permits are issued pursuant to the NPDES program under the CWA. In addition to limits on the concentration of specific contaminants, discharge permits may also include limits on the total mass of a pollutant discharged to the receiving stream—known as TMDL limits—and on the quality of the water in the receiving stream itself (e.g., minimum DO limits). For reuses that involve a discharge to surface waters, such as IPR or stream augmentation, states may choose to regulate them through the NPDES permit program. In this case, the discharge for the reuse would need to comply, at a minimum, with state surface water quality standards and any TMDLs that would apply to the particular receiving water. Though not specifically addressed, water reuse is encouraged by the CWA.

Discharged water quantity may also be regulated locally by terms of the ESA or specific water rights law as described in Section 4.3.1. The ESA has been applied to require water users to maintain minimum flows in western rivers to protect the habitat of various species of fish whose survival is threatened by increases in water demand. Such regulations may be continuous or seasonal, and may or may not correspond to periods associated with reclaimed water demand as required by the NPDES permit. To ensure compliance with the ESA, state regulatory programs for water reuse should establish a process by which projects that will divert all or a portion of a wastewater treatment facility's effluent from a surface water discharge to consumptive reuse will be coordinated with appropriate federal (i.e., U.S. Fish & Wildlife Service) and state agencies. Consumptive reuse refers to reuse that does not return wastewater back to the wastewater treatment facility or reclamation system from which it received reclaimed water.

4.3.4 Drinking Water Source Protection

Where reclaimed water may impact drinking water sources, the SDWA comes into play. The SDWA is the main federal law that ensures the quality of Americans' drinking water. Under SDWA, EPA sets national health-based standards, or MCLs, for drinking water quality and oversees the states, localities, and water suppliers that implement those standards. SDWA was originally passed by Congress in 1974 and amended in 1986 and 1996. While the original law focused primarily on treatment standards, the 1996 amendments greatly enhanced the existing law by setting requirements for source water protection. The SDWA's Source Water Assessment program requires each state to conduct an assessment of its sources of drinking water (rivers, lakes, reservoirs, springs, and groundwater wells) to identify significant potential sources of water quality contamination. State regulatory programs for water reuse must be compatible and consistent with federal and state SDWA regulatory programs to ensure the protection of drinking water sources (surface and ground).

4.3.5 Land Use

Several western states have adopted laws that require new developments to adopt sustainable water management plans, which may encourage water reuse [US-AZ-Sierra Vista]. In chronically water-short or environmentally-sensitive areas, use of reclaimed water may even be a prerequisite for new developments.

4.4 Suggested Regulatory Guidelines for Water Reuse Categories

As defined in Chapter 1, water reuse for the purposes of these guidelines refers to the use of treated municipal wastewater (reclaimed water). Many states have rules, regulations or guidelines for a wide range of reclaimed water end uses (or reuses), and prescribe different requirements for different reuses. This subsection examines categories of water reuses and suggested regulatory guideline for the water reuses in these categories.

4.4.1 Water Reuse Categories

For the purposes of this chapter, the most common water reuses regulated by states have been inventoried and divided into water reuse categories as described in **Table 4-3**. Minimum suggested regulatory guidelines are presented in **Table 4-4**. Although reuse categories and their descriptions included in an individual state, territory, or tribe's rules, regulations or guidelines may differ from the reuse categories and descriptions presented in **Table 4-3**, the purpose of the information provided therein is to facilitate the comparison of existing rules, regulations and guidelines adopted by states, territories, and tribes and suggest minimum regulatory guidelines using common categories.

4.4.2 Suggested Regulatory Guidelines

Table 4-4 presents suggested treatment processes, reclaimed water quality, monitoring frequency, and setback distances for water reuses in various categories. These guidelines apply to domestic wastewater from municipal or other wastewater treatment facilities having a limited input of industrial waste. The suggested regulatory guidelines are predicated principally on water reclamation and reuse information from the United States and are intended to apply to reclamation and reuse facilities in the United States. These guidelines may also be used by tribal nations in establishing water reuse programs. Local social, economic, regulatory, technological, and other conditions may limit the applicability of these guidelines in some countries (see Chapter 9).

4.4.3 Rationale for Suggested Regulatory Guidelines

The rationale for the suggested treatment processes, reclaimed water quality, monitoring frequency, and setback distances in porous media is based on:

- Water reuse experience in the United States and elsewhere
- Research and pilot plant or demonstration study data
- Technical material from the literature
- Various states' reuse rules, regulations, policies, or guidelines
- Attainability
- Sound engineering practice
- Use with a multiple barrier approach

These guidelines are not intended to be used as definitive water reclamation and reuse criteria. They are intended to provide reasonable guidance for water reuse opportunities, particularly in states that have not developed their own criteria or guidelines.

Adverse health consequences associated with the use of raw or improperly treated wastewater are well documented. As a consequence, water reuse regulations and guidelines are principally directed at public health protection and generally are based on the control of pathogenic microorganisms for nonpotable reuse applications and control of both health-significant microorganisms and chemical contaminants for IPR applications.

Table 4-3 Water reuse categories and number of states with rules, regulations or guidelines addressing these reuse categories [1]

Category of reuse		Description	Number of States or Territories with Rules, Regulations, or Guidelines Addressing Reuse Category
Urban Reuse	**Unrestricted**	The use of reclaimed water for nonpotable applications in municipal settings where public access is not restricted	32
	Restricted	The use of reclaimed water for nonpotable applications in municipal settings where public access is controlled or restricted by physical or institutional barriers, such as fencing, advisory signage, or temporal access restriction	40
Agricultural Reuse	**Food Crops**	The use of reclaimed water to irrigate food crops that are intended for human consumption	27
	Processed Food Crops and Non-food Crops	The use of reclaimed water to irrigate crops that are either processed before human consumption or not consumed by humans	43
Impoundments	**Unrestricted**	The use of reclaimed water in an impoundment in which no limitations are imposed on body-contact water recreation activities (some states categorize snowmaking in this category)	13
	Restricted	The use of reclaimed water in an impoundment where body contact is restricted (some states include fishing and boating in this category)	17
Environmental Reuse		The use of reclaimed water to create, enhance, sustain, or augment water bodies, including wetlands, aquatic habitats, or stream flow	17
Industrial Reuse		The use of reclaimed water in industrial applications and facilities, power production, and extraction of fossil fuels	31
Groundwater Recharge – Nonpotable Reuse		The use of reclaimed water to recharge aquifers that are not used as a potablewater source	16
Potable Reuse	**Indirect Potable Reuse (IPR)**	Augmentation of a drinking water source (surface or groundwater) with reclaimed water followed by an environmental buffer that precedes normal drinking water treatment	9
	Direct Potable Reuse (DPR)	The introduction of reclaimed water (with or without retention in an engineered storage buffer) directly into a water treatment plant, either collocated or remote from the advanced wastewater treatment system	0

[1] Individual state reuse programs often incorporate different terminology so the reader should exercise caution in comparing the categories in these tables directly to state regulatory definitions

Table 4-4 Suggested guidelines for water reuse

Reuse Category and Description	Treatment	Reclaimed Water Quality [2]	Reclaimed Water Monitoring	Setback Distances [3]	Comments
Urban Reuse					
Unrestricted The use of reclaimed water in nonpotable applications in municipal settings where public access is not restricted.	▪ Secondary(4) ▪ Filtration(5) ▪ Disinfection(6)	▪ pH = 6.0-9.0 ▪ ≤ 10 mg/l BOD (7) ▪ ≤ 2 NTU (8) ▪ No detectable fecal coliform /100 ml (9,10) ▪ 1 mg/l Cl_2 residual (min.) (11)	▪ pH – weekly ▪ BOD - weekly ▪ Turbidity - continuous ▪ Fecal coliform - daily ▪ Cl_2 residual – continuous	▪ 50 ft (15 m) to potable water supply wells; increased to 100 ft (30 m) when located in porous media (18)	▪ At controlled-access irrigation sites where design and operational measures significantly reduce the potential of public contact with reclaimed water, a lower level of treatment, e.g., secondary treatment and disinfection to achieve < 14 fecal coli/100 ml may be appropriate. ▪ Chemical (coagulant and/or polymer) addition prior to filtration may be necessary to meet water quality recommendations. ▪ The reclaimed water should not contain measurable levels of pathogens. (12) ▪ Reclaimed water should be clear and odorless. ▪ Higher chlorine residual and/or a longer contact time may be necessary to assure that viruses and parasites are inactivated or destroyed. ▪ Chlorine residual > 0.5 mg/l in the distribution system is recommended to reduce odors, slime, and bacterial regrowth. ▪ See Section 3.4.3 in the 2004 guidelines for recommended treatment reliability requirements.
Restricted The use of reclaimed water in nonpotable applications in municipal settings where public access is controlled or restricted by physical or institutional barriers, such as fencing, advisory signage, or temporal access restriction	▪ Secondary (4) ▪ Disinfection (6) ▪	▪ pH = 6.0-9.0 ▪ ≤ 30 mg/l BOD (7) ▪ ≤ 30 mg/l TSS ▪ ≤ 200 fecal coliform /100 ml (9, 13, 14) ▪ 1 mg/l Cl_2 residual (min.) (11)	▪ pH – weekly ▪ BOD – weekly ▪ TSS – daily ▪ Fecal coliform - daily ▪ Cl_2 residual – continuous	▪ 300 ft (90 m) to potable water supply wells ▪ 100 ft (30 m) to areas accessible to the public (if spray irrigation)	▪ If spray irrigation, TSS less than 30 mg/l may be necessary to avoid clogging of sprinkler heads. ▪ See Section 3.4.3 in the 2004 guidelines for recommended treatment reliability requirements. ▪ For use in construction activities including soil compaction, dust control, washing aggregate, making concrete, worker contact with reclaimed water should be minimized and a higher level of disinfection (e.g. < 14 fecal coli/100 ml) should be provided when frequent worker contact with reclaimed water is likely.
Agricultural Reuse					
Food Crops [15] The use of reclaimed water for surface or spray irrigation of food crops which are intended for human consumption, consumed raw.	▪ Secondary (4) ▪ Filtration (5) ▪ Disinfection (6)	▪ pH = 6.0-9.0 ▪ ≤ 10 mg/l BOD (7) ▪ ≤ 2 NTU (8) ▪ No detectable fecal coliform/100 ml (9,10) ▪ 1 mg/l Cl_2 residual (min.) (11)	▪ pH – weekly ▪ BOD - weekly ▪ Turbidity - continuous ▪ Fecal coliform - daily ▪ Cl_2 residual – continuous	▪ 50 ft (15 m) to potable water supply wells; increased to 100 ft (30 m) when located in porous media (18)	▪ See Table 3-5 for other recommended chemical constituent limits for irrigation. ▪ Chemical (coagulant and/or polymer) addition prior to filtration may be necessary to meet water quality recommendations. ▪ The reclaimed water should not contain measurable levels of pathogens. (12) ▪ Higher chlorine residual and/or a longer contact time may be necessary to assure that viruses and parasites are inactivated or destroyed. ▪ High nutrient levels may adversely affect some crops during certain growth stages. ▪ See Section 3.4.3 in the 2004 guidelines for recommended treatment reliability requirements.
Processed Food Crops [15] The use of reclaimed water for surface irrigation of food crops which are intended for human consumption, commercially processed. ***Non-Food Crops*** The use of reclaimed water for irrigation of crops which are not consumed by humans, including fodder, fiber, and seed crops, or to irrigate pasture land, commercial nurseries, and sod farms.	▪ Secondary (4) ▪ Disinfection (6)	▪ pH = 6.0-9.0 ▪ ≤ 30 mg/l BOD (7) ▪ ≤ 30 mg/l TSS ▪ ≤ 200 fecal coli/100 ml (9,13, 14) ▪ 1 mg/l Cl_2 residual (min.) (11)	▪ pH – weekly ▪ BOD - weekly ▪ TSS - daily ▪ Fecal coliform - daily ▪ Cl_2 residual – continuous	▪ 300 ft (90 m) to potable water supply wells ▪ 100 ft (30 m) to areas accessible to the public (if spray irrigation)	▪ See Table 3-5 for other recommended chemical constituent limits for irrigation. ▪ If spray irrigation, TSS less than 30 mg/l may be necessary to avoid clogging of sprinkler heads. ▪ High nutrient levels may adversely affect some crops during certain growth stages. ▪ See Section 3.4.3 in the 2004 guidelines for recommended treatment reliability requirements. ▪ Milking animals should be prohibited from grazing for 15 days after irrigation ceases. A higher level of disinfection, e.g., to achieve < 14 fecal coli/100 ml, should be provided if this waiting period is not adhered to.

Table 4-4 Suggested guidelines for water reuse

Reuse Category and Description	Treatment	Reclaimed Water Quality [2]	Reclaimed Water Monitoring	Setback Distances [3]	Comments
Impoundments					
Unrestricted The use of reclaimed water in an impoundment in which no limitations are imposed on body-contact.	▪ Secondary (4) ▪ Filtration (5) ▪ Disinfection (6)	▪ pH = 6.0-9.0 ▪ ≤ 10 mg/l BOD (7) ▪ ≤ 2 NTU (8) ▪ No detectable fecal coliform/100 mi (9,10) ▪ 1 mg/l Cl_2 residual (min.) (11)	▪ pH – weekly ▪ BOD – weekly ▪ Turbidity – continuous ▪ Fecal coliform - daily ▪ Cl_2 residual – continuous	▪ 500 ft (150 m) to potable water supply wells (min.) if bottom not sealed	▪ Dechlorination may be necessary to protect aquatic species of flora and fauna. ▪ Reclaimed water should be non-irritating to skin and eyes. ▪ Reclaimed water should be clear and odorless. ▪ Nutrient removal may be necessary to avoid algae growth in impoundments. ▪ Chemical (coagulant and/or polymer) addition prior to filtration may be necessary to meet water quality recommendations. ▪ Reclaimed water should not contain measurable levels of pathogens. (12) ▪ Higher chlorine residual and/or a longer contact time may be necessary to assure that viruses and parasites are inactivated or destroyed. ▪ Fish caught in impoundments can be consumed. ▪ See Section 3.4.3 in the 2004 guidelines for recommended treatment reliability requirements.
Restricted The use of reclaimed water in an impoundment where body-contact is restricted.	▪ Secondary (4) ▪ Disinfection (6)	▪ ≤ 30 mg/l BOD (7) ▪ ≤ 30 mg/l TSS ▪ ≤ 200 fecal coliform/100 ml (9,13, 14) ▪ 1 mg/l Cl_2 residual (min.) (11)	▪ pH – weekly ▪ TSS – daily ▪ Fecal coliform - daily ▪ Cl_2 residual – continuous	▪ 500 ft (150 m) to potable water supply wells (min.) if bottom not sealed	▪ Nutrient removal may be necessary to avoid algae growth in impoundments. ▪ Dechlorination may be necessary to protect aquatic species of flora and fauna. ▪ See Section 3.4.3 in the 2004 guidelines for recommended treatment reliability requirements.
Environmental Reuse					
Environmental Reuse The use of reclaimed water to create wetlands, enhance natural wetlands, or sustain stream flows.	▪ Variable ▪ Secondary (4) and disinfection (6) (min.)	Variable, but not to exceed: ▪ ≤30 mg/l BOD (7) ▪ ≤ 30 mg/l TSS ▪ ≤ 200 fecal coliform/100 ml (9,13, 14) ▪ 1 mg/l Cl_2 residual (min.) (11)	▪ BOD – weekly ▪ SS – daily ▪ Fecal coliform - daily ▪ Cl_2 residual – continuous		▪ Dechlorination may be necessary to protect aquatic species of flora and fauna. ▪ Possible effects on groundwater should be evaluated. ▪ Receiving water quality requirements may necessitate additional treatment. ▪ Temperature of the reclaimed water should not adversely affect ecosystem. ▪ See Section 3.4.3 in the 2004 guidelines for recommended treatment reliability requirements.
Industrial Reuse					
Once-through Cooling	▪ Secondary (4)	▪ pH = 6.0-9.0 ▪ ≤ 30 mg/l BOD (7) ▪ ≤ 30 mg/l TSS ▪ ≤ 200 fecal coliform/100 ml (9,13, 14) ▪ 1 mg/l Cl_2 residual (min.) (11)	▪ pH – weekly ▪ BOD – weekly ▪ TSS – weekly ▪ Fecal coliform - daily ▪ Cl_2 residual – continuous	▪ 300 ft (90 m) to areas accessible to the public	▪ Windblown spray should not reach areas accessible to workers or the public.
Recirculating Cooling Towers	▪ Secondary (4) ▪ Disinfection (6) (chemical coagulation and filtration (5) may be needed)	Variable, depends on recirculation ratio: ▪ pH = 6.0-9.0 ▪ ≤ 30 mg/l BOD (7) ▪ ≤ 30 mg/l TSS ▪ ≤ 200 fecal coliform/100 ml (9,13, 14) ▪ 1 mg/l Cl_2 residual (min.) (11)		▪ 300 ft (90 m) to areas accessible to the public. May be reduced if high level of disinfection is provided.	▪ Windblown spray should not reach areas accessible to workers or the public. ▪ Additional treatment by user is usually provided to prevent scaling, corrosion, biological growths, fouling and foaming. ▪ See Section 3.4.3 in the 2004 guidelines for recommended treatment reliability requirements.
Other Industrial uses – e.g. boiler feed, equipment washdown, processing, power generation, and in the oil and natural gas production market (including hydraulic fracturing) have requirements that depends on site specific end use (See Chapter 3)					
Groundwater Recharge – Nonpotable Reuse					
The use of reclaimed water to recharge aquifers which are not used as a potable drinking water source.	▪ Site specific and use dependent ▪ Primary (min.) for spreading ▪ Secondary (4) (min.) for injection	▪ Site specific and use dependent	▪ Depends on treatment and use	▪ Site specific	▪ Facility should be designed to ensure that no reclaimed water reaches potable water supply aquifers. ▪ See Chapter 3 of this document and Section 2.5 of the 2004 guidelines for more information. ▪ For injection projects, filtration and disinfection may be needed to prevent clogging. ▪ For spreading projects, secondary treatment may be needed to prevent clogging. ▪ See Section 3.4.3 in the 2004 guidelines for recommended treatment reliability requirements.

Table 4-4 Suggested guidelines for water reuse

Reuse Category and Description	Treatment	Reclaimed Water Quality [2]	Reclaimed Water Monitoring	Setback Distances [3]	Comments
Indirect Potable Reuse					
Groundwater Recharge by Spreading into Potable Aquifers	▪ Secondary [(4)] ▪ Filtration [(5)] ▪ Disinfection [(6)] ▪ Soil aquifer treatment	Includes, but not limited to, the following: ▪ No detectable total coliform/100 ml [(9, 10)] • 1 mg/l Cl_2 residual (min.) [(11)] ▪ pH = 6.5 – 8.5 ▪ ≤ 2 NTU [(8)] ▪ ≤ 2 mg/l TOC of wastewater origin ▪ Meet drinking water standards after percolation through vadose zone	Includes, but not limited to, the following: ▪ pH – daily ▪ Total coliform – daily ▪ Cl_2 residual – continuous ▪ Drinking water standards – quarterly ▪ Other [(17)] – depends on constituent ▪ TOC – weekly ▪ Turbidity – continuous ▪ Monitoring is not required for viruses and parasites: their removal rates are prescribed by treatment requirements	▪ Distance to nearest potable water extraction well that provides a minimum of 2 months retention time in the underground.	▪ Depth to groundwater (i.e., thickness to the vadose zone) should be at least 6 feet (2m) at the maximum groundwater mounding point. ▪ The reclaimed water should be retained underground for at least 2 months prior to withdrawal. ▪ Recommended treatment is site-specific and depends on factors such as type of soil, percolation rate, thickness of vadose zone, native groundwater quality, and dilution. ▪ Monitoring wells are necessary to detect the influence of the recharge operation on the groundwater. ▪ Reclaimed water should not contain measurable levels of pathogens after percolation through the vadose zone.[(12)] ▪ See Section 3.4.3 in the 2004 Guidelines for recommended treatment reliability requirements. ▪ Recommended log-reductions of viruses, *Giardia*, and *Cryptosporidium* can be based on challenge tests or the sum of log-removal credits allowed for individual treatment processes. Monitoring for these pathogens is not required. ▪ Dilution of reclaimed water with waters of non-wastewater origin can be used to help meet the suggested TOC limit.
Groundwater Recharge by Injection into Potable Aquifers	▪ Secondary [(4)] ▪ Filtration [(5)] ▪ Disinfection [(6)] ▪ Advanced wastewater treatment [(16)]	Includes, but not limited to, the following: ▪ No detectable total coliform/100 ml [(9, 10)] ▪ 1 mg/l Cl_2 residual (min.) [(11)] ▪ pH = 6.5 – 8.5 ▪ ≤ 2 NTU [(8)] ▪ ≤ 2 mg/l TOC of wastewater origin ▪ Meet drinking water standards	Includes, but not limited to, the following: ▪ pH – daily ▪ Turbidity – continuous ▪ Total coliform – daily ▪ Cl_2 residual – continuous ▪ TOC – weekly ▪ Drinking water standards – quarterly ▪ Other [(17)] – depends on constituent ▪ Monitoring is not required for viruses and parasites: their removal rates are prescribed by treatment requirements	▪ Distance to nearest potable water extraction well that provides a minimum of 2 months retention time in the underground.	▪ The reclaimed water should be retained underground for at least 2 months prior to withdrawal. ▪ Monitoring wells are necessary to detect the influence of the recharge operation on the groundwater. ▪ Recommended quality limits should be met at the point of injection. ▪ The reclaimed water should not contain measurable levels of pathogens at the point of injection. ▪ Higher chlorine residual and/or a longer contact time may be necessary to assure virus inactivation. ▪ See Section 3.4.3 in the 2004 Guidelines for recommended treatment reliability requirements. ▪ Recommended log-reductions of viruses, *Giardia*, and *Cryptosporidium* can be based on challenge tests or the sum of log-removal credits allowed for individual treatment processes. Monitoring for these pathogens is not required. ▪ Dilution of reclaimed water with waters of non-wastewater origin can be used to help meet the suggested TOC limit.
Augmentation of Surface Water Supply Reservoirs	▪ Secondary [(4)] ▪ Filtration [(5)] ▪ Disinfection [(6)] ▪ Advanced wastewater treatment [(16)]	Includes, but not limited to, the following: ▪ No detectable total coliform/100 ml [(9, 10)] ▪ 1 mg/l Cl_2 residual (min.) [(11)] ▪ pH = 6.5 – 8.5 ▪ ≤ 2 NTU [(8)] ▪ ≤ 2 mg/l TOC of wastewater origin ▪ Meet drinking water standards		▪ Site specific – based on providing 2 months retention time between introduction of reclaimed water into a raw water supply reservoir and the intake to a potable water treatment plant.	▪ The reclaimed water should not contain measurable levels of pathogens. [(12)] ▪ Recommended level of treatment is site-specific and depends on factor such as receiving water quality, time and distance to point of withdrawal, dilution and subsequent treatment prior to distribution for potable uses. ▪ Higher chlorine residual and/or a longer contact time may be necessary to assure virus and protozoa inactivation. ▪ See Section 3.4.3 in the 2004 Guidelines for recommended treatment reliability requirements. ▪ Recommended log-reductions of viruses, *Giardia*, and *Cryptosporidium* can be based on challenge tests or the sum of log-removal credits allowed for individual treatment processes. Monitoring for these pathogens is not required. ▪ Dilution of reclaimed water with water of non-wastewater origin can be used to help meet the suggested TOC limit.

Footnotes

(1) These guidelines are based on water reclamation and reuse practices in the U.S., and are specifically directed at states that have not developed their own regulations or guidelines. While the guidelines should be useful in may areas outside the U.S., local conditions may limit the applicability of the guidelines in some countries (see Chapter 9). It is explicitly stated that the direct application of these suggested guidelines will not be used by USAID as strict criteria for funding.

(2) Unless otherwise noted, recommended quality limits apply to the reclaimed water at the point of discharge from the treatment facility.

(3) Setback distances are recommended to protect potable water supply sources from contamination and to protect humans from unreasonable health risks due to exposure to reclaimed water.

(4) Secondary treatment process include activated sludge processes, trickling filters, rotating biological contractors, and may stabilization pond systems. Secondary treatment should produce effluent in which both the BOD and SS do not exceed 30 mg/l.

(5) Filtration means; the passing of wastewater through natural undisturbed soils or filter media such as sand and/or anthracite; or the passing of wastewater through microfilters or other membrane processes.

(6) Disinfection means the destruction, inactivation, or removal of pathogenic microorganisms by chemical, physical, or biological means. Disinfection may be accomplished by chlorination, ozonation, other chemical disinfectants, UV, membrane processes, or other processes.

(7) As determined from the 5-day BOD test.

(8) The recommended turbidity should be met prior to disinfection. The average turbidity should be based on a 24-hour time period. The turbidity should not exceed 5 NTU at any time. If SS is used in lieu of turbidity, the average SS should not exceed 5 mg/l. If membranes are used as the filtration process, the turbidity should not exceed 0.2 NTU and the average SS should not exceed 0.5 mg/l.

(9) Unless otherwise noted, recommended coliform limits are median values determined from the bacteriological results of the last 7 days for which analyses have been completed. Either the membrane filter or fermentation tube technique may be used.

(10) The number of total or fecal coliform organisms (whichever one is recommended for monitoring in the table) should not exceed 14/100 ml in any sample.

(11) This recommendation applies only when chlorine is used as the primary disinfectant. The total chlorine residual should be met after a minimum actual modal contact time of at least 90 minutes unless a lesser contact time has been demonstrated to provide indicator organism and pathogen reduction equivalent to those suggested in these guidelines. In no case should the actual contact time be less than 30 minutes.

(12) It is advisable to fully characterize the microbiological quality of the reclaimed water prior to implementation of a reuse program.

(13) The number of fecal coliform organisms should not exceed 800/100 ml in any sample.

(14) Some stabilization pond systems may be able to meet this coliform limit without disinfection.

(15) Commercially processed food crops are those that, prior to sale to the public or others, have undergone chemical or physical processing sufficient to destroy pathogens.

(16) Advanced wastewater treatment processes include chemical clarification, carbon adsorption, reverse osmosis and other membrane processes, advanced oxidation, air stripping, ultrafiltration, and ion exchange.

(17) Monitoring should include inorganic and organic compounds, or classes of compounds, that are known or suspected to be toxic, carcinogenic, teratogenic, or mutagenic and are not included in the drinking water standards.

(18) See Section 4.4.3.7 for additional precautions that can be taken when a setback distance of 100 ft (30 m) to potable water supply wells in porous media is not feasible.

The suggested regulatory guidelines presented in **Table 4-4** are essentially those contained in the 2004 guidelines (EPA, 2004), with some minor modifications that include the following:

1. Two categories of agricultural reuse (non-food crops and commercially processed food crops) have been combined because the reuse water quality and monitoring recommendations include identical criteria.

2. Information included for IPR guidelines have changed and include changes to TOC and TOX monitoring requirements.

   The minimum recommended guideline for TOC monitoring has been reduced from 3 mg/L to 2 mg/L. Measurement of TOC in reclaimed water is a gross measure of the organic constituents of wastewater origin; due to increasing interest in addressing trace organic compounds in reclaimed water for potable reuses, the minimum recommended TOC has been modified. This is consistent with the move toward using reduced TOC concentrations for monitoring in the new California draft groundwater replenishment regulations (CDPH, 2011), which would require TOC concentrations less than 0.5 mg/L. However, due to the limit of quantitation for analytical instrumentation commonly used for TOC measurements, these guidelines provide a recommendation of 2.0 mg/L, which is more conservative than the 2004 guidelines.

   Because the guidelines already provide recommendations that reclaimed water for IPR uses meet drinking water standards, TOX has been removed. TOX is a gross measurement of halogenated compounds, intended to be an indicator disinfection by-products formed during chlorine disinfection. Primary drinking water standards already include a comprehensive list of halogenated organic compounds. While the list is certainly not comprehensive, it provides a good indication of the presence of disinfection by-products. TOX measurements can have a high level of variability and without additional information on specific compounds does not provide additional information over that provided by TOC and total residual chlorine data.

3. There have been minor changes to the names of the reuse categories as follows:

   a. “Urban reuse” is now “Urban Reuse – Unrestricted”

   b. “”Restricted access irrigation” is now “Urban Reuse – Restricted”

   c. “Recreational impoundments” is now “Impoundments – Unrestricted”

   d. “Landscape impoundments” is now “Impoundments – Restricted”

4.4.3.1 Combining Treatment Process Requirements with Water Quality Limits

The combination of both treatment process requirements and water quality limits are recommended for the following reasons:

- Water quality criteria that include the use of surrogate parameters may not adequately characterize reclaimed water quality.
- A combination of treatment and quality requirements known to produce reclaimed water of acceptable quality obviates the need to routinely monitor the finished water for certain constituents, e.g., some health-significant chemical constituents or pathogenic microorganisms.
- Monitoring of real-time surrogates of key treatment processes for their performance now allows assurances of removal of pathogens. (While new methods are emerging for monitoring of pathogenic microorganisms and chemical constituents that can produce information that may be valuable to the public, routine monitoring is not recommended at this time.)
- Treatment reliability is enhanced.

4.4.3.2 Water Quality Requirements for Disinfection

The guidelines suggest that, regardless of the type of reclaimed water use, some level of disinfection should be provided to avoid adverse health consequences from inadvertent contact or accidental or intentional misuse of a water reuse system. For nonpotable uses of reclaimed water, two disinfection threshold levels are recommended, depending on the probability of human contact. Reclaimed water used for applications where no direct public or worker contact with the water is expected should be disinfected to achieve an average fecal coliform concentration not exceeding 200/100 mL because, at this indicator bacteria concentration:

- Most pathogens will be reduced to low levels
- Disinfection of secondary effluent to this coliform level is readily achievable at minimal cost
- Disinfection to lower levels may not further decrease human health risk, because there is no direct contact with the reclaimed water

For uses where direct or indirect contact with reclaimed water is likely or expected, and for dual water systems where there is a potential for cross-connections with potable water lines, disinfection to produce reclaimed water with no detectable fecal coliform organisms per 100 mL is recommended as a minimum treatment goal. In order to meet this disinfection objective, filtration is generally required. Treatment performance has been shown to produce reclaimed water that is essentially free of measurable levels of bacterial and viral pathogens in volumes of about 10 to 100 L using current culture methods.

For indirect potable uses of reclaimed water, where reclaimed water is intentionally introduced into the raw water supply for the purposes of increasing the total volume of water available for potable use, disinfection to produce reclaimed water having no detectable total coliform organisms per 100 mL is recommended. Total coliform is recommended, in lieu of fecal coliform, to be consistent with the SDWA National Primary Drinking Water Regulations (NPDWR) that regulate drinking water standards for producing potable drinking water.

4.4.3.3 Indicators of Disinfection

It would be impractical to routinely monitor reclaimed water for all of the chemical constituents and pathogenic organisms of concern, and surrogate parameters are universally accepted. In the United States, total and fecal coliforms are the most commonly used indicator organisms in reclaimed water as a measure of disinfection efficiency. While coliforms are used as indicator organisms for many bacterial pathogens, they are, by themselves, poor indicators of parasites and viruses. The total coliform analysis includes enumeration of organisms of both fecal and nonfecal origin, while the fecal coliform analysis is specific for coliform organisms of fecal origin. Therefore, fecal coliforms are better indicators of fecal contamination than total coliforms, and these suggested guidelines use fecal coliform as the indicator organism. Either the multiple-tube fermentation technique or the membrane filter technique may be used to quantify the coliform levels in the reclaimed water. Due to the limitations of the total and fecal bacteria indicators, significant research has gone into determining better indicator species. Alternative indicator organisms that may be adopted in the future for water quality monitoring include *Enterococci* (a genus of bacteria capable of forming spores); Bacteroides (fecal bacteria that have a high degree of host specificity and low potential to proliferate in the environment, allowing for source tracking of fecal contamination); and new choices of bacteriophages (viruses that infect bacteria).

These guidelines do not include suggested specific parasite or virus limits. There has been considerable interest in recent years regarding the occurrence and significance of *Giardia* and *Cryptosporidium* in reclaimed water (Huffman et al., 2006). However, parasite levels, where they have been monitored for at water reuse operations in the United States, and at the treatment and quality limits recommended in these guidelines have been deemed acceptable (e.g., Florida).

Viruses are of concern in reclaimed water, but virus limits are not recommended in these guidelines for the following reasons:

- A significant body of information exists indicating that the enteroviruses are reduced or inactivated to low or non-culturable levels in about 10 to 100 L via appropriate wastewater treatment with disinfection. Adenoviruses, however, are beginning to receive some attention, as they are resistant to UV disinfection.
- The identification and enumeration of viruses in wastewater are hampered by relatively low virus recovery rates, the complexity and high cost of current cell culture laboratory procedures, and the limited number of facilities having the personnel and equipment necessary to perform the analyses.

- The laboratory culturing procedures to determine the presence or absence of pathogenic viruses in a water sample takes about 14 days, and an additional 14 days are required to indentify the viruses. In addition, some enteric viruses do not have permissive cell cultures and therefore cannot be monitored using cell culture techniques.
- Molecular and genomic technology is providing new tools to rapidly detect and quantify viruses in water (e.g., nucleic acid probes and polymerase chain reaction technology), including viruses that are non-culturable. However, molecular and genomic methods currently in use are not able to differentiate between infective and non-infective virus particles. Therefore, these methods are useful in examining physical removal (by filtration, including membranes) but currently cannot fully determine degree of inactivation through disinfection steps. Methods that combine cell culture with molecular and genomic techniques may be able to improve quantification, while also giving an indication of infectivity.
- The value of bacteriophages as indicators for pathogenic viruses is currently an area of debate and ongoing research.
- There have been no documented cases based on limited epidemiological studies of viral disease resulting from water reuse operations in the United States.

4.4.3.4 Water Quality Requirements for Suspended and Particulate Matter

The removal of suspended matter is related to virus removal. Many pathogens are particulate-associated, and that particulate matter can shield both bacteria and viruses from disinfectants such as chlorine and UV. Also, organic matter consumes chlorine, thus making less of the disinfectant available for disinfection. There is general agreement that particulate matter should be reduced to low levels, e.g., 2 NTU or 5 mg/L total suspended solids (TSS), prior to disinfection to ensure reliable destruction of pathogenic microorganisms during the disinfection process. TSS limits are suggested as a measure of organic and inorganic particulate matter in reclaimed water that has received secondary treatment. Suspended solids measurements are typically performed daily on a composite sample and only reflect an average value. Continuously monitored turbidity is superior to daily suspended solids measurements as it provides immediate results that can be used to adjust treatment operations.

4.4.3.5 Water Quality Requirements for Organic Matter

The need to remove suspended organic matter is related to the type of reuse. Some of the adverse effects associated with organic substances are that they are aesthetically displeasing (may be malodorous and impart color), provide food for microorganisms, adversely affect disinfection processes, and consume oxygen. The recommended BOD limit is intended to indicate that the organic matter has been stabilized, is non-putrescible, and has been lowered to levels commensurate with anticipated types of reuse. The recommended BOD and TSS limits are readily achievable at well-operated water reclamation plants.

4.4.3.6 Setback Distances

Many states have established setback distances or buffer zones between wastewater outfalls, reuse irrigation sites, and various facilities such as potable water supply wells, drinking fountains, property lines, residential areas, and roadways. Requirements for setback distances vary depending on the quality of reclaimed water introduced to the environment, and the method of application. Although the suggested setback distances are somewhat subjective, they are intended to protect drinking water supplies from contamination and, where appropriate, to protect humans from exposure to the reclaimed water. In irrigation, the general practice is to limit, through design or operational controls, exposure to aerosols and windblown spray produced from reclaimed water that is not, or only minimally, disinfected.

Setback distances from potable wells are intended to maintain a zone immediately around a well that is not subject to irrigation. Overall the imperative is to control sources of reuse water and its possible contaminant content, and minimize infiltration (movement of water from the surface into the soil), and any vertical or horizontal component of transport of potential contaminants through the subsurface soils. Once the water has infiltrated into the soil formation, the zone of saturation may also encounter zones of preferential flow that can lead to more rapid transport of any contaminant or solute. In media that has highly-variable porosity or transmissivity (e.g., sensitive hydrogeological areas such as karst or fractured bedrock), the ground water residence time is often too uncertain to be useful; or protective. Overall a larger setback distance should be considered in porous soils compared to lower permeability soils. This is because most soils are not well-classified or mapped. In the absence of such information (usually gleaned from geotechnical evaluations), a more conservative setback distance is recommended. These setback distances are often applied also to physical separation between the well and any other non-potable source in another buried conveyance, such as sewer pipes. In addition, most states also have parallel drinking water regulations for well-head protection that identify separation distances from various operations that may introduce water into or onto sensitive areas. Where these separation distances are not achievable, designers/regulators should consider additional precautions (e.g., use area controls or design components) to maintain an adequate margin of public health protection through the potable water system.

The recommended setback distances outlined in Table 4-4 are greater for the Restricted Urban category than the Unrestricted Urban category and greater for the Agricultural Reuse for Processed Food Crops and Non-Food Crops category than for the Agricultural Reuse for Food Crop category. These increased recommended setback distances are to maintain protection of public health, given that the suggested level of treatment and resulting water quality are less stringent than for Unrestricted Urban reuse or Agricultural Reuse for Food Crops.

4.4.3.7 Specific Considerations for IPR

Only a limited number of states have IPR reuse regulations, some of which are implemented through groundwater recharge rules. In states where IPR regulations or guidelines exist, these include requirements for treatment processes and reclaimed water quality and monitoring. States may specify the requirement of a pretreatment program, pilot plant studies, and public hearings. Water quality requirements for IPR typically include limits for TSS, nitrogen, TOC, turbidity, and total coliform. California draft IPR regulations also require limits for specific organics and design requirements for pathogen removal. Most states also specify a minimum time the reclaimed water must be retained in an environmental buffer (e.g., bioretention cells, properly-designed rain gardens, etc.) prior to being withdrawn as a source of drinking water, or the separation distance between a point of recharge and a point of withdrawal. As noted in Table 4-4, it is appropriate to consider increasing the separation distance when the project is located in porous soils.. In this context, the definition of porous media includes soils that are sandy (sand, sandy loam, sandy clay loam, loam), gravels, or interbedding thereof; soil formations wherein clay lenses are not predominant. Other sources of high-transmissivity may be found in rural or urban areas, and call for special consideration of well fields that border construction landfills (where buried construction debris can exhibit high transmissivity), and vacant lots. In addition to IPR regulations, drinking water standards also apply to public water supplies, since the reclaimed water will be processed through a drinking water treatment plant prior to potable reuse.

As needs for alternative water supplies grow, reclaimed water is anticipated to be intentionally used more in potable supply applications, and while no illnesses have been directly connected to the use of properly treated and managed reclaimed water, it is well recognized that the understanding of the risks from constituents of emerging concern is a rapidly evolving field, and that regulatory requirements need to be based on best available science. By example, in California, the SWRCB included a provision in their Recycled Water Policy to establish a Science Advisory Panel to provide guidance for developing monitoring programs that assess potential threats from chemicals of emerging concern (CECs) and pathogens in landscape irrigation and IPR applications.

The Science Advisory Panel's study made the following conclusion about pathogen monitoring in irrigation and IPR:

> *"Given the multiple barrier concept and water treatment process redundancy requirements in place, the Panel believes that the potential public health risk associated with exposure to pathogens in recycled water used for landscape irrigation or groundwater recharge is very small. However, the Panel acknowledges that some uncertainties exist regarding the occurrence of emerging waterborne microbial pathogens and encourages additional research into their fate in water reuse systems." (Anderson et al., 2010)*

Regarding CECs, the panel provided a conceptual framework for determining which CECs should be monitored out of thousands of potential targets and applied the framework to identify a list of chemicals that should be monitored presently, as described in Chapter 6 (Anderson et al., 2010). The Panel also urged California to reapply this prioritization process on at least a triennial basis and establish a state independent review panel that can provide a periodic review to the CEC monitoring efforts. The most recent draft regulations for Groundwater Replenishment Reuse in California would require annual monitoring of an indicator compound with the ability to characterize the presence of pharmaceuticals, endocrine disrupting chemicals, personal care products, and other indicators of the presence of municipal wastewater (CDPH, 2011). In general, as states adopt or update guidelines and regulations for water reuse, an adaptive, risk-based approach to addressing reclaimed water quality monitoring is appropriate (NRC, 2012).

When considering projects that may impact potable aquifers, use of multiple barriers is prudent and designers and regulators may consider the incorporation of additional precautions for public health protection, including:

- Multiple, independent barriers for removing and or transforming microbiological and chemical contaminants. Some emphasis should be placed on gaining a better understanding of soils via focused geotechnical site investigation or review of geotechnical reports for the area of interest.
- Advanced technologies that address a broader variety of contaminants with greater reliability;
- An operational plan with documented retention time and its effectiveness in attenuation of contaminants for a given barrier measure; and a monitoring program tailored to specific barriers and local conditions with appropriate systems to respond to potential system malfunctions.

4.4.4 Additional Requirements

In addition to reclaimed water quality and treatment requirements, states also adopt requirements governing monitoring, reliability, storage, and irrigation application rates. Appendix A of the 2004 guidelines illustrates the difference in state requirements for many of these requirements (EPA, 2004). However, as these requirements are often updated, refer to the state regulatory websites contained in Appendix C for the most current state rules, regulations or guidelines related to water reuse.

4.4.4.1 Reclaimed Water Monitoring Requirements

Water quality monitoring is an important component of reclaimed water projects to ensure that public health and the environment are protected. Monitoring requirements vary greatly from state to state and again depend on the type of reuse. Typical monitoring programs focus on parameters with numeric water reuse criteria, including many of those included in **Table 4-4**, such as BOD, TSS, turbidity, and pathogens or pathogen indicators. Depending on the project and state permitting procedures, monitoring can also include parameters such as salts, minerals, and constituents with MCLs, to determine if the designated uses of receiving waters, both groundwater and surface water, are being protected. Real-time online process monitoring of surrogate parameters is sometimes specified.

Typically, reclaimed water monitoring requirements specify that monitoring be conducted at the water reclamation plant before reclaimed water is distributed for use. However, several states specifically require monitoring of groundwater where reclaimed water is used for irrigation. For groundwater recharge projects, including those to provide saltwater intrusion barriers, monitoring may be required using lysimeters, monitoring wells, or groundwater production wells. For reservoir augmentation projects, monitoring may be required for surface water and treated drinking water. For IPR projects, additional monitoring locations may be required (Crook, 2010).

4.4.4.2 Treatment Facility Reliability

Some states have adopted facility reliability regulations or guidelines in place of, or in addition to, water quality requirements. Generally, these requirements consist of alarms warning of power failure or failure of essential unit processes, automatic standby power sources, emergency storage, and the provision that each treatment process be equipped with multiple units or a back-up unit. These processes are described in Section 2.3.4. Section 4 of the 2004 guidelines describes some of the regulatory approaches with respect to reliability, which generally include specifications for engineered redundancy, system capacity, and backup systems (EPA, 2004).

4.4.4.3 Reclaimed Water Storage

Storage is discussed in Chapter 2. Current regulations and guidelines regarding storage requirements are primarily based upon the need to limit or prevent surface water discharge and are not related to storage required to meet diurnal or seasonal variations in supply and demand for water reuse. Reclaimed water storage requirements vary from state to state and are generally dependent on geographic location, site conditions, and the existence of alternative disposal options. A comparison of regulatory approaches to storage is included in Section 4 of the 2004 guidelines (EPA, 2004).

4.5 Inventory of State Regulations and Guidelines

A survey was conducted to inventory the reuse regulations and guidelines promulgated by U.S. states, tribal communities, and territories for this document. Regulatory agencies in all 50 states and the District of Columbia were contacted to obtain information concerning their current regulations or guidelines governing water reuse. EPA's liaison offices for tribal communities, Guam, Puerto Rico, the U.S. Virgin Islands, American Samoa, and Commonwealth of the Northern Mariana Islands were likewise contacted.

4.5.1 Overall Summary of States' Regulations

Table 4-5 provides a summary of the current regulations and guidelines governing water reuse by state and by reuse category. The table identifies those states that have regulations, those with guidelines and those states that currently do not have either. The table also distinguishes between states where the intent of the regulations or guidelines is oversight of water reuse from states where the intent of the regulations or guidelines is to facilitate disposal and water reuse is considered incidental. This distinction of intent among states' regulations and guidelines can be quite subjective and open to interpretation, but is provided here to capture some of the nuance in interpreting a state's regulatory context.

As of August 2012, 22 states have adopted regulations and 11 states have guidelines or design standards with water reuse as the primary intent. Additionally, eight states and CNMI, a U.S. Pacific Insular Area Territory, have regulations and four have guidelines that implicate water reuse primarily from a disposal perspective. Lastly, 27 states have undergone or just completed revisions to their current reuse regulations or guidelines as shown in **Table 4-5**.

To date, no states have developed or proposed regulations or guidelines specifically governing DPR. However, some states may issue project-specific permits for this reuse with detailed treatment, reclaimed water quality and monitoring requirements. DPR is discussed further in Chapter 3.

A table with links to state regulatory websites is provided in Appendix C. The WateReuse Association will maintain links of the state regulatory sites containing water reuse regulations as links and current regulations are subject to change by the states. Readers may access the state regulations link at <https://www.watereuse.org/government-affairs/usepa-guidelines>.

As shown in **Table 4-5**, 27 states reported undergoing or just completing revisions to their current reuse regulations or guidelines as of August 2012. To date, no states have developed or proposed regulations or guidelines specifically addressing DPR. It should be noted that some states may issue project specific permits with detailed treatment/quality and monitoring requirements. DPR is discussed further in Chapter 3.

4.5.1.1. Case-By-Case Considerations

In states with no specific regulations or guidelines for water reclamation and reuse, projects may still be permitted on a case-by-case basis, such as in Connecticut and Wisconsin. Likewise, some states that do have rules enable consideration of reuse options that are not specifically addressed within their existing rules or regulations. For example, Florida's rules and Virginia's regulations governing water reuse enable these states to permit other uses if the applicant demonstrates that public health will be protected. Several other activities (including use in laundries, vehicle washing, mixing of concrete, and making ice for ice rinks) are specifically identified as being allowable within Florida's reuse rules.

Table 4-5 Summary of State and U.S. Territory water reuse regulations and guidelines*

● The intent of the state's regulations or guidelines is oversight of water reuse

□ The intent of the state's regulations or guidelines is oversight of disposal and water reuse is considered incidental

-- The state does not have water reuse regulations or guidelines but may permit reuse on a case-by-case basis.

State	Regulations	Guidelines	No Regulations or Guidelines (1)	Change from 2004 Edition	Urban Reuse – Unrestricted	Urban Reuse – Restricted	Agricultural Reuse – Food Crops	Agricultural Reuse – Processed Food Crops and Non-Food Crops	Impoundments – Unrestricted	Impoundments – Restricted	Environmental Reuse	Industrial Reuse	Groundwater Recharge – Nonpotable Reuse	Indirect Potable Reuse
Alabama		□				□		□						
Alaska	□							□						
Arizona	●			Update	●	●	●	●		●	●	●	●	●
Arkansas	□			New (2)			□							
California	●			Update	●	●	●	●	●	●		●	●	●
Colorado	●				●	●						●		
Commonwealth of the Northern Mariana Islands (CNMI)	□			(3)		□		□						
Connecticut			--											
Delaware	●			Update	●	●	●	●	●	●		●	□	
District of Columbia			--											
Florida	●			Update	●	●	●	●			●	●	●	●
Georgia		●		Update	●	●		●						
Guam				(4)										
Hawaii		●			●	●	●	●		●		●	●	●
Idaho	●			Update	●	●	●	●				●	●	
Illinois	●				●	●		●						
Indiana	□			Update	□	□	□	□						
Iowa	●					●		●						
Kansas		□			□	□	□	□				□		
Kentucky			--											
Louisiana			--							●				

Table 4-5 Summary of State and U.S. Territory reuse regulations and guidelines*

● The state's regulations or guidelines intent is for the oversight of water reuse

□ The state's regulations or guidelines intent is for the oversight of disposal and water reuse is incidental

-- The state does not have water reuse regulations or guidelines but may permit reuse on a case-by-case basis.

State	Regulations	Guidelines	No Regulations or Guidelines (1)	Change from 2004 Edition	Urban Reuse – Unrestricted	Urban Reuse – Restricted	Agricultural Reuse – Food Crops	Agricultural Reuse – Processed Food Crops and Non-Food Crops	Impoundments – Unrestricted	Impoundments – Restricted	Environmental Reuse	Industrial Reuse	Groundwater Recharge – Nonpotable Reuse	Indirect Potable Reuse
Maine			--											
Maryland		●		Update	●	●		●			●	●	●	
Massachusetts	●			New (2)	●	●	●	●	●	●	●	●	●	●
Michigan	□						□	□						
Minnesota		●		(5)	●	●	●	●	□			●		
Mississippi	□					□		□				□		
Missouri	●					●		●		□	□	□		
Montana	●			Update (6)	●	●	●	●	●	●		●	●	
Nebraska	□			Update	□	□	□	□	●	●		□	●	
Nevada	●			Update	●	●		●		●	●	●		
New Hampshire			--											
New Jersey	●	●		New (7)	●	●	●	●				●		
New Mexico		●		Update (8)	●	●	●	●		●	●	●		
New York			--	(9)										
North Carolina	●			Update	●	●	●	●			●	●		
North Dakota		●		Update	●	●		●	●		●	●	●	
Ohio		●			●	●		●						
Oklahoma	●			Update	●	●		●				●		
Oregon	●			Update (10)	●	●	●	●	●	●		●	●	
Pennsylvania		●			●	●	●	●	●	●	●	●		●
Rhode Island		●		New (11)	●	●		●				●		
South Carolina	●				●	●		●						
South Dakota		□		Update		□	□	□			□		□	

Table 4-5 Summary of State and U.S. Territory reuse regulations and guidelines*

● The state's regulations or guidelines intent is for the oversight of water reuse

□ The state's regulations or guidelines intent is for the oversight of disposal and water reuse is incidental

-- The state does not have water reuse regulations or guidelines but may permit reuse on a case-by-case basis.

State	Regulations	Guidelines	No Regulations or Guidelines (1)	Change from 2004 Edition	Urban Reuse – Unrestricted	Urban Reuse – Restricted	Agricultural Reuse – Food Crops	Agricultural Reuse – Processed Food Crops and Non-Food Crops	Impoundments – Unrestricted	Impoundments – Restricted	Environmental Reuse	Industrial Reuse	Groundwater Recharge – Nonpotable Reuse	Indirect Potable Reuse
Tennessee		□		Update (12)	□	□		□	□	□	□	□		
Texas	●			Update	●	●	●	●	●	●	●	●		
Utah	●					●	●	●		●	●	●		●
Vermont	●					●		□						
Virginia	●			New (13)	●	●	●	●	●	●	●	●	□	●
Washington		●		Update (14)	●	●	●	●	●	●	●	●	●	●
West Virginia	□			(15)			□	□						
Wisconsin	□			Update			□	□				□	□	
Wyoming	●			Update	●	●	●	●				●		

(1) Specific regulations or guidelines on reuse not adopted; however, reuse may be approved on a case-by-case basis
(2) The state had guidelines prior, and now has adopted regulations.
(3) CNMI regulations were not listed in the 2004 guidelines.
(4) Guam has regulations pertaining to Urban Restricted Reuse and Indirect Potable Reuse but they are not regulated by reuse or disposal regulations.
(5) Minnesota has been using the California rules as their Municipal Wastewater Reuse guidance since the mid 90's. This was not reflected in the 2004 guidelines, which indicated that Minnesota had no guidance.
(6) Montana is in the midst of promulgating new reuse regulations, which are anticipated to be finalized by the time of this publication.
(7) The state had guidelines prior, and now has adopted reuse regulations as well as guidelines.
(8) Reclaimed water projects in New Mexico are permitted under either a Ground Water Discharge Permit (which also controls use above ground) or a Construction Industries Permit if use in a building is included.
(9) Current interpretation is that New York has no regulations or guidelines.
(10) Groundwater recharge was added to Oregon's reuse regulations in 2008.
(11) The state previously had no guidelines or regulations and has adopted guidelines.
(12) Tennessee was listed as having regulations in the 2004 Guidelines; however, these were later deemed to be guidelines not regulations.
(13) The state previously had no guidelines or regulations and has adopted regulations.
(14) The Washington State currently has no regulations governing the use of reclaimed water. Draft regulations have been developed by the Department of Ecology in coordination with Department of Health and formal rules advisory committee. The draft rules are incomplete. Adoption of the rules has been delayed until after June 30, 2013. The reclaimed water use statute and formal standards, guidance and procedures adopted in 1997 remain in effect.
(15) In the 2004 guidelines West Virginia was listed as having regulations; however, these appear to be wastewater treatment regulations and do not specifically govern reuse.

* No information is available at this time on regulations or guidelines on water reuse promulgated by federally recognized tribal nations, Puerto Rico, the U.S. Virgin Islands, and American Samoa.

Four case studies specifically focus on policy and regulatory processes in states around the U.S.

Arizona [US-AZ-Blue Ribbon Panel]
This case study describes the special Blue Ribbon Panel on Water Sustainability (BRP) formed by the Governor of Arizona in 2009. The BRP's charge was to focus on water conservation and recycling as strategies to improve water sustainability in Arizona. The BRP was jointly chaired by officials from the ADEQ, Arizona Department of Water Resources (ADWR) and Arizona Corporation Commission (ACC), Arizona's constitutionally established regulatory body for privately owned utilities. The case study describes the participatory process the BRP went through and some of the key recommendations.

California [US-CA-Regulations]
This case study chronicles the evolution of water reuse laws in California, from the first water quality guidance for the use of raw or settled sewage for agricultural irrigation as far back as 1906 through the 2011 draft regulations for IPR.

Virginia [US-VA-Regulations]
Virginia recently completed the process of creating a water reuse regulation and adopted the Virginia Water Reclamation and Reuse Regulation in 2008. This case study describes the multiple state agencies that play a role in regulating water reuse in Virginia and the unique aspects of water reuse in the state.

Washington [US-WA-Regulations]
Washington State has a reclaimed water program governed by comprehensive guidelines that define water quality standards and a variety of allowed beneficial uses. This case study describes how the State Departments of Ecology and Health jointly administer the reclaimed water program and the process since 2006 to develop regulations.

4.5.1.2 Reuse or Treatment and Disposal Perspective

The underlying objectives of regulations and guidelines vary considerably from state to state. States such as Arizona, California, Colorado, Florida, Georgia, Hawaii, Massachusetts, Nevada, New Jersey, New Mexico, North Carolina, Ohio, Oregon, Pennsylvania, Rhode Island, Texas, Utah, Virginia, Washington, and Wyoming have developed regulations or guidelines and standards that strongly encourage water reuse as a water resources conservation strategy. These states have developed comprehensive regulations or guidelines specifying water quality requirements, treatment processes, or both, for the full spectrum of reuse applications. The objective in these states is to derive the maximum resource benefits of the reclaimed water while protecting the environment and public health.

Other states have regulations or guidelines that focus on land treatment of wastewater-derived effluent, emphasizing additional treatment or effluent disposal rather than reuse, even though the effluent may be used for irrigation of agricultural sites, golf courses, or public access lands. When regulations specify application or hydraulic loading rates, the regulations generally pertain to land application systems that are used primarily for additional wastewater treatment for disposal rather than reuse. When systems are developed chiefly for the purpose of land treatment or disposal, the objective is often to dispose of as much effluent on as little land as possible; thus, application rates are often far greater than irrigation demands and limits are set for the maximum hydraulic loading. On the other hand, when the reclaimed water is managed as a valuable resource, the objective is to apply the water according to irrigation needs rather than maximum hydraulic loading, and application limits are rarely specified. Optimal irrigation application rates are based on site conditions (FAO, 1985).

There are many differences in the definition and approach to water reuse between states. Due to these differences, the same practice that may be considered reuse in one state may be considered primarily a means of disposal or additional "land treatment" in another. The primary reuse of reclaimed wastewater in South Dakota is by land application to non-food crops. Although South Dakota has some guidelines on land application to food crops, no one is currently doing this. South Dakota also has a few facilities that are using infiltration or evaporation/ percolation basins as a component of their wastewater treatment facility, rather than a disposal activity. Nevada reports similar use of percolation basins as a disposal activity. Florida, however, would consider this activity reuse by surficial groundwater recharge if the percolation basins were allowed to be loaded and rested alternately.

In most states, the release of reclaimed water to a stream or other water body is still considered and permitted as a point source discharge despite the fact that it may create, enhance or sustain the water bodies receiving that water. In Texas, reuse for stream environmental enhancement or recreational reuse requires a discharge permit if the supplemental discharge point for these reuses will be at a location different from that of the primary discharge location of the treatment facility. For example, SAWS has a discharge permit for the Dos Rios Water Reclamation Facility (into the confluence of the San Antonio and Medina Rivers), one permitted discharge upstream in Salado Creek to maintain creek water quality, and three permitted discharge points into the San Antonio River to maintain flow and water quality in the San Antonio River through the River Walk entertainment area.

4.5.2 Summary of Ten States' Reclaimed Water Quality and Treatment Requirements

Reclaimed water quality and treatment requirements are a significant part of each state's regulations and guidelines for water reuse and may vary among the different reuse categories listed in **Table 4-5** above. Generally, where water reuse involves unrestricted public exposure, reclaimed water must be more highly treated for the protection of public health. Where public exposure is not likely, however, a lower level of treatment is usually acceptable.

Many states include design requirements based on a certain removal of bacterial, viral, or protozoa pathogens for public health protection. Total and fecal coliform counts are generally used as indicator organisms for many bacterial pathogens and provide a measure of disinfection process efficacy. Monitoring of viral indicators is generally not required, though virus removal rates are often prescribed by treatment requirements for system design. A limit on turbidity is usually specified as a real-time monitoring tool to verify the performance of filtration in advanced treatment facilities. The performance of disinfection processes is monitored in real time using chlorine residual or UV intensity, depending on the disinfection method. Disinfection is also verified using bacteria cell culture methods. In addition, water quality limits are generally imposed for BOD and TSS. Water quality parameters are discussed in greater detail in Chapter 6 and monitoring protocols are discussed in Chapter 2.

A summary of the reclaimed water quality and treatment requirements follows of the following 10 states: Arizona, California, Florida, Hawaii, Nevada, New Jersey, North Carolina, Texas, Virginia, and Washington. These states' regulations and guidelines were chosen because these states provide a collective wisdom of successful reuse programs and, in most cases, long-term experience. In addition to water quality and treatment requirements, states provide requirements or guidance on a wide range of other aspects of reuse, such as but not limited to, monitoring, reliability, storage, loading rates, and setback distances. For additional details of state regulations, readers are referred to the state regulatory websites contained in Appendix C of this document.

The following sections generally describe reuse categories that were presented in **Table 4-3**. It is of note that the 10 states, discussed herein, have all established types or levels of reclaimed water based on water quality. States including North Carolina, Virginia, and Texas have established only two types of reclaimed water, while others like Arizona and Washington have a greater number of categories. In any case, the regulatory framework has been established to ensure that the water quality is appropriate for the end use. Information for these 10 representative states is presented in **Tables 4-7** through **4-16**. The reclaimed water quality type or level that applies to the specific reuse category is noted, where applicable, in the header of the table. Additional details on each of the states' reclaimed water types and quality can be found in the links provided in Appendix C.

As a matter of brevity for tabular presentation of information, several abbreviations have been used throughout the tables as noted in **Table 4-6.**

Table 4-6 Abbreviations of terms for state reuse rules descriptions

Term	Abbreviation
Annual	ann
Average	avg
Corrective action threshold	CAT
Day	d
Geometric mean	geom
Hour	hr
Maximum	max
Median	med
Minimum	min
Month	mon
UV dose requirements including: • 100 mJ/cm^2 for media filtration • 80 mJ/cm^2 for membrane filtration • 50 mJ/cm^2 for RO treatment There are additional requirements for bioassay validation and UV system design considerations	NWRI UV Guidelines*
Product of the total residual chlorine and contact time	C_rT**
Total residual chlorine	TRC
Week	wk
Year	yr

*Most states reference either the 2000 or 2003 NWRI Guidelines or reference the most recent version. A new revision to the document was published during preparation of this document and is now available; a description of the updates is provided in Section 6.4.3.2.

** Also abbreviated as CT.

In addition, where TRC is listed in the tables, it is measured after the indicated contact time.

4.5.2.1 Urban Reuse – Unrestricted

Unrestricted urban reuse involves the use of reclaimed water where public exposure is likely in the reuse application, thereby requiring a high degree of treatment. In general, all states that specify a treatment process require a minimum of secondary treatment and disinfection prior to unrestricted urban reuse. However, the majority of states require additional levels of treatment that may include oxidation, coagulation, and filtration. Texas does not specify the type of treatment processes required but sets limits on the reclaimed water quality. At this time, no states have set limits on specific pathogenic organisms for unrestricted urban reuse. However, Florida does require monitoring of *Giardia* and *Cryptosporidium* with sampling frequency based on treatment plant capacity. **Table 4-7** shows the reclaimed water quality and treatment requirements for unrestricted urban reuse for the selected states.

4.5.2.2 Urban Reuse – Restricted

Restricted urban reuse involves the use of reclaimed water where public exposure to the reclaimed water is controlled; therefore, treatment requirements may not be as strict as those for unrestricted urban reuse. Florida imposes the same requirements on both unrestricted and restricted urban access reuse. In general, the states require a minimum of secondary or biological treatment followed by disinfection prior to restricted urban reuse. Florida requires additional levels of treatment with filtration and possibly coagulation prior to restricted urban reuse. As in unrestricted urban reuse, Texas does not specify the type of treatment processes required but sets limits on the reclaimed water quality. At this time, no states have set limits on specific pathogenic organisms for restricted urban reuse. Florida does not require monitoring of *Giardia* and *Cryptosporidium* for Restricted Urban Reuse. **Table 4-8** shows the reclaimed water quality and treatment requirements for restricted urban reuse.

4.5.2.3 Agricultural Reuse – Food Crops

The use of reclaimed water for irrigation of food crops is prohibited in some states, while others allow irrigation of food crops with reclaimed water only if the crop is to be processed and not eaten raw. For example, some of the states that allow for irrigation of food crops, such as Florida, Nevada, and Virginia, require that the reclaimed water does not come in contact with the crop to be eaten or that the crop is peeled or thermally process prior to being eaten, with a few exceptions. Nevada allows only surface irrigation of fruit or nut bearing trees. In Florida, direct contact (spray) irrigation of edible crops that will not be peeled, skinned, cooked, or thermally-processed before consumption is not allowed except for tobacco and citrus. Indirect contact methods (ridge and furrow, drip, subsurface application system) can be used on any type of edible crop. However, other states, such as California, do not have this stipulation but have more stringent quality standards at or near potable quality. Depending on the type of crop or type of irrigation, states' treatment requirements range from secondary treatment and disinfection, to oxidation, coagulation, filtration, and high-level disinfection. North Carolina has specific limits for *Clostridium* and coliphage for indirect contact irrigation for crops that will not be peeled, skinned, or thermally processed. Florida requires monitoring of *Giardia* and *Cryptosporidium* with sampling frequency, reclaimed water quality and treatment requirements as shown in **Table 4-9** for irrigation of food crops.

4.5.2.4 Agricultural Reuse – Processed Food Crops and Non-food Crops

The use of reclaimed water for agricultural irrigation of non-food crops or for food crops intended for human consumption that will be commercially processed presents a reduced opportunity of human exposure to the water, resulting in less stringent treatment and water quality requirements than other forms of reuse. However, in cases where milking animals would graze on fodder crops irrigated with reclaimed water, there are additional requirements for waiting periods for grazing and a higher level of disinfection is recommended, if a waiting period is not adhered to. In the majority of the states, secondary treatment followed by disinfection is required. There are several states that do not require disinfection if certain buffer requirements are met. At this time, no states have set limits on specific pathogenic organisms for agricultural reuse on non-food crops. **Table 4-10** shows the reclaimed water quality and treatment requirements for irrigation of non-food crops.

4.5.2.5 Impoundments – Unrestricted

As with unrestricted urban reuse, unrestricted reuse for impoundments involves the use of reclaimed water where public exposure is likely, thereby requiring a high degree of treatment. Only half of the 10 states (Arizona, California, Nevada, Texas, and Washington) have regulations or guidelines pertaining specifically to unrestricted impoundments. Of these states, only Texas does not specify treatment requirements. It is also of note that neither Arizona nor Nevada allow full-body contact (e.g., wading) in unrestricted impoundments. **Table 4-11** shows reclaimed water quality and treatment requirements for unrestricted impoundments.

4.5.2.6 Impoundments – Restricted

State regulations and guidelines regarding treatment and water quality requirements for restricted reuse for impoundments are generally less stringent than for unrestricted reuse for impoundments because the public exposure to the reclaimed water is less likely. Six of the 10 states (Arizona, California, Hawaii, Nevada, Texas, and Washington) have regulations specifically pertaining to this category of reuse. Texas does not specify treatment process requirements. The remaining states require secondary treatment with disinfection, with some of the states requiring oxidation and filtration. At this time, no states have set limits on specific pathogenic organisms for restricted impoundments reuse. **Table 4-12** shows the reclaimed water quality and treatment requirements for restricted recreational reuse.

4.5.2.7 Environmental Reuse

Florida, Nevada, North Carolina, and Washington have regulations pertaining to the use of reclaimed water to create, enhance, sustain, or augment wetlands, other aquatic habitats, or streamflows. Florida has comprehensive and complex rules governing the discharge of reclaimed water to wetlands. Treatment and disinfection levels are established for different types of wetlands, different types of uses, and the degree of public access. Most wetland systems in Florida are used for tertiary wastewater treatment, and wetland creation, restoration, and enhancement projects can be considered reuse. Washington also specifies different treatment requirements for different types of wetlands and based on the degree of public access. **Table 4-13** shows the reclaimed water quality and treatment requirements for environmental reuse.

4.5.2.8 Industrial Reuse

Eight of the 10 states (California, Florida, Hawaii, Nevada, North Carolina, Texas, Virginia, and Washington) have regulations or guidelines pertaining to industrial reuse of reclaimed water. Arizona and New Jersey review industrial reuse on a case-by-case basis and determine regulations accordingly. Reclaimed water quality and treatment requirements vary based on the final use of the reclaimed water and exposure potential. For example, California has different requirements for the use of reclaimed water as cooling water, based on whether or not a mist is created. In North Carolina, reclaimed water produced by industrial facilities is not required to meet the reuse criteria if the reclaimed water is used in a process that has no public access. Use in toilets and urinals or fire suppression systems will be approved on a case-by-case basis if no risk to public health is demonstrated. **Table 4-14** shows the reclaimed water quality and treatment requirements for industrial reuse.

4.5.2.9 Groundwater Recharge – Nonpotable Reuse

Spreading basins, percolation ponds, and infiltration basins have a long history of providing both effluent disposal and groundwater recharge. Most state regulations allow for the use of relatively low quality water (i.e., secondary treatment with basic disinfection) based on the fact that these systems have a proven ability to provide additional treatment. Traditionally, potable water supplies have been protected by requiring a minimum separation between the point of application and any potable supply wells. These groundwater systems are also typically located so that their impacts to potable water withdrawal points are minimized. While such groundwater recharge systems may ultimately augment potable aquifers, that is not their primary intent and experience suggests current practices are protective of raw water supplies.

California, Florida, Hawaii, and Washington have regulations or guidelines for reuse with the specific intent of groundwater recharge of nonpotable aquifers. Hawaii does not specify required treatment processes, determining requirements on a case-by-case basis. The Hawaii Department of Health Services bases the evaluation on all relevant aspects of each project, including treatment provided, effluent quality and quantity, effluent or application spreading area operation, soil characteristics, hydrogeology, residence time, and distance to withdrawal. Hawaii requires a groundwater monitoring program. Arizona regulates groundwater recharge through their Aquifer Protection Permit process. Washington has extensive guidelines for the use of reclaimed water for direct groundwater recharge of nonpotable aquifers although all aquifers in the state are considered to be potable. Recharge of nonpotable aquifers in Washington first requires the redesignation of the aquifer to nonpotable. **Table 4-15** shows reclaimed water quality and treatment requirements for groundwater recharge via rapid-rate (surface spreading) application systems.

4.5.2.10 Indirect Potable Reuse (IPR)

IPR involves use of reclaimed water to augment surface or groundwater sources that are used or will be used for public water supplies or to recharge groundwater used as a source of public water supply. Unplanned (*de facto*) IPR is occurring in many river systems today. Additionally, many types of reuse projects inadvertently contribute to groundwater as an unintended result of the primary activity. For example, irrigation can replenish groundwater sources that will eventually be withdrawn for use as a potable water supply. IPR systems, as defined here, are distinguished from typical groundwater recharge systems and surface water discharges by both intent and proximity to subsequent withdrawal points for potable water use. IPR involves intentional introduction of reclaimed water into the raw water supply for the purposes of increasing the volume of water available for potable use. In order to accomplish this objective, the point at which reclaimed water is introduced into the environment must be selected to ensure it will flow to the point of withdrawal. Typically the design of these systems assumes there will be little additional treatment in the environment after discharge, and all applicable water quality requirements are met at the point of release of the reclaimed water.

Four of the 10 states (California, Florida, Hawaii, and Washington) have regulations or guidelines specifically pertaining to IPR. For groundwater recharge of potable aquifers, most of the states require a pretreatment program, public hearing requirements prior to project approval, and a groundwater monitoring program. Florida and Washington require pilot plant studies to be performed. In general, all the states that specify treatment processes require secondary treatment with filtration and disinfection. Washington has different requirements for surface percolation, direct groundwater recharge, and streamflow augmentation. Hawaii does not specify the type of treatment processes required, determining requirements on a case-by-case basis. Texas and Virginia do not have specific IPR regulations but review specific projects on a case-by-case basis.

Most states specify a minimum time the reclaimed water must be retained underground prior to being withdrawn as a source of drinking water. Several states also specify minimum separation distances between a point of recharge and the point of withdrawal as a source of drinking water. **Table 4-16** shows the reclaimed water quality and treatment requirements for IPR.

Table 4-7 Urban reuse – unrestricted

		Arizona Class A	California Disinfected Tertiary	Florida	Hawaii R1 Water	Nevada Category A	New Jersey Type I RWBR	North Carolina Type 1	Texas Type I	Virginia Level 1	Washington Class A
Treatment (System Design) Requirements	Unit processes	Secondary treatment, filtration, disinfection	Oxidized, coagulated, filtered, disinfected	Secondary treatment, filtration, high-level disinfection	Oxidized, filtered, disinfected	Secondary treatment, disinfection	Filtration, high-level disinfection	Filtration (or equivalent)	*NS*	Secondary treatment, filtration, high-level disinfection	Oxidized, coagulated, filtered, disinfected
	UV dose, if UV disinfection used	*NS*	NWRI UV Guidelines	NWRI UV Guidelines enforced, variance allowed	NWRI UV Guidelines	*NS*	100 mJ/cm^2 at max day flow	*NS*	*NS*	*NS*	NWRI UV Guidelines
	Chlorine disinfection requirements, if used	*NS*	C_rT > 450 mg·min/L; 90 minutes modal contact time at peak dry weather flow	TRC > 1 mg/L; 15 minutes contact time at peak hr flow[1]	Min residual > 5 mg/L; 90 minutes modal contact time	*NS*	Min residual > 1 mg/L; 15 minutes contact time at peak hr flow	*NS*	*NS*	TRC CAT < 1 mg/L; 30 minutes contact time at avg flow or 20 minutes at peak flow	Chlorine residual > 1 mg/L; 30 minutes contact time (C_rT > 30 may be required
Monitored Reclaimed Water Quality Requirements	BOD_5 (or $CBOD_5$)	*NS*	*NS*	$CBOD_5$: -20 mg/L (ann avg) -30 mg/L (mon avg) -45 mg/L (wk avg) -60 mg/L (max)	30 mg/L or 60 mg/L depending on design flow	30 mg/L (30-d avg)	NS	-10 mg/L (mon avg) -15 mg/L (daily max)	5 mg/L	10 mg/L (mon avg) or $CBOD_5$: 8 mg/L (mon avg)	30 mg/L
	TSS	*NS*	*NS*	5 mg/l (max)	30 mg/L or 60 mg/L depending on design flow	30 mg/L (30-d avg)	5 mg/l	-5 mg/l (mon avg) -10 mg/l (daily max)	*NS*	*NS*	30 mg/L; this limit is superseded by turbidity
	Turbidity	-2 NTU (24-hr avg) -5 NTU (max)	-2 NTU (avg) for media filters -10 NTU (max) for media filters -0.2 NTU (avg) for membrane filters -0.5 NTU (max) for membrane filters	Case-by-case (generally 2 to 2.5 NTU) Florida requires continuous on-line monitoring of turbidity as indicator for TSS	-2 NTU (95-percentile) -0.5 NTU (max)	*NS*	2 NTU (max) for UV	10 NTU (max)	3 NTU	-2 NTU (daily avg), CAT > 5 NTU	-2 NTU (avg) -5 NTU (max)
	Bacterial indicators	Fecal coliform: -none detectable in last 4 of 7 samples -23/100mL (max)	Total coliform: -2.2/100mL (7-day med) -23/100mL (not more than one sample exceeds this value in 30 d) -240/100mL (max)	Fecal coliform: -75% of samples below detection -25/100mL (max)	Fecal coliform: -2.2/100mL (7-day med) -23/100mL (not more than one sample exceeds this value in 30 d) -200/100mL (max)	Total coliform: -2.2/100mL (30-d geom) -23/100mL (max)	Fecal coliform: -2.2/100mL (wk med) -14/100mL (max)	Fecal coliform or *E. coli*: -14/100mL (mon mean) -25/100mL (max)	Fecal coliform or *E. coli:* -20/100mL (30-d geom) -75/100mL (max) *Enterococci:* -4/100mL (30-d geom) -9/100mL (max)	Fecal coliform: -14/100mL (mon geom), CAT > 49/100mL *E. coli:* -11/100mL (mon geom), CAT > 35/100mL *Enterococci:* -11/100mL (mon geom), CAT > 24/100mL	Total coliform -2.2/100mL (7-d med) -23/100mL (max)
	Pathogens	*NS*	*NS*	*Giardia* and *Cryptosporidium* sampling once each 2-yr period for plants ≥1 mgd; once each 5-yr period for plants ≤ 1 mgd	*TR*	*TR*	*NS*	*NS*	*NS*	*NS*	*NS*
	Other	If nitrogen > 10 mg/L, special requirements may be mandated to protect groundwater	-	-	-	-	(NH_3-N + NO_3-N) < 10 mg/L (max)	Ammonia as NH_3-N: -4 mg/L (mon avg) -6 mg/L (daily max)	-	-	Specific reliability or redundancy requirements based on formal reliability assessment

NS = not specified by the state's reuse regulation; TR = monitoring is not required but virus removal rates are prescribed by treatment requirements

[1] In Florida when chlorine disinfection is used, the product of the total chlorine residual and contact time (CrT) at peak hour flow is specified for three levels of fecal coliform as measured prior to disinfection. (See Section 6.4.3.1 for further discussion of CrT.) If the concentration of fecal coliform prior to disinfection: is ≤ 1,000 cfu per 100 mL, the CrT shall be 25 mg·min/L; is 1,000 to 10,000 cfu per 100 mL the CrT shall be 40 mg·min/L; and is ≥ 10,000 cfu per 100 mL the CrT shall be 120 mg·min/L.

Table 4-8 Urban reuse – restricted

		Arizona Class B	California Disinfected Secondary-23	Florida[1]	Hawaii R2 Water	Nevada Category B	New Jersey Type II RWBR	North Carolina[2] Type 1	Texas Type II	Virginia Level 2	Washington Class C
Treatment (System Design) Requirements	Unit processes	Secondary treatment, disinfection	Oxidized, disinfected	*NS*	Oxidized, disinfected	Secondary treatment, disinfection	Case-by-case	Filtration (or equivalent)	*NS*	Secondary treatment, disinfection	Oxidized, disinfected
	UV dose, if UV disinfection used	*NS*	*NS*	*NS*	*NS*	*NS*	75 mJ/cm^2 at max day flow	*NS*	*NS*	NS	NWRI UV Guidelines
	Chlorine disinfection requirements, if used	*NS*	*NS*	*NS*	Chlorine residual > 5 mg/L, actual modal contact time of 10 minutes	*NS*	Chlorine residual > 1 mg/L; 15 minute contact time at peak hr flow	*NS*	*NS*	TRC CAT < 1 mg/L 30 minutes contact time at avg flow or 20 minutes at peak flow	Chlorine residual > 1 mg/L; 30 minutes contact time
Monitored Reclaimed Water Quality Requirements	BOD_5 (CBOD for Florida)	*NS*	*NS*	*NS*	30 mg/L or 60 mg/L depending on design flow	30 mg/L (30-d avg)	*NS*	-10 mg/L(mon avg) -15 mg/L (daily max)	Without pond system: 20 mg/L (or CBOD 15 mg/L) With pond: 30 mg/L	-30 mg/L (mon avg) -45 mg/L (max wk) or $CBOD_5$ -25 mg/L (mon avg) -40 mg/L (max wk)	30 mg/L
	TSS	*NS*	*NS*	*NS*	30 mg/L or 60 mg/L depending on design flow	30 mg/L (30-d avg)	30 mg/L	-5 mg/L (mon avg) -10 mg/L (daily max)	*NS*	-30 mg/L (mon avg) -45 mg/L (max wk)	30 mg/L
	Turbidity	*NS*	*NS*	*NS*	*NS*	NS	*NS*	10 NTU (max)	*NS*	*NS*	*NS*
	Bacterial indicators	Fecal coliform: -less than 200/100mL in last 4 of 7 samples -800/100mL (max)	Total coliform: -23/100mL (7-d med) -240/100 (not more than one sample exceeds this value in 30 d)	*NS*	Fecal coliform: -23/100mL (7-day med) -200/100mL (not more than one sample exceeds this value in 30 d)	Fecal coliform: -2.2/100mL (30-d geom) -23/100mL (max)	Fecal coliform: -200/100mL (mon geom) -400/100mL (wk geom)	Fecal coliform or *E. coli:* -14/100mL (mon mean) -25/100mL (daily max)	Fecal coliform or *E. coli:* -200/100mL (30-d geom) -800/100mL (max) *Enterococci:* -35/100mL (30-day geom) -89/100mL (max)	Fecal coliform: -200/100mL (mon geom), CAT > 800/100mL *E. coli:* -126/100mL (mon geom), CAT > 235/100mL *Enterococci:* -35/100mL (mon geom), CAT > 104/100mL	Total coliform: -23/100mL (7-d med) -240/100mL (max)
	Other	If nitrogen > 10 mg/L, special requirements may be mandated to protect groundwater	-	-	-	-	(NH_3-N + NO_3-N): < 10 mg/L (max)	Ammonia as NH_3-N: -4 mg/L (mon avg) -6 mg/L (daily max)	-	-	-

NS = not specified by the state reuse regulation

[1] Florida does not specifically include urban reuses in its regulations for restricted public access under F.A.C. 62-610-400; requirements for restricted public access reuse are provided in Agricultural Reuse – Non-food Crops, Table 4-9.

[2] There is no expressed designation between unrestricted and restricted urban reuse in North Carolina regulations.

Table 4-9 Agricultural reuse - food crops

		Arizona Class A	California Disinfected Tertiary	Florida[1]	Hawaii R1 Water	Nevada	New Jersey Type III RWBR	North Carolina Processed Type 1	North Carolina NOT processed Type 2	Texas[1] Type I Reclaimed Water	Virginia[3] Level 1	Washington Class A
Treatment (System Design) Requirements	Unit processes	Secondary treatment, filtration, disinfection	Oxidized, coagulated, filtered, disinfected	Secondary treatment, filtration, high-level disinfection	Oxidized, filtered, disinfected	*NP*	Filtration, high-level disinfection	Filtration (or equivalent)	Filtration, dual UV/chlorination (or equivalent)	*NS*	Secondary treatment, filtration, high-level disinfection	Oxidized, coagulated, filtered, disinfected
	UV dose, if UV disinfection used	*NS*	NWRI UV Guidelines	NWRI UV Guidelines enforced, variance allowed	NWRI UV Guidelines	*NP*	100 mJ/cm^2 at max day flow	*NS*	dual UV/chlorination (or equivalent)	*NS*	NS	NWRI UV Guidelines
	Chlorine disinfection requirements, if used	*NS*	C_TT > 450 mg·min/L; 90 minutes modal contact time at peak dry weather flow	TRC > 1 mg/L; 15 minutes contact time at peak hr flow[2]	Min residual > 5 mg/L, actual modal contact time of 90 minutes	*NP*	Min residual > 1 mg/L; 15 minutes contact at peak hr flow	*NS*	dual UV/chlorination (or equivalent)	*NS*	TRC CAT > 1 mg/L; 30 minutes contact time at avg flow or 20 minutes at peak flow	Chlorine residual > 1; 30 minutes contact time
Monitored Reclaimed Water Quality Requirements	BOD$_5$ (or CBOD$_5$)	*NS*	*NS*	CBOD$_5$: -20 mg/L (ann avg) -30 mg/L (mon avg) -45 mg/L (wk avg) -60 mg/L (max)	30 mg/L or 60 mg/L depending on design flow	*NP*	*NS*	-10 mg/L (mon avg) -15 mg/L (daily max)	-5 mg/L (mon avg) -10 mg/L (daily max)	5 mg/L	10 mg/L (mon avg) or CBOD5 8 mg/L (mon avg)	30 mg/L
	TSS	*NS*	*NS*	5 mg/L (max)	30 mg/L or 60 mg/L depending on design flow	*NP*	5 mg/L	-5 mg/L (mon avg) -10 mg/L (daily max)	-5 mg/L (mon avg) -10 mg/L (daily max)	*NS*	*NS*	30 mg/L
	Turbidity	-2 NTU (24-hr avg) -5 NTU (max)	-2 NTU (avg) for media filters -10 NTU (max) for media filters -0.2 NTU (avg) for membrane filters -0.5 NTU (max) for membrane filters	Case-by-case (generally 2 to 2.5 NTU) Florida requires continuous on-line monitoring of turbidity as indicator for TSS	-2 NTU (95-percentile) -0.5 NTU (max)	*NP*	2 NTU (max) for UV	10 NTU (max)	5 NTU (max)	3 NTU	2 NTU (daily avg) CAT > 5 NTU	-2 NTU (avg) -5 NTU (max)
	Bacterial indicators	Fecal coliform: -none detectable in last 4 of 7 samples -23/100mL (max)	Total coliform: -2.2/100mL (7-day med) -23/100mL (not more than one sample exceeds this value in 30 d) -240/100mL (max)	Fecal coliform: -75% of samples below detection -25/100mL (max)	Fecal coliform: -2.2/100mL (7-day med) -23/100mL (not more than one sample exceeds this value in 30 d) -200/100mL (max)	*NP*	Fecal coliform: -2.2/100mL (wk med) -14/100mL (max)	Fecal coliform or *E. coli:* -14/100mL (mon mean) -25/100mL (daily max)	Fecal coliform or *E. coli:* -3/100mL (mon mean) -25/100mL (mon mean)	Fecal coliform or *E. coli:* -20/100mL (30-d geom) -75/100mL (max) *Enterococci:* -4/100mL (30-d geom) -9/100mL (max)	Fecal coliform: -14/100mL (mon geom), CAT > 49/100mL *E. coli:* -11/100mL (mon geom), CAT > 35/100mL *Enterococci:* -11/100mL (mon geom), CAT > 24/100mL	Total coliform: -2.2/100mL (7-d med) -23/100mL (max)
	Viral indicators	*NS*	*NS*	*NS*	*TR*	*NP*	*NS*	*NS*	Coliphage: - 5/100mL (mon mean) - 25/100mL (daily max)	*NS*	*NS*	*NS*
	Pathogens	*NS*	NS	*Giardia, Cryptosporidium* sampling once per 2-yr period for plants ≥ 1 mgd; once per 5-yr period for plants ≤ 1 mgd	-	*NP*	*NS*	*NS*	Clostridium: - 5/100mL (mon mean) - 25/100mL (daily max)	*NS*	*NS*	*NS*
	Other	If nitrogen > 10 mg/L, special requirements may be mandated to protect groundwater	-	-	Oxidized, filtered, disinfected	-	(NH_3-N + NO_3-N): < 10mg/L (max) *Special information, crop tests may be required*	Ammonia as NH_3-N: -4 mg/L (mon avg) -6 mg/L (daily max)	Ammonia as NH_3-N: -1 mg/L (mon avg) -2 mg/L (daily max)	-	-	Specific reliability and redundancy requirements based on formal assessment

NS = not specified by the state's reuse regulation; TR = monitoring is not required but virus removal rates are prescribed by treatment requirement; NP = not permitted by the state

[1] In Texas and Florida, spray irrigation (i.e., direct contact) is not permitted on foods that may be consumed raw (except Florida makes an exception for citrus and tobacco), and only irrigation types that avoid reclaimed water contact with edible portions of food crops (such as drip irrigation) are acceptable.

[2] In Florida when chlorine disinfection is used, the product of the total chlorine residual and contact time (CrT) at peak hour flow is specified for three levels of fecal coliform as measured prior to disinfection. (See Section 6.4.3.1 for further discussion of CrT.) If the concentration of fecal coliform prior to disinfection: is ≤ 1,000 cfu per 100 mL, the CrT shall be 25 mg·min/L; is 1,000 to 10,000 cfu per 100 mL the CrT shall be 40 mg·min/L; and is ≥ 10,000 cfu per 100 mL the CrT shall be 120 mg·min/L.

[3] The requirements presented for Virginia are for food crops eaten raw. There are different requirements for food crops that are processed, which are presented in Table 4-10.

Table 4-10 Agricultural reuse – non-food crops and processed food crops (where permitted)

		Arizona		California Undisinfected Secondary	Florida	Hawaii R2 Water	Nevada[2] Category E	New Jersey Type II RWBR	North Carolina Type 1	Texas Type II	Virginia Level 2	Washington Class C
		Class B	Class C									
Treatment (System Design) Requirements	Unit processes	Secondary treatment, disinfection	Secondary treatment, with or without disinfection	Oxidized	Secondary treatment, basic disinfection	Secondary-23: oxidized, disinfected	Secondary treatment [1]	Case-by-case	Filtration (or equivalent)	*NS*	Secondary treatment, disinfection	Oxidized, disinfected
	UV dose, if UV disinfection used	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	75 mJ/cm^2 at max day flow	*NS*	*NS*	*NS*	NWRI UV Guidelines
	Chlorine disinfection requirements, if used	*NS*	*NS*	*NS*	TRC > 0.5 mg/L; 15 minutes contact time at peak hr flow[1]	Chlorine residual > 5 mg/L; 10 minutes actual modal contact time	*NS*	Chlorine residual > 1 mg/L; 15 minute contact time at peak hr flow	*NS*	*NS*	TRC CAT < 1 mg/L; 30 minutes contact time at avg flow or 20 minutes at peak flow	Chlorine residual > 1 mg/L; 30 minutes contact time
Monitored Reclaimed Water Quality Requirements	BOD_5 (or $CBOD_5$)	*NS*	*NS*	*NS*	$CBOD_5$: -20 mg/L (ann avg) -30 mg/L (mon avg) -45 mg/L (wk avg) -60 mg/L (max)	30 mg/L or 60 mg/L depending on design flow	30 mg/L (30-d avg)	*NS*	-10 mg/L (mon avg) -15 mg/L (daily max)	Without pond: 20 mg/L (or CBOD5 15 mg/L) With pond: 30 mg/L	-30 mg/L (mon avg) -45 mg/L (max wk) or CBOD5 -25 mg/L (mon avg) -40 mg/L (max wk)	30 mg/L
	TSS	*NS*	*NS*	*NS*	-20 mg/L (ann avg) -30 mg/L (mon avg) -45 mg/L (wk avg) -60 mg/L (max)	30 mg/L or 60 mg/L depending on design flow	30 mg/L (30-d avg)	30 mg/L	-5 mg/L (mon avg) -10 mg/L (daily max)	*NS*	-30 mg/L (mon avg) -45 mg/L (max wk)	30 mg/L
	Turbidity	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	10 NTU (max)	*NS*	*NS*	*NS*
	Bacterial indicators	Fecal coliform: -200/100mL in last 4 of 7 samples -800/100mL (max)	Fecal coliform: -1000/100mL in last 4 of 7 samples -4000/100mL (max)	*NS*	Fecal coliform: -200/100mL (avg) -800/100mL (max)	Fecal coliform: -23/100mL (7-day med) -200/100mL (not more than one sample exceeds this value in 30 d)	*NS*	Fecal coliform: -200/100mL (mon geom) -400/100mL (wk geom)	Fecal coliform or *E. coli:* -14/100mL (mon mean) -25/100mL (daily max)	:Fecal coliform or *E. coli:* -200/100mL (30-d geom) -800/100mL (max) *Enterococci:* -35/100mL (30-d geom) -89/100mL (max)	Fecal coliform: -200/100mL (mon geom), CAT > 800/100mL *E. coli:* -126/100mL (mon geom), CAT > 235/100mL *Enterococci:* -35/100mL (mon geom), CAT > 104/100mL	Total coliform: -23/100mL (7-d med) -240/100mL (max)
	Other	If nitrogen > 10 mg/L, special requirements may be mandated to protect groundwater	If nitrogen > 10 mg/L, special requirements may be mandated to protect groundwater	-	-	-	-	(NH_3-N + NO_3-N): < 10 mg/L (max)	Ammonia as NH_3-N: -4 mg/L (mon avg) -6 mg/L (daily max)	-	-	-

NS = not specified by the state's reuse regulation

[1] In Florida when chlorine disinfection is used, the product of the total chlorine residual and contact time (CrT) at peak hour flow is specified for three levels of fecal coliform as measured prior to disinfection. (See Section 6.4.3.1 for further discussion of CrT.) If the concentration of fecal coliform prior to disinfection: is ≤ 1,000 cfu per 100 mL, the CrT shall be 25 mg·min/L; is 1,000 to 10,000 cfu per 100 mL the CrT shall be 40 mg·min/L; and is ≥ 10,000 cfu per 100 mL the CrT shall be 120 mg·min/L.

[2] Nevada prohibits public access and requires a minimum buffer zone of 800 feet for spray irrigation of non-food crops. (Category E, NAC 445A.2771).

Table 4-11 Impoundments – unrestricted

		Arizona[1] Class A	California Disinfected Tertiary	Florida	Hawaii	Nevada	New Jersey	North Carolina	Texas Type I	Virginia Level 1	Washington Class A
Treatment (System Design) Requirements	Unit processes	Secondary treatment, disinfection	Oxidized, coagulated, filtered, disinfected[2]	*NR*	*NR*	*NP*	*NR*	*NS*	*NS*	Secondary treatment, filtration, high-level disinfection	Oxidized, coagulated, filtered and disinfected
	UV dose, if UV disinfection used	*NS*	NWRI UV Guidelines	*NR*	*NR*	*NP*	*NR*	*NS*	*NS*	*NS*	NWRI UV Guidelines
	Chlorine disinfection requirements, if used	*NS*	C_rT > 450 mg·min/L; 90 minutes modal contact time at peak dry weather flow	*NR*	*NR*	*NP*	*NR*	*NS*	*NS*	TRC CAT < 1 mg/L after minimum contact time of 30 mins at avg flow or 20 mins at peak flow	Chlorine residual > 1 mg/L; 30 minutes contact time
Monitored Reclaimed Water Quality Requirements	BOD_5	*NS*	*NS*	*NR*	*NR*	*NP*	*NR*	*NS*	5 mg/L	10 mg/L (mon avg) or $CBOD_5$: 8 mg/L (mon avg)	30 mg/L
	TSS	*NS*	*NS*	*NR*	*NR*	*NP*	*NR*	*NS*	NS	*NS*	30 mg/L
	Turbidity	*NS*	-2 NTU (avg) for media filters -10 NTU (max) for media filters -0.2 NTU (avg) for membrane filters -0.5 NTU (max) for membrane filters	*NR*	*NR*	*NP*	*NR*	*NS*	3 NTU	2 NTU (daily avg), CAT > 5 NTU	-2 NTU (avg) -5 NTU (max)
	Bacterial indicators	Fecal coliform: -none detectable in last 4 of 7 samples -23/100mL (max)	Total coliform: -2.2/100mL (7-day med) -23/100mL (not more than one sample exceeds this value in 30 d) -240/100mL (max)	*NR*	*NR*	*NP*	*NR*	*NS*	Fecal coliform or *E.coli:* -20/100mL (avg) -75/100mL (max) *Enterococci:* -4/100mL (avg) -9/100mL (max)	Fecal coliform: -14/100mL (mon geom), CAT > 49/100mL *E. coli:* -11/100mL (mon geom), CAT > 35/100mL *Enterococci:* -11/100mL (mon geom), CAT > 24/100mL	Total coliform: -2.2/100mL (7-day med) -23/100mL (max)
	Other	If nitrogen > 10 mg/L, special requirements may be mandated to protect groundwater	Supplemental pathogen monitoring	-	-	*NP*	*NR*	-	-	-	Specific reliability and redundancy requirements based on formal assessment

NS = not specified by the state's reuse regulation; NR = not regulated by the state under the reuse program; NP = not permitted by the state

1 Arizona does not allow reuse for swimming or "other full-immersion water activity with a potential of ingestion" [AAC R18-9-704(G)(1)(b)]. Arizona also allows "Class A" and "A+" waters to be used for snowmaking, which is included in this definition.

2 Disinfected tertiary recycled water that has not received conventional treatment shall be sampled/analyzed monthly for *Giardia*, enteric viruses, and *Cryptosporidium* during first 12 months of operation and use. Following the first 12 months, samples will be collected quarterly and ongoing monitoring may be discontinued after the first two years, with approval.

Table 4-12 Impoundments – restricted

		Arizona Class B	California Disinfected Secondary-2.2	Florida	Hawaii R-2 Water	Nevada Category A	New Jersey	North Carolina	Texas Type II	Virginia Level 2	Washington Class B
Treatment (System Design) Requirements	Unit processes	Secondary treatment, disinfection	Oxidized, disinfected	*NR*	Oxidized, disinfected	Secondary treatment, disinfection	*NR*	*NS*	*NS*	Secondary treatment, disinfection	Oxidized, disinfected
	UV dose, if UV disinfection used	*NS*	*NS*	*NR*	*NS*	*NS*	*NR*	*NS*	*NS*	*NS*	NWRI UV Guidelines
	Chlorine disinfection requirements, if used	*NS*	*NS*	*NR*	Chlorine residual > 5 mg/L; actual modal contact time of 10 minutes	*NS*	*NR*	*NS*	*NS*	TRC CAT < 1 mg/L after minimum contact time of 30 mins at avg flow or 20 mins at peak flow	Chlorine residual > 1 mg/L; 30 minutes contact time
Monitored Reclaimed Water Quality Requirements	BOD_5	*NS*	*NS*	*NR*	30 mg/L or 60 mg/L depending on design flow	30 mg/L (30-d avg)	*NR*	*NS*	Without pond: 20 mg/L (or CBOD5 15 mg/L) With pond: 30 mg/L	30 mg/L (mon avg) 45 mg/L (max wk) or $CBOD_5$: 25 mg/L (mon avg) 40 mg/L (max wk)	30 mg/L
	TSS	*NS*	*NS*	*NR*	30 mg/L or 60 mg/L depending on design flow	30 mg/L (30-d avg)	*NR*	*NS*	*NS*	30 mg/L (mon avg) 45 mg/L (max wk)	30 mg/L
	Turbidity	*NS*	*NS*	*NR*	*NS*	*NS*	*NR*	*NS*	*NS*	*NS*	NS
	Bacterial indicators	Fecal coliform: -200/100mL in last 4 of 7 samples -800/100mL (max)	Total coliform: -2.2/100mL (7-d med) -23/100 (not more than one sample exceeds this value in 30 d)	*NR*	Fecal coliform: -23/100mL (7-day med) -200/100mL (not more than one sample exceeds this value in 30 d)	Total coliform: -2.2/100mL (30-d geom) -23/100mL (max)	*NR*	*NS*	Fecal coliform or *E. coli:* -200/100mL (30-d geom) -800/100mL (max) *Enterococci:* -35/100mL (30-d geom) -89/100mL (max)	Fecal coliform: -200/100mL (mon geom), CAT > 800/100mL *E. coli:* -126/100mL (mon geom), CAT > 235/100mL Enterococci: -35/100mL (mon geom), CAT > 104/100mL	Total coliform: -2.2/100mL (7-d med) -23/100mL (max)
	Other	If nitrogen > 10 mg/L, special requirements may be mandated to protect groundwater	-	-	-	-	*NR*	-	-	-	Specific reliability and redundancy requirements based on formal assessment

NS = not specified by the state's reuse regulation; NR = not regulated by the state under the reuse program; TR = monitoring is not required but virus removal rates are prescribed by treatment requirements

Table 4-13 Environmental reuse

		Arizona[1]	California	Florida[2]	Hawaii	Nevada Category C	New Jersey	North Carolina Type 1	Texas	Virginia[4]	Washington Class A
Treatment (System Design) Requirements	**Unit processes**	*NR*	*NR*	Secondary treatment, nitrification, basic disinfection	*NR*	Secondary treatment, disinfection	*NR*	Filtration (or equivalent)	*NR*	*NS*	Oxidized, coagulated, filtered, disinfected
	UV dose, if UV disinfection used	*NR*	*NR*	*NS*	*NR*	*NS*	*NR*	*NS*	*NR*	*NS*	NWRI UV Guidelines
	Chlorine disinfection requirements, if used	*NR*	*NR*	TRC > 0.5 mg/L; 15 minutes contact time at peak hr flow[3]	*NR*	*NS*	*NR*	*NS*	*NR*	*NS*	Chlorine residual > 1 mg/L; 30 minutes contact time
Monitored Reclaimed Water Quality Requirements	**BOD_5 (or $CBOD_5$)**	*NR*	*NR*	$CBOD_5$: -5 mg/L (ann avg) -6.25 mg/L (mon avg) -7.5 mg/L (wk avg) -10 mg/L (max)	*NR*	30 mg/L (30-d avg)	*NR*	-10 mg/L (mon avg) -15 mg/L (daily max)	*NR*	*NS*	20 mg/L
	TSS	*NR*	*NR*	-5 mg/L (ann avg) -6.25 mg/L (mon avg) -7.5 mg/L (wk avg) -10 mg/L (max)	*NR*	30 mg/L (30-d avg)	*NR*	-5 mg/L (mon avg) -10 mg/L (daily max)	*NR*	*NS*	20 mg/L
	Bacterial indicators	*NR*	*NR*	Fecal coliform: -200/100mL (avg) -800/100mL (max)	*NR*	Fecal coliform: -23/100mL (30-d geom) -240/100mL (max)	*NR*	Fecal coliform or *E. coli*: -14/100mL (mon mean) -25/100mL (daily max)	*NR*	*NS*	Total coliform: -2.2/100mL (7-d med) -23/100mL (max)
	Total Ammonia	*NR*	*NR*	-2 mg/L (ann avg) -2 mg/L (mon avg) -3 mg/L (wk avg) -4 mg/L (max)	*NR*	*NS*	*NR*	Ammonia as NH_3-N: -4 mg/L (mon avg) -6 mg/L (daily max)	*NR*	*NS*	Not to exceed chronic standards for freshwater
	Nutrients	*NR*	*NR*	Phosphorus: -1 mg/L (ann avg) -1.25 mg/L (mon avg) -1.5 mg/L (wk avg) -2 mg/L (max) Nitrogen: -3 mg/L (ann avg) -3.75 mg/L (mon avg) -4.5 mg/L (wk avg) -6 mg/L (max)	*NR*	*NS*	*NR*	Phosphorus: 1 mg/L (max)[5] Nitrogen: 4 mg/L (max)[5]	*NR*	*NS*	Phosphorus: 1 mg/L (ann avg)[6]

NS = not specified by the state's reuse regulation; NR = not regulated by the state under the reuse program

[1] Though Arizona reuse regulations do not specifically cover environmental reuse, treated wastewater effluent meeting Arizona's reclaimed water classes is discharged to waters of the U.S. and creates incidental environmental benefits. Arizona's NPDES Surface Water Quality Standards includes a designation for this type of water, "Effluent Dependent Waters."

[2] Florida requirements are for a natural receiving wetland regulated under Florida Administrative Code Chapter 62-611 for Wetlands Application.

[3] In Florida when chlorine disinfection is used, the product of the total chlorine residual and contact time (CrT) at peak hour flow is specified for three levels of fecal coliform as measured prior to disinfection. (See Section 6.4.3.1 for further discussion of CrT.) If the concentration of fecal coliform prior to disinfection: is ≤ 1,000 cfu per 100 mL, the CrT shall be 25 mg·min/L; is 1,000 to 10,000 cfu per 100 mL the CrT shall be 40 mg·min/L; and is ≥ 10,000 cfu per 100 mL the CrT shall be 120 mg·min/L.

[4] Wetlands in Virginia, whether natural or created as mitigation for impacts to existing wetlands, are considered state surface waters; release of reclaimed water into a wetland is regulated as a point source discharge and subject to applicable surface water quality standards of the state.

[5] These limits are not to be exceeded unless net environmental benefits are provided by exceeding these limits.

[6] The phosphorous limit is as an annual average for wetland augmentation/restoration while for stream flow augmentation is the same as that required to NPDES discharge limits, or in other words variable.

Table 4-14 Industrial reuse[1]

		Arizona[2]	California[3] Disinfected Tertiary	Florida[3]	Hawaii[1] R-2 Water	Nevada Category E	New Jersey Type IV RWBR	North Carolina Type 1	Texas[1,5] Type II	Virginia[6] Level 2	Washington[5] Class A
Treatment (System Design) Requirements	**Unit processes**	Individual Reclaimed Water Permit, case-specific[2]	Oxidized, coagulated, filtered, disinfected	Secondary treatment, filtration, high-level disinfection	Oxidized, disinfected	Secondary treatment, disinfection	Case-by-case	Filtration (or equivalent), unless there is no public access or employee exposure	*NS*	Secondary treatment, disinfection	Oxidized, coagulated, filtered and disinfected
	UV dose, if UV disinfection used	*NS*	NWRI UV Guidelines	NWRI UV Guidelines enforced, variance allowed	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	NWRI UV Guidelines
	Chlorine disinfection requirements, if used	*NS*	C_rT > 450 mg·min/L; 90 minutes modal contact time at peak dry weather flow	TRC > 1 mg/L; 15 minutes contact time at peak hr flow[4]	Chlorine residual > 5 mg/L, actual modal contact time of 10 minutes	*NS*	*NS*	*NS*	*NS*	TRC CAT < 1 mg/L; 30 minutes contact time at avg flow or 20 minutes at peak flow	Chlorine residual > 1 mg/L; 30 minutes contact time
Monitored Reclaimed Water Quality Requirements	**BOD_5 (or $CBOD_5$)**	*NS*	*NS*	$CBOD_5$: -20 mg/L (ann avg) -30 mg/L (mon avg) -45 mg/L (wk avg) -60 mg/L (max)	30 mg/L or 60 mg/L depending on design flow	30 mg/L (30-d avg)	*NS*	-10 mg/L (mon avg) -15 mg/L (daily max)	Without pond: 20 mg/L (or CBOD5 15 mg/L) With pond: 30 mg/L	-30 mg/L (mon avg) -45 mg/L (max wk) or $CBOD_5$ -25 mg/L (mon avg) -40 mg/L (max wk)	30 mg/L
	TSS	*NS*	*NS*	5 mg/L (max)	30 mg/L or 60 mg/L depending on design flow	30 mg/L (30-d avg)	Case-by-case	-5 mg/ (mon avg) -10 mg/L (daily max)	*NS*	-30 mg/L (mon avg) -45 mg/L (max wk)	30 mg/L
	Turbidity	*NS*	-2 NTU (avg) for media filters -10 NTU (max) for media filters -0.2 NTU (avg) for membrane filters -0.5 NTU (max) for membrane filters	Case-by-case (generally 2 to 2.5 NTU) Florida requires continuous on-line monitoring of turbidity as indicator for TSS	*NS*	NS	*NS*	10 NTU (max)	*NS*	*NS*	-2 NTU (avg) -5 NTU (max)
	Bacterial indicators	*NS*	Total coliform: -2.2/100mL (7-day med) -23/100mL (not more than one sample exceeds this value in 30 d) -240/100mL (max)	Fecal coliform: -75% of samples below detection -25/100mL (max)	Fecal coliform: -23/100mL (7-day med) -200/100mL (not more than one sample exceeds this value in 30 d)	Fecal coliform: -2.2/100mL (30-d geom) -23/100mL (max)	*NS*	Fecal coliform or *E. coli:* -14/100mL (mon mean) -25/100mL (daily max)	Fecal coliform or *E. coli:* -200/100mL (30-d geom) -800/100mL (max) *Enterococci:* -35/100mL (30-d geom) -89/100mL (max)	Fecal coliform: -200/100mL (mon goem), CAT > 800/100mL *E. coli:* 126/100mL (mon geom), CAT > 235/100mL *Enterococci:* -35/100mL (mon geom) -CAT > 104/100mL	Total coliform: -2.2/100mL (7-d med) -23/100mL (max)
	Pathogens	*NS*	*NS*	*Giardia, Cryptosporidium* sampling once each 2-yr period if high-level disinfection is required	*NS*	*TR*	*NS*	*NS*	*NS*	*NS*	*NS*

NS = not specified by the state's reuse regulation; NR = not regulated by the state under the reuse program; TR = monitoring is not required but virus removal rates are prescribed by treatment requirements

1 All state requirements are for cooling water that creates a mist or with exposure to workers, except for Texas and Hawaii. Texas requirements are for cooling tower makeup water and Hawaii includes industrial processes that do not generate mist, do not involve facial contact with recycled water, and do not involve incorporation into food or drink for humans or contact with anything that will contact food or drink for humans. Additional regulations for other industrial systems are in Appendix A of the 2004 Guidelines.

2 Arizona regulates industrial reuse through issuance of an Individual Reclaimed Water Permit (Arizona Administrative Code [A.A.C.] R18-9-705 and 706), which provides case-specific reporting, monitoring, record keeping, and water quality requirements.

3 For industrial uses in Florida, such as once-through cooling, open cooling towers with minimal aerosol drift and at least a 300 ft setback to the property line, wash water at wastewater treatment plants, or process water at industrial facilities that does not involve incorporation of reclaimed water into food or drink for humans or contact with anything that will contact food or drink for humans, that do not create a mist or have potential for worker exposure, less stringent requirements, such as basic disinfection (e.g., TRC > 0.5 mg/L, no continuous on-line monitoring of turbidity, fecal coliform < 200/100 mL, etc.), secondary treatment standards (e.g., TSS < 20 mg/L annual average, etc.), no sampling for pathogens (except in the case of open cooling towers regardless of setbacks), may apply.

4 In Florida when chlorine disinfection is used, the product of the total chlorine residual and contact time (CrT) at peak hour flow is specified for three levels of fecal coliform as measured prior to disinfection. (See Section 6.4.3.1 for further discussion of CrT.) If the concentration of fecal coliform prior to disinfection: is ≤ 1,000 cfu per 100 mL, the CrT shall be 25 mg·min/L; is 1,000 to 10,000 cfu per 100 mL the CrT shall be 40 mg·min/L; and is ≥ 10,000 cfu per 100 mL the CrT shall be 120 mg·min/L.

5 For industrial uses, that do not create a mist or have potential for worker exposure, less stringent requirements may apply.

6 In Virginia, these are the minimum reclaimed water standards for most industrial reuses of reclaimed water; more stringent standards may apply as specified in the regulation. For industrial reuses not listed in the regulation, reclaimed water standards may be developed on a case-by-case basis relative to the proposed industrial reuse.

Table 4-15 Groundwater recharge - nonpotable reuse[1]

		Arizona[2]	California	Florida[3]	Hawaii	Nevada	New Jersey[5]	North Carolina	Texas	Virginia[6]	Washington Class A
Treatment (System Design) Requirements	**Unit processes**	Regulated by Aquifer Protection Permit[2]	Case-by-case	Secondary treatment, basic disinfection	Case-by-case	*ND*	*NR*	Aquifer Storage and Recovery in accordance with G.S. 143-214.2.	*NR*	*NS*	Oxidized, coagulated, filtered, nitrogen reduced, disinfected
	UV dose, if UV disinfection used	*NS*	*NS*	*NS*	*NS*	*ND*	*NR*	*NR*	*NR*	*NS*	NWRI UV Guidelines
	Chlorine disinfection requirements, if used	*NS*	*NS*	TRC > 0.5 mg/L; 15 minutes contact time at peak hr flow[4]	*NS*	*ND*	*NR*	*NR*	*NR*	*NS*	Chlorine residual > 1 mg/L 30 minutes contact time at peak hr flow
Monitored Reclaimed Water Quality Requirements	**BOD_5 (or $CBOD_5$)**	*NS*	*NS*	$CBOD_5$: -20 mg/L (ann avg) -30 mg/L (mon avg) -45 mg/L (wk avg) -60 mg/L (max)	*NS*	*ND*	*NR*	*NR*	*NR*	*NS*	5 mg/L
	TSS	*NS*	*NS*	-20 mg/L (ann avg) -30 mg/L (mon avg) -45 mg/L (wk avg) -60 mg/L (max)	*NS*	*ND*	*NR*	*NR*	*NR*	*NS*	5 mg/L
	Turbidity	*NS*	*NS*	*NS*	*NS*	*ND*	*NR*	*NR*	*NR*	*NS*	-2 NTU (avg) -5 NTU (max)
	Bacterial indicators	*NS*	*NS*	Fecal coliform: -200/100mL (avg) -800/100mL (max)	*NS*	*ND*	*NR*	*NR*	*NR*	*NS*	Total coliform: -2.2/100mL (7-d med) -23/100mL (max day)
	Total Nitrogen	*NS*	*NS*	NS (nitrate < 12 mg/L)	*NS*	*ND*	*NR*	*NR*	*NR*	*NS*	Case-by-case
	TOC	*NS*	*NS*	*NS*	*NS*	*ND*	*NR*	*NR*	*NR*	*NS*	Case-by-case
	Primary and Secondary Drinking Water Standards	*NS*	*NS*	*NS*	*NS*	*ND*	*NR*	*NR*	*NR*	*NS*	Case-by-case

NR = not regulated by the state under the reuse program; ND = regulations have not been developed for this type of reuse; NS = not specified by the state's reuse regulation

1 All state requirements are for groundwater recharge of a nonpotable aquifer.

2 Groundwater recharge using reclaimed water is pervasive in Arizona but is not considered part of the reclaimed water program; Arizona Department of Environmental Quality (ADEQ) regulates quality under the Department's Aquifer Protection Permit Program (which governs all discharges that might impact groundwater). The Arizona Department of Water Resources (ADWR) oversees a program to limit withdrawals of groundwater to prevent groundwater depletion; municipalities and other entities can offset these pumping limitations by recharging reclaimed water through detailed permits under its Recharge Program.

3 Higher treatment standards may be require, such as filtration, high level disinfection, total nitrogen below 10 mg/L, and meeting primary and secondary drinking water standards, if there may be a connection to a potable aquifer or other conditions such as groundwater recharge overlying the Biscayne Aquifer in Southeast Florida.

4 In Florida when chlorine disinfection is used, the product of the total chlorine residual and contact time (CrT) at peak hour flow is specified for three levels of fecal coliform as measured prior to disinfection. (See Section 6.4.3.1 for further discussion of CrT.) If the concentration of fecal coliform prior to disinfection: is ≤ 1,000 cfu per 100 mL, the CrT shall be 25 mg·min/L; is 1,000 to 10,000 cfu per 100 mL the CrT shall be 40 mg·min/L; and is ≥ 10,000 cfu per 100 mL the CrT shall be 120 mg·min/L.

5 All discharges to groundwater for nonpotable reuse are regulated via a New Jersey Pollutant Discharge Elimination System Permit in accordance with N.J.A.C. 7:14A-1 et seq. and must comply with applicable Groundwater Quality Standards (N.J.A.C. 7:9C).

6 In Virginia, groundwater recharge of a nonpotable aquifer may be regulated in accordance with regulations unrelated to the Water Reclamation and Reuse Regulation (9VAC25-740).

Table 4-16 Indirect potable reuse (IPR)

											Washington		
		Arizona[1]	California[2]	Florida[4]	Hawaii	Nevada	New Jersey[7]	North Carolina	Texas	Virginia	Surface Percolation Class A	Direct Groundwater Recharge[8] Class A	Streamflow Augmentation Case-by-case
Treatment (System Design) Requirements	Unit processes	*NR*	Oxidized, coagulated, filtered, disinfected, multiple barriers for pathogen and organics removal	Secondary treatment, filtration, high-level disinfection, multiple barriers for pathogen and organics removal	Case-by-case	*ND*	*NR*	*NR*	Case-by-case	Case-by-case	Oxidized with nitrogen reduction, filtered, disinfected	Oxidized, coagulated, filtered, RO-treated, disinfected	Oxidized, clarified, disinfected
	UV dose, if UV disinfection used	*NR*	NWRI Guidelines[3]	NWRI UV Guidelines enforced, variance allowed	*NS*	*ND*	*NR*	*NR*	*NS*	*NS*	NWRI Guidelines	NWRI Guidelines	NWRI Guidelines
	Chlorine disinfection requirements, if used	*NR*	C_rT > 450 mg·min/L; 90 minutes modal contact time at peak dry weather flow[3]	TRC > 1 mg/L; 15 minutes contact time at peak hr flow[5]	*NS*	*ND*	*NR*	*NR*	*NS*	*NS*	Chlorine residual > 1 mg/L; 30 minutes contact time at peak hr flow	Chlorine residual > 1 mg/L; 30 minutes contact time at peak hr flow	Chlorine residual to comply with NPDES permit
Monitored Reclaimed Water Quality Requirements	BOD_5 (or $CBOD_5$)	*NR*	*NS*	$CBOD_5$: -20 mg/L (ann avg) -30 mg/L (mon avg) -45 mg/L (wk avg) -60 mg/L (max)	*NS*	*ND*	*NR*	*NR*	5 mg/L	*NS*	30 mg/L	5 mg/L	30 mg/L
	TSS	*NR*	*NS*	5 mg/L (max)	*NS*	*ND*	*NR*	*NR*	*NS*	*NS*	30 mg/L	5 mg/L	30 mg/L
	Turbidity	*NR*	-2 NTU (avg) for media filters -10 NTU (max) for media filters -0.2 NTU (avg) for membrane filters -0.5 NTU (max) for membrane filters	Case-by-case (generally 2 to 2.5 NTU) Florida requires continuous on-line monitoring of turbidity as indicator for TSS	*NS*	*ND*	*NR*	*NR*	3 NTU	*NS*	-2 NTU (avg) -5 NTU (max)	-0.1 NTU (avg) -0.5 NTU (max)	*NS*
	Bacterial indicators	*NR*	Total coliform: -2.2/100mL (7-day med) -23/100mL (not more than one sample exceeds this value in 30 d) -240/100mL (max)	Total coliform: -4/100mL (max)	*NS*	*ND*	*NR*	*NR*	Fecal coliform or *E. coli* -20/100mL (30-d geom) -75/100mL (max) Enterococci -4/100mL (30-d geom) -9/100mL (max)	*NS*	Total coliform: -2.2/100 (7-d med) -23/100 (max)	Total coliform: -1/100mL (avg) -5/100mL (max)	Fecal coliform: -200/100mL (avg) -400/100mL (max wk)
	Total Nitrogen	*NR*	10 mg/l (avg of 4 consecutive samples)	10 mg/L (ann avg)	*NS*	*ND*	*NR*	*NR*	*NS*	*NS*	NA	10 mg/L	NPDES requirements to receiving stream
	TOC	*NR*	0.5 mg/L	-3 mg/L (mon avg) -5 mg/L (max); TOX[6]: < 0.2 (mon avg) or 0.3 mg/L (max); alternate limits allowed	*NS*	*ND*	*NR*	*NR*	*NS*	*NS*	NA	1 mg/L	NS
	Primary and Secondary Drinking Water Standards	*NR*	Compliance with most primary and secondary	Compliance with most primary and secondary	*NS*	*ND*	*NR*	*NR*	*NS*	*NS*	Compliance with SDWA MCLs	Compliance with most primary and secondary	NPDES requirements to receiving stream
	Pathogens	*NR*	*TR*	*Giardia, Cryptosporidium* sampling quarterly	*NS*	*ND*	*NR*	*NR*	*NS*	*NS*	*NS*	*NS*	*NS*

NS = not specified by the state's reuse regulation; NR = not regulated by the state under the reuse program; ND = regulations have not been developed for this type of reuse; TR = monitoring is not required but virus removal rates are prescribed by treatment requirements

[1] Arizona currently does not have IPR regulations; however, ADEQ regulates recharge facilities where mixed groundwater-reclaimed water may be recovered by a drinking water well through its Aquifer Protection Permit program (see Groundwater Recharge). The Governor's Blue Ribbon Panel on Water Sustainability issued a Report including a recommendation to develop a more robust regulatory/policy program to address IPR [US-AZ-Blue Ribbon Panel].

[2] These requirements are DRAFT and were taken from CDPH *Draft Regulations for Groundwater Replenishment with Recycled Water* (CDPH, 2011).

[3] Additional pathogen removal is required for groundwater recharge through other treatment processes in order to achieve 12 log enteric virus reduction, 10 log *Giardia* cyst reduction, and 10 log *Cryptosporidium* oocysts reduction.

[4] Florida requirements are for the planned use of reclaimed water to augment Class F-I, G-I or G-II groundwaters (US drinking water sources) with a background TDS of 3,000 mg/L or less. For G-II groundwaters greater than 3,000 mg/L TDS, the TOC and TOX limits do not apply. Florida also includes discharges to Class I surface waters (public water supplies) or discharges less than 24 hours travel time upstream from Class I surface waters as IPR. For discharge to Class I surface waters or water contiguous to or tributary to Class I waters (defined as a discharge located less than or equal to 4 hours travel time from the point of discharge to arrival at the boundary of the Class I water), secondary treatment with filtration, high-level disinfection, and any additional treatment required to meet TOC and applicable surface water quality limits is required. The reclaimed water must meet primary and secondary drinking water standards, except for asbestos, prior to discharge. The TOX limit does not apply and a total nitrogen limit is based on the surface water quality. Outfalls for surface water discharges are not to be located within 500 feet (150 m) of existing or approved potable water intakes within Class I surface waters. Pathogen monitoring for Class I surface water augmentation is the same, except that if discharge is 24 to 48 hr travel time from domestic water supply, *Giardia, Cryptosporidium* sampling is once every 2 years.

[5] In Florida when chlorine disinfection is used, the product of the total chlorine residual and contact time (CrT) at peak hour flow is specified for three levels of fecal coliform as measured prior to disinfection. (See Section 6.4.3.1 for further discussion of CrT.) If the concentration of fecal coliform prior to disinfection: is ≤ 1,000 cfu per 100 mL, the CrT shall be 25 mg·min/L; is 1,000 to 10,000 cfu per 100 mL the CrT shall be 40 mg·min/L; and is ≥ 10,000 cfu per 100 mL the CrT shall be 120 mg·min/L.

[6] Total organic halides (TOX) are regulated in Florida.

[7] For groundwater recharge reuse is on a case-by-case basis, State Groundwater Quality Standards must be met.

[8] Washington requires the minimum horizontal separation distance between the point of direct recharge and point of withdrawal as a source of drinking water supply to be 2,000 feet (610 meters) and must be retained underground for a minimum of 12 months prior to being withdrawn as a drinking water supply.

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CHAPTER 5
Regional Variations in Water Reuse

This chapter summarizes current water use in the United States, discusses expansion of water reuse nationally to meet water needs, provides an overview of numerous water reuse case studies within the United States compiled for this document, and discusses variations pertaining to water reuse among different regions across the country. Representative water reuse practices are also described for each region.

5.1 Overview of Water Use and Regional Reuse Considerations

This section describes the sources, volumes, and uses of freshwater in the United States.

5.1.1 National Water Use

According to the USGS, total U.S. water use in 2005 was 410,000 mgd (1.55 billion m^3/d), up from 402,000 mgd (1.52 billion m^3/d) in 1995 (Kenny et al., 2009). Freshwater withdrawals made up 85 percent of the total, with the remaining 15 percent saline water withdrawals, mostly where seawater and brackish coastal water is used to cool thermoelectric power plants. About 80 percent of the total withdrawals were from surface water sources, with the remaining 20 percent of withdrawals sourcing groundwater (mostly freshwater as opposed to saline groundwater).

As illustrated in **Figure 5-1**, the largest freshwater demands were associated with thermoelectric power and agriculture (irrigation, aquaculture, and livestock). Thermoelectric power plant cooling uses freshwater (34 percent of total withdrawals) and nearly all of the saline water withdrawals (15 percent of total withdrawals), totaling 49 percent of the demand. Agriculture requires freshwater for irrigation (31 percent of total withdrawals), aquaculture (2 percent), and livestock (1 percent), for a total of 34 percent of total withdrawals in the United States. Public supply and domestic self-supply water uses constitute 12 percent of the total demand. The remaining categories of industrial and mining water uses together were less than 5 percent of total water withdrawals estimated in this report (Kenny et al., 2009). Even though reclaimed water can be a significant source of cooling water for power plants (particularly in Arizona, California, Florida, and Texas), the 2005 USGS report did not include specific volumes of reclaimed water in the reference tables and figures (Kenny et al., 2009). The report tabulated water withdrawals from fresh surface water and groundwater and saline groundwater. The freshwater volumes did not recognize contributions from reclaimed water augmentation or wastewater plant discharges that contributed to the source water.

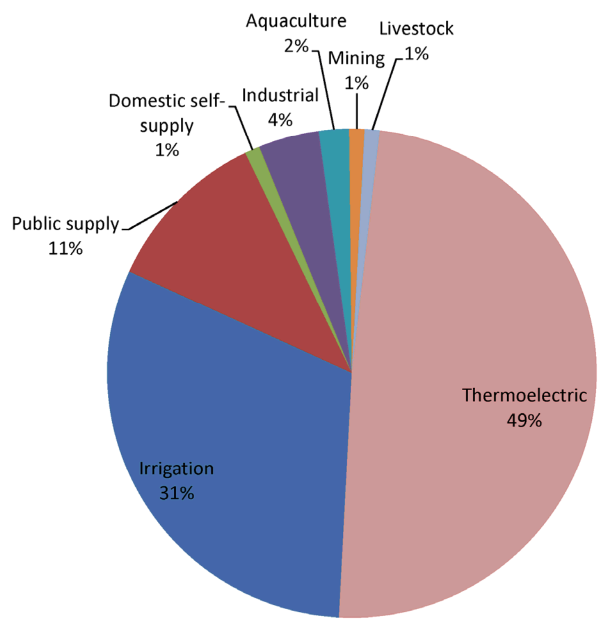

Figure 5-1
Freshwater use by category in the United States (Source: Kenny et al., 2009)

Treated municipal wastewater represents a significant potential source of reclaimed water. As a result of the Federal Water Pollution Control Act Amendments of 1972, the CWA of 1977 and its subsequent amendments, centralized wastewater treatment has become commonplace in urban areas of the United States. Within the United States, the population generates an estimated 32 bgd (121 million m^3/d) of municipal wastewater. The NRC Water Science & Technology Board estimates that a third of this could be reused (GWI, 2010; Miller, 2011; and NRC, 2012). Currently only about 7 to 8 percent of this water is reused, leaving a large area for potential expansion of the use of reclaimed water in the future (GWI, 2010 and Miller, 2012). As the world population continues to shift from rural to urban, the number of centralized wastewater collection and treatment systems will also increase, creating significant opportunities to implement reclaimed water systems to augment water supplies and, in many cases, improve the quality of surface waters.

A key issue nationally in water reuse is the existing potable water rates. Low potable water rates typically make water reuse less favorable. A comparison of potable and reclaimed water rates is provided in **Table 7-1.**

5.1.2 Examples of Reuse in the United States

High water demand areas might benefit by augmenting existing water supplies with reclaimed water. Arid regions of the United States (such as the Southwest) are natural candidates for water reclamation, and significant reclamation projects are underway throughout this region. Yet, arid regions are not the only viable candidates for water reuse. As shown in **Figure 5-2**, water reuse is practiced widely throughout much of the United States, according to a survey conducted for this document. While the survey of reuse locations is not exhaustive, the information collected is meant to illustrate how widespread water reuse is in the United States. Data sources consulted for this survey included:

- WRA database of water reuse installations
- California SWRCB inventory of reuse projects in California, available online (SWRCB, 2011)
- FDEP inventory of reuse projects in Florida, available online (FDEP, 2011a)
- Tennessee water reuse survey provided online by Tennessee Tech University (TTU) for years 2006 to 2011 (TTU, 2012)
- TCEQ list of reuse installations
- North Carolina Department of Environment and Natural Resources Division of Water Quality inventory of reuse installations
- Georgia Environmental Protection Division inventory of reuse installations
- Case studies discussed in the 2004 EPA *Guidelines for Water Reuse*
- Locations mentioned by other state regulators and experts in the review of this chapter

Figure 5-2 also shows the location of United States case studies on reclaimed water projects that were collected for this document to show the wide variety of types of applications. The case studies can be found in Appendix D. The map legend indicates the full title and authors of the case study, and provides a link to the location of the case study in the Appendix.

5.2 Regional Considerations

This section provides an overview of the context for water reuse in the United States. For the purposes of this document, states have been combined into eight regions corresponding with EPA's regional division of the nation. The regions and states within each region are as follows:

Northeast: (EPA Regions 1 and 2) Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont, Puerto Rico, the U.S. Virgin Islands (USVI), and eight federally recognized tribal nations.

Mid-Atlantic: (EPA Region 3) Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, and West Virginia.

Southeast: (EPA Region 4) Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.

Midwest and Great Lakes: (EPA Regions 5 and 7) Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, Ohio, and Wisconsin.

South Central: (EPA Region 6) Arkansas, Louisiana, New Mexico, Oklahoma, and Texas.

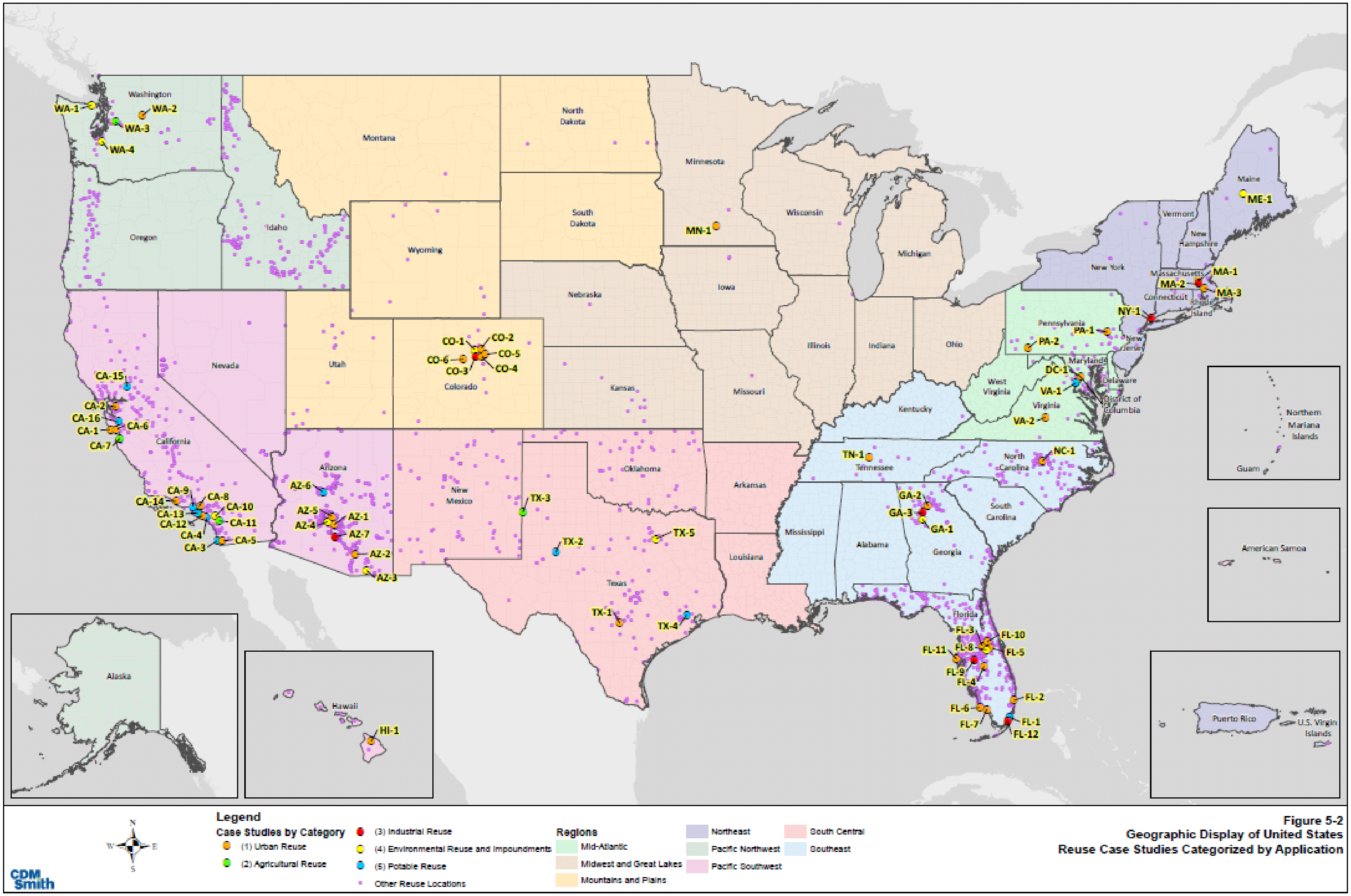

Figure 5-2
Geographic Display of United States
Reuse Case Studies Categorized by Application

Figure 5-2 Legend

Map Code	Text code	Case Study Name
AZ-1	US-AZ-Gilbert	Town of Gilbert Experiences Growing Pains in Expanding the Reclaimed Water System
AZ-2	US-AZ-Tucson	Tucson Water: Developing a Reclaimed Water Site Inspection Program
AZ-3	US-AZ-Sierra Vista	Environmental Operations Park
AZ-4	US-AZ-Phoenix	91st Avenue Unified Wastewater Treatment Plant Targets 100 Percent Reuse
AZ-5	US-AZ-Blue Ribbon Panel	Arizona Blue Ribbon Panel on Water Sustainability
AZ-6	US-AZ-Prescott Valley	Effluent Auction in Prescott Valley, Arizona
AZ-7	US-AZ-Frito Lay	Frito-Lay Process Water Recovery Treatment Plant, Casa Grande, Arizona
CA-1	US-CA-Psychology	The Psychology of Water Reclamation and Reuse: Survey Findings and Research Roadmap
CA-2	US-CA-San Ramon	Managing a Recycled Water System through a Joint Powers Authority: San Ramon Valley
CA-3	US-CA-San Diego	City of San Diego – Water Purification Demonstration Project
CA-4	US-CA-Orange County	Groundwater Replenishment System, Orange County, California
CA-5	US-CA-North City	EDR at North City Water Reclamation Plant
CA-6	US-CA-Santa Cruz	Water Reuse Study at the University of California Santa Cruz Campus
CA-7	US-CA-Monterey	Long-term Effects of the Use of Recycled Water on Soil Salinity Levels in Monterey County
CA-8	US-CA-Southern California MWD	Metropolitan Water District of Southern California's Local Resource Program
CA-9	US-CA-Los Angeles County	Montebello Forebay Groundwater Recharge Project using Reclaimed Water, Los Angeles County, California
CA-10	US-CA-Elsinore Valley	Recycled Water Supplements Lake Elsinore
CA-11	US-CA-Temecula	Replacing Potable Water with Recycled Water for Sustainable Agricultural Use
CA-12	US-CA-Santa Ana River	Water Reuse in the Santa Ana River Watershed
CA-13	US-CA-VanderLans	Leo J. Vander Lans Water Treatment Facility
CA-14	US-CA-Pasteurization	Use of Pasteurization for Pathogen Inactivation for Ventura Water, California
CA-15	US-CA-Regulations	California State Regulations
CA-16	US-CA-West Basin	West Basin Municipal Water District: Five Designer Waters
CO-1	US-CO-Denver Zoo	Denver Zoo
CO-2	US-CO-Denver	Denver Water
CO-3	US-CO-Denver Energy	Xcel Energy's Cherokee Station
CO-4	US-CO-Denver Soil	Effects of Recycled Water on Soil Chemistry
CO-5	US-CO-Sand Creek	Sand Creek Reuse Facility Reuse Master Plan
CO-6	US-CO-Water Rights	Water Reuse Barriers in Colorado
DC-1	US-DC-Sidwell Friends	Smart Water Management at Sidwell Friends School
FL-1	US-FL-Miami So District Plant	South District Water Reclamation Plant
FL-2	US-FL-Pompano Beach	City of Pompano Beach OASIS
FL-3	US-FL-Orlando E. Regional	Eastern Regional Reclaimed Water Distribution System
FL-4	US-FL-Economic Feasibility	Economic Feasibility of Reclaimed Water to Users
FL-5	US-FL-Reedy Creek	Reuse at Reedy Creek Improvement District
FL-6	US-FL-Marco Island	Marco Island, Florida, Wastewater Treatment Plant
FL-7	US-FL-Everglade City	Everglade City, Florida
FL-8	US-FL-Orlando Wetlands	City of Orlando Manmade Wetlands System

Figure 5-2 Legend

Map Code	Text code	Case Study Name
FL-9	US-FL-SWFWMD Partnership	Regional Reclaimed Water Partnership Initiative of the Southwest Florida Water Management District
FL-10	US-FL-Altamonte Springs	The City of Altamonte Springs: Quantifying the Benefits of Water Reuse
FL-11	US-FL-Clearwater	Evolution of the City of Clearwater's Integrated Water Management Strategy
FL-12	US-FL-Turkey Point	Assessing Contaminants of Emerging Concern (CECs) in Cooling Tower Drift
GA-1	US-GA-Clayton County	Sustainable Water Reclamation Using Constructed Wetlands: The Clayton County Water Authority Success Story
GA-2	US-GA-Forsyth County	On the Front Lines of a Water War, Reclaimed Water Plays a Big Role in Forsyth County, Georgia
GA-3	US-GA-Coca Cola	Recovery and Reuse of Beverage Process Water
HI-1	US-HI-Reuse	Reclaimed Water Use in Hawaii
MA-1	US-MA-Southborough	Sustainability and LEED Certification as Drivers for Reuse: Toilet Flushing at The Fay School
MA-2	US-MA-Hopkinton	Decentralized Wastewater Treatment and Reclamation for an Industrial Facility, EMC Corporation Inc., Hopkinton, Massachusetts
MA-3	US-MA-Gillette Stadium	Sustainability and Potable Water Savings as Drivers for Reuse: Toilet Flushing at Gillette Stadium
ME-1	US-ME-Snow	Snowmaking with Reclaimed Water
MN-1	US-MN-Mankato	Reclaimed Water for Peaking Power Plant: Mankato, Minnesota
NC-1	US-NC-Cary	Town of Cary, North Carolina, Reclaimed Water System
NY-1	US-NY-PepsiCo	Identifying Water Streams for Reuse in Beverage Facilities: PepsiCo ReCon Tool
PA-1	US-PA-Kutztown	The Water Purification Eco-Center
PA-2	US-PA-Mill Run	Zero-Discharge, Reuse, and Irrigation at Fallingwater, Western Pennsylvania Conservancy
TN-1	US-TN-Franklin	Franklin, Tennessee Integrated Water Resources Plan
TX-1	US-TX-San Antonio	San Antonio Water System Water Recycling Program
TX-2	US-TX-Big Spring	Raw Water Production Facility: Big Spring Plant
TX-3	US-TX-Landscape Study	Site Suitability for Landscape Use of Reclaimed Water in the Southwest
TX-4	US-TX-NASA	U.S. Water Recovery System on the International Space Station
TX-5	US-TX-Wetlands	East Fork Raw Water Supply Project: A Natural Treatment System Success Story
VA-1	US-VA-Occoquan	Potable Water Reuse in the Occoquan Watershed
VA-2	US-VA-Regulation	Water Reuse Policy and Regulation in Virginia
WA-1	US-WA-Sequim	City of Sequim's Expanded Water Reclamation Facility and Upland Reuse System
WA-2	US-WA-Regulations	Washington State Regulations
WA-3	US-WA-King County	Demonstrating the Safety of Reclaimed Water for Garden Vegetables
WA-4	US-WA-Yelm	City of Yelm, Washington

Mountains and Plains: (EPA Region 8) Colorado, Montana, South Dakota, North Dakota, Utah, and Wyoming.

Pacific Southwest: (EPA Region 9) Arizona, California, Hawaii, Nevada, U.S. Pacific Insular Area Territories (Territory of Guam, Territory of American Samoa, and the Commonwealth of the Northern Mariana Islands (CNMI), and 147 federally recognized tribal nations.

Pacific Northwest: (EPA Region 10) Oregon, Washington, Idaho, and Alaska.

In this section, five areas of variation are discussed for each region related to water reuse. These include:

- Population and land use
- Precipitation and climate
- Water use by sector
- States' regulatory context
- Context and drivers of water reuse

The following are the sources of data cited for these discussions:

- **Population:** U.S. Census Bureau (USCB) – percent change in 2000 and 2010 resident population data in each region (USCB, n.d.)
- **Land Use:** National Resources Inventory – percent change from 1997 to 2007 in developed, non-federal land in each region, as a percentage of total region land area (USDA, 2009)
- **Precipitation:** National Oceanic and Atmospheric Administration (NOAA) 30-year annual rainfall data for each state (1971 to 2000). City precipitation figures were averaged for each state, except where noted for New Hampshire (NOAA, n.d.)
- **Water use:** *Estimated Use of Water in the United States in 2005*, USGS. Water use by sector was first calculated for each state, after which a regional average was calculated (Kenny et al, 2009)

States and territories were surveyed to obtain information on regulations and guidelines governing water reuse. An overall summary of the states and territories that have water reuse regulations and guidelines is provided in **Table 4-5**. Links to regulatory websites are provided in Appendix C.

As population growth is a key driver for infrastructure development, including water reuse facilities, the changes in population and developed land are presented for each region in the sections that follow. As an overview, the population change since 1990 is also provided in **Table 5-1** for all of the regions.

5.2.1 Northeast: Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont, Puerto Rico, the U.S. Virgin Islands, and Eight Federally Recognized Tribal Nations

While EPA Regions 1 and 2 comprise Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont, Puerto Rico, the U.S. Virgin Islands, and eight federally recognized tribal nations, this section focuses only on the regulatory context and drivers for water reuse in the seven states in the Northeast region of the United States and the USVI, a U.S. territory. Information is not available at this time for Puerto Rico and the eight federally recognized tribal nations in Region 2.

There are both challenges and opportunities to wastewater reclamation and reuse in the Northeast. The major drivers include state regulatory changes, urban hydrology, precipitation, seasonal use, water rates, and water use by sector. Generally speaking, wastewater reclamation is growing at a very slow rate, with an estimated reuse of approximately 8 to 10 mgd (350 to 438 L/s) of reclaimed water. Reuse in the Northeast is still a novel concept. Where reuse has been implemented, it has been used by municipalities to augment and buffer stressed potable water supplies, landscape irrigation, or on-site installations (e.g., LEED certified facilities). Often, private developers, industry, and in some cases public-private partnerships collaborate to go beyond the standards of basic environmental compliance and create a vision for integrated and sustainable water resources. Water reuse then becomes a key element in their water supply plans.

Table 5-1 Percent change in resident population in each region during the periods 1990-2000, 2000-2010, and 1990-2010 (USCB, n.d.)

State or Region	% change 1990-2000	% change 2000-2010	% change 1990-2010
United States	**13.2**	**9.7**	**24.1**
NORTHEAST REGION	6.1	3.2	9.5
Connecticut	3.6	4.9	8.7
Maine	3.8	4.2	8.2
Massachusetts	5.5	3.1	8.8
New Hampshire	11.4	6.5	18.7
Rhode Island	4.5	0.4	4.9
Vermont	8.2	2.8	11.2
New Jersey	8.9	4.5	13.7
New York	5.5	2.1	7.7
MID-ATLANTIC REGION	7.3	7.2	15.1
Delaware	17.6	14.6	34.8
District of Columbia	-5.7	5.2	-0.9
Maryland	10.8	9.0	20.7
Pennsylvania	3.4	3.4	6.9
Virginia	14.4	13.0	29.3
West Virginia	0.8	2.5	3.3
SOUTHEAST REGION	19.1	14.7	36.6
Alabama	10.1	7.5	18.3
Florida	23.5	17.6	45.3
Georgia	26.4	18.3	49.5
Kentucky	9.7	7.4	17.7
Mississippi	10.5	4.3	15.3
North Carolina	21.4	18.5	43.9
South Carolina	15.1	15.3	32.7
Tennessee	16.7	11.5	30.1
MIDWEST AND GREAT LAKES REGION	8.0	3.9	12.2
Illinois	8.6	3.3	12.2
Indiana	9.7	6.6	16.9
Michigan	6.9	-0.6	6.3
Minnesota	12.4	7.8	21.2
Ohio	4.7	1.6	6.4
Wisconsin	9.6	6.0	16.3
Iowa	5.4	4.1	9.7
Kansas	8.5	6.1	15.2
Missouri	9.3	7.0	17.0
Nebraska	8.4	6.7	15.7

Table 5-1 Percent change in resident population in each region during the periods 1990-2000, 2000-2010, and 1990-2010 (USCB, n.d.)

State or Region	% change 1990-2000	% change 2000-2010	% change 1990-2010
SOUTH CENTRAL REGION	17.9	15.5	36.1
Arkansas	13.7	9.1	24.0
Louisiana	5.9	1.4	7.4
New Mexico	20.1	13.2	35.9
Oklahoma	9.7	8.7	19.3
Texas	22.8	20.6	48.0
MOUNTAINS AND PLAINS REGION	22.7	16.1	42.4
Colorado	30.6	16.9	52.7
Montana	12.9	9.7	23.8
North Dakota	0.5	4.7	5.3
South Dakota	8.5	7.9	17.0
Utah	29.6	23.8	60.4
Wyoming	8.9	14.1	24.3
PACIFIC SOUTHWEST REGION	18.1	13.0	33.5
Arizona	40.0	24.6	74.4
California	13.8	10.0	25.2
Hawaii	9.3	12.3	22.7
Nevada	66.3	35.1	124.7
PACIFIC NORTHWEST REGION	21.3	14.2	38.5
Alaska	14.0	13.3	29.1
Idaho	28.5	21.1	55.7
Oregon	20.4	12.0	34.8
Washington	21.1	14.1	38.2

5.2.1.1 Population and Land Use

Another factor in the development of reuse programs in the Northeast is the significant change in urbanization of major population centers and in the land use surrounding those centers. As population increases, water resources are stressed and water reuse can become an attractive option. **Figure 5-3** compares the percent change in the overall population of the Northeast region to the population change of the entire United States over the past decade, along with the change in the percentage of developed land.

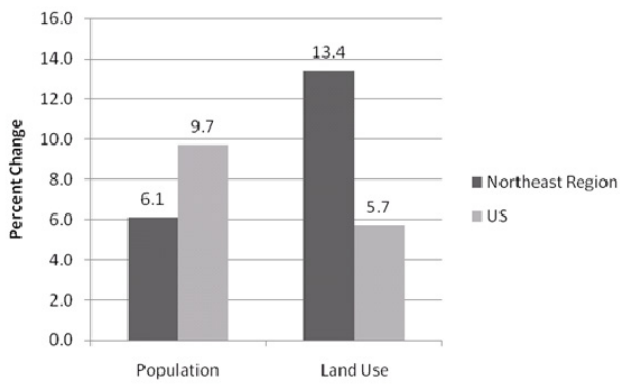

Figure 5-3
Percent change in population (2000-2010) and developed land (1997-2007) in the Northeast Region, compared to the United States

While the percent population change in the Northeast has lagged behind other regions, the developed land percent change in the Northeast has outpaced the United States average.

5.2.1.2 Precipitation and Climate

The most significant impediment to reuse is the prolific amount of annual precipitation in the Northeast. The annual average precipitation is approximately 42 in (106.5 cm), with monthly precipitation between 3 in (7.5 cm) and 4 in (10 cm). The annual average temperature in the region is approximately 53 degrees F (11.6 degrees C). The region's high precipitation and low annual temperature, combined with a lower than average water evaporation rate, results in an abundance of water for recharge of water resources on a regional basis. **Figure 5-4** depicts typical monthly precipitation by state.

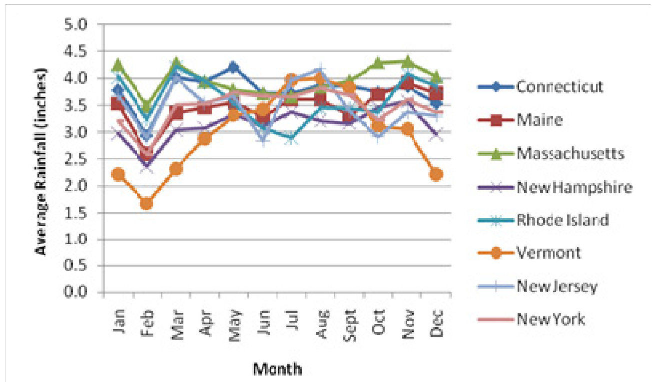

Figure 5-4
Average monthly precipitation (1971-2000) for states in the Northeast region

5.2.1.3 Water Use by Sector

Figure 5-5 shows freshwater use by sector in the Northeast.

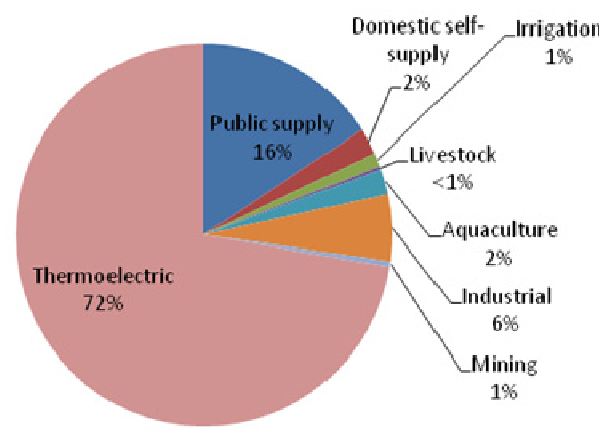

Figure 5-5
Freshwater use by sector for the Northeast region

The opportunities for water reuse are similar among the Northeast states. The greatest benefit resides in the energy sector, followed by irrigation and the industrial sector. These sectors define the future for reclamation in the Northeast and highlight the importance of the energy-water nexus. Sustainable water management requires balancing these potable demands through source substitution with reclaimed water, which can reduce stress on potable water supplies.

The energy sector in Connecticut is second only to Massachusetts energy water demands. Recently, the University of Connecticut developed a plan for using reclaimed water at its power plant on campus. Another industrial facility in Connecticut uses reclaimed water where it's feasible to meet a zero-discharge wastewater permit. Maine has significant potable water resources and, as illustrated in **Figure 5-5,** has the greatest opportunity for water reclamation within the energy and industrial sector. Because the manufacturing of paper and wood products demands large amounts of water, it is likely that water reuse projects will develop in these sectors as potable water resources are seasonally and locally stressed.

The energy sector in Massachusetts has already provided water reclamation opportunities at power plants like Dominion Power's Brayton Point Power Plant in Somerset, Mass. Industrial wastewater reclamation is also a growing market sector. An excellent example of industrial wastewater reclamation is the EMC Headquarters in Hopkinton [US-MA-Hopkinton]. Additionally, the use of reclaimed wastewater for golf course irrigation is also a market sector that has growth potential.

Similar to the opportunities described above, New Hampshire has looked at development of water reuse at industrial parks. Rhode Island reuse projects include the irrigation of the Jamestown Golf Course, as well as a private golf course in Portsmouth, both of which are island communities in Narragansett Bay. Also in Rhode Island, there is a planned reuse project in a mixed-use community in Kingston. A power plant based at the Central Landfill in Johnston, R.I., is the largest reclaimed water project in the Northeast. In Vermont, the energy sector provides the greatest opportunity for water reuse, followed by industrial reuse. There is limited water reuse in New York with one case study in Chapter 5.7.7 of the 2004 guidelines discussing the Oneida Indian Nation (EPA, 2004). In this document, Section 2.4.2 Alternative Water Resources includes a discussion of on-site reuse in Battery Park, New York City, N.Y.

An additional potential driver for reuse in the Northeast is increasingly strict nutrient removal requirements in NPDES permits. In locations with new nutrient limits, water reuse may be a favorable alternative to enhanced treatment purely for discharge, as has been demonstrated in other parts of the United States, including Florida, Oregon, and Washington.

5.2.1.4 States' and Territories' Regulatory Context

Based on the limited number of water reuse projects undertaken in the Northeast, regulatory requirements or guidelines for reuse projects have not been implemented in most states. Massachusetts, New Jersey, and Vermont are the only states in the Northeast with water reuse regulations.

There are no comprehensive inventories of reuse projects by state, nor is there a data warehouse on the guidelines or permitted water quality criteria applied to each project.

Massachusetts

The Commonwealth of Massachusetts promulgated water reuse regulations in March 2009. The regulations were developed within 314 Code of Massachusetts Regulations (CMR) 20.00 entitled "Reclaimed Water Permit Program and Standards" and 314 CMR 5.00 regulations entitled "Groundwater Discharge." The key elements of the regulations were to protect public groundwater supplies by requiring a TOC limit when there is a discharge to the groundwater as a surrogate for endocrine disrupting compounds and contaminants within a specified travel time in the aquifer.

New Hampshire

New Hampshire does not have regulations governing water reuse but encourages it and has developed a position statement recognizing that water reuse can both reduce stress on groundwater resources as well as decrease surface water quality degradation. The New Hampshire Department of Environmental Services developed a guidance document identifying design criteria for reuse of reclaimed wastewater. Water reclamation projects are approved on a case-by-case basis.

Rhode Island

Rhode Island developed water reuse guidelines in 2007 for four allowable water reuse categories, including restricted irrigation, unrestricted irrigation, non-contact cooling water, and agricultural reuse for non-food crops. The Department of Environmental Management's Office of Water Resources has established water quality criteria, signage, and set-back distances for these four categories of reuse.

Vermont

Vermont has adopted rules for indirect discharge that require that land-based discharge (including forested spray fields) be considered prior to approval of surface water discharge.

New York

There are no formal guidelines or regulations in New York, and initial work on guidelines was suspended due to budget constraints. In highly developed areas such as Manhattan, the cost to extend dual piping systems from central wastewater reclamation facilities is cost prohibitive. There are isolated uses of reclaimed water in the state for cooling purposes with supply and quality parameters agreed to in site specific contracts. The 2004 guidelines (Chapter 5.7.7) recounts development of an intergovernmental agreement between the Oneida Indian Nation and the city of Oneida. The city's reclaimed water was supplied to the Indian Nation to enable development of a casino and golf complex by allowing the irrigation demands of the complex to be met without stressing water resources.

New Jersey

In January 2005, the New Jersey Department of Environmental Protection issued a draft "Technical Manual for Reclaimed Water for Beneficial Reuse," and proposed regulation in 2008. These regulations were codified on January 5, 2009 as New Jersey Administrative Code 7:14A-2.15. Section 2.15 establishes application requirements for Reclaimed Water for Beneficial Reuse (RWBR) and states that any feasibility studies conducted shall be performed in accordance with the Technical Manual. The regulations define two main categories of RWBR—public access and restricted access. The Technical Manual provides detailed information to applicants on the procedure for developing and implementing an RWBR program.

Connecticut and Maine

There are no formal regulations regarding water reuse in Connecticut or Maine. Installations are approved on a case-by-case basis.

USVI

Currently, there are no water reuse regulations promulgated by the USVI. Water reuse for irrigation is limited to small, on-site installations and no large scale or public projects have been undertaken. Discharges to above ground irrigation systems are regulated under the USVI Territorial Pollutant Discharge Elimination System Permitting and Compliance permit program, while below ground dispersal systems are reviewed on a case-by-case basis. At the time of publication, USVI is reviewing draft regulations for small scale water reuse systems for groundwater recharge and irrigation. Water reuse for IPR, industrial, or recreational applications have not been proposed in the USVI, but if proposed, they would be approved on a case-by-case basis.

5.2.1.5 Context and Drivers of Water Reuse

Potable water rates vary fairly dramatically by state and regionally within each state in the Northeast, depending on whether the source is a surface water or groundwater resource. Several aquifers are stressed on a seasonal basis; there are even instances of surface waters being depleted within coastal river basins in recent years, driving up potable water rates. Obviously, the high cost of the potable water supply provides an incentive for wastewater reclamation. For example, in Massachusetts the Ipswich River Basin ran dry during the peak summer demands of 2006 and 2007. Currently, potable water rates in the Northeast range from a low of less than $1.00/1,000 gallons ($0.26/1000 L) to a high of over $9.00/1,000 gallons ($2.38/1000 L) regionally.

Since adequate potable water supply is not always available for large industrial projects regardless of the water rate, industrial facilities such as power plants have developed the largest water reclamation projects in the region. Rhode Island has the distinction of having the largest reclaimed water project in the Northeast at a power plant at the Central Landfill in Johnston, R.I. that pumps 5 mgd (219 L/s) of reclaimed water 12 mi (19.3 km) from the Cranston, R.I., WWTP for use in the on-site cooling towers. In Connecticut there are two active reuse projects (for golf course irrigation and an industrial manufacturing facility) and one facility near start-up at the University of Connecticut.

Reclaimed water is used for snowmaking in several states in New England as a means to allow for continued discharge of treated effluent from zero discharge lagoon and LAS during the winter. Several ski resorts in Maine utilize reclaimed water for snowmaking, as described in a case study (US-ME-Snow). In Vermont, one ski area, one highway rest area, and one building at the University of Vermont are currently using reclaimed water for toilet and urinal flushing. In addition, forested spray fields are used for disposal of treated wastewater in areas of Vermont.

Several water reclamation systems from Massachusetts are highlighted in the case studies. In Southborough, a private school has installed a small wastewater treatment system to reclaim water for toilet flushing as part of a campus expansion that included LEED certification of buildings [US-MA-Southborough]. In Hopkinton, a manufacturer of electronic data storage systems has installed a wastewater treatment and reclamation plant to reuse water for toilet flushing and irrigation, which recharges groundwater. As Hopkinton has faced water shortages during summer peak seasonal demand, the project has reduced the potable water demand on a seasonally limited aquifer and has provided needed groundwater recharge [US-MA-Hopkinton]. In the town of Foxborough, when the new Gillette Stadium was being built, the New England Patriots management worked with the town and the Massachusetts Department of Environmental Protection to construct a new wastewater reclamation system for toilet flushing and groundwater recharge. The increase in wastewater generated during home games would have otherwise overwhelmed the town's wastewater treatment system, as well as severely stressed the town's groundwater supplies [US-MA-Gillette Stadium]. The Metropolitan Area Planning Council (MAPC) published a guide for expanding water reuse in Massachusetts that includes several other case studies on water reuse in the state (MAPC, 2005).

The objective of the RWBR program in the state of New Jersey is to incorporate RWBR language into all sanitary sewerage treatment plant permits. As of 2011, 118 facilities have been permitted to utilize RWBR. Of these facilities, 27 are utilizing RWBR for a variety of uses ranging from cooling water, WWTP wash down, and golf course irrigation to cage/pen washing at a county zoo.

USVI

Public potable water supply serves approximately 30 percent of the USVI, while the remaining 70 percent collect rainwater or use wells to draw groundwater for drinking. Of that 70 percent, approximately 15 percent use wells, with the remaining population relying on rainwater cisterns. While the annual rainfall is significant, there is a dry season, and the eastern end of the island of St. Croix is particularly dry year round, providing a drive to conserve water. There also have been recent shortages of public water supply on the island of St. Thomas. Overall, however, provided conservation practices are used, water demands are generally met by supply. Thus, scarcity is not a driver for large-scale water reuse. Nonetheless, small-scale water reuse for irrigation of small plots, primarily for landscaping, does occur in the USVI, particularly in the drier areas (e.g., the eastern end of St. Croix). Commercial agriculture, primarily located on St. Croix, currently does not employ water reuse.

5.2.2 Mid-Atlantic: Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, and West Virginia

This section focuses on the regulatory context and drivers for water reuse in five states and the District of Columbia in the Mid-Atlantic region.

5.2.2.1 Population and Land Use

According to the 2010 U.S. Census, the population in the Mid-Atlantic states totals around 30 million with the largest population density being the Washington, D.C.-Baltimore-Northern Virginia metropolitan area. The coastal areas of the upper Mid-Atlantic region have been thoroughly urbanized, with little to no areas of rural farmland. However, West Virginia and parts of Virginia remain largely rural with pockets of urbanization. **Figure 5-6** compares the percent change population in the Mid-Atlantic to the entire United States from 2000-2010 and percent change in developed land coverage from 1997-2007.

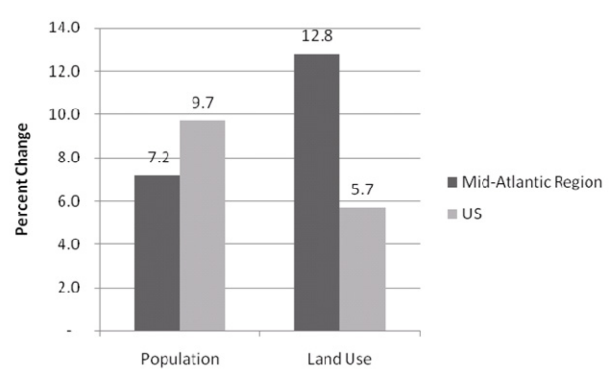

Figure 5-6
Change in population (2000-2010) and developed land (1997-2007) in the Mid-Atlantic region, compared to the United States

5.2.2.2 Precipitation and Climate

The climate in the Mid-Atlantic region is largely classified as humid subtropical. Spring and fall are warm, while winter is cool with annual snowfall averaging 14.6 in (37 cm). Winter temperatures average around 38 degrees F (3.3 degrees C) from mid-December to mid-February. Summers are hot and humid with a July daily average of 79.2 degrees F (26.2 degrees C). The combination of heat and humidity in the summer brings very frequent thunderstorms and, therefore, abundant precipitation during the warmest months. **Figure 5-7** depicts average monthly precipitation in the Mid-Atlantic region by state.

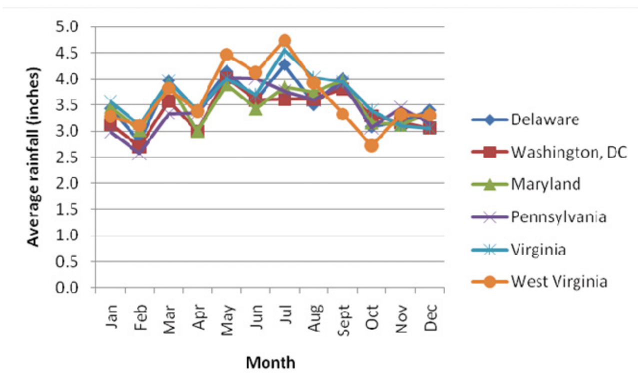

Figure 5-7
Average monthly precipitation in the Mid-Atlantic region

5.2.2.3 Water Use by Sector

Figure 5-8 shows freshwater use by sector in the Mid-Atlantic Region.

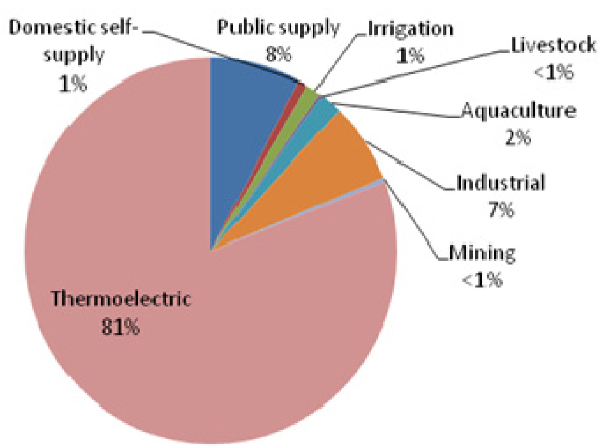

Figure 5-8
Freshwater use by sector for the Mid-Atlantic region

As for the Northeast region, the greatest possible opportunity for water reuse in the Mid-Atlantic region is in the energy sector.

5.2.2.4. States' Regulatory Context

Delaware

The Delaware Division of Water administers the state's reclaimed water permits, which are primarily for agricultural irrigation, a reuse that has been practiced since the 1970s. There are 23 permitted agricultural operations covering more than 2,200 acres, plus two golf courses and several wooded tracks. State regulations require advanced treatment for unrestricted access use; specify water quality limitations, including bacteriological standards; and require set back distances. Agricultural application rates are limited both hydraulically and by nutrient loading limits. Reclaimed water irrigation of crops intended for human consumption without processing is not allowed.

District of Columbia

The District of Columbia currently does not have any regulations or guidelines addressing water reuse but considers projects on a case-by-case basis. The city is currently developing rules and water quality requirements for stormwater use.

Pennsylvania and Maryland

Pennsylvania and Maryland have guidelines for water reuse. The Maryland Department of Environment has Guidelines for Land Application/Reuse of Treated Municipal Wastewaters, last revised in 2010. There are two quality levels (Class I and II). The guidelines provide buffer zone requirements and requirements for zero nitrogen addition to groundwaters in new permits. The 2010 amendments added a Class III water for non-restricted urban irrigation use and regulations proposed for reuse with a Class IV water allowing use in commercial settings (laundries, car wash, snowmaking, air conditioning, closed loop cooling, window washing, and pressure cleaning), irrigation for food crops (with no contact with the edible portion of the crop), and industrial facilities (washing aggregate, cooling waters, concrete manufacture, parts washing, and equipment operations).

Virginia

Virginia adopted new regulations for water reuse in 2008 under the Department of Environmental Quality (DEQ). In addition to the DEQ regulations, which govern the centralized reclamation of domestic, municipal, or industrial wastewater and subsequent reuse, other Virginia state agencies have regulations or guidelines that affect water reuse, determined in most cases by the type of wastewater to be reclaimed. The Virginia Department of Health has regulations that allow the on-site treatment and reuse of reclaimed water in conjunction with a permitted on-site system for toilet flushing, and provides guidelines for the use of harvested rainwater and graywater. The Virginia Department of Housing and Community Development has regulations for the indoor treatment and plumbing of graywater and harvested rainwater, and for the indoor plumbing of reclaimed water meeting appropriate regulatory standards administered by the DEQ for indoor uses. The Virginia Department of Conservation and Recreation has limited regulations for the use of stormwater and evaluates such proposals on a case-by-case basis. A discussion of the development of the Virginia water reuse regulations is provided in a case study [US-VA-Regulations].

Water rights in Virginia adhere to the Riparian Doctrine, which protects the beneficial water uses of downstream riparian owners. A more detailed discussion of water rights and how they may affect the reclamation and reuse of wastewater is provided in Chapter 4. As a result of the Riparian Doctrine and Virginia's water withdrawal permit program, communities that do not have downstream riparian owners or permitted withdrawals to contend with may have a greater range of water reclamation and reuse options, including IPR and nonpotable uses. In contrast, communities with downstream riparian owners may implement IPR in lieu of nonpotable reuse of reclaimed water in order to avoid water rights conflicts. Where IPR is proposed, generators and distributors of reclaimed water will need to work more closely with downstream users within a larger regulatory context to protect water supply quantity and quality.

West Virginia

No information was available from West Virginia at the time of publication.

5.2.2.5 Context and Drivers of Water Reuse

Virginia

One of the longest operating and successful reclamation projects in the country was initiated in 1978 by the UOSA. UOSA was created to provide regional collection and advanced treatment of wastewater generated from multiple small communities, many with inadequate wastewater treatment facilities and failing individual septic systems. Project details are described in a case study [US-VA-Occoquan]. The UOSA discharge provides significant contributions to the Occoquan Reservoir, which is the raw water supply for Fairfax Water, a utility that provides potable water to northern Virginia. The UOSA system is also the longest operating planned surface water IPR project in the United States.

Subsequent to the effective date of Virginia's Water Reclamation and Reuse Regulation in October 2008, several new water reclamation and reuse projects were authorized. These included, among others, the following projects:

- The Broad Run WRF in Loudoun County is permitted to produce 11 mgd (482 L/s) of Level 1 reclaimed water (secondary treatment, filtration, and higher level disinfection) for a variety of uses including turf and landscape irrigation; toilet flushing; fire fighting and protection; and evaporative cooling, primarily at data centers.

- The Noman Cole, Jr. Pollution Control Plant in Fairfax County is permitted to produce 6.6 mgd (289 L/s) of Level 1 reclaimed water. A portion of this water is delivered to an energy resource recovery facility for cooling, boiler blowdown and washdown and to the Fairfax County Park Authority for irrigation of a golf course, recreation area, and park.

- The Parham Landing WWTP in New Kent County is permitted to produce 2.0 mgd (88 L/s) of Level 1 reclaimed water. A portion of this water is delivered to two golf courses for irrigation and to a horse racing track for irrigation and dust suppression.

- The Bedford City WWTP in Bedford County is permitted to produce 2.0 mgd (88 L/s) of Level 2 reclaimed water (secondary treatment and standard disinfection). A portion of this water is delivered to a food packaging facility for cooling.

- The Maple Avenue WWTP in Halifax County is permitted to produce 1.0 mgd (43 L/s) of Level 2 reclaimed water. Most of this water will be delivered to a wood-burning power producer for cooling and boiler feed.

Other projects that have been grandfathered until they expand their reclaimed water production or distribution capacity include the Proctors Creek Wastewater Treatment Facility (WWTF) and the Remington WWTF in Chesterfield and Fauquier Counties, respectively. Both facilities provide treated effluent of quality better than or equal to Level 2 reclaimed water to coal-burning power generation facilities for cooling or stack scrubbing (Bennett, 2010).

Delaware

Delaware has a long history of promoting reuse of reclaimed water. Some fields in Delaware have been receiving reclaimed water since the 1970s with no adverse effects to the fields, crop yields, or the water table beneath the field. As previously mentioned, there are 23 facilities permitted in Delaware that use reclaimed water largely for agricultural irrigation as well as to irrigate two golf courses and several tracks of wooded land.

District of Columbia

While many facilities in the District of Columbia are practicing graywater use, only one water reuse project has been implemented to date. The Sidwell Friends Middle School campus was recently renovated for LEED Platinum certification, including on-site water reuse, as described in the associated case study [US-DC-Sidwell Friends]. The University of the District of Columbia is similarly considering on-site water reuse for its campus and is working with District of Columbia Water and Sewer Authority (D.C. Water), the District Department of the Environment, and the Department of Health to develop the potential project.

Pennsylvania

In Pennsylvania, an advanced treatment facility provides reclaimed water for Pennsylvania State University and the surrounding area from the Spring Creek Pollution Control Facility. Treatment includes activated sludge with biological nutrient removal (BNR) followed by diversion to the reclamation facilities consisting of MF/RO and UV disinfection with sodium hypochlorite added to a 1.5 million gallon storage tank serving the distribution system (Smith and Wert, 2007). Other projects include dust control and toilet/urinal flushing (Grantville and Pittsburg Convention Center) and the Falling Water garden in Mill Run, Pa. (Vandertulip and Pype, 2009 and [US-PA-Mill Run]. In Kutztown, the Rodale Institute has installed a water reclamation system as part of its Water Purification Eco-Center. The project highlights water reuse as an alternative to traditional sewage management for a broad audience, including elementary school children, municipal officials, land developers, watershed management groups, planning commissioners, policy makers, and environmental enforcement officers [US-PA-Kutztown]. Although interior residential reuse would not be permitted under current guidelines, Hundredfold Farm in Adams County was the first rural cohousing community in Pennsylvania and uses their treated wastewater for toilet flushing as well as irrigation. There are also 11 industrial establishments and 14 municipal treatment plants that use their treated wastewater for irrigation purposes.

Maryland

Maryland has 35 spray irrigation systems using reclaimed water, with the largest being 0.75 mgd (32 L/s). The majority of the systems are for agricultural irrigation. Nine of the spray irrigation systems are for golf course irrigation. Other reuse systems included four rapid infiltration systems, two overland flow, and three drip irrigation systems (Tien, 2010).

5.2.3 Southeast: Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee

This section focuses on the regulatory context and drivers for water reuse in eight states in the Southeast.

5.2.3.1 Population and Land Use

The Southeast is one of the most populous and fastest growing regions in the United States. With nearly 19 million people, Florida is the most populous of the southeastern states. It is followed by Georgia and North Carolina, each with approximately 10 million residents, and then Tennessee with over 6 million people. Historically, the Southeast states have relied heavily on agriculture. However, in the last few decades, the region has become more urban and industrialized. Despite this development, some southeastern states still have not implemented sophisticated reuse programs. Florida, however, has one of the largest reuse programs in the country. A factor that has contributed greatly to the significant development of reuse in Florida and the Southeast is the significant increase in urbanization of the states' major population centers and in the land use surrounding those centers. As population increases, particularly in coastal areas, water resources are stressed, and water reuse becomes an integral part of meeting the projected future water demand. **Figure 5-9** compares the percent change in population in the Southeast region to the entire United States from 2000 to 2010 and percent change in developed land coverage from 1997 to 2007.

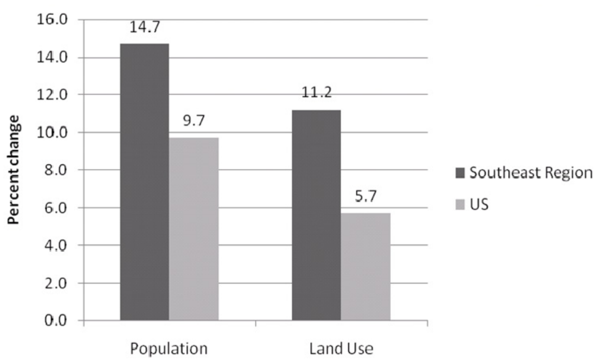

Figure 5-9
Change in population (2000-2010) and developed land (1997-2007) in the Southeast region, compared to the United States

Florida experienced huge growth in population from 1980 to 2010 (93 percent increase), and with that came a dramatic increase in developed land at nearly 100 percent over what it was in 1982. Georgia, North Carolina, South Carolina, and Tennessee likewise saw population growth exceeding the national average. In these states, population growth likewise corresponded to an increase in developed land exceeding the national rate. Because of this stress from growth and development, Florida and some of the other southeastern states, particularly in the large urban centers, present huge opportunities for reuse.

5.2.3.2 Precipitation and Climate

The predominate climate in the Southeast is humid subtropical with a small area of wet/dry-season tropical zone in South Florida. Compared to the rest of the country, states in the Southeast get the most average rainfall, with close to or above 50 in (127 cm) per year. Yet, it may be surprising that Florida has probably the most reuse flow going to landscape irrigation at 360 million gallons per day (403,200 ac-ft/yr) (15.8 m^3/s) than any other state. Part of the explanation lies in an initial regulatory driver to reuse instead of increasing deep well disposal. **Figure 5-10** depicts typical monthly precipitation in the Southeast by state.

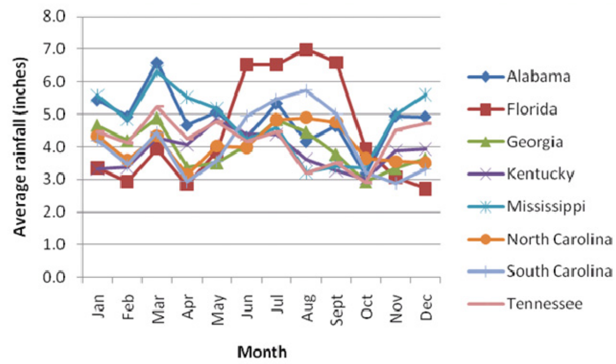

Figure 5-10
Average monthly precipitation in the Southeast region

It is clear that the springtime rainy season in the Southeast occurs in March, which is the wettest time for most of the southeast states. However, Florida's wettest season is during the summer months. For irrigation uses, this rainy cycle during the best growing months creates a disconnect between the supply and demand rates of reclaimed water for urban and agriculture reuse programs. This must be solved through the use of seasonal storage (tanks, lakes, aquifer storage, and recovery wells), diversification of the reuse program (bulk interruptible users, large industrial users, aquifer recharge, etc.), development of supplemental water sources, by permitting a limited wet-weather discharge, or by having a permitted back-up disposal option such as deep well injection or surface water discharge.

5.2.3.3 Water Use by Sector

The opportunities for water reuse differ somewhat among the Southeast states. All of the states have large opportunities for water reuse in the energy sector. In Florida and Mississippi, irrigation demand also provides a large opportunity for reuse. **Figure 5-11** shows freshwater use by sector in the Southeast.

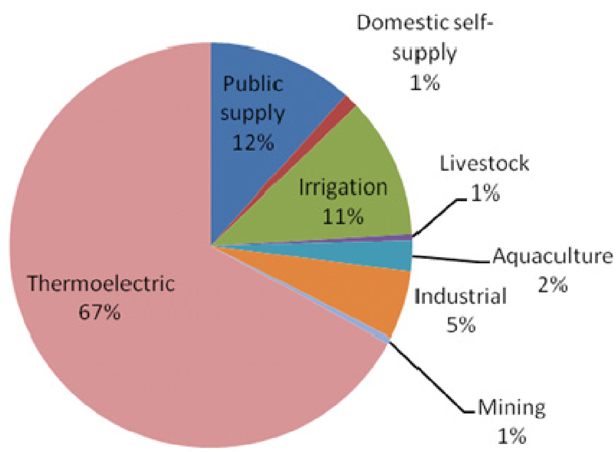

Figure 5-11
Freshwater use by sector for the Southeast region

While irrigation does not seem to present a huge opportunity for reuse in Alabama, South Carolina, and Tennessee, the use of reclaimed water for irrigation in certain circumstances (e.g., where irrigated hayfields or golf courses are located next to a domestic WWTF) in these states should not be overlooked. Likewise, in Florida and Mississippi, where the use of freshwater in the energy sector is largely overshadowed by reuse for irrigation, the use of reclaimed water in cooling towers and other uses at thermoelectric power plants can be a huge local opportunity for reuse in areas where those plants are located. In Florida, power plants can be a reuse utility's largest bulk customer.

In many parts of Florida, reclaimed water is an integral part of the water supply portfolio, and this trend is expected to continue. With limited freshwater in many areas, reclaimed water has allowed communities to grow and has reduced the need for development of other alternatives. Irrigation demands in Florida are second only to Arkansas. This may partly explain why Florida's most popular use of reclaimed water (68 percent of the total reuse flow) is irrigation (public access areas, 58 percent, and agricultural irrigation 10 percent) (FDEP, 2012a). Farming is the largest industry in Florida, and the use of surface water and groundwater sources for irrigation remain significant withdrawals of the freshwater supply in the state. There are two main impeding factors to expanding the use of reclaimed water for agricultural activities: negative perception of reclaimed water by farmers and their customers, and the rural nature of farmland, which means that there are high financial and energy costs to supply reclaimed water to these areas. The public use of water is also huge and indicates a big opportunity for aquifer recharge and potable reuse; however, this represents the most stringent level of treatment and most potential for public resistance.

Florida is not a center of heavy industry, and as a result, industry is the smallest of the water uses in Florida. Leading industries include food processing, electric and electronic equipment, transportation equipment, and chemicals. While the industrial and energy sectors are not huge parts of the total water use in Florida, the opportunities presented by these industries, particularly in the towns where large industrial facilities and power plants are located, are desirable to reclaimed water providers. Alabama, Georgia, Mississippi, South Carolina, and Tennessee all have higher industrial water use demands that are in the range of 5 to10 percent.

Potable Water Availability and Rates

With the exception of Florida, Arkansas, and Mississippi, the majority of freshwater withdrawn in the Southeast comes from surface water sources. In Florida, nearly 90 percent of the potable water is supplied by groundwater. Potable water rates are still relatively cheap due to the low cost of production (very little treatment required). However, in some parts of the state, particularly in the Tampa Bay area and Southeast parts of the state and along the coastline in the Northeast and parts of the Panhandle, the aquifers are stressed. In these stressed areas, called Water Resource Caution Areas by state statutes, potable water rates may be higher and may be a better reflection of the real cost of providing water. Within these Water Resource Caution areas, investigating the feasibility of reuse programs is mandated, and utilities (water supply and wastewater management) as well as water users must implement reuse to the extent that is determined to be feasible.

Potable water rates in several municipalities surveyed in Florida in 2003 ranged from a low of $0.50/1,000 gallons ($0.13/1000 L) to a high of more than $10.00/1,000 gallons ($2.64/1000 L), depending on the gallon usage (tiered rate); however, for most residential uses the average potable water rate was around $1.50/1,000 gallons ($0.40/1,000 L) (Whitcomb, 2005). (See also **Table 7-1** for sample rates.) Note that as utilities in Florida adopt conservation rate structures, potable water rates have increased above these 2003 values. Reclaimed water rates in the same year in Florida were very competitive, ranging from $0.19 to $5.42/1,000 gallons ($0.05 to $1.43/1,000 L) for residential customers and from $0.05 to $18.30/1,000 gallons ($0.01 to $4.83/1,000 L) for non-residential customers (FDEP, 2012a). Except for a few isolated instances, water in the southeastern states is generally undervalued, therefore inhibiting the perceived need for water reuse.

5.2.3.4. States' Regulatory Context

Alabama, Georgia, Kentucky, Mississippi, South Carolina, and Tennessee

Alabama and Georgia each have guidelines governing various aspects of reuse. Kentucky does not have regulations or guidelines governing reuse. Mississippi has regulations that cover the potential for reclaimed water to be reused for restricted urban reuse, agricultural reuse for non-food crops, and industrial reuse. South Carolina has regulations governing reuse that stipulate that wastewater facilities that apply to discharge to surface waters must conduct an alternatives analysis to demonstrate that water reuse is not economically or technologically reasonable. Tennessee allows reclaimed water to be distributed for land application reuse by industrial customers, commercial developments, golf courses, recreational areas, residential developments, and other nonpotable uses. Implementation of reuse programs are through the NPDES or state operating permit programs with additional requirements for reuse that are specified in the permits. Tennessee guidelines for reuse include the *Design Guidelines for Wastewater Treatment Systems Using Spray Irrigation*.

Florida

Florida has one of the more mature water reuse programs that continues to evolve with new environmental and regulatory drivers. Florida leads the United States with 49 percent of treated wastewater reclaimed and reused (FDEP, 2012a). The reuse capacity in the state is higher—up to 64 percent of the state's permitted domestic wastewater capacity is dedicated to reuse. In 2006, FDEP's Water Reuse Program was the first recipient of the EPA Water Efficiency Leader Award. However, Florida realizes only a fraction of reuse opportunities. In 2011, a total of 57 large domestic wastewater treatment facilities did not provide reuse of any kind. This unused capacity presents a potential to expand the availability of reclaimed water in the state. The 2008 Legislature enacted laws that prohibit ocean discharge of treated wastewater by 2025 except as a backup to a reuse system. Sixty percent of the water currently discharged in ocean outfalls will have to be reused for a beneficial purpose, increasing reclaimed water use by at least 180 mgd (7.9 m^3/s) by 2025.

The 2007 to 2008 droughts highlighted the need to use all sources of water efficiently. In lieu of new legislation considered in 2008, FDEP initiated three workshops to gather input on water reuse issues and goals for Florida. Meeting attendees included representatives from the FDEP, the five water management districts, local government, utilities, and other parties with an interest in reuse. Issues discussed included regulatory authority, offsets, irrigation, supplementation (augmentation), funding, optimization of reclaimed water resources; mandatory reuse zones, communication and coordination, and reuse feasibility study preparation. The regulatory authority may be the result of increased value seen in reclaimed water with utilities believing that they should control the resource that they spend money to create, cities wanting some control, and water management districts believing reclaimed water falls under the legislative grant of jurisdiction to regulate the consumptive use of water.

Another interesting issue is the discussion on supplementation, which is also referred to as augmentation. In most instances, augmentation is the addition of highly treated reclaimed water to a surface water body or aquifer for IPR. In Florida, for some utilities, the opportunity to supplement reclaimed water with other water sources helps promote a higher percentage use of reclaimed water because it makes availability to a larger number of users more reliable. However, some environmental organizations and other local governments have expressed concern over this practice. For more information, consult the FDEP *Connecting Reuse and Water Use: A Report of the Reuse Stakeholders Meetings* (FDEP, 2009). An outcome of these workshops was the establishment of a reclaimed water workgroup consisting of representatives from the same stakeholders. After the first three workshops, the workgroup continued to meet almost monthly for three years, coming to some kind of consensus on these issues. The workgroup's efforts resulted in statutory changes, rule changes, and increased coordination among stakeholders. The workgroup's final report was published in May 2012.

North Carolina

Reclaimed water systems are classified in North Carolina as either conjunctive or non-conjunctive systems. A conjunctive reclaimed water system refers to a system where beneficial use of reclaimed water is an option and reuse is not necessary to meet the wastewater disposal needs of the facility. In this case, other wastewater utilization or disposal methods (i.e., NPDES permit) are available to the facility at all times. A non-conjunctive reclaimed water system typically has evolved from land disposal system permits and refers to a system where the reclaimed water utilization option is required (or dedicated) to meet the wastewater disposal needs of the facility and no other disposal or utilization options are available. Of the 128 active reclaimed water permits in North Carolina, approximately 48 percent are for conjunctive use systems and approximately 64 percent of those are from municipalities. Changes in the North Carolina regulations now allow more flexibility for utilities to expand use beyond dedicated land disposal in the remaining non-conjunctive permits. The projected increase in reclaimed water demand due to the rule changes were estimated based on newly approved uses of food crop irrigation, wetlands augmentation, residential conjunctive drip irrigation systems, and the estimated increase in residential irrigation demand (NCAC 2012).

5.2.3.5 Context and Drivers of Water Reuse

Alabama

In Foley, Ala., model studies and a constructed wetland/percolation pond were studied at 20,000 gpd (0.9 L/ s) flow rate using secondary treatment effluent as feed to confirm application for groundwater recharge in the future.

Georgia

Water reuse in Georgia varies from constructed wetlands to augment shallow aquifers and spring flow to creeks, to landscape irrigation, and even flushing urinals and toilets in permitted buildings. Two case studies [US-GA-Clayton County] and [US-GA-Forsyth County] highlight the state's success in augmenting surface water supplies and offsetting potable water demands within the state.

Historically, water reuse has been limited in Georgia due to perceived adequate rainfall and water resources. This perception began to change during an intense drought period in 2007 and 2008, after which many communities re-evaluated how they would meet future water supply needs if a lack of rainfall persisted.

In Coastal Georgia specifically, the 2007 and 2008 drought period only compounded the already occurring issue of overproduction of drinking wells in the area, which was resulting in saltwater intrusion of coastal aquifers. In fact, the Georgia Environmental Protection Division (GEPD) had already developed a Coastal Georgia Water and Wastewater Permitting Plan for Managing Salt Water Intrusion (2006 Coastal Plan) that required a non-agricultural groundwater permittee to develop a Water Reuse Feasibility Plan. The primary focus of the plan is halting the intrusion of salt water into the Upper Floridan aquifer (GEPD, 2007).

The recommended uses for reuse water in Georgia were further expanded when on January 1, 2011; the Georgia Plumbing Code was amended to allow reclaimed water to be used for toilet and urinal flushing and for other approved uses in buildings where occupants do not have access to plumbing. This amendment to the plumbing code helped provide the framework to facilitate the use of reclaimed water in buildings in LEED-certification endeavors.

Another driver for increasing water reuse in Georgia was a federal court decision affecting the use of Lake Lanier, a reservoir in the northern portion of the state that supplies water to many metro-Atlanta communities and other nearby communities. Lake Lanier is the uppermost of four major water bodies along the Chattahoochee River system that runs from the North Georgia Mountains, through Atlanta, Ga., Columbus, Ga., and the Florida Panhandle, and eventually discharges to the Gulf of Mexico. Lake Lanier has been the subject of water rights disputes among Georgia, Alabama, and Florida for more than two decades. A federal court decision on July 17, 2009, ruled that Lake Lanier was not authorized as a water supply reservoir, which meant that metro Atlanta would have to find another source of drinking water unless a political solution could be achieved. In response, the governor created a Water Contingency Planning Task Force that included elected officials, consultants, and representatives from several communities to conduct feasibility planning to determine the impact of the ruling and discuss methods of managing water resources in North Georgia if the ruling stood (Georgia Governor's Office, 2009).

As part of the response, the Metropolitan North Georgia Water Planning District developed a water management plan identifying options and concluded that alternative sources could not be developed by the 2012 deadline in the ruling. The plan acknowledged that unplanned indirect potable reuse was already occurring by augmenting the supply of Lake Lanier and Lake Allatoona with high quality reclaimed water and capture of upstream discharges comingled in the river. The Clayton County Water Authority [US-GA-Clayton County] project was identified as a planned indirect potable reuse project. Several established nonpotable reuse projects were also acknowledged.

On June 28, 2011, the 11th Circuit Court of Appeals overturned the July 2009 court decision, finding that Lake Lanier was created as a water supply reservoir and directed the USACE to prepare a water allocation plan for Lake Lanier, after which both Alabama and Florida appealed. On June 25, 2012 the U.S. Supreme Court denied a request by Alabama and Florida for a review of the water case. While there will likely be more to this issue, it is serving as a driver for Georgia's communities to integrate water reuse options into their regional water planning.

Florida

According to Florida's 2011 Annual Reuse Inventory, the state has a total of 487 domestic wastewater treatment facilities with permitted capacities of 0.1 mgd (4.4 L/ s) or above that make reclaimed water available for reuse. These treatment facilities serve 434 reuse systems, where 722 mgd (31.6 m^3/ s) of reclaimed water from these facilities is reused for beneficial purposes. The total reuse capacity associated with these systems is 2,336 mgd (102.3 m^3/ s), which is 64 percent of the total capacity of domestic wastewater treatment facilities in the state and more than three times larger than the state's reuse capacity in 1986 (FDEP, 2012a). **Figure 5-12** shows the type of reuse that is occurring in Florida. To date, percentage of reuse by category of application is only available for Florida and California, states that compile the information.

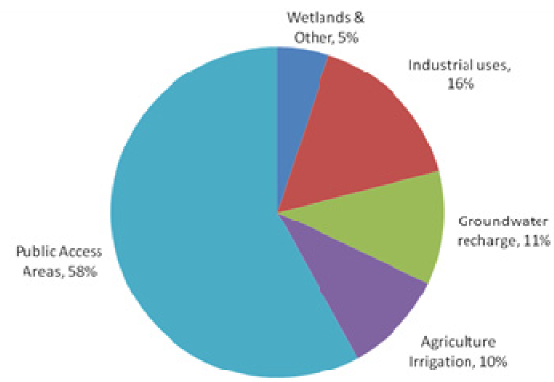

Figure 5-12
Water reuse in Florida by type (FDEP, 2012)

Figure 5-13 depicts the large population centers in Florida where reuse has the largest opportunity for growth. The statewide per capita usage based on 2011 population estimates and total reclaimed water utilization in 2011 was 38 gpd (143.8 L/day) of reuse per person in Florida. The Orlando-Tampa metropolitan area averages well over 50 gpd (189 L/day) per person, while Miami-Dade and Jacksonville Metropolitan areas average 7 and 10 gpd (26.5 and 37.9 L/day) per person, respectively (FDEP, 2011).

A future water quality issue that numerous stakeholder groups, including water resources utilities, have been watching in the state of Florida is the development of Numeric Nutrient Criteria (NNC). The national NNC dialogue began in 1998 with EPA's National Nutrient Strategy that detailed the approach EPA envisioned "in developing nutrient information and working with states and tribes to adopt nutrient criteria as part of their water quality standards." (EPA, 2007)

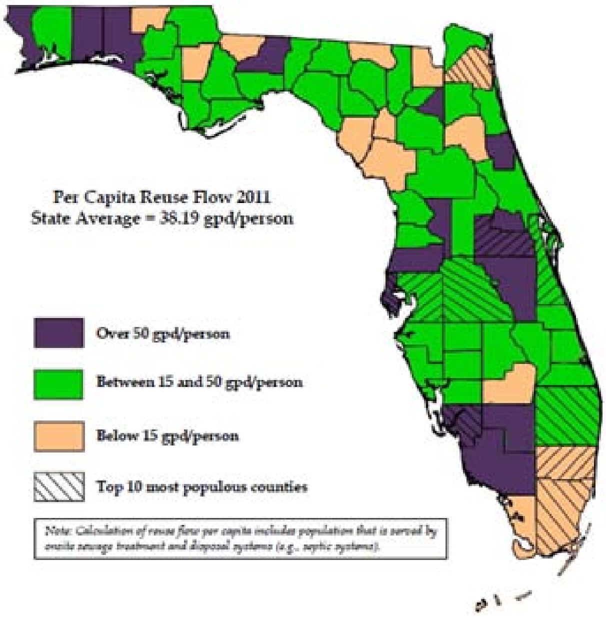

Figure 5-13
Map of per capita reuse flow by county in Florida (FDEP, 2012)

Working in partnership with EPA, FDEP established a Technical Advisory Committee in January 2003 and began development of state criteria. In 2008, a federal legal and rulemaking process ensued, which led to EPA developing their own freshwater NNC in 2010 and working towards proposing rules for primarily marine waters in 2012. Additionally in 2012, the FDEP NNC passed through the state rulemaking and legal process, and that rule has been submitted to EPA for review. It is still uncertain whether the federal or state led NNC rulemaking process will eventually evolve into the NNC rule that will be implemented in the state of Florida. Interested parties should stay tuned to both the federal and state processes to track important milestones over the coming year (EPA, n.d.; FDEP, 2012b; FR 77, 2012:13496-13499).

Unrelated to NNC, the 2008 legislature enacted laws that prohibit ocean discharge of treated wastewater by 2025 except as a backup to a reuse system. Sixty percent of the water currently discharged in ocean outfalls will have to be reused for a beneficial purpose, increasing reclaimed water use by at least 180 mgd (7.9 m^3/s) by 2025. These requirements are based in part on reducing nutrient load to the coastal waters (Goldenberg et al., 2009).

North Carolina

North Carolina is the sixth fastest growing state in the United States, especially in the Research Triangle area, because of the benefits and popularity of the area. This growth increases the need for planning and timely response to meet growing resource demands. Recognition of this growth allows planners to consider an integrated water management approach to their water, wastewater, and reclaimed water utilities.

Climate change, recurring drought cycles, and increasing local temperatures result in an increase in irrigation demand to meet crop evaporation rates. At the same time, changes in precipitation patterns are causing planners to reassess previous plans. Even if the annual rainfall remains relatively constant, higher intensity rainfall can result in more runoff that is not as beneficial as multiple, less intense events. Shifts in time of year for rainfall events can significantly impact soil moisture during critical planting and harvesting periods. This can lead to an increase in supplemental irrigation for predictable crop yields. Recent changes in the North Carolina Reclaimed Water Regulations treat reclaimed water as a resource, allow many uses of reclaimed water by regulation, and increase the potential to use reclaimed water in agricultural applications, especially with Type 2 reclaimed water, the higher of two defined reuse qualities (NCAC, 2011). This higher quality reclaimed water has few agricultural restrictions (one being a 24-hour waiting period following application of reclaimed water prior to harvest). These new rules allow utilities to now consider wholesale supply of reclaimed water to agricultural interest, assuming both parties can come to agreement regarding the value of this water.

Although there may not yet be large power generating needs for reclaimed water in North Carolina, cooling water and industrial process water are attractive to industries and can be supportive of economic development for a community. New residential developments in communities facing water shortages are often able to develop and provide a benefit to residents if reclaimed water is included in a dual water system, allowing homeowners to establish landscape without water restrictions increasing their water bills or use restrictions negating their landscape investments.

In North Carolina today, nutrient reduction requirements and TMDLs resulting in new or re-issued discharge permits that will require installation of advanced wastewater treatment to meet limit of technology nutrient removal are much like events in 1972 that led to the creation of the dual-piped reclaimed water system for St. Petersburg, Fla. The Wilson-Grizzle Act was passed by the Florida legislature in 1972. It required all utilities to cease discharge into Tampa Bay unless they installed advanced wastewater treatment equipment to meet nutrient reduction requirements. Today, St. Petersburg is known as the largest residential reclaimed water service provider in the United States (Crook, 2005). This same opportunity to develop dual piped water systems for new developments could increase use of reclaimed water for residential irrigation over time, minimize increased demands on the potable water system, and delay or eliminate costly nutrient removal improvements at WWTPs.

Going green (or, in some cases, gray) is sometimes driven by new development decisions to create a LEED-certified development or building. In the certification process, up to 10 points can be obtained through use of reclaimed water or on-site use of alternate waters. Currently in North Carolina, the use of graywater without treatment is not allowed (15A NCAC 18A); however, 2011 Session law has called for the development of graywater reuse rules to facilitate its safe and beneficial use. Currently, state/local plumbing authorities allow for the use of graywater for toilet flushing. Both national plumbing codes (Uniform Plumbing Code and International Plumbing Code) require use of purple pipe for all alternate water on-site. Alternate water is defined as reclaimed water, harvested rainwater, graywater, stormwater, and air conditioning condensate. This can create some confusion if a utility provides reclaimed water to a new development that also has alternate waters with some or no treatment.

The town of Cary has one of the more established reclaimed water systems in North Carolina, starting in 2001 with 9 mi of distribution pipeline from the North Cary WRF serving 350 customers (Miles, et al., 2003; The Town of Cary, n.d.; and [US-NC-Cary]). The town also provided a central bulk fill station at the North Cary WRF as shown in **Figure 5-14**. Since system inception, town staff members have trained over 800 bulk water users, mainly landscape and irrigation contractors, in the proper use of reclaimed water. This training is required in order to obtain and apply bulk reclaimed water from the WRF. A recent industry article identified the Cary reclaimed water as "Purple…the new Gold" by serving as a resource during the drought to maintain landscape (Westmiller, 2010).

Figure 5-14
Cary, N.C., bulk fill station allows approved contractors, landscapers, and town staff to use reclaimed water

Durham County, N.C., expanded its reclaimed water program with storage, plant improvements, and a new distribution and metering system to supply supplemental reclaimed water to the town of Cary to begin service to the Cary West Reclaimed Water Service Area. Improvements at the County's Triangle WWTP included a 400,000-gallon ground storage tank, a new high-service reclaimed water distribution pump station, a bulk liquid chlorine feed system, a 24/20/16-in distribution system to serve the town of Cary and other county demands, and a town of Cary metering station.

The city of Raleigh Public Utilities Department currently manages two reclaimed water distribution systems (City of Raleigh, 2012). One is located in the Zebulon service area and currently serves seven customers, totaling approximately 36 million gallons (1.6 m^3/s) annually. The larger Southeast Raleigh reclaimed water distribution system from the Neuse River WWTP is being extended to serve the Walnut Creek Environmental Education Center and the North Carolina State NCSU Centennial Campus and Poole Golf Course.

Raleigh has four bulk reclaimed water stations located throughout the service area at the Neuse River WWTP (southeast Raleigh), E. M. Johnson Water Treatment Plant (North Raleigh), Little Creek WWTP (Zebulon), and Smith Creek WWTP (Wake Forest). Bulk reclaimed water is free of charge after a user completes certification training by the Public Utilities Department. Uses for bulk reclaimed water include irrigation, hydro-seeding, pesticide and herbicide application, concrete production, power/pressure washing, and dust control.

There is also a small on-site reclaimed water system in Wilkerson Park in the city of Raleigh. Wastewater is collected, treated, and reused on-site under a permit issued by the local health department.

The University of North Carolina (UNC) at Chapel Hill began addressing high water use a decade ago with traditional water conservation efforts (low flow showerheads, faucet aerators, and dual flush toilets) and by creating closed loop water service to research laboratories resulting in a 27 percent reduction in water use per square foot. More stringent stormwater regulations in the town of Chapel Hill and Jordan Lake nutrient reductions imposed by the state led to rainwater harvesting on the UNC campus. Harvested rainwater and stormwater is stored in cisterns (constructed under playing fields) and used for irrigating the soccer/intramural fields and baseball stadium, landscaping, and toilet flushing. Two 100-year drought events within 7 years led to the addition of reclaimed water to support campus activities in 2009. Five interconnected chilled water plants (50,000 ton capacity) on campus use 0.5 mgd (21.9 L/s). The UNC Hospital chiller plant uses an additional 0.2 mgd (8.8 L/s). The football and baseball fields are supplied with 0.03 mgd (1.3 L/s) of reclaimed water. Utilization of reclaimed water for uses previously provided potable water reduced potable water use by 37 percent. Finally, to increase system reliability and diversify supply, the rainwater/stormwater cistern system was provided with supply connections from the reclaimed water system (Elfland, 2010).

South Carolina

Water reuse is governed under the state land application rules and is most common along the coast via golf course irrigation. Where controlled access is part of the program, secondary treatment is acceptable. If a more publicly-accessible site is to be used, higher levels of treatment would be required. Some small towns use land application in lieu of surface water discharge in areas where land is inexpensive to purchase. A primary focus of land application permitting is groundwater protection. Therefore, the higher the level of treatment and the greater the depth to groundwater, the more flexible a permit can be written.

Tennessee

Water reuse occurs throughout the state of Tennessee, including in Cumberland, Fayette, Franklin, Lawrence, Maury, Moore, Rutherford, Washington, Williamson, and White counties. Most reuse is for irrigation of golf courses, followed by irrigation for pasture land, residential areas, and parks. Reuse systems in Tennessee operate under a State Operation Permit issued by the Tennessee Department of Environment and Conservation's Division of Water Pollution Control. None of the existing facilities, however, use the reclaimed water for edible crop irrigation, groundwater recharge, or IPR applications. One case study in Tennessee highlights the importance of reuse in integrated planning as a means to address nutrient loading limits to a receiving stream as a result of urban growth [US-TN-Franklin].

5.2.4 Midwest and Great Lakes: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, Ohio, and Wisconsin

This section focuses on the regulatory context and drivers for water reuse in 10 states in the Midwest and Great Lakes region.

5.2.4.1 Population and Land Use

According to the 2010 United States Census, the population in the Midwest and Great Lakes Regions is around 65 million. The geographic center of the contiguous United States is found in Kansas. Chicago, Ill. and its suburbs form the largest metropolitan area in the Midwest, followed by Detroit, Mich.; the Twin Cities (Minneapolis and St. Paul, Minn.); Cleveland, Ohio; St. Louis, Mo. and the Kansas City, Mo. area. **Figure 5-15** shows change in population in the Midwest in the past decade, relative to the United States. The figure also shows the percent change in developed land coverage from 1997-2007.

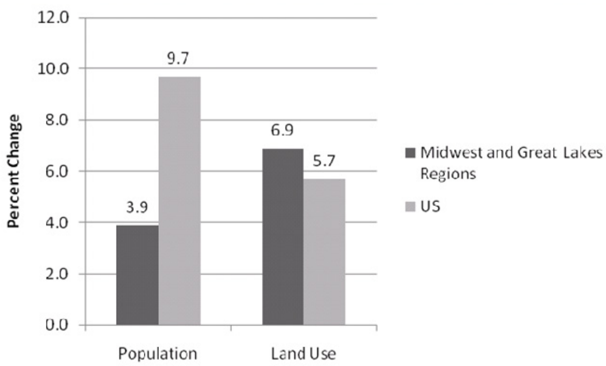

Figure 5-15
Change in population (2000-2010) and developed land (1997-2007) in the Midwest and Great Lakes Region, compared to the United States

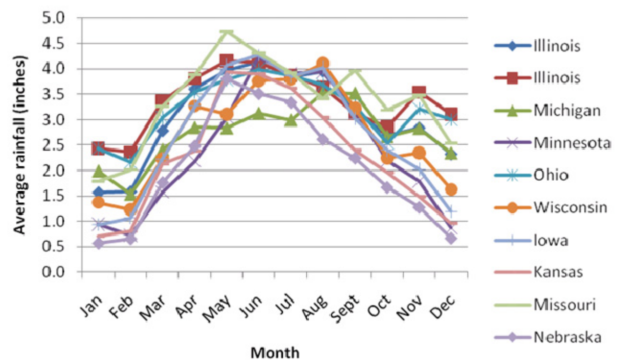

Figure 5-16
Average monthly precipitation in the Midwest

5.2.4.2 Precipitation and Climate

The Midwest states have varying hydrologic and climatic conditions that impact water use. The differences in population and land use in each state also affect consideration of reclaimed water over traditional water supplies. Common to most of the Midwest is a larger proportion of agricultural land and related agricultural processing industries. There are also heavy industrial areas that include mining, auto manufacturing, refining, and metal finishing.

The vast central area of the United States, located between the Central Atlantic coastal states and the Interior Plains states just east of the Rockies, is a landscape of low, flat to rolling terrain typified by vast acres of farmland largely affected by the Mississippi River Drainage System, as well as by the Missouri and Ohio Rivers and the Great Lakes. Rainfall decreases from east to west across the region. Much of the Midwest experiences a humid continental climate, which is typified by large seasonal temperature differences—warm to hot (and often humid) summers and cold (sometimes severely cold) winters. This region of the country is known for extreme weather events: floods in the winter and spring and droughts in the summer months. **Figure 5-16** depicts average monthly precipitation in the Midwest region by state.

5.2.4.3 Water Use by Sector

Figure 5-17 shows freshwater use by sector in the Midwest and Great Lakes Region.

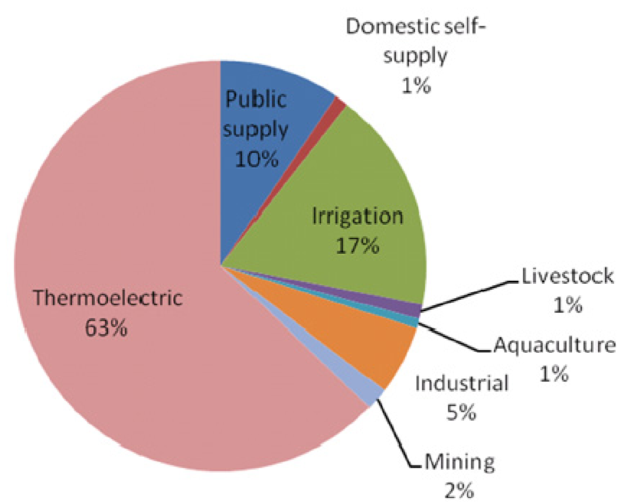

Figure 5-17
Freshwater use by sector for the Midwest and Great Lakes region

Given the different climatic regions and types of industry in the Midwest, water use varies among states. One common use for states with larger river sources such as the Mississippi, Missouri, and Ohio Rivers is the non-consumptive use for once-through cooling water at power generation facilities. This water use is not the optimum candidate for reclaimed water since it does not replace a consumed supply of groundwater or surface water, as would be the case for power plants with recirculated cooling systems. Lower effluent limit requirements being set for some municipal dischargers is expected to result in more municipal wastewater facilities considering water reuse for future improvements projects.

An analysis of one state, Minnesota, is provided as a perspective on water use in other Midwest states.

More than 60 percent of the water used in Minnesota is for power generation facilities, mainly for once-through cooling, as depicted in **Figure 5-18**. Power generation facilities are supplied mostly by surface waters.

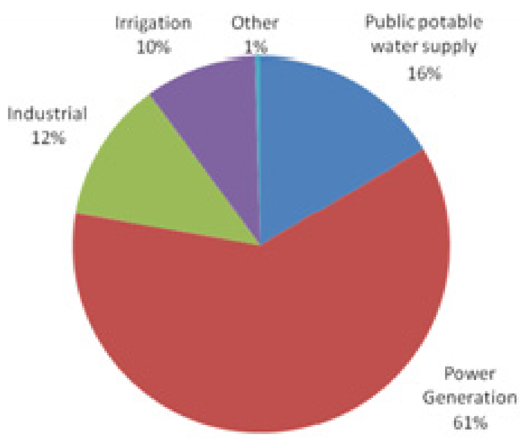

Figure 5-18
Water use in Minnesota, 2007 (Source: MDNR 2008)

The next largest use of water, around 16 percent of the total, is for potable water supply (water utilities), distributed by municipalities for domestic, commercial and industrial uses. Nearly two-thirds of the potable water in Minnesota is supplied by groundwater, as shown in **Figure 5-19**.

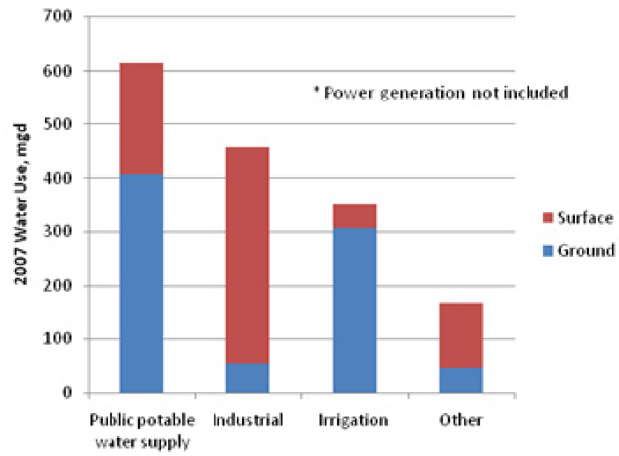

Figure 5-19
Water use in Minnesota by source*, 2007 (Source: MDNR 2008)

Water withdrawn by industries (those not served by water utilities) for various processing needs accounts for about 12 percent of the total water used in Minnesota. The majority of this is surface water used by the pulp and paper and mining industries. Agricultural processing accounts for the largest use of groundwater by industry. Irrigation accounts for about 9 percent of the total water used, and all other water uses comprise about 4 percent of the total water use.

Like many Midwest states, the larger users of groundwater in Minnesota are not always in proximity to populated areas with a sufficient reclaimed water supply, notably for agricultural irrigation and processing facilities. In 2005, the total industrial water use in Minnesota, excluding surface water supplies for power facilities, was estimated to be 445 mgd (19.5 m^3/s), of which 75 mgd (3.3 m^3/s) was used by industries in the Twin Cities area. The total WWTF discharge for the state is 425 mgd (18.6 m^3/s), and 255 mgd (11.2 m^3/s) is from WWTFs in the Twin Cities (Metropolitan Council Environmental Services, 2007).

5.2.4.4. States' Regulatory Context

The Midwest states are beginning to develop regulations and guidelines for water reuse, prompted by recent water reuse installations motivated by shrinking water supplies and other factors. Illinois, Indiana, Iowa, Michigan, Missouri, and Nebraska have water reuse regulations whereas Kansas, Minnesota, and Ohio have guidelines. Wisconsin currently does not have regulations or guidelines governing reuse.

5.2.4.5 Context and Drivers of Water Reuse

This section identifies drivers and characteristics that broadly apply to Midwest states with examples of current reuse practices and develops a range of considerations using Minnesota as an example. There are a variety of opportunities for broader implementation of water reuse practices in the Midwest. There are also a host of factors that affect the feasibility of reuse implementation. Water reuse practices in the Midwest are site-specific and based on a variety of drivers. The drivers can be grouped into four categories: water quality, water quantity, sustainable economic growth, and environmental stewardship (MCES, 2007).

Water Quality

A safe, cost-effective, and adequate water supply generally has been readily attained for most Midwest communities and industries. Historic water reuse applications have been water quality driven. Agricultural irrigation using treated wastewater effluent has been practiced in the Midwest's rural areas in lieu of summer pond discharges for facilities a significant distance from an acceptable receiving stream. More recent water reuse applications driven by discharge limitations include golf course irrigation in urban and resort areas and toilet flush water for buildings.

Water quality issues will drive future water reuse in the Midwest. As growing communities generate additional wastewater, there will be a need to provide higher levels of wastewater treatment to maintain or decrease discharge loads to the region's waterways. The development of TMDLs in the Mississippi River basin's sub watersheds will result in reduced effluent limits for phosphorus, solids, and total nitrogen for many municipal dischargers. Water reuse may become a cost-effective practice for communities where advanced treatment processes are required to meet new receiving stream discharge limits. If these communities are experiencing or forecasting water supply limitations, the benefits of a water reuse option could be even more pronounced. A new advanced WWTF in East Bethel, Minn. in the Twin Cities metro area will discharge high quality reclaimed water to rapid infiltration basins rather than discharging to the river.

Water Quantity

While water quality discharge limitations will increasingly be a factor in the Midwest, it is anticipated that water supply limitations will be a driver in the near future. There are regions and areas specific to each state with an insufficient quantity of ground or surface water and/or impaired quality from various pollution sources.

In terms of water demand for crop irrigation, the northern plains states use 64 percent of total water withdrawals for agricultural irrigation, versus 14 percent for states to the east (Wu et al., 2009). This significant difference in water use is related to less precipitation in the northern plains states as well as a proportionately smaller population with a demand for municipal and power supply uses.

The mid-2000s surge in the biofuel industry prompted investigations for water supply options other than local groundwater in the Midwest's water supply limited regions. Ethanol facilities in North Dakota and Iowa are currently using reclaimed water.

Limited groundwater supply was also the driver for using reclaimed water for a sand washing operation in Marshfield, Wis., and several power generation facilities, such as those supplied by the Heart of the Valley Metropolitan Sewerage District, Wis.; Clear Lake Sanitary District, Iowa; and Mankato, Minn.

Sustainable Economic Growth

Water has historically been undervalued in the Midwest. With the exception of local or sub-regional areas with limited supplies of adequate quality, residents of the Midwest typically pay less for their water supply than areas of the United States with higher levels of water reuse.

While the past decades have focused on protecting the aquatic habitat of the Great Lakes resource and regional watersheds of the Mississippi River basin, future decades will increase efforts to protect ground and surface waters used for potable water supply. As observed with the surge of the biofuel industry, water demand for irrigation and industrial use already has exceeded or may at some point exceed the available groundwater supply in some areas. Communities that want to share in the economic gains of the industry need to be able to provide a sustainable water supply, and there may be more incentive to consider reclaimed water.

Environmental Stewardship

Conservation has been a part of many states' water protection programs, along with more stringent regulations for surface water dischargers. This stewardship ethic can drive reuse projects even when other drivers are not present and when economics would not point to reuse.

For example, the Shakopee Mdewakanton Sioux (Dakota) Community's (SMSC) 0.96 mgd (42 L/s) WRF, constructed in 2006, was initiated as part of SMSC's ongoing activities toward self-sufficiency and natural resources protection. The community's commitment to environmental stewardship is explained as follows: "The Dakota way is to plan for the Seventh Generation, to make sure that resources will be available in the future to sustain life for seven generations to come" (SMSC, n.d.). The facility, located in Prior Lake, Minn., is permitted to discharge to one of two wetlands, shown in **Figure 5-20**, with downstream ponded areas that provide water for SMSC's golf course irrigation system. State and federal agencies are working with the SMSC to explore aquifer recharge to be used primarily in the winter when irrigation is not needed.

Figure 5-20
The SMSC WRF and wetlands

Reclaimed water from Columbia, Mo., is directed to a series of managed wetlands operated by the Missouri Department of Conservation. The wastewater is fed through a series of channels and gates, largely by gravity, offsetting water that would have to be pumped from the ground or the nearby Missouri River for the wetlands. This saves on electrical costs, allowing the scarce public money to be spent instead on habitat work, while preserving freshwater for additional uses. These 1,100 ac of wetlands provide habitat for migratory waterfowl and other wildlife. They are a very popular destination for bird watching and, in the fall, for duck hunting.

Emerging Water Reuse Practices

In some areas of the Midwest, additional emerging drivers may include augmenting or preserving both surface water supplies and groundwater supplies, power generation, and recreational/aesthetic reuse.

In the Chicago metro area, significant flows from regional wastewater treatment pass through the Lockport Powerhouse. Built in 1907, the powerhouse is used by the Metropolitan Water Reclamation District of Greater Chicago to control the flow of the Sanitary and Ship Canal and limit the diversion of water from the Lake Michigan Watershed. The district received approximately $3 million of credit from Commonwealth Edison for transferring approximately 60 million kWhs of power safely generated through hydropower.

On Chicago's west side, a water reuse feasibility study was conducted for service in the vicinity of the Kirie WWTP. Three business/industrial parks in three separate villages are located near the plant, and O'Hare International Airport is to the southeast. Potential uses for reclaimed water to replace potable water use range from 1.3 to 1.9 mgd (57 to 83 L/s) based on the time of year. Potential uses include irrigation, cooling towers, industrial process water, stormwater basin cleaning, municipal solid waste truck washout, and wetland augmentation.

In some Midwest communities, recreational or aesthetic reuse occurs in the form of using reclaimed water to augment golf course ponds, both landscape ponds and water hazard features. This may be indirectly augmenting golf course irrigation needs.

The Village of Richmond, Ill., a small rural community west of Chicago, recently developed an ordinance to promote the preservation of rapidly shrinking groundwater supplies when other sources of water exist for specific uses. The ordinance describes specific instances where municipal water supply users would be required to use reclaimed water. The ordinance encourages water reuse in general. For example, industries are encouraged to use reclaimed water for nonpotable industrial processes. There are both mandated and recommended applications. The following applications are mandated uses:

- Landscape watering except in playgrounds
- Landscape water features except in playgrounds frequented by children 10 years of age or under
- Industrial cooling water
- Toilet flushing at commercial, industrial, and public facilities
- Commercial car wash facilities
- Commercial, industrial, and public boiler feed water

The ordinance encourages other industrial users to consider reclaimed water for appropriate nonpotable industrial processes, specifically mentioning water for construction practices, commercial uses, enhancement of wildlife habitat, and recreation impoundments.

Recently, the state of Missouri was approached about the reuse of treated wastewater in intensive agriculture. The proposals would use wastewater to grow cellulosic biofuel crops in fields specifically constructed with wastewater reuse in mind to maximize production. In instances where all of the wastewater generated by a small town can be used during the summer recreation season, rather than discharged to a water body, it may enable that town to avoid costly upgrades due to new water quality regulations.

Water Reuse Practices in Minnesota

Current Minnesota reuse projects include five for golf course irrigation, one for building toilet flush water, one for wetland enhancement, one for energy plant cooling water, and 32 for agricultural irrigation (non-food crops; main discharge for seasonal stabilization ponds).

Limited water supply was the key driver for the largest water reuse application in Minnesota. The city of Mankato expanded its WWTF in 2006, shown in **Figure 5-21**, to provide the Mankato Energy Center, a 365-MW facility (ultimate capacity of 630 MW), with cooling water. The city provides up to 6.2 mgd (272 L/s) of reclaimed water to the Mankato Energy Center, which returns its cooling water discharge to the WWTF (approximately 25 percent of the volume supplied) as a permitted industrial discharger. The cooling water is commingled with the WWTF process stream prior to dechlorination. Refer to [US-MN-Mankato] for more details.

Figure 5-21
Mankato Water Reclamation Facility

Water supply scarcity in Minnesota's southwest region affected the siting of ethanol facilities during the biofuel industry expansion of the mid-2000s. In conjunction with other planning activities, state agencies increased inventory research on groundwater resources and streamlined permitting practices. In addition, the state legislature became involved by supporting initiatives for water reuse, emphasizing the economic sustainability goals tied to water (MPCA, 2010a).

Legislation under H.F. 1231 introduced in 2009 provided in-kind matching grants for capital projects incorporating water reuse, including specific funds targeting ethanol facilities. Water conservation legislation passed in 2008, based on environmental stewardship and conservation drivers, could affect how municipalities plan for their water supplies. Public water suppliers serving more than 1,000 people (85 percent of Twin Cities metro suppliers) must implement a water conservation rate structure. The rate structure was required by Twin Cities metro area suppliers by 2010, and all remaining water suppliers are to implement the conservation rate structure by 2013 (MPCA 2010b).

Long-term planning for water reuse in Minnesota and other Midwest communities will be influenced by the development of TMDL programs. For example, the Lake Pepin TMDL is projected to require a reduction of one-half the phosphorus and solids loads to Lake Pepin (Mississippi River segment), which will affect nearly two-thirds of Minnesota.

Implementation Considerations in Minnesota

Minnesota is one of several states that have not developed state water reuse criteria. Currently, Minnesota uses California's *Water Recycling Criteria* (State of California, 2000) to evaluate water reuse projects on a case-by-case basis. In Minnesota, water reuse requirements are included in NPDES permits administered by the Minnesota Pollution Control Agency. This model has served well for the permits issued to date, but there is limited information available for those seeking to explore water reuse, and questions have surfaced regarding the applicability of the California criteria for cold-winter climates and specific issues for the Midwest region.

The modifications for reclaimed water production must continue to meet existing NPDES and other permit requirements and consider future permit conditions. Some treatment technologies result in concentrated waste streams, and there is concern that pollutant concentration discharge limits (i.e., TDS, chloride, sulfate, boron, and specific conductance) may exceed the water quality standards for some receiving streams. There are existing industries that cannot expand operations because they cannot cost effectively reduce salt concentrations in the discharge and meet their NPDES permit. Recent requirements for monitoring salty discharges at municipal WWTFs in Minnesota indicate that permit limits may be forthcoming for parameters that some WWTFs cannot currently achieve. The incorporation of reclaimed water practices may increase salt concentrations in the WWTF effluent and become a deterrent to water reuse at some facilities (MPCA 2011).

Most reclaimed water uses will require higher quality water than is currently produced by a WWTP, as with cooling water. Many Midwest communities have hard and high salt waters, which lead to more concentrated salts in the wastewater, particularly for areas relying on home softening systems. Removal of hardness and high salt levels significantly adds to the cost.

Reclaimed water is an emerging water supply for Minnesota communities and industries. Economic development, water supply limitations, and environmental regulations and stewardship will increasingly drive the need to find alternative water supplies. Looking to balance income from water supply and the need to build more infrastructure, communities can partner with local industries and businesses to provide conditions where water reuse can provide environmental benefits and economic advantages for all partners.

5.2.5 South Central: Arkansas, Louisiana, New Mexico, Oklahoma, and Texas

This section focuses on the regulatory context and drivers for water reuse in five states in the South Central region.

5.2.5.1 Population and Land Use

Figure 5-22 compares the change in population in the South Central region to the United States over the past decade. The figure also compares the percent change in developed land between the region and the United States.

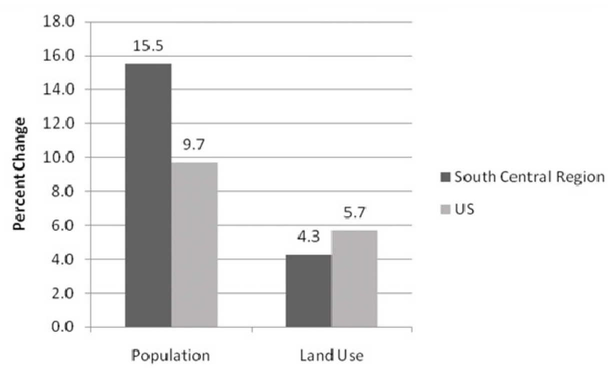

Figure 5-22
Change in population (2000-2010) and developed land (1997-2007) in the South Central region, compared to the United States

Compared to other regions, the South Central region is second only to the Mountain and Plains region in percent population growth. In the Southwest, the greatest population growth over the past decade has occurred in Texas (20.9 percent) and New Mexico (13.2 percent).

5.2.5.2 Precipitation and Climate

Figure 5-23 depicts average monthly precipitation in the South Central region by state.

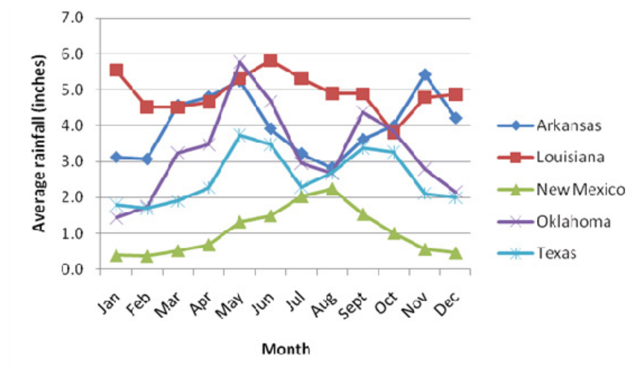

Figure 5-23
Average monthly precipitation in the South Central region

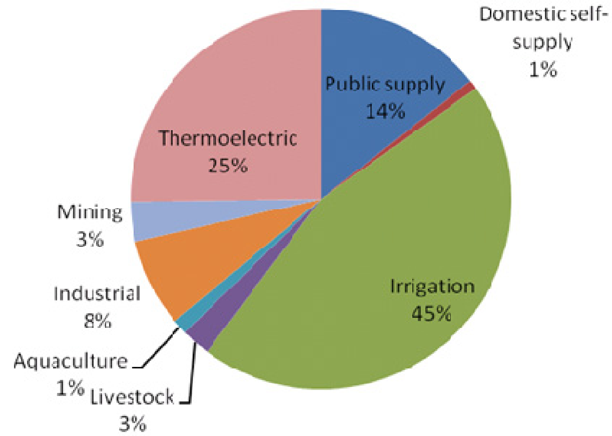

Figure 5-24
Freshwater use by sector for the South Central region

The graphs above present long-term average precipitation. Drought conditions for the last three years in the region have depleted surface water reservoirs and reduced recharge to groundwater aquifers. According to the U.S. Drought Monitor, as of May 1, 2012, over 83 percent of Texas was still in severe (D-3) to exceptional (D-5) drought conditions (Rosencrans, 2012). Southeastern New Mexico shares the fate of West Texas with severe to exceptional drought over most of the state, with relieve to abnormally dry (D-0) conditions in the northwest corner of New Mexico.

With reservoir and aquifer levels dropping, many communities are increasing their conversion to or use of reclaimed water. In West Texas, the Colorado River Municipal Water District is constructing a 2.3 mgd (101 L/s) IPR project that will convert Big Spring wastewater into higher than potable quality and blend the product water with raw water from one of three reservoirs that still has some water. The blended water is then treated at surface water treatment plants in six different communities [US-TX-Big Spring]. The community of Brownwood is in design/construction of a direct potable augmentation plant to supplement supply from a reservoir that may be depleted by the end of 2012 without significant rainfall.

5.2.5.3 Water Use by Sector

Figure 5-24 shows freshwater use by sector in the South Central region.

Irrigation is the largest water user in the region, and reclaimed water is commonly used for irrigation. However, the cost of incremental treatment and distribution for irrigation is a barrier to significant expansion in this sector. Thermoelectric power generation is another large potential use sector for expanding reuse.

5.2.5.4. States' Regulatory Context

Arkansas and Louisiana

At this time, Louisiana does not have regulations or guidelines specifically addressing water reuse. Arkansas had guidelines prior and now has adopted land disposal regulations with a provision for irrigation of forage and non-contact crops.

New Mexico

In 2007, New Mexico Environment Department (NMED) created an updated reclaimed water guidance document "NMED Ground Water Quality Bureau Guidance: Above Ground Use of Reclaimed Domestic Wastewater" that supersedes 1985 and 2003 policy statements. Current guidance identifies four different qualities of reclaimed water, with Class 1A being the highest quality for unrestricted urban uses. Class 1A is based on treatment processes that remove colloidal material and color that can interfere with disinfection. Classes 1B, 2, and 3 are based on secondary treatment processes. Spray irrigation of food crops is not allowed, although surface irrigation with Class 1B or 1A is allowed without contact with edible portions of crops.

Oklahoma

Oklahoma has proposed and adopted new water reuse regulations in Chapter 627 Water Reuse and Chapter 656 Water Pollution Control Facility Construction Standards, which became effective July 1, 2012. The new rules create four categories of reclaimed water (Categories 2 through 5). Each category has a different level of treatment and permitted uses. Regulations for Category 2 for unrestricted access irrigation exclude application on food crops that could be eaten unprocessed and on processed food crops within 30 days of harvest. For Category 3 reclaimed water, the regulations also exclude use on athletic fields with potential for skin to ground contact.

Current reuse applications in Oklahoma have been primarily small community irrigation systems. Uses have expanded into higher intensity agricultural irrigation, unrestricted golf course irrigation, livestock watering, dust control and soil compaction, concrete mixing, cooling towers and chilled water cooling, industrial process water, boiler feed, and land vehicle and equipment washing, excluding self-service car washes.

Texas

Reclaimed water use in Texas is regulated by TCEQ based on Chapter 210 Regulations in the state code. Chapter 210 was first created in 1997 with additions in 2002 to add sub-chapter E specifically addressing industrial process water reuse; in 2005 with sections added at 210, 281, and 285 to describe conditions for graywater use; and in 2009 to amend section 210.33 related to bacterial limitation revisions. Monitoring for *Enterococci* with a limit of 4 CFU/100 mL as a monthly geometric mean and no single sample greater than 9 CFU/100 mL was added for Type I Reclaimed Water (unrestricted use) with a limit of 35 CFU/100 mL added for Type II Reclaimed Water (restricted use). Many stakeholders participated in a three-year review of the 210 rules with changes proposed to TCEQ in 2003 (Vandertulip, et al., 2004). Some of the proposed revisions were incorporated into a revised WWTP design rule when Chapter 317 was revised to Chapter 217 by TCEQ, effective August 28, 2008.

Reclaimed water use in Texas is by authorization from the TCEQ Executive Director upon application by a reclaimed water producer. The producer must have a permitted WWTP and provide reclaimed water of the quality (Type I or II) required for the intended use and meet all Chapter 210 requirements. In 2007, the city of Midland petitioned TCEQ for new rulemaking relative to siting, permitting, and construction of satellite reclamation facilities. Chapter 321 P was created and effective November 28, 2008. Chapter 321 extends the executive director authorization process by allowing construction and operation of a satellite WRF upstream of an existing permitted WWTP. If special siting requirements are met, the facility can be constructed by authorization without additional hearings or permits. The buffer zone requirement doubles to 300 ft (91 m) from any treatment unit unless the reclamation facility is in a building with odor control, then the buffer zone drops to 50 ft (15 m). All screenings and waste biosolids must be returned to the wastewater collection system, and no increase in permitted treatment capacity is included (Vandertulip and Pype, 2009).

For larger systems serving a population of more than 1 million, the state legislature passed House Bill 1922 in 2009, allowing larger systems to commingle reclaimed water supplies in a common distribution system and to discharge from the reclaimed water system at any permitted discharge point. This legislation was proposed based on supply reliability and balancing system capacity, specifically to address the transmission loop for SAWS. With three water reclamation facilities feeding into the reclaimed water distribution system and seven discharge points, portions of the system were isolated by valves as TCEQ determined that discharge from one plant could not supply a system with a discharge point permitted to another WRF. HB 1922 clarified that a looped system operated by one entity could operate with multiple feeds and multiple discharge points. If a permit violation were to exist and the offending WRC could not be identified, any permit violations would apply to the largest WRF in service (Schenk and Vandertulip, 2009).

5.2.5.5 Context and Drivers of Water Reuse

In arid regions from Texas west through Arizona (including Oklahoma and New Mexico), reuse is becoming a vital component of water management. These communities have embraced the use of alternative sources of water to meet the growing need for the vital element. Drought conditions in the Southwest and many parts of Texas have driven municipalities to exploit the use of reclaimed water for nonpotable uses as well as for stream and aquifer augmentation.

Texas

El Paso Water Utility (EPWU) began pilot testing for IPR to augment the Hueco Bolson aquifer in 1978 with operation of an 8 mgd (351 L/s) facility beginning in 1985. They have expanded their portfolio of water reuse by conventional distribution of reclaimed water for irrigation, doubling the aquifer augmentation system and implementation of the largest inland brackish desalination project in the United States with 27.5 mgd (1.2 m^3/s) of supply added to the municipal water system. This integrated resource approach is being followed by the Colorado River Municipal Utility District (CRMUD) direct blending project in Big Spring, Texas [US-TX-Big Spring], where CRMUD is constructing a 2.3 mgd (101 L/s) water purification plant to treat Big Spring secondary filtered wastewater effluent through an MF/RO/advanced oxidation process (AOP) treatment process resulting in a product water with quality superior to potable quality. This product water will be blended in a raw water transmission main with water from Lake Spence and delivered as raw water to six existing surface water treatment plants operated by CRMUD member communities.

Reclaimed water is marketed as having significant advantages, both for the consumer as well as for the supplier. The ability to have a reliable source of water during drought and at a lower rate than potable water provides the greatest advantages to the consumer. However, in the supplier's standpoint, meeting contractual agreements whether based on quantity, redundancy, or even quality may become costly in the short or long term.

Water Quality and Soil Conditions

In some areas of the West, as is the case of El Paso, the source water has higher levels of salts than many water sources in other water rich communities. This creates a domino effect as it impacts the quality of reclaimed water, which has about twice the levels of salts than its source water. The reuse projects extend to areas within proximity of the treatment facilities. The soils in these areas are clay, caliche, or a combination of the two. Clay and caliche soils prevent the percolation or leaching of salts, creating a surface accumulation of salts, which hinders the proper development of plants. The areas where optimal soil conditions are found are limited and might be far from the treatment facility. Thus, application of reclaimed water must be carefully managed to prevent detrimental effects on soil quality and performance of the vegetative landscape due to unfavorable soil characteristics (Miyamoto, 2000, 2001, and 2003) [US-TX-Landscape Study].

To offset impact of saline water supplies, EPWU has incorporated into its project planning a protocol to perform a soil suitability assessment to determine the preliminary condition of the soil that will be subjected to reclaimed water application and the vegetative landscape to set a benchmark condition of the plants and assess any potential to damages after exposure to reclaimed water (Miyamoto, 2004). This tool has been significantly important, as it ranks the suitability of all potential customer sites in order of suitable, suitable with some modification requirements, or non-suitable, prior to finalizing the project and selecting those customers that will be allowed to connect. Customers that are categorized as non-suitable or suitable with some modification are offered the opportunity to explore the level of retrofitting required for reuse. Customers who do not wish to invest in any amendment, are withdrawn from the project, thus minimizing, in most cases, the need to extend pipelines to areas where there are not a high number of customers and where it may not be financially feasible to recuperate the investment.

In the El Paso scenario, mitigation of seasonal spikes in salinity of reclaimed water has been addressed in a more rudimentary fashion. Although concentration of salts in reclaimed water above the maximum limits required by a specific customer may not happen every year, the utility has learned that these fluctuations in TDS can be mitigated by the ability to blend with potable water at a localized point, thus preventing claims for plant damage. To dilute reclaimed water with elevated salinity, reservoirs are fitted with piping that can be manually operated to add potable water to the reservoir to blend with the reclaimed water. The cost to the customer is not modified when potable water is added to the system; it does, however, increase the operational costs to the utility.

In addition to the ability to blend with potable water, the reservoirs have been equipped with recirculating and chlorine injection systems that allow for chemical addition and water mixing, thereby preventing pathogen regrowth by maintaining a minimum chlorine residual level.

Careful consideration of soil composition and existing plant material in selection of potential irrigation customers and impacts of aggressive conservation programs are all aspects of balancing water that have reshaped the planning and phasing of reuse programs in the United States.

In-depth evaluation of soils subjected to irrigation with reclaimed water has been one of the most important considerations in planning a reuse program in El Paso. These studies have been instrumental in the effective use of reclaimed water and prevention of further soil degradation. Costs for biennial soil monitoring have also been budgeted by the utility, with no cost assessed to the customer. Customers do absorb the cost for any plant loss and soil amendments necessary.

Conservation Impact on RW Quality

Other conservation measures, such as use of low and ultra-low flow showerheads, toilets, sinks, washers, etc., continue to increase throughout the United States, so wastewater flows to the treatment facilities may be decreasing. Added to this is the increased use of *in-situ* graywater systems and increased tendencies for achieving sustainability for "green buildings" energy and conservation credits, where applicable. All combined, these factors may, in some instances, impact not only the quantity but also the quality of wastewater available for reclamation.

A study performed by EPWU in 2007 reflected the fact that increased conservation measures contributed to a decline of flows into WWTPs (**Figures 5-25** and **5-26**). In a period from 1994 to 2006, the strength of the wastewater inflow increased in terms of BOD_5 (**Figure 5-27**) and ammonia nitrogen (NH_3-N) (**Figure 5-28**) at three of the WWTPs studied. Total suspended solids (TSS) concentration also increased at one of the WWTPs (**Figure 5-29**) (Ornelas, 2007).

Impacts from water conservation must also be considered during a reuse project planning phase, including reductions in flow where no population increases are expected to overcome decreases in flow. Similar impacts to reduced wastewater influent flows and higher strength wastewater influents have been found in San Antonio and San Diego.

Oklahoma

Reclaimed water has been used in some portions of Oklahoma (Oklahoma University golf course, Norman, Okla.) since 1996. More recently, the city of Norman conducted public forums on Sustainable Water Resources in 2010 and included water reuse as one of the available options to conserve and extend the regional water resources (Clinton, 2010).

On May 9, 2011, the Bureau of Reclamation (USBR) announced the selection of nine feasibility studies for funding under WaterSMART's Title XVI Water Reclamation and Reuse Program in California, Oklahoma, and Texas. The Central Oklahoma Water Conservancy District will conduct a feasibility study in collaboration with surrounding entities to assess alternatives to augment the supply of Lake Thunderbird in Central Oklahoma through the treatment of effluent or surface water. The study will assess alternatives to help postpone or eliminate withdrawals from the local aquifer and alleviate pressure to secure inter-basin water transfers (WRA News, 2011).

Title XVI of P.L. 102-575 provides authority for the USBR water reuse program. WaterSMART is a program of the U.S. Department of the Interior that focuses on improving water conservation and sustainability (USBR, 2012).

New Mexico

New Mexico also is beginning to use more reclaimed water to augment limited natural resources. Projects are in place in many communities (Las Cruces, Alamogordo, Hobbs, Gallup, Santa Fe, and Clovis), and larger projects are expanding in Albuquerque and the surrounding area. The Albuquerque Bernalillo County Water Utility Authority operates the Southeast Water Reclamation plant, which provides reclaimed water to several golf courses, city parks, and a power plant under a simplified regulatory framework. Irrigation of park green space replaces 12 percent of the city's water demand (Stomp, 2004). Including reclaimed water to reduce aquifer withdrawals is critical to slowing aquifer decline and subsidence in Albuquerque.

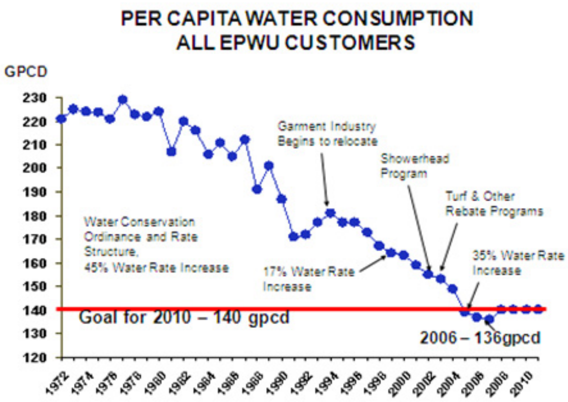

Figure 5-25
Water consumption in El Paso, Texas

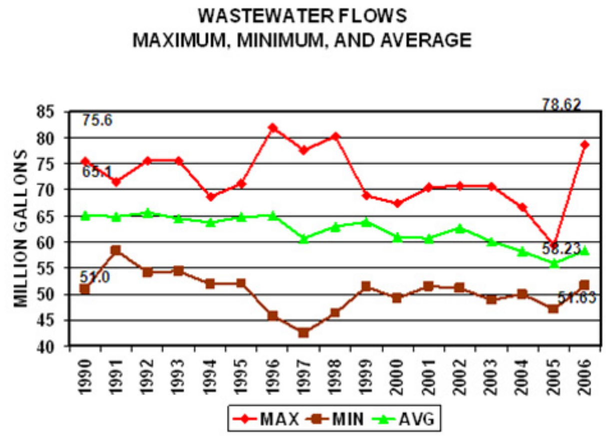

Figure 5-26
Wastewater flows in El Paso, Texas

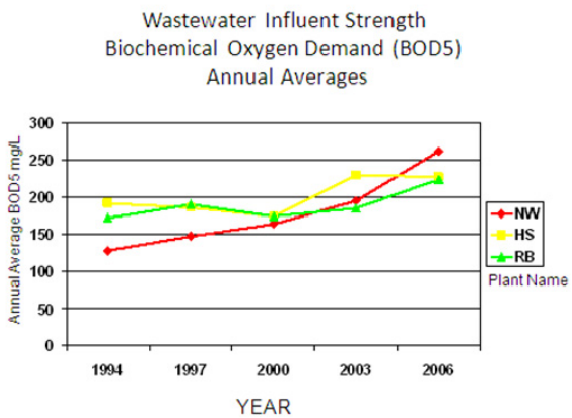

Figure 5-27
Wastewater influent strength, BOD_5

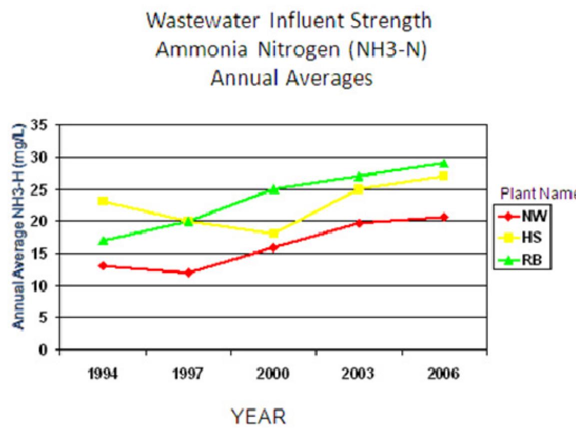

Figure 5-28
Wastewater influent strength, NH3-N

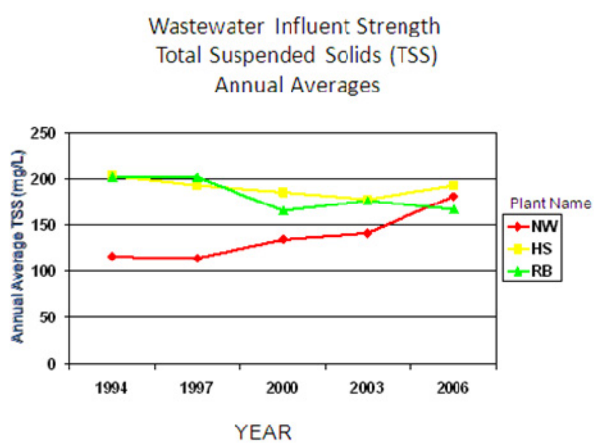

Figure 5-29
Wastewater influent strength, TSS

The state's fastest-growing community, Rio Rancho (located to the northwest of Albuquerque) could not obtain adequate potable water without meeting some of its needs with reclaimed water. One design-build project constructed two 0.6 mgd (26.3 L/s) MBR reclamation plants (Mariposa WRF and Cabezon WRF) that provide high quality reclaimed water for landscape and golf course irrigation. The Cabezon WRF design provides for future addition of increased treatment for indirect potable applications under a direct injection aquifer recharge project (Ryan, 2006).

North of Albuquerque at the Tamaya Resort, Santa Ana Pueblo built a WRF in conjunction with a Native American Casino/Resort and began using reclaimed water to irrigate the Pueblo's golf course in the late 1990s. The facility was further upgraded in 2007 (WaterWorld, n.d.).

5.2.6 Mountain and Plains: Colorado, Montana, South Dakota, North Dakota, Utah, and Wyoming

This section focuses on the regulatory context and drivers for water reuse in six states in the Mountain and Plains region.

5.2.6.1 Population and Land Use

Figure 5-30 compares the percent change in population and in developed land coverage in the Mountain and Plains Regions to the entire United States over the past decade.

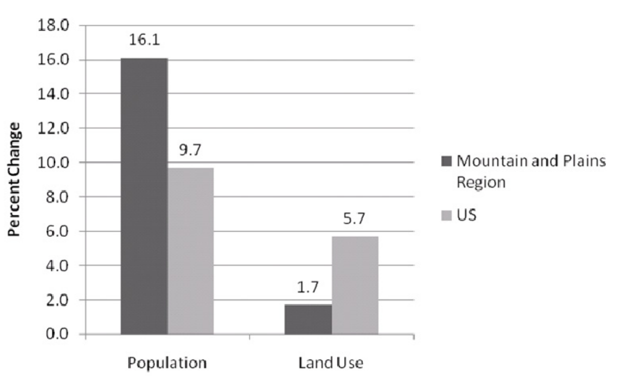

Figure 5-30
Change in population (2000-2010) and developed land (1997-2007) in the Mountain and Plains region, compared to the United States

While Montana, North Dakota, and South Dakota have seen less than 10 percent population growth over the past decade, other states in the region have had more rapid growth. Population growth in Wyoming (14.1 percent), Utah (23.8 percent), and Colorado (16.9 percent) bring the regional population growth above the national average. In fact, on a percentage basis, this region has seen the largest population growth in the nation over this period.

5.2.6.2 Precipitation

Figure 5-31 depicts average monthly precipitation in the Mountain and Plains region by state.

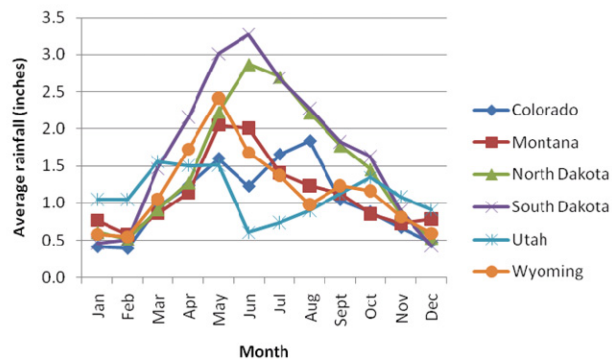

Figure 5-31
Average monthly precipitation in the Mountain and Plains region

Rainfall in this region typically peaks during the summer growing months. Combined with low density development (on average), this weakens some demand for reclaimed water use. As noted previously for Colorado, due to water rights conflicts, rainfall capture is not allowed to supplement local water demands.

5.2.6.3 Water Use by Sector

Figure 5-32 shows freshwater use by sector in the Mountain and Plains region.

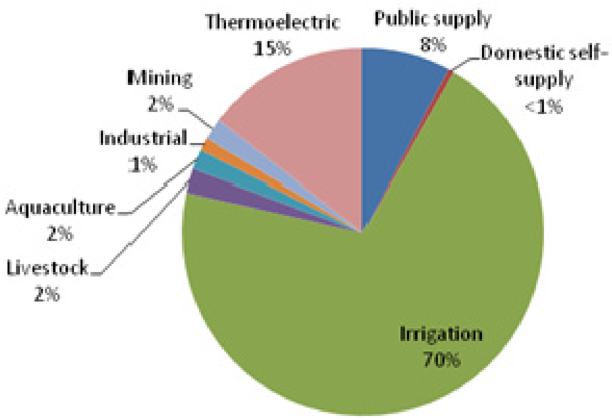

Figure 5-32
Freshwater use by sector for the Mountain and Plains region

Although irrigation is the largest water user in the region and reclaimed water is commonly used for irrigation, cost of incremental treatment and distribution to is an impediment to expansion of reclaimed water integration.

5.2.6.4. States' Regulatory Context

Colorado

The Colorado Water Quality Control commission administers four reclaimed water regulations in the Code of Colorado Regulations 1002-84 Reclaimed Water Control Regulations. The regulation identifies three qualities of reclaimed water: Classes 1, 2, and 3, with Class 3 being the highest quality. Class 3 requires secondary treatment filtration and disinfection for use in unrestricted urban applications. Colorado water rights limit the amount of reclaimed water that can be used, with quantities limited to water quantities imported from western Colorado to the east side of the Rocky Mountains [US-CO-Water Rights].

Montana

Montana established graywater rules in 2007 and updated those rules in 2009 as one step in providing higher quality on-site treatment and reducing water demands. Over the last three years, Montana DEQ staffs have been developing new wastewater design and treatment regulations, including a guidance document on reclaimed water. As of the time of publication, the new rules and standards are currently under review and public hearings.

South Dakota

South Dakota has guidelines on the reuse of reclaimed water for irrigation of food and non-food crops (including restricted urban reuse). Environmental reuse (in this case, releasing treated wastewater back to a water body) and groundwater recharge are covered by rules governing surface water quality standards and wastewater discharge permits.

North Dakota

North Dakota has guidance on water reuse for a number of categories (urban, agriculture, industrial, environmental, and groundwater recharge). While other categories of reuse are not explicitly covered at this time, guidance would allow it on a case-by-case basis.

Utah

Utah Division of Water Quality rules appear in Chapter R317-1, Utah Administrative Code. The rules provide for on-site use of reclaimed water inside a treatment plant boundary for landscape irrigation, washdown, and chlorination system feed water. Chapter R317-3-11 provides for alternate disposal methods of land application and reuse of either Type I (potential human contact) or Type II (human contact unlikely). Type I reuse is allowed for residential irrigation, urban uses, food crop irrigation, pastures, and recreational impoundments where human contact is likely. As of 2005, 10 projects were reusing over 8,500 ac-ft (7.6 mgd or 333 L/s) of reclaimed water, primarily for agricultural, golf course, and landscape irrigation (The Utah Division of Water Resources, 2005).

Wyoming

Wyoming does not have specific regulations or guidelines for water reuse; however, surface water discharge (environmental reuse) and groundwater recharge are covered through the discharge permitting rules. Any other uses, such as restricted and unrestricted urban reuse, agriculture irrigation, and both food and non-food crops are addressed on a case-by-case basis using the construction permitting regulations.

5.2.6.5 Context and Drivers of Water Reuse

Colorado

Prior to the inception of the Code of Colorado Regulations 1002-84 Reclaimed Water Control Regulations, several communities had been using reclaimed water for irrigation for many years.

Currently, 28 facilities in Colorado treat and distribute reclaimed water for beneficial uses, including irrigation, animal exhibit cleaning at the Denver Zoo, and cooling water for the Excel Energy Plant [US-CO-Denver, US-CO-Denver Zoo, US-CO-Denver Energy, and US-CO-Sand Creek]. Several communities depend on reclaimed water in order to meet their irrigation needs. There are now more than 400 approved sites for the use of reclaimed water in Colorado. With current demands for water and expanding drought conditions, the use of reclaimed water in Colorado is moving not only to include new facilities, but possibly new uses, as well.

Montana

One of the earliest water reuse projects in Montana was at Colstrip, Mont. (Vandertulip and Prieto, 2008), which was originally a company mining town providing coal for locomotives. The mine and town were later sold to a power company, and reclaimed water was used for cooling and other industrial applications. Industrial applications, being less seasonal, are still considered a viable opportunity for reclaimed water.

South Dakota

The primary reuse of reclaimed water in South Dakota is irrigation of non-food crops.

North Dakota

Tharaldson Ethanol recognized the opportunity to provide reclaimed water for a 120 million gallon ethanol facility in Casselton, N.D. A 1.4 mgd (61 L/s) advanced membrane facility was constructed to treat city of Fargo WWTF effluent and transport it 26 miles to the ethanol facility by Cass Rural Water District. Waste streams from the ethanol facility are conveyed back to the Fargo WWTF and treated as part of the discharge to the Red River. In addition, reclaimed water is used in Jamestown, Fargo, and Dickinson for hydraulic fracturing.

Utah

Agricultural reuse, primarily for disposal purposes, has been the primary use of reclaimed water in Utah. To date, there has not been significant demand for alternative water sources, such as reclaimed water, for other uses. One agricultural project for the Heber Valley Special Service District uses 1.4 mgd (61 L/s) in agricultural applications to comply with a zero discharge requirement to the Provo River. There are several golf course irrigation projects and planning for future uses in areas where population growth will likely exceed zero discharge capacity (Utah Division of Water Resources, 2005).

Wyoming

Until recently, water reuse projects in Wyoming were few and relatively small. Cheyenne launched the first major water recycling program in Wyoming, winning the WRA Education Program of the Year Award in 2008. Water reuse is regulated through issuance of construction permits, and up to nine facilities have been identified as using nearly 1,000 ac-ft (0.9 mgd or 39 L/s) of reclaimed water per year (0.3 billion gallons per year), primarily for irrigation. Recently, the Red Desert treatment facility opened in Rawlins, Wyo., treating up to 0.9 mgd (39 L/s) of water from hydraulic fracturing operations for reuse in subsequent hydraulic fracturing operations. Marathon Oil's Adams Ranch treatment facility in Sheridan, Wyo., is treating up to 1.5 mgd (66 L/s) of "produced water" through an innovative green sand, ion exchange softening, and RO process. This project, which returns water to the ranch for irrigation and stream flow augmentation, was recognized by the American Academy of Environmental Engineers with its 2012 Honor Award for Industrial Waste Practice.

5.2.7 Pacific Southwest: Arizona, California, Hawaii, Nevada, U.S. Pacific Insular Area Territories (Territory of Guam, Territory of American Samoa, and the Commonwealth of the Northern Mariana Islands), and 147 Federally Recognized Tribal Nations

This section focuses on the regulatory context and drivers for water reuse in the Pacific Southwest region of the United States, which includes Arizona, California, Hawaii, Nevada, the U.S. Pacific Insular Area Territories, and 147 federally recognized tribal nations.

5.2.7.1 Population and Land Use

Figure 5-33 compares the percent change in population for the Pacific Southwest states of Arizona, California, Hawaii, and Nevada to the entire United States over the past decade. The figure also compares the percent change in coverage of developed land in the region and the United States over the past decade.

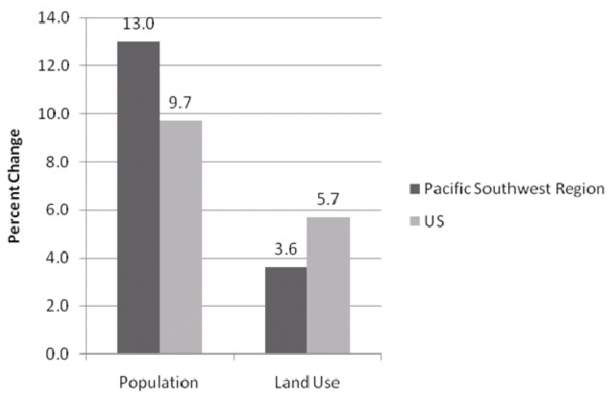

Figure 5-33
Change in population (2000-2010) and developed land (1997-2007) in the Pacific Southwest region, compared to the United States

The Pacific Southwest states have seen significant population growth over the past decade, particularly in Arizona (24.6 percent) and Nevada (35 percent). Looking back at two decades, Arizona and Nevada have experienced truly staggering growth, with 74.4 percent and 124.7 percent growth, respectively, since 1990. These two states experienced the greatest growth rates in the nation since 1990. California's growth rate over the past decade was similar to the national average, at 10.0 percent, but has grown by 25.2 percent since 1990. With California being the most populous state in the nation, home to 37.3 million residents, the growth rate is nonetheless quite significant from a standpoint of natural resources, since the state added 3.4 million residents in 10 years. In terms of absolute numbers, this represents the largest population increase in the country during this period.

Hawaii has exceeded the national average, with a growth rate of 12.3 percent. Hawaii has a resident population of 1.36 million people and annual visitor arrivals of 9.13 million. It is the only state not located on the North American continent and the only state located within the tropics. Lying 2,100 mi west and south of California, Hawaii shares the same general north latitude as Mexico City, Calcutta, Hong Kong, Mecca, and the Sahara Desert. Six major islands (Hawaii, Maui, Oahu, Kauai, Molokai and Lanai) and two smaller islands (Niihau and Kahoolawe) totaling 6,463 mi^2 comprise an island chain stretching northwest to southeast over a zone 430 mi long.

5.2.7.2 Precipitation and Climate

Figure 5-34 depicts average monthly precipitation in the states of the Pacific Southwest—Arizona, California, Hawaii, and Nevada.

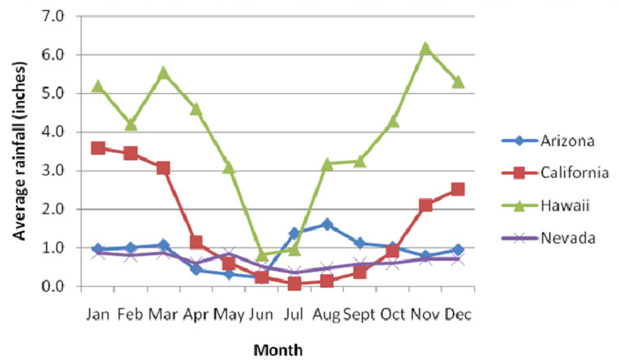

Figure 5-34
Average monthly precipitation in the Pacific Southwest region

There is obvious variance in annual rainfall between Hawaii and the three contiguous states. Within California, the average condition shown in the graph is potentially misleading, with an annual average low rainfall of 1.6 in (4 cm) at Cow Creek in Death Valley and 104.18 in (264.6 cm) at Honeydew in northern California. With a statewide average of 22.2 in (56.3 cm), California ranks 40 in the list of wettest states (Coolweather, n.d.). Arizona averages 13.61 in (34.6 cm) per year with an annual range from 3.01 in (7.6 cm) in Yuma to 22.91 in (58.2 cm) in Flagstaff. Arizona is ranked the 47th wettest state (Coolweather, n.d.). Nevada is the driest state in the United States. Annual rainfall varies from 4.49 in (11.4 cm) per year in Las Vegas to 9.97 in (25.4 cm) in Ely (NOAA, n.d.). With the largest population and driest climate in the state, Las Vegas faces a significant challenge in meeting its water resource needs.

Hawaii's extreme geographical variations are manifest in extreme geographical rainfall variations. Although almost half the state is within 5 mi (8 km) of the seashore, 50 percent of the state is above 2,000 ft (609.6 m) in elevation and 10 percent is above 7,000 ft (2,133.6 m). Three mountain masses rise over 10,000 ft (3,048) above mean sea level, with Mauna Loa and Mauna Kea rising over 13,000 ft (3,962.4 m).

It is not unusual for snow to cap the summits of Mauna Loa, Mauna Kea, and Haleakala when winter storm events are combined with below freezing temperatures.

Dominant trade winds blowing in a general east to west direction and the influence of the islands' terrain provide special climatic character to the islands.

Constant flow of fresh ocean air across the islands and small variation in solar energy are principal reasons for the slight seasonal temperature variations through much of Hawaii. Lowland daytime temperatures are commonly 70 to 80 degrees F (21.1 to 26.6 degrees C), and nighttime temperatures commonly range from 60 to 70 degrees F (15.5 to 21.1 degrees C).

Hawaii's steep rainfall gradients are reflected in the significant variations in precipitation throughout the islands and across individual islands. The lowest annual average precipitation is 5.7 in (14.5 cm) at Puako, Hawaii Island, and the highest average annual precipitation of 460.00 in (11.7 m) is at Mount Waialeale, Kauai. Overall, however, Hawaii's actual average annual rainfall is about 70 in (178 cm). **Figure 5-34** depicts average monthly precipitation in Hawaii.

5.2.7.3 Water Use by Sector

Figure 5-35 shows freshwater use by sector in the Pacific Southwest region states of Arizona, California, Hawaii, and Nevada.

The Pacific Southwest includes several of the driest states in the continental United States and Hawaii, with equally dry areas contrasted by areas with high rainfall. California has a long history of water reuse, while Hawaii's experience is more recent.

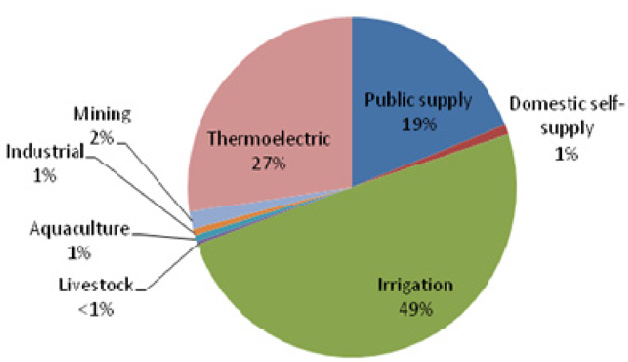

Figure 5-35
Freshwater use by sector for the Pacific Southwest region

Irrigation use is common among the four states with California's use for agricultural and landscape irrigation accounting for 54 percent of the reuse. Arizona has significant water reuse in the power industry with over 80 mgd (3.5 m^3/s) devoted to supporting power generation at Palo Verde Nuclear Generation Station. One trend in each of the states is increased interest in IPR to support sustainable potable water supplies to meet growing populations.

5.2.7.4. States' Regulatory Context

Arizona

Reclaimed water regulations in Arizona have evolved since initial adoption in January 1972. The current regulations, adopted in January 2001, address reclaimed water permitting, requirements for reclaimed water conveyances, reclaimed water quality standards, and allowable end uses. These rules are codified in Arizona Administrative Code Title 18, Chapter 9, Articles 6 and 7 (Reclaimed Water Quality Conveyances and Direct Reuse of Reclaimed Water, respectively), and Title 18, Chapter 11, Article 3 (Reclaimed Water Quality Standards). Under the Chapter 11 provisions regarding reclaimed water quality standards, Arizona established five qualities of reclaimed water from A+ to C, with A+ being the highest quality. Class A+ reclaimed water in Arizona receives secondary treatment followed by filtration, disinfection, and nitrogen reduction to less than 10 mg/L total nitrogen. Table A in the regulation identifies the appropriate minimum quality for 27 categories of approved uses. Quality required for industrial reuse is industry specific and will be determined on a case-by-case basis by the ADEQ.

In August 2009, the Governor formed a Blue Ribbon Panel on Water Sustainability consisting of 40 panelists representing a cross-section of state interest [UA-AZ-Blue Ribbon Panel]. The purpose of the panel was "To advance statewide sustainability of water by increasing the reuse, recycling and conservation of water to support continued economic development in the state of Arizona while protecting Arizona's water supplies and natural environment." To accomplish this, the panel developed five goals and five working groups to address: 1) Increasing the volume of reclaimed water used for beneficial purposes in place of raw or potable water; 2) Advancing water conservation; 3) Reducing the amount of energy needed to produce, deliver, treat, reclaim, and reuse water; 4) Reducing the amount of water required to produce and provide energy by Arizona power generators; and 5) Increasing public awareness and acceptance of reclaimed water uses. The Panel's 18 recommendations were released in a final report on November 30, 2010. The panel concluded that no new regulatory programs or major reconstruction of existing programs were needed and that current programs "constitute an exceptional framework within which water sustainability can be pursued." The panel's recommendations focused on improving existing capabilities in water management, education, and research.

Significant research is being conducted in Arizona in support of the Blue Ribbon Panel recommendations, including chemical water quality; microbial water quality; optimization and life cycle analysis; and societal, legal, and institutional Issues.

California

Current regulations in California related to water reuse are complex and have been in a state of continual flux as water districts and utilities look to expand their use of reclaimed water. California statutes governing water use and the protection of water quality are contained in the California Water Code, which includes varying degrees of permitting authority by nine Regional Water Quality Control Boards (RWQCB), the SWRCB, and the CDPH. Each RWQCB is given authority to regulate specific reclaimed water discharges through the establishment of Water Quality Control Plans (Basin Plans), which include water quality objectives to protect beneficial uses of surface waters and groundwaters within the region. The SWRCB is authorized to adopt statewide policies for water quality control, which are then implemented by each RWQCB. The RWQCB issues the permits based on CDPH Title 22 requirements and comments on the specific project. Finally, CDPH is required to establish uniform statewide water reuse criteria for each type of reclaimed water, wherever the uses are related to public health.

In 2009, the SWRCB adopted a Recycled Water Policy to provide uniformity in the interpretation and implementation of a 1968 anti-degradation policy by each RWQCB for water reuse projects. The policy includes specific requirements for salt/nutrient management plans, special provisions for groundwater recharge projects, anti-degradation, and monitoring for constituents of emerging concern.

Salt/nutrient management plans are a critical component of the new Recycled Water Policy, as the accumulation of salts within soils and groundwater basins has been a long-term challenge in a state with little rainfall, high evaporation rates, and large agricultural and irrigation demands. The salt/nutrient management plans are being adopted by individual RWQCBs as amendments to their current basin plans and will include sources and loadings of salts, nutrients, and other pollutants of concern for each basin; implementation measures to manage pollutant loadings on a sustainable basis; and anti-degradation analysis demonstrating that all reclaimed water projects identified in the plan will collectively satisfy the state's anti-degradation policy and applicable water-quality objectives in the basin plans.

The special provisions for groundwater recharge projects in the Recycled Water Policy require site-specific, project-by-project review and establish criteria for RWQCB approval, including a one year, expedited permit process for projects that use RO treatment for surface spreading.

CDPH regulations are codified within the California Code of Regulations, with specific provisions related to reclaimed water within California Code of Regulations Title 22 and 17. Regulations governing nonpotable reuse include specific water quality, treatment, and monitoring requirements identified in California Code of Regulations Title 22 and enforced by the various RWQCBs. These regulations have remained relatively static over the last 10 years, with recent changes related primarily to laboratory and operator certification requirements.

In addition, CDPH has developed a series of draft groundwater recharge regulations that are used as a basis for the case-by-case approval of individual groundwater replenishment projects. Current codified regulations in California Code of Regulations Title 22 include only narrative requirements for IPR, without specific provisions for treatment or water quality. Amendments to the California Water Code (CWC) made in 2010 require CDPH to adopt formal groundwater recharge regulations by December 31, 2013, while developing surface water augmentation regulations and a policy on direct potable reuse by December 31, 2016 (CWC 13350, 13521, and 13560 to 13569).

The current draft of the groundwater recharge regulations was published in November 2011 and defines separate requirements for direct injection, surface spreading, and surface spreading without advanced treatment. Full advanced treatment, defined as RO followed by advanced oxidation, is required for direct injection or for surface spreading projects where strict TOC limits cannot be met and reclaimed water contribution to the groundwater exceeds 20 percent. The draft regulations include specific limits for TOC, total nitrogen, and other regulated and previously unregulated water quality parameters, as well as pathogen reduction requirements that include a 12-log reduction for enteric virus, 10-log for *Giardia* cyst, and 10-log for *Cryptosporidium* oocyst. Recharged water must be retained underground for a minimum of two months. The regulations also allow for alternative treatment approaches evaluated on a case-by-case basis and give credit for soil aquifer treatment when surface spreading is employed.

Hawaii

All water reuse projects in the state of Hawaii are subject to the review and approval by the Hawaii State Department of Health Wastewater Branch. The Hawaii State Department of Health issued the "Guidelines for the Treatment and Use of Reclaimed Water" in November 1993. The guidelines were adopted into Hawaii Administrative Rules Title 11, Chapter 62, Wastewater Systems updated in May 2002 and re-titled, "Guidelines for the Treatment and Use of Recycled Water."

The guidelines define three classes of reclaimed water as R-1, R-2, and R-3 water:

1. **R-1 Water** is the highest quality reclaimed water. It is treated effluent that has undergone filtration and disinfection and can be utilized for spray irrigation without restrictions on use.

2. **R-2 Water** is disinfected secondary (biologically) treated effluent. Its uses are subjected to specific restrictions and controls.

3. **R-3 Water** is the lowest quality reclaimed water. It is undisinfected, secondary treated effluent whose uses are severely limited.

Nevada

In addition to regulations, Nevada has guidelines for reuse in the form of Water Technical Sheets: WTS-1A (General Design Criteria for Reclaimed Water Irrigation Use) and WTS-1B (General Criteria for Preparing an Effluent Management Plan). These documents describe criteria to be included in the required engineering plan for irrigation reuse projects and information to be evaluated in preparing a management plan for reclaimed water use.

U.S. Pacific Insular Area Territories (Territory of Guam, Territory of American Samoa, and CNMI), and 147 federally recognized tribal nations

CNMI has regulations that allow the reuse of wastewater. The regulations include defined treatment standards for land application, including limited types of irrigation. Use of reclaimed water for food crops, parks, playgrounds, schoolyards, residential/commercial garden landscaping, or fountains is specifically prohibited. The CNMI regulations require other safety measures for reuse, including contingency planning, reporting requirements, design requirements, and signage requirements in the Chamorro, Carolinian, and English languages. No information was located on regulations or guidelines promulgated by the territories of Guam and American Samoa or by federally recognized tribal nations.

5.2.7.5 Context and Drivers of Water Reuse

Arizona

Water reuse has become critical to many communities in Arizona as a means of ensuring a stable alternative water supply. In Gilbert, reclaimed water is an important element of the town's ability to demonstrate a 100-year assured water supply (a requirement of the Arizona Groundwater Management Act's stringent water conservation requirements). Without water reuse, the town would be subject to a state imposed growth moratorium [US-AZ-Gilbert]. Further north in the town of Prescott Valley, a national precedent was set in 2006 when the town held an auction for its effluent, creating marketable rights for effluent as a commodity for the first time in Arizona and in the United States as a whole [US-AZ-Prescott Valley].

Significant reclaimed water is used in Arizona for energy production and building cooling needs. The Palo Verde Nuclear Generating Station operated by Arizona Public Service has been receiving reclaimed water from the 91st Avenue Water Reclamation Plant in Phoenix for 25 years. Recent use has been 67,000 ac-ft/yr (6.0 mgd or 263 L/s), and a new contract was signed in 2010 allocating 80,000 ac-ft (7.2 mgd or 314 L/s) of reclaimed water per year for cooling water demand [US-AZ-Phoenix]. Other significant programs in Arizona include the city of Tucson water reuse program; the Scottsdale Water Campus; the city of Peoria Butler Drive WRF; the Cave Creek Water Reclamation Plant; and the City of Surprise, with a 6.6 mgd (289 L/s) distribution of Class A+ reclaimed water for direct reuse (35 percent) and aquifer recharge.

The city of Tucson's reclaimed water use in 2010 is shown in **Figure 5-36**. The city's program includes an established delivery system and model cross-connection control and site inspection program [US-AZ-Tucson].

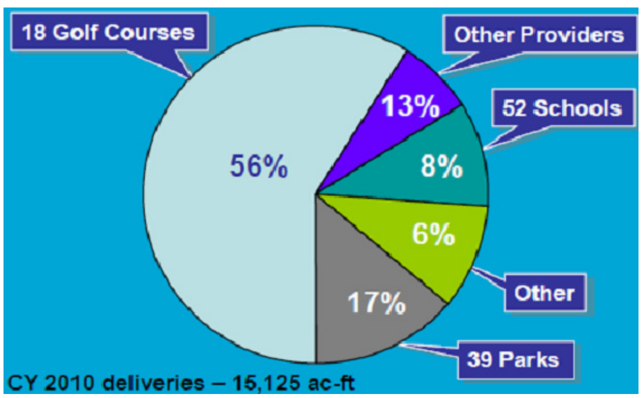

Figure 5-36
2010 Reclaimed water use in Tucson, Ariz.

A prominent addition to industrial water reclamation is represented by the expansion of the Frito-Lay production facility in Casa Grande with a 0.65 mgd (29 L/s) industrial Process Water Recovery Treatment Plant (PWRTP) that saves 100 million gallons of water per year. This facility and other environmental achievements are described in a case study [US-AZ-Frito-Lay].

The EOP is operated by the city of Sierra Vista, Arizona, in Cochise County in the southeastern corner of the state to polish 2.5 mgd (110 L/s) of current flow through constructed wetlands and to recharge the local aquifer in order to mitigate the adverse impacts of continued groundwater pumping in the San Pedro River system. This project is detailed in a case study [US-AZ-Sierra Vista].

Overall, the ADEQ estimates that 65 percent of the WWTPs in Arizona now distribute treated wastewater for reuse, including 10 of the 12 largest plants.

California

Due to low seasonal rainfall, large population centers, and strong agricultural demands, reclaimed water has been utilized within the state of California for almost a century to meet irrigation and other nonpotable water needs. Initiated in 1960 with spreading basin recharge at the Montebello Forebay, IPR has been employed to supplement over-stressed potable water supplies, both through surface water spreading and through direct injection into potable water aquifers [US-CA-Los Angeles County]. A 2009 Municipal Wastewater Recycling Survey released by the SWRCB identified 669,000 ac-ft/yr (600 mgd) of reclaimed water being used in California, with 37 percent of this used for agricultural irrigation, 24 percent for landscape and golf course irrigation, and 19 percent for groundwater recharge and injection into seawater intrusion barriers (SWRCB, 2011). **Figure 5-37** identifies the uses of reclaimed water from the 2009 survey.

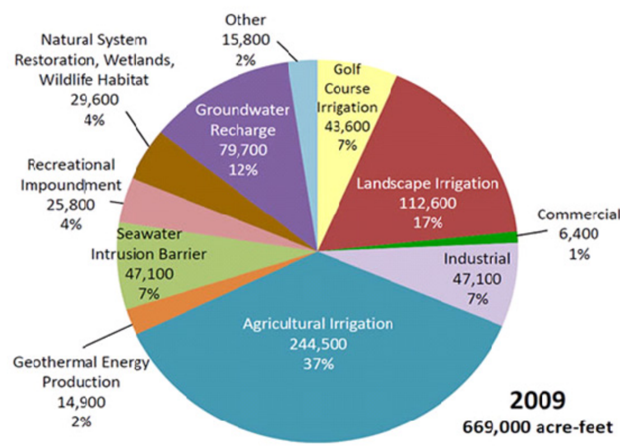

Figure 5-37
Uses of recycled water in Calif. (SWRCB 2011)

Agricultural reuse is the largest user of reclaimed water in California. In Monterey, reclaimed water has been used since 1998 on prime farmland to grow cool season vegetables as part of an effort to reduce groundwater extraction [US-CA-Monterey]. Long-term (10-year) studies of soil salinity have been implemented to understand how different soil types in the region respond to the salt content of reclaimed water. In San Diego, the North City Reclamation Plant uses an electrodialysis reversal (EDR) system to desalinate advanced treated reclaimed water to provide a new source of high quality irrigation water, thereby reducing demand on the freshwater supply [US-CA-North City]. The desalinated reclaimed water is used to irrigate golf courses, plant nurseries, parks, highway green belts, and residential areas. In the city of Temecula, north of San Diego, local avocado, citrus, and grape farmers currently use fully treated drinking water for irrigation. Faced with rising potable water costs, farmers may go out of business. Recognizing the un-sustainability of the current system, the Rancho California Water District recently conducted a feasibility study to replace part of the irrigation water with reclaimed water [US-CA-Temecula].

An example of reuse for ecological purposes comes from Lake Elsinore, a recreational lake [US-CA-Elsinore Valley]. Lake Elsinore was plagued for decades by low water levels and high concentrations of nutrients, causing algal blooms. To improve lake levels while addressing nutrient concentrations, 5 mgd (219 L/s) of reclaimed water is now sent to the lake.

An example of two utility districts teaming together as a cost-effective solution to distribute reclaimed water comes from the San Ramon Valley Reclaimed Water Program [US-CA-San Ramon]. DSRSD and the East Bay Municipal Utility District (EBMUD) formed a joint powers authority to develop and manage the San Ramon Valley Reclaimed Water Program. Despite differences in size, structure, and culture, the two agencies have successfully joined to plan a system that serves both newly built and retrofitted neighborhoods with reclaimed water for landscape irrigation.

While the majority of water reuse in the state remains nonpotable, indirect potable uses have been growing rapidly, forcing adaptation and development of recycled water regulations to address the changing demands. In the 1970s, RO began being utilized in Orange County to treat wastewater before injecting it into barrier wells, preventing seawater intrusion into the potable water supply aquifer [US-CA-Orange County]. San Diego has identified IPR through reservoir augmentation as the preferred strategy to reduce reliance on imported water [US-CA-San Diego]. The Water Purification Demonstration Project currently underway is evaluating the feasibility of using advanced treatment technology to produce water that can be sent to the city's San Vicente Reservoir, to be later treated for distribution as potable water.

Today there are four large-scale facilities in southern California utilizing membrane filtration, RO, and varying levels of UV disinfection and advanced oxidation to produce high quality purified water for direct injection into potable water aquifers. The four facilities are the Orange County Groundwater Replenishment System [US-CA-Orange County], West Basin Municipal Water District Edward C. Little Water Recycling Facility [US-CA-West Basin], Los Angeles Bureau of Sanitation Terminal Island Water Reclamation Plant, and the Water Replenishment District of Southern California Leo J. Vander Lans Water Treatment Facility [US-CA-Vander Lans].

Other facilities are also utilizing infiltration basins for surface spreading to recharge previously over-drafted aquifers with advanced treated wastewater, including the Montebello Forebay [US-CA-Los Angeles County] and the Inland Empire Utility Agency [US-CA-Santa Ana River]. The Water Replenishment District of Southern California operates a program to artificially replenish groundwater basins by spreading and injecting replenishment water, which includes imported water and reclaimed water [US-CA-Vander Lans].

Some regional entities in water scarce parts of California are providing support and incentives for new water reuse projects. The Santa Ana River watershed encompasses parts of four large counties in Southern California. The Santa Ana Watershed Project Authority has a comprehensive, integrated planning process called "One Water One Watershed," to increase reuse from 10 to 17 percent by 2030. Reclaimed water uses include municipal use, agricultural irrigation, groundwater recharge, habitat and environmental protection, industrial use, and lake stabilization. A 40-year salinity management program is a key aspect of the integrated planning.

The Metropolitan Water District of Southern California is a regional water wholesaler serving approximately 19 million people across six counties [US-CA-Southern California MWD]. To meet long-term water demands, Metropolitan provides a regional financial incentive program to encourage development of reclaimed water and groundwater recovery projects that reduce demand on imported water supplies. To date, Metropolitan has provided incentives to 64 water reuse projects throughout Metropolitan's service area, which are expected to produce an ultimate yield of about

323,000 ac-ft (105 billion gallons) per year when fully implemented.

Hawaii

Each Hawaiian island has wet areas and dry areas with great surpluses in some areas and great deficiencies in others. Historically, there has been an overall abundance of water, but the challenge has been one of distribution rather than a general water shortage. The majority of Hawaii's potable water sources are groundwater. A growing population is increasing stress on the sustainability of these limited groundwater resources.

Almost 70 percent of Hawaii's potable water is used to irrigate agricultural crops, golf courses, and residential and commercial landscaping. The state of Hawaii, the city and county of Honolulu (Oahu), the county of Maui (Maui, Lanai, and Molokai), the county of Kauai, and the county of Hawaii are increasing water conservation and water reuse efforts to manage and preserve potable water resources.

The Hawaii State Department of Land and Natural Resources Commission on Water Resource Management in partnership with USACE have determined that a water conservation plan for the state of Hawaii should be established. Water reuse is anticipated to be a significant component of the plan's policy and program development.

Although all six major Hawaiian Islands have reclaimed water projects, the existence or nonexistence of reclaimed water programs varies by county.

The county of Maui and city and county of Honolulu have committed significant resources to promote and develop their respective reclaimed water programs. The county of Kauai does not have a stated reclaimed water program. The county of Hawaii does not have a reclaimed water program. Please see the case study [US-HI-Reuse] for more detail on reuse applications in Hawaii and a timeline of implementation.

Nevada

As the driest state whose largest population base is located in Las Vegas, Nevada is faced with a significant potable water supply challenge. Lake Mead serves as the primary water supply for the city, along with some groundwater resources. Within the Las Vegas area drainage, all reclaimed water and stormwater return to Lake Mead, which results in a continuous water reuse cycle, fed by new river inflows. With this knowledge, high levels of treatment are provided and high technology water quality monitoring is applied to meet potable water quality for utility customers. Individual on-site graywater reuse is not allowed in Nevada, as little treatment is provided in the graywater systems compared to the municipal treatment systems, and water rights accounting does not recognize graywater, even if used in place of potable water.

CNMI

One of the golf courses on Saipan—the main inhabited island of the CNMI—uses land application of reclaimed water on non-accessible areas of the grounds (not on the playing greens).

Federally Recognized Tribal Nations

In Region 9, several tribal nations practice water reuse, particularly at facilities with transient populations in arid areas. For example, in rural Capay Valley, Calif., the Yoche Dehe Wintun Nation's Cache Creek Casino Resort has on-site water reclamation and reuse for golf course irrigation, toilet flushing, and decorative water features (S. Roberts Co., 2009). To manage salinity for irrigation, the system includes desalination. In Alpine, Calif. the Viejas Band of Kumeyaay Indians have incorporated water reuse for landscape irrigation on their reservation, which has 400 non-transient residents and an average of 5,000 transient residents who are visitors to the Viejas Casino, an Outlet Mall and Recreational Vehicle Park (Bassyouni et al., 2006).

5.2.8 Pacific Northwest: Alaska, Idaho, Oregon, and Washington

This section focuses on the regulatory context and drivers for water reuse in four states in the Pacific Northwest region.

5.2.8.1 Population and Land Use

Figure 5-38 compares the percent change in population and developed land coverage in the Pacific Northwest compared to the entire United States over the past decade.

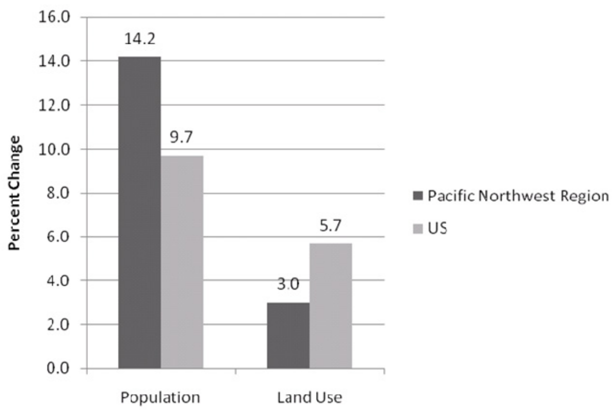

Figure 5-38
Change in population (2000-2010) and developed land (1997-2007) in the Pacific Northwest region, compared to the United States

The Pacific Northwest region's population grew at 14.2 percent over the past decade, with significant population increases in Alaska (13.3 percent), Idaho (21.1 percent), Oregon (12.0 percent), and Washington (14.1 percent).

Alaska has a population of 0.7 million residents, adding about 80,000 residents over the past decade. Idaho is the 39th most populous state with 1.6 million residents and the 14th largest state by land area.

Oregon has 3.8 million residents. Washington State is the 13th most populous state with 6.7 million residents. The Cascade Range runs north-south, bisecting the state.

5.2.8.2 Precipitation and Climate

Figure 5-39 depicts average monthly precipitation in the Pacific Northwest region by state.

Western Washington, from the Cascades westward, has a mostly marine west coast climate with mild temperatures and wet winters, autumns, and springs, and relatively dry summers. Eastern Washington, east of the Cascades, has a relatively dry climate. Summers are warmer, winters are colder and precipitation is less than half of western Washington. Eastern Washington has roughly twice the land area and one-third the population of western Washington.

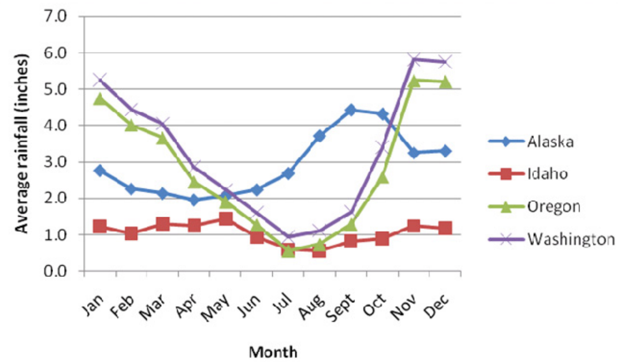

Figure 5-39
Average monthly precipitation in the Pacific Northwest region

The climate in Oregon varies greatly between the western and eastern regions of the state. The Columbia and Snake rivers delineate much of Oregon's northern and eastern boundaries, respectively. The landscape in Oregon is diverse and varies from rain forest in the Coast Range in the western region to barren desert in the southeast. An oceanic climate predominates in Western Oregon, and a much drier semi-arid climate prevails east of the Cascade Range in Eastern Oregon. Population centers lie mostly in the western part of the state, which is generally moist and mild, while the lightly populated high deserts of Central and Eastern Oregon are much drier.

The four seasons are distinct in all parts of Idaho, but different parts of the state experience them differently. Spring comes earlier and winter later to Boise and Lewiston, which are protected from severe weather by nearby mountains and call themselves "banana belts." Eastern Idaho has a more continental climate, with more extreme temperatures; climatic conditions there and elsewhere vary with the elevation. Humidity is low throughout the state. Precipitation in southern Idaho averages 13 in (33 cm) per year; in the north, precipitation averages over 30 in (76 cm) per year. Average annual precipitation (1971 to 2000) at Boise was 12.2 in (31 cm), with more than 21 in (53 cm) of snow. Much greater accumulations of snow are experienced in the mountains.

Though possibly perceived as a state with high precipitation, Alaska actually ranks as the 39th wettest state (22.70 in or 57.7 cm annually) with an annual rainfall range from 4.16 in (10.6 cm) in Barrow on the north coast to 75.35 in (191 cm) in Kodiak in the south. Due to a colder climate, snowfall ranges from 30.3 in (77 cm) per year in Barrow to 322.9 in (8.2 m) in Valdez. The colder weather conditions limit agricultural applications, one of the historically high uses for reclaimed water.

5.2.8.3 Water Use by Sector

Figure 5-40 shows freshwater use by sector in the Pacific Northwest.

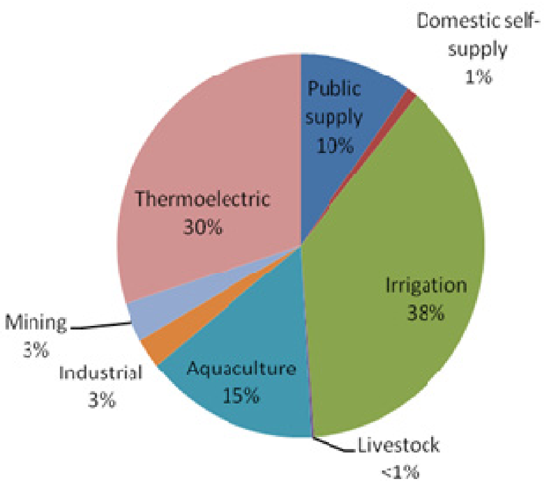

Figure 5-40
Freshwater use by sector for the Pacific Northwest region

Idaho, Oregon, and Washington have well developed regulations and standards. Idaho's continuing efforts to support reuse, considering the different types of land application and treatment systems and end uses, have led to updates in state regulations and guidance over the years. With emphasis on in-stream water quality, focused on nutrients and sediment, all of the sectors in Idaho, Oregon, and Washington could anticipate increased interest in water reuse.

5.2.8.4. States' Regulatory Context

Alaska

Alaska does not have regulations that specifically address water reuse.

Idaho

Idaho has both reuse regulations and guidelines whose scope includes treatment and beneficial reuse of municipal and industrial wastewater. Water reuse by different types of land application facilities is allowed by state regulations. In 1988, Idaho's Wastewater Land Application permitting rules were promulgated and guidance was developed. Idaho has a public advisory working group that meets periodically to advise guidance development and review existing and future reuse guidance. In 2011 reuse regulations were updated, and the name of the rules changed to Recycled Water Rules (IDAPA 58.01.17). Idaho DEQ is the state agency tasked with issuing both industrial and municipal reuse permits. In Idaho, the NPDES permit program, which includes discharge of reclaimed water to surface waters, is administered by EPA, which means EPA is responsible for issuing and enforcing all NPDES permits in Idaho.

Oregon

The Oregon Administrative Rules, Chapter 340, Division 55 (OAR 340-055), "Recycled Water Use," prescribe the requirements for the use of reclaimed water for beneficial purposes while protecting public health and the environment. The Oregon DEQ is responsible for implementing these rules. The department coordinates closely with other state agencies to ensure consistency; in particular, the Oregon Department of Human Services and the Oregon Water Resources Department also play key roles in implementing these rules. Facilities are required to manage and operate reclaimed water projects under a water reuse management plan. These plans are specific to each facility and are considered part of a facility's NPDES or water pollution control facility (WPCF) water quality permit. Site-specific conditions, such as application rates and setbacks, may be established to ensure the protection of public health and the environment.

Washington

In 1992 the Washington State Legislature passed the Reclaimed Water Act, Chapter 90.46 RCW. The Reclaimed Water Act and Chapters 90.48 and 90.82 RCW encourage the development and use of reclaimed water, require consideration of reclaimed water in wastewater and water supply planning, and recognize the importance of reclaimed water as a strategy within water resource management statewide. Reclaimed water is recognized as a resource that can be integrated into state, regional, and local strategies to respond to population growth and climate change. The state also recognizes reclaimed water as an important mechanism for reducing discharge of treated wastewater into Puget Sound and other sensitive areas for improving water quality in the Sound. For more history on the regulatory context in Washington state, refer to the case study [US-WA-Regulations].

5.2.8.5 Context and Drivers of Water Reuse

Alaska

Water reuse in Alaska is not regularly implemented.

Idaho

Idaho has been supporting reuse since 1988, and 2011 Idaho DEQ data indicate that 8.5 billion gallons of wastewater were reused by municipal and industrial sites. The drivers for the use of reclaimed water include more stringent discharge regulations, water supply demands, the need to offset potable water use, and a need to reduce pollutant loads and discharge volumes in receiving waters. There are 136 reuse permits in the state, and the number of permits is expected to grow due to strict TMDL limits for pollutants such as phosphorus. The first municipal land application/reuse permit was issued to the city of Rupert in 1989, and the first industrial reuse permit was issued in 1990 to Lamb Weston, a potato processor.

Although municipal reuse has been permitted for many years, the city of Meridian is the first municipal system in the state with a city-wide Class A permit. Several years ago the city had a desire to explore the use of reclaimed water at the city park, located one and a-half miles north of the WWTP. The city was able to convert a seldom used outfall line to transport reclaimed water from the plant to the park for irrigation. Additionally, this outfall line provided the chlorine contact time required to meet the city's site-specific permit. The elevated chlorine levels at the park and nutrients in the reclaimed water presented challenges with the clarity of the holding pond that the city discharged into prior to irrigation. This and other factors led to the city moving to a pressurized reclaimed water system that is currently going through startup testing. This system, coupled with a citywide reuse permit, will allow the city to use reclaimed water at a new interchange, the city park, the WWTP, and a car wash.

Since 2004 the Idaho DEQ has hosted an annual water reuse conference designed to enable water and wastewater professionals to continue their education, network, and discuss key issues related to water reuse in Idaho and the West.

Oregon

Water reuse has been practiced in Oregon for several decades. There are more than two dozen facilities that implement water reuse programs throughout the state. Many people may think of water reuse in terms of crop or pasture irrigation. While this is a valuable use, there are many other uses practiced in Oregon, including irrigation of golf courses, playing fields, poplar tree plantations, and commercial landscapes; cooling in the production of electricity; and for wetland habitats. The drivers for water reuse in Oregon include limitations imposed by new surface water discharge regulations, impaired water bodies with TMDLs, opportunities due to upgrades with advanced treatment technologies, and water supply needs.

The following are a few examples of how reclaimed water is used in Oregon:

- City of Prineville—golf course and pasture**.** Several years ago, the city of Prineville needed to look at non-discharge alternatives to the Crooked River during the summer months. An EPA construction grant assisted the city in developing a golf course irrigation system in which reclaimed water is used. The city owns and operates the golf course, thus generating revenue through playing fees. The city recently expanded the use of reclaimed water to irrigate nearby pasture land.

- Clean Water Services (Washington County)—golf courses, playing fields, plant nursery. This public utility serving nearly 500,000 customers operates four major WWTFs and works with 12 member cities to provide reclaimed water for a variety of uses. Reclaimed water is used for irrigation of three golf courses, two school playing fields, and a plant nursery.

- Metropolitan Wastewater Management Commission—poplar tree plantation. Serving the cities of Eugene and Springfield, this regional WWTF provides reclaimed water to its Biocycle Farm for a 596-ac poplar tree plantation. The irrigation system is designed to minimize overspray, wind drift, surface runoff, and ponding. Fences, buffers, and signage restrict unauthorized access to the site.

- Albany Talking Water Gardens Projects—wetlands. A 37-ac integrated wetland treatment system enhances wildlife habitat while reducing the temperature, TDS, and nutrients in reclaimed water (CH2MHill, 2011). In addition, 13 ac of perimeter landscaping provides the opportunity to reuse effluent for irrigation to support more diverse habitat. The system is first in the nation designed to treat a unique combination of municipal and industrial WWTP effluents.

- City of Silverton Oregon Garden Project—wetlands. Similar to the system in Albany, the city of Silverton's reclaimed water is used to create a thriving habitat through 17 acres of terraced ponds with cascading water, pools, and wetlands plants to a holding tank where it then flows into an irrigation system used to irrigate a garden (Oregon Garden, n.d.). The system lowers the temperature and removes nitrate and phosphorous prior to discharge in Brush Creek. The wetlands also play an active role in the education programs at The Garden.

Washington

There are more than 25 reclaimed water facilities operating in Washington State—about one-third are located in eastern Washington and two-thirds are located in western Washington. The design capacity for these facilities range from less than 1 mgd (43.8 L/s) to 21 mgd (920 L/s). Approximately 35 reclaimed water facilities are in the planning or design phase.

The drivers for reclaimed water facilities in Washington vary by facility and include discharge regulations, impaired water bodies with TMDLs, efforts to restore Puget Sound, opportunities due to upgrades or new facilities with advanced treatment technologies, and water supply needs.

Water reuse in Washington includes golf course irrigation; urban uses, such as street sweeping; agricultural irrigation; forest irrigation; groundwater recharge; ASR; wetlands enhancement; stream-flow augmentation; and commercial and industrial processes. King County and the University of Washington collaborated in a study to demonstrate the safety of using Class A reclaimed water in a vegetable garden, as detailed in a case study [US-WA-King County]. In Sequim, a reclaimed water distribution system uses reclaimed water for toilet flushing, irrigation, stream augmentation, vehicle washing, street cleaning, fire truck water, and dust control [US-WA-Sequim], relying on a marine outfall to discharge wastewater when the reclamation process fails and seasonally when reclaimed water demand drops. In Yelm, reclaimed water is used in a wetlands park to have a highly visible and attractive focal point promoting reclaimed water use [US-WA-Yelm]. In addition, as part of planning for expansion of the reclaimed water system, a local ordinance was adopted establishing the conditions of reclaimed water use, which includes a "mandatory use" clause requiring construction of reclaimed water distribution facilities as a condition of development approval.

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CHAPTER 6
Treatment Technologies for Protecting Public and Environmental Health

When discussing treatment for reuse, the key objective is to achieve a quality of reclaimed water that is appropriate for the intended use and is protective of human health and the environment. Secondary objectives for reclaimed water treatment are directly tied to the end application, and can include aesthetic goals (e.g., additional treatment for color or odor reduction) or specific user requirements (e.g., salt reduction for irrigation or industrial reuse). As described in Section 1.5 "Fit for Purpose," treatment for reclaimed water is and should be tailored to a specific purpose so that treatment objectives can be appropriately set for public health and environmental protection, while being cost effective. Additionally, the appropriate treatment for reuse will vary depending upon state-specific requirements. Some states require specific treatment processes, others impose reclaimed water quality criteria, and some require both. Many states also include requirements for treatment reliability and resilience to process upsets, power outages, or equipment failure (see Chapter 4 for additional regulatory discussion).

There have been hundreds of reuse projects implemented in the United States for various end uses and these projects, cumulatively, have demonstrated that use of properly treated reclaimed water meeting cross connection controls and use area requirements is protective of human health and the environment. While specifically proving the negative is difficult, i.e., that there have not been human health or environmental impacts associated with use of reclaimed water, at least one report notes that, "There have not been any confirmed cases of infectious disease that have been documented in the U.S. as having been caused by contact, ingestion, or inhalation of pathogenic microorganisms at any landscape irrigation site subject to reclaimed water criteria" (WRRF, 2005). Further, with respect to chemical hazards and risks, the NRC reports that, "To date, epidemiological analyses of adverse health effects likely to be associated with use of reclaimed water have not identified any patterns from water reuse projects in the United States" (NRC, 2012).

There is a continuum of possible scenarios for nonpotable and potable reuse, ranging from distributed nonpotable reclaimed water, to long-term storage in an environmental buffer prior to reuse, to direct replenishment of potable water sources (prior to additional drinking water treatment). As an example, **Figure 6-1** depicts a variety of treatment scenarios that have been developed for indirect or direct potable end use applications. There are other treatment technologies, not reflected in **Figure 6-1**, such as conventional secondary followed by natural treatment systems (wetlands or soil aquifer treatment prior to augmentation of drinking water supplies, which is described further in Section 6.4.5).

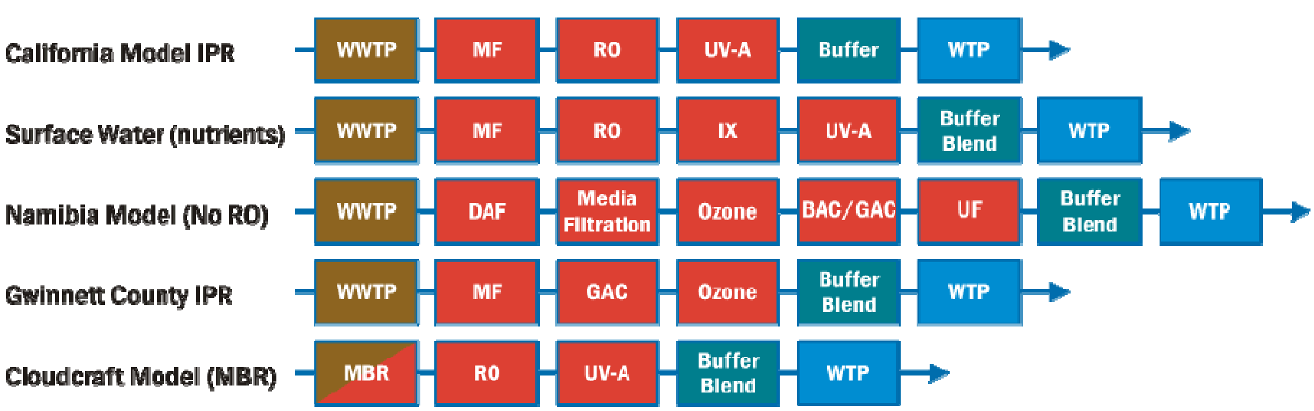

Figure 6-1
Potable reuse treatment scenarios (Chalmers et al., 2011)

The important lesson is that now, regardless of the end use and desired reclaimed water quality there are technologies available to treat water to whatever level is required for the targeted end use. In addition to successful implementation of current advanced treatment technologies for producing reclaimed water, there is ongoing research into optimizing these processes and investigating emerging technologies to meet treatment objectives for both pathogens and chemical constituents (WRRF, 2007a; 2012a).

6.1 Public Health Considerations

The most critical objective in any reuse program is to protect public health and a portfolio of treatment options exists to mitigate microbial and chemical contaminants in reclaimed water and meet specific water quality goals (NRC, 2012). Other objectives, such as preventing environmental degradation, avoiding public nuisance, and meeting user requirements, must also be satisfied, but the starting point remains the safe delivery and use of properly treated reclaimed water. In order to put concerns about protecting public health and the environment into perspective with respect to water reclamation, it is important to consider several key questions.

6.1.1 What is the Intended Use of the Reclaimed Water?

Protection of public health is achieved by 1) reducing or eliminating concentrations of pathogenic bacteria, parasites, and enteric viruses in reclaimed water; 2) controlling chemical constituents in reclaimed water; and 3) limiting public exposure (contact, inhalation, or ingestion) to reclaimed water. Reclaimed water projects may vary significantly in the level of human exposure incurred, with a corresponding variation in the potential for health risks. Where human exposure is likely, reclaimed water should be treated to a high degree prior to its use (**Table 6-1**). Reclaimed water used for irrigation of non-food crops on a restricted agricultural site may be of lesser quality than water for landscape irrigation at a public park or school, which may be of a lesser quality than reclaimed water intended to augment potable supplies. To make reuse cost-effective, the level of treatment must be "fit for purpose." Secondary effluent can become reclaimed water nonpotable reuse by addition of filtration and enhanced disinfection. Higher level uses (e.g., potable reuse) may include additional processes, such as membranes, advanced oxidation, or soil aquifer treatment to remove chemical and biological constituents.

Table 6-1 Types of reuse appropriate for increasing levels of treatment

Treatment Level	Increasing Levels of Treatment →			
	Primary	Secondary	Filtration and Disinfection	Advanced
Processes	Sedimentation	Biological oxidation and disinfection	Chemical coagulation, biological or chemical nutrient removal, filtration, and disinfection	Activated carbon, reverse osmosis, advanced oxidation processes, soil aquifer treatment, etc.
End Use	No Uses Recommended	Surface irrigation of orchards and vineyards	Landscape and golf course irrigation	Indirect potable reuse including groundwater recharge of potable aquifer and surface water reservoir augmentation and potable reuse
		Non-food crop irrigation	Toilet flushing	
		Restricted landscape impoundments	Vehicle washing	
		Groundwater recharge of nonpotable aquifer	Food crop irrigation	
		Wetlands, wildlife habitat, stream augmentation	Unrestricted recreational impoundment	
		Industrial cooling processes	Industrial systems	
Human Exposure	Increasing Acceptable Levels of Human Exposure →			
Cost	Increasing Levels of Cost →			

Regardless of the reclaimed water use, whether irrigation, IPR, potable reuse, or car washing, the most critical treatment objective is pathogen inactivation. The reclaimed water must not pose an unreasonable risk due to infectious agents if there is human contact, which could occur by whole body contact or ingestion. EPA has established risk assessment methods and criteria that have been used in developing standards and criteria for microbial risks for both drinking water and whole body contact.

These risk assessment methods and acceptable levels of risks are described in the *Use of Microbial Risk Assessment in Setting U.S. Drinking Water Standards* and the draft *Recreational Water Quality Criteria* (EPA, 1992; 2011). While the potential human health impacts of reclaimed water is the subject of ongoing research, (e.g., WRRF project 10-07, *Bio-analytical Techniques to Assess the Potential Human Health Impacts of Reclaimed Water*, currently in preparation), additional discussion specific to risk assessment methods and tools specific to water reuse and exposure to reclaimed water are provided in other recent research reports (WRRF, 2007b; 2010a).

6.1.2 What Constituents are Present in a Wastewater Source, and What Level of Treatment is Applicable for Reducing Constituents to Levels That Achieve the Desired Reclaimed Water Quality?

Constituents that may be present in wastewater are described in Section 6.2. Numerous studies and full-scale projects have demonstrated that combining several treatment processes in sequence provides multiple barriers to remove almost all constituents to currently-accepted analytical detection levels and does not allow microbial and chemical contaminants to reach finished water at levels of potential concern. In addition, the effective use of pretreatment requirements can prevent introduction of refractory or difficult to treat contaminants to the incoming wastewater in the first place. Section 6.4 discusses the state of treatment technologies to provide extensive control of microbial and chemical contaminants for reuse projects. It is important to note that the NRC's recent survey of epidemiological studies of reuse concluded that "adverse health effects likely to be associated with use of reclaimed water have not identified any patterns from water reuse projects in the United States" (NRC, 2012).

The successful record of water reuse installations in the United States and around the world is the result of highly-engineered redundant treatment processes, which assure the safety of human health and the environment based on current standards. However, based on the last two decades of intensive experience in reuse, numerous studies, technology advances, and monitoring of successful projects, it may not always be necessary to provide such high levels of redundancy in the treatment train given the effectiveness and reliability of available technologies. For example, AOP may not be generally necessary when additional treatment will be applied at a drinking water plant, and UV alone can provide removal of the disinfection by-product NDMA, if needed; UV/AOP prior to discharge to a surface water storage reservoir may also be unnecessary. Excellent reduction of nitrogen and phosphorus nutrients may be essential for reclaimed water discharge to a storage reservoir, whereas these nutrients represent an advantage for certain irrigation applications and might not need to be removed.

The allowable concentrations of microbial and chemical constituents in reclaimed water are a function of the specific reuse application or category of reuse. And while these requirements may vary slightly from state to state, they have been designed to be protective of human health given some of the current thinking. Reclaimed water quality standards and practices have evolved, based on both scientific studies and practical experience. In particular, reclamation for potable reuse will meet drinking water standards; thus, it is not necessary to create a national list of concentration limits for specific chemical constituents for indirect or direct potable reuse projects (similar to drinking water MCLs), regardless of whether reclaimed water is part of the supply. Treatment guidelines and drinking water health advisory-type benchmarks for emerging chemicals of potential interest (pharmaceuticals, pesticides, and other "chemicals of emerging concern") are useful for assisting engineers in design of the multiple barriers that continue to protect the public from health risks.

6.1.3 Which Sampling/Monitoring Protocols are Required to Ensure that Water Quality Objectives are Being Met?

The successful record of water reuse installations is also the result of programs that ensure treatment reliability, establish cross-connection controls, manage conveyance and distribution system controls, display user area controls (such as signage, color-coded pipes and appurtenances, and setback distances), and monitor water quality to ensure safety, as described in Chapter 4. It is also essential to have an appropriate HACCP-type management system; to employ appropriate, reliable, and multi-barrier redundant treatments; and to utilize as much as possible real-time monitoring of surrogates to assure continuous performance. While a number of online methods for performance monitoring are currently being used (e.g., turbidity and chlorine residual), the WRRF has funded additional research on monitoring for reliability and process control for potable reuse projects under project number WRF-11-01, which is anticipated for publication in 2015.

6.2 Wastewater Constituents and Assessing Their Risks

Before a particular treatment process train design can be selected for implementation in a reuse project, it is important to understand which constituents are of concern and in what concentrations. Untreated municipal wastewater contains a range of constituents, from dissolved metals and trace organic compounds to large solids such as rags, sticks, floating objects, grit, and grease. All reuse systems require a minimum of secondary treatment, which addresses large objects and particles, most dissolved organic matter, some nutrients, and other inorganics. However, there are some particles, including microorganisms and dissolved organic and inorganic constituents that remain in the secondary-treated wastewater, and further treatment is most often required before it can be reused. This section provides an overview of the key wastewater constituents that are addressed in reclaimed water treatment systems.

6.2.1 Microorganisms in Wastewater

Microorganisms are ubiquitous in nature, and most are not pathogenic to humans. Microorganisms, also called microbes, are diverse and are critical to nutrient recycling in ecosystems. In wastewater treatment systems, which are effectively engineered ecosystems, they act as beneficial decomposers of nutrients and organic matter. Concentrations of microorganisms are typically reported on a logarithmic scale (e.g., 1 million = 10^6 microorganisms) because they can be present in very high concentrations. Likewise, they can be removed to significant extents, and logarithmic scales help capture these huge ranges in concentrations. Removal of microorganisms is typically reported logarithmically, where 1-log indicates 90 percent removal, 2-log is 99 percent removal, 3-log is 99.9 percent removal, 4-log is 99.99 percent removal, and so forth.

In addition to beneficial microorganisms, raw domestic wastewater can contain a large variety of pathogenic microorganisms that are derived principally from the feces of infected humans and primarily transmitted by the “fecal-oral” route. A pathogen is a microorganism that causes disease in its host. Most pathogens found in untreated wastewater are known as ‘enteric’ microorganisms; they inhabit the intestinal tract where they can cause disease, such as diarrhea. The source of human pathogens in wastewater is the feces of infected individuals who exhibit disease symptoms, as well as carriers with inapparent infections. Pathogens may also be present in urine, including pathogens that can cause urinary schistosomiasis, typhoid fever, leptospirosis, and some sexually transmitted infections. However, the first three diseases represent very low disease incidence in the United States, and the latter cannot survive for long in wastewater conditions. Thus, pathogens from urine are of low public health risk in water reuse.

Table 6-2 lists many of the infectious agents potentially present in raw domestic wastewater. These are classified into three broad groups: bacteria, parasites (parasitic protozoa and helminths), and viruses. **Table 6-2** also lists some of the diseases associated with each pathogen. The concentration of pathogens in wastewater varies greatly depending on the health of the general population, as well as the season. Concentrations of some organisms observed in the research are reported in **Table 6-2** to provide a general comparison, but available data are sparse due to lack of funding for these types of testing.

Water bodies, such as rivers, lakes, streams, landscape impoundments, engineered stormwater channels, groundwater, and swimming pools, can become contaminated from exposure to untreated or inadequately treated domestic sewage and agricultural runoff. Pathogen survival in the aquatic environment is governed by distance of travel, rate of transport, temperature, soil moisture content, humidity, exposure to sunlight, water chemistry (pH, salinity, etc.), and predation by other organisms, but varies greatly from pathogen to pathogen.

Table 6-2 Infectious agents potentially present in untreated (raw) wastewater

Pathogen	Disease	Numbers in Raw Wastewater (per liter)
Bacteria		
Shigella	Shigellosis (bacillary dysentery)	Up to 10^4
Salmonella	Salmonellosis, gastroenteritis (diarrhea, vomiting, fever), reactive arthritis, typhoid fever	Up to 10^5
Vibro cholera	Cholera	Up to 10^5
Enteropathogenic *Escherichia coli* (many other types of *E. coli* are not harmful)	Gastroenteritis and septicemia, hemolytic uremic syndrome (HUS)	
Yersinia	Yersiniosis, gastroenteritis, and septicemia	
Leptospira	Leptospirosis	
Campylobacter	Gastroenteritis, reactive arthritis, Guillain-Barré syndrome	Up to 10^4
Atypical mycobacteria	Respiratory illness (hypersensitivity pneumonitis)	
Legionella	Respiratory illness (pneumonia, Pontiac fever)	
Staphylococcus	Skin, eye, ear infections, septicemia	
Pseudomonas	Skin, eye, ear infections	
Helicobacter	Chronic gastritis, ulcers, gastric cancer	
Protozoa		
Entamoeba	Amebiasis (amebic dysentery)	Up to 10^2
Giardia	Giardiasis (gastroenteritis)	Up to 10^5
Cryptosporidium	Cryptosporidiosis, diarrhea, fever	Up to 10^4
Microsporidia	Diarrhea	
Cyclospora	Cyclosporiasis (diarrhea, bloating, fever, stomach cramps, and muscle aches)	
Toxoplasma	Toxoplasmosis	
Helminths		
Ascaris	Ascariasis (roundworm infection)	Up to 10^3
Ancylostoma	Ancylostomiasis (hookworm infection)	Up to 10^3
Necator	Necatoriasis (roundworm infection)	
Ancylostoma	Cutaneous larva migrams (hookworm infection)	
Strongyloides	Strongyloidiasis (threadworm infection)	
Trichuris	Trichuriasis (whipworm infection)	Up to 10^2
Taenia	Taeniasis (tapeworm infection), neurocysticercosis	
Enterobius	Enterobiasis (pinwork infection)	
Echinococcus	Hydatidosis (tapeworm infection)	
Viruses		
Enteroviruses (polio, echo, coxsackie, new enteroviruses, serotype 68 to 71)	Gastroenteritis, heart anomalies, meningitis, respiratory illness, nervous disorders, others	Up to 10^6
Hepatitis A and E virus	Infectious hepatitis	
Adenovirus	Respiratory disease, eye infections, gastroenteritis (serotype 40 and 41)	Up to 10^6
Rotavirus	Gastroenteritis	Up to 10^5
Parvovirus	Gastroenteritis	

Table 6-2 Infectious agents potentially present in untreated (raw) wastewater

Pathogen	Disease	Numbers in Raw Wastewater (per liter)
Viruses		
Astrovirus	Gastroenteritis	
Caliciviruses (including Norovirus and Sapovirus)	Gastroenteritis	Up to 10^9
Coronavirus	Gastroenteritis	

(Sources: NRC, 1996; Sagik et. al., 1978; Hurst et. al., 1989; WHO, 2006; Feachem et al., 1983, Mara and Silva, 1986; Oragui et al., 1987, Yates and Gerba, 1998, da Silva et al., 2007, Haramoto et al., 2007, Geldreich, 1990; Bitton, 1999; Blanch and Jofre, 2004; and EPHC, 2008)

The main potential routes of waterborne disease transmission, in the context of water reclamation, include ingestion or consumption of contaminated water or foods from vectors via hand-to-mouth contact, or by inhalation from breathing in a mist or aerosolized water containing suspended pathogens. The potential transmission of infectious disease by pathogenic agents is the most common concern associated with reuse of treated municipal wastewater.

Fortunately, treatment technologies are capable of removing pathogens from water to below detection limits. However, it is still useful to understand what pathogenic microorganisms are potentially present in wastewater so that appropriate treatment can be applied. The following sections provide information on the major classes of microorganisms in wastewater.

6.2.1.1 Protozoa and Helminths

Parasites can be excreted in feces as spores, cysts, oocysts, or eggs, which are robust and resistant to environmental stresses such as desiccation, heat, freezing, and sunlight. Most parasite spores, cysts, oocysts, and eggs range in size from 1 μm to over 60 μm (larger than bacteria). Helminths can be present as the adult organism, larvae, eggs, or ova. The eggs and larvae, which range in size from about 10 μm to more than 100 μm, are resistant to environmental stresses. The occurrence of these microorganisms in reclaimed water has been the subject of recent research (WRRF, 2012b), which confirms that eliminating protozoa and helminthes from wastewater can be achieved through either a "removal" or an "inactivation" process (WRRF, 2012b). In reclaimed water, protozoa and helminths can be physically removed by sedimentation or filtration (Section 6.4) because of their relatively large size. Protozoa and helminths may be resistant to disinfection by chlorination or other chemical disinfectants, but may be inactivated using UV disinfection (Section 6.4.3.2) by inducing mutations in their DNA. Recent research on development of molecular assays that can rapidly discriminate between infectious cysts and cysts unable to cause an infection in reclaimed water have confirmed this mode of disinfection (WRRF, 2012c).

6.2.1.2 Bacteria

Bacteria are microscopic organisms ranging from approximately 0.2 to 10 μm in length. Many types of harmless bacteria colonize in the human intestinal tract and are routinely shed in the feces. Pathogenic bacteria are also present in the feces of infected individuals; therefore, municipal wastewater can contain a wide variety and concentration range of bacteria, including those pathogenic to humans. The numbers and types of these agents are a function of their prevalence in the animal and human community from which the wastewater is derived.

Bacterial levels in wastewater can be significantly lowered through removal or inactivation processes, which typically involve the physical separation of the bacteria from the wastewater through sedimentation and/or filtration. Due to density considerations, bacteria do not settle as individual cells or even colonies. Bacteria can adsorb to particulate matter or floc particles, and these particles settle during sedimentation, secondary clarification, or during an advanced treatment process such as coagulation/ flocculation/sedimentation. Bacteria can also be removed by using a filtration process that includes sand filters, disk (cloth) filters, or membrane processes. Bacteria can also be inactivated by disinfection. Both filtration and disinfection are discussed further in Section 6.4.

6.2.1.3 Viruses

Viruses occur in various shapes and range in size from 0.01 to 0.3 μm, a fraction of the size of bacteria. Bacteriophages are viruses that infect bacteria; they have not been implicated in human infections and are often used as indicators. Coliphages are host-specific viruses that infect coliform bacteria. Enteric viruses multiply in the intestinal tract and are released in fecal matter of infected persons. Not all types of enteric viruses have been determined to cause waterborne disease, but more than 100 different enteric viruses are capable of producing infections or disease.

In general, viruses are more resistant to environmental stresses than many bacteria, and some viruses persist for only a short time in wastewater. Similar to bacteria and protozoan parasites, viruses can be physically removed or inactivated (Myrmel et al., 2006). However, due to the relatively small size of typical viruses, sedimentation and filtration processes are less effective at removal. Significant virus removal can be achieved with ultrafiltration membranes, possibly in the 3- to 4-log range. However, for viruses, inactivation is generally considered the more important of the two main reduction methods and is often accomplished by UV disinfection. Interestingly, disinfection of viruses requires relatively higher doses of UV compared to inactivation of bacteria and protozoa.

While monitoring specific virus pathogens in wastewater samples would provide more reliable information for risk assessments of waterborne viral infections, direct monitoring of several viral pathogens in water is challenging and impractical, despite the recent development of real-time quantitative polymerase chain reaction (PCR) analyses (LeCann et al. 2004; Van den Berg et al. 2005). Until more data regarding the detection of active, infectious viruses is available, data generated from seeded studies to evaluate the efficacy of wastewater treatment processes should be carefully evaluated to provide treatment designs that remove infectious viruses.

6.2.1.4 Aerosols

Aerosols are particles less than 50 μm in diameter that are suspended in air. Viruses, most pathogenic bacteria, and pathogenic protozoa are in the respirable size range; hence, inhalation of aerosols is a possible direct means of human infection. Aerosols are most often a concern where improperly-treated reclaimed water is applied to urban or agricultural sites with sprinkler irrigation systems or where it is used for cooling water make-up. Infection or disease may be contracted directly through inhalation or indirectly from aerosols deposited on surfaces, such as food, vegetation, and clothes. The infective dose of some pathogens is lower for respiratory infections than for infections via the gastrointestinal tract; thus, for some pathogens, inhalation may be a more likely route for disease transmission than either contact or ingestion.

Thus, for intermittent spraying of disinfected reclaimed water, occasional inadvertent contact should pose little health hazard from inhalation. Cooling towers issue aerosols continuously and may present a greater concern if the water is not properly disinfected. In either case, aerosol exposure is limited through design or operational controls that are discussed in detail in the 2004 guidelines (EPA, 2004).

6.2.1.5 Indicator Organisms

It is important to distinguish between the actual pathogens versus indicator microorganisms that are used to measure treatment performance of a particular treatment system with respect to addressing pathogenic organisms from fecal contamination. Indicators are not themselves dangerous to human health, but are used to indicate the likelihood of occurrence of a health risk. The variety and often lower concentrations of pathogenic microorganisms in environmental waters, necessitating concentration combined with specialized analytical methodologies for pathogen detection, makes it difficult for the typical wastewater laboratory to run such tests. Regulatory agencies have historically required routine monitoring of other more abundant and more easily detected fecal bacteria as indicators of the presence of fecal contamination. In some states, total coliform bacteria are used as an indicator; however, in most states that have specific regulations, the microbiological safety of reclaimed water is evaluated by daily monitoring of fecal coliform bacteria in disinfected effluent based on a single, 100-mL grab sample.

Some states do require monitoring of certain pathogens, such as *Giardia* and *Cryptosporidium* requirements in Florida, Arizona, and California. Monitoring for viruses is also required for reclaimed water used for irrigation of food-crops in North Carolina. The specific monitoring requirements for these states are provided in Section 4.5.2. In addition, pathogen analyses are sometimes conducted as part of special studies or by proactive utilities that wish to confirm the treatment reliability of the process used to produce reclaimed water. More often, indicators including total coliforms; fecal coliforms, a subset of total coliforms; *Escherichia coli (E. coli)*; *enterococci*; and coliphage are used to validate performance of treatment and the quality of the final reclaimed water quality. The main drawback to using microbial indicators is that they are somewhat limited in their ability to predict the presence of pathogens. Also, all current uses of microbial indicators employ cultivation methods that delay results for at least 24 hours. For example, nonpathogenic coliforms, such as those that may be found in soil, can grow in water under certain conditions, leading to positive results that may not be indicative of wastewater impact. Additionally, coliform bacteria do not adequately reflect the occurrence of pathogens in disinfected reclaimed water due to their relatively high susceptibility to chemical disinfection and failure to correlate with protozoan parasites such as *Cryptosporidium* and enteric viruses (Bonadonna, et al., 2002; Havelaar et al., 1993).

Alternative microbiological indicators have been suggested for evaluation of wastewater, drinking water, and environmental waters, including *Enterococcus*, *Clostridium*, and coliphages. But there have been only a few studies of reclaimed water in which the levels of indicator organisms have been directly compared to those of viral, bacterial, or protozoan pathogens at each stage of treatment, and additional research on this topic is needed (Harwood et al., 2005). Analytical methods for actual pathogen monitoring continue to evolve, and recent studies have not relied solely on the traditional standard culture methods (Fox, 2001; Sloss et al., 1996; Sloss et al., 1999; Yanko 1999). PCR is now commonly used to study pathogens and indicators by detecting the DNA or RNA in the environment. PCR is useful because the methods are sensitive. In addition, PCR can be much less expensive and time consuming than traditional pathogen methods, and culture methods are not currently available for some pathogens. Recent studies have reported pathogen DNA and RNA in secondary and advanced municipal wastewater effluents, some recycled water, groundwater, and in ocean water impacted by wastewater discharges (Aw and Gin, 2010; De Roda et al., 2009; Hunt et al., 2010; Jjemba et al., 2010; Symonds et al., 2009, da Silva et al., 2008; da Silva et al., 2007; Haramoto et al, 2007). However, it is important to emphasize that PCR does not determine pathogen viability or infectivity; it only indicates the existence of DNA or RNA derived from the microorganisms. There is ongoing research using PCR-based detection methods into how this information can be used to evaluate potential risk; quantitative PCR in particular has potential to provide data for quantitative microbial risk assessment (QMRA), however, it must be kept in mind that indicators only evaluate “potential” risk. These indicators have not been related to any epidemiological risks except for *E. coli* and *enterococci* in recreational settings (Section 6.3.1). Additionally, evaluation of certain disinfection processes is particularly limited with respect to using molecular tools and indicators, although molecular viability methods are emerging.

6.2.1.6 Removal of Microorganisms

Removal of indicators and pathogens can be demonstrated both by challenge testing and operational monitoring. Challenge testing allows large log removals to be demonstrated by spiking influent concentrations with higher than normal microorganism concentrations to allow detection in the effluent. Because detected concentrations of actual pathogens tend to approach or fall at the lowest detectable concentrations of current analytical methods, further research in this area could provide greater confidence in the sensitivity of operational monitoring. **Table 6-3** presents an indicative range of microbial log reductions reported in the literature for different treatment processes, which are further discussed in Section 6.4. These ranges are intended to present relative removals; they should not be used as the basis of design for treatment schemes.

Table 6-3 Indicative log removals of indicator microorganisms and enteric pathogens during various stages of wastewater treatment

Type of Microorganism	Indicator microorganisms			Pathogenic microorganisms				
	Escherichia coli (indicator bacteria)	*Clostridium perfringens*	Phage (indicator virus)	Enteric bacteria (e.g., *Campylobacter*)	Enteric viruses	*Giardia lamblia*	*Cryptosporidium parvum*	Helminths
Bacteria	X	X		X				
Protozoa and helminths						X	X	X
Viruses			X		X			
Indicative Log Reductions in Various Stages of Wastewater Treatment[1]								
Secondary treatment	1 - 3	0.5 - 1	0.5 - 2.5	1 - 3	0.5 - 2	0.5 - 1.5	0.5 - 1	0 - 2
Dual media filtration[2]	0 - 1	0 - 1	1 - 4	0 - 1	0.5 - 3	1 - 3	1.5 - 2.5	2 - 3
Membrane filtration (UF, NF, and RO)[3]	4 - >6	>6	2 - >6	>6	2 - >6	>6	4 - >6	>6
Reservoir storage	1 - 5	N/A	1 - 4	1 - 5	1 - 4	3 - 4	1 - 3.5	1.5 - >3
Ozonation	2 - 6	0 - 0.5	2 - 6	2 - 6	3 - 6	2 - 4	1 - 2	N/A
UV disinfection	2 - >6	N/A	3 - >6	2 - >6	1 ->6	3 - >6	3 - >6	N/A
Advanced oxidation	>6	N/A	>6	>6	>6	>6	>6	N/A
Chlorination	2 - >6	1 - 2	0 - 2.5	2 - >6	1 - 3	0.5 - 1.5	0 - 0.5	0 – 1

(Sources: Bitton, 1999; EPHC, 2008; Mara and Horan, 2003; NRC, 1998; NRC, 2012; Rose et al., 1996; Rose, et al., 2001; EPA, 1999a, 2003, 2004; WHO, 1989)

[1]Reduction rates depend on specific operating conditions, such as retention times, contact times and concentrations of chemicals used, pore size, filter depths, pretreatment, and other factors. Ranges given should not be used as design or regulatory bases—they are meant to show relative comparisons only.
[2]Including coagulation
[3]Removal rates vary dramatically depending on the installation and maintenance of the membranes.
N/A = not available

6.2.1.7 Risk Assessment of Microbial Contaminants

While most microbes are harmless or beneficial, some are extremely dangerous—these are sometimes referred to as biological agents of concern (BAC). All BAC can cause serious and often fatal illness, but they differ in their physical characteristics, movement in the environment, and process of infection. QMRA measures microbes' behavior to identify where they can become a danger and estimate the risk (including the uncertainty in the risk) that they pose to human health. QMRA has four stages, based on the National Academy of Sciences framework for Quantitative Risk Analysis, but is modified to account for the properties of living organisms like BAC (NAS, 1983):

Hazard Identification: This process describes a microorganism and the disease it causes, including symptoms, severity, and death rates from the microbe; it identifies sensitive populations that are particularly prone to infection.

Dose-Response: Establishing the relationship between the dose (number of microbes received) and the resulting health effects is a critical step in the process. Data sets from human and animal studies allow the construction of mathematical models to predict dose-response.

Exposure Assessment: This step describes the pathways that allow a microbe to reach individuals and cause infection (through the air, through drinking water, etc.). It is necessary to determine the size and duration of exposure by each pathway as well as estimate the number of people exposed and the categories of people affected.

Risk Characterization: The final step of the process integrates information from previous steps into a single mathematical model to calculate risk—the probability of an outcome such as infection, illness, or death. Because the first three steps do not provide a single value but instead offer a range of values for exposure, dose, and hazard, risk needs to be calculated for all values across those ranges. This is accomplished using Monte Carlo analysis, and the result is a full range of possible risks, including average and worst-case scenarios. These are the risks decision-makers evaluate when defining regulatory policy and the risks that scientists review to determine where additional research is needed to obtain better information.

Additional information on QMRA is available in a 2006 report to the European Commission entitled *QMRA*: *Its Value for Risk Management* (Medema and Ashbolt, 2006).

6.2.2 Chemicals in Wastewater

All water is ultimately reused in the natural cycle and contains detectable levels of various chemicals. Rainwater collects chemicals from atmospheric contact; groundwater contains inorganics from the geology; surface waters collect natural products and possibly pesticides and other chemicals from runoff and discharges from industrial and other facilities. Wastewater contains chemicals, and the number and concentrations of the constituents detected depends on many factors, including the municipal source, the condition of the collection system, and the treatment processes employed.

6.2.2.1 Inorganic Chemicals

Inorganic constituents in wastewater include metals, salts, oxyhalides, nutrients, and, potentially, engineered nanomaterials. The concentrations of inorganic constituents in reclaimed water depend mainly on the source of wastewater and the degree of treatment the water has received. The presence of inorganic constituents may affect the acceptability of reclaimed water for different reuse applications. Wastewater treatment using existing technology can generally reduce many trace elements to below recommended maximum levels for irrigation and drinking water. In general, the health hazards associated with the ingestion of inorganic constituents, either directly or through food, are well established. Under the SDWA, the EPA has set MCLs for contaminants in drinking water.

Aggregate measures of most inorganic constituents in water are TDS and conductivity, although they both may include some organic constituents, as well. Residential use of water typically adds about 300 mg/L of dissolved inorganic solids, although the amount added can range from approximately 150 mg/L to more than 500 mg/L (Metcalf & Eddy, 2003).

Metals and Salts. Regulatory statutes for treated wastewater discharge and industrial pretreatment regulations promulgated through the CWA specifically target toxic metals; as a result, most municipal effluents have concentrations of toxic metals below public health guidelines and standards. Boron, a metalloid in detergents, can be present in domestic wastewater, but concentrations generally are well below EPA health advisory and WHO guidelines. Boron can be toxic to some plants at concentrations approaching levels that may be present in reclaimed water, which can limit the types of plants that can be irrigated with the water. Likewise, salts (measured as TDS) present in reclaimed water generally do not exceed thresholds of concern to human health but can affect crops [Israel/Jordan-Brackish Irrigation]. Salinity can cause leaf burn, reduce the permeability of clay-bearing soils, and affect soil structure. Salinity also can cause aesthetic concerns (e.g., taste in potable reuse or residues in car washing operations), scaling, and corrosion. Salinity can be removed in treatment, but options tend to be costly, and liquid waste (brine) disposal is an issue. Salinity management in irrigation reuse applications is described further in Chapter 3.

Oxyhalides. Oxyhalides of concern in water reuse include bromate, chlorate, and perchlorate. Bromate can be created when bromide-containing wastewater is ozonated; therefore, treatment facilities must be designed and operated properly to minimize oxyhalide formation during treatment. Bromate, chlorate, and perchlorate can be derived from household bleach. Perchlorate, a component of propellants, can bioaccumulate in certain plants and must be managed in irrigation.

Nutrients. Nitrogen and phosphorus from human waste products can pose environmental and health concerns but can also be beneficial in certain irrigation applications. Therefore, the need to remove nutrients during treatment for reuse depends on the intended use of the product water.

Engineered Nanomaterials. Nanomaterials are materials with morphological features on the nanoscale (1 nm = 10-9 m), that often have special properties stemming from their dimensions. Nanomaterials have one or more dimensions ranging from 1 to 100 nm: nanofilms (one dimension), nanotubes (two dimensions), and nanoparticles (three dimensions). Larger particles, such as zeolites (1,000 to 10,000 nm, or 1 to 10 µm), may also be considered nanomaterials because their pores fall into the nanoscale size range (0.4 to 1 nm). Nanomaterials can be organic, inorganic, or a combination of organic and inorganic components.

Nanotechnology promises exciting new possibilities in water treatment and water quality monitoring. Nanosorbents, nanocatalysts, bioactive nanoparticles, nanostructured catalytic membranes, and nanoparticle-enhanced filtration are categories of novel nanotechnologies that may change water treatment and water quality monitoring (Savage and Diallo, 2005). Indeed, research is ongoing to develop novel membranes for water and wastewater treatment (including desalination) built around nanotube pores. Many consumer products now contain engineered nanomaterials because of their unique surface chemistry, catalytic properties, strength, weight, and conductive properties compared to their larger-scale counterparts (National Science and Technology Council, 2011; WEF, 2008). The market for nanomaterials in consumer products is taking off—the United Nations Environment Programme projects that the market for nanomaterial-containing products could exceed $2 trillion by 2014 (United Nations Environment Programme, 2007).

While naturally-occurring particles in this range include viruses and natural organic matter, the more recent introduction of engineered nanomaterials into the environment from consumer products poses new questions about the fate and potential environmental and health effects of these materials. Preliminary studies to determine the health effects caused by exposure to nanomaterials and the risk assessment, toxicity, and treatability of nanomaterials show inconsistent results, warranting ongoing investigation (WEF, 2008). To date, no link has been made between trace levels of engineered nanoparticles in wastewater and an adverse human health impact (O'Brien and Cummins, 2010). Because most engineered nanoparticles in municipal wastewater originate from household and personal care products, direct exposure in the household itself is likely far greater than from potential exposure in water reuse. However, potential ecotoxicological risk posed by the release of nanoparticles to surface waters highlights the need for guidance and restriction on the usage and disposal of nanomaterial-containing commercial products (O'Brien and Cummins, 2010). A review of research on the relevance of nanomaterials in water reuse has been compiled (WRRF, 2012d). Limited research has been conducted on their fate in wastewater treatment, but initial findings suggest that engineered nanoparticles will associate with biosolids or remain in effluents, depending on their size and surface chemistry, as well as the type of treatment process employed (Kaegi et al., 2011; Kiser et al., 2009; and WEF, 2008).

6.2.2.2 Organics

The organic composition of raw wastewater includes naturally-occurring humic substances, fecal matter, kitchen wastes, liquid detergents, oils, grease, consumer products, industrial wastes, and other substances that, in one way or another, become part of the sewage stream. The level of treatment for these constituents in reclaimed water is related to the end use of reclaimed water. Some of the adverse effects associated with organic substances include:

- **Aesthetic effects**. Organics may be malodorous and impart color to the water.
- **Clogging**. Particulate matter may clog sprinkler heads or accumulate in soil and affect permeability.
- **Proliferation of microorganisms**. Organics provide food for microorganisms.
- **Oxygen consumption**. Upon decomposition, organic substances deplete the DO content in streams and lakes. This negatively impacts the aquatic life that depends on the oxygen supply for survival.
- **Use limitation**. Many industrial applications cannot tolerate water that is high in organic content.

- **Disinfection effects**. Organic matter can interfere with chlorine, ozone, and UV disinfection, thereby making them less available for disinfection purposes. Further, chlorination may result in formation of potentially harmful chlorinated DBPs.
- **Health effects**. Ingestion of water containing certain organic compounds may result in acute or chronic health effects.

The detection of a variety of organic chemicals in municipal wastewater effluent has raised concerns about the potential presence of wastewater-derived chemical contaminants in reclaimed water as well as about their health effects. And, for some reuse applications, regulatory agencies and utilities have struggled with this issue of wastewater-derived compounds, some of which are often present at extremely low concentrations. Because many of these compounds are not currently regulated, current research has focused on the composition of highly processed wastewaters to identify residual chemicals that might be a health concern, determine what studies would be needed as a basis for risk assessment, and develop lists of compounds for which more information is needed to assess the potential human health concerns (WRRF, 2012e). Additionally, the WRRF has funded work on identification and validation of surrogate parameters and analytical methods for wastewater-derived contaminants to predict removal of wastewater-derived contaminants in reclaimed-water treatment systems (WRRF, 2008).

Parameters that have historically been used for this purpose and can serve as aggregate measures of organic matter include TOC, dissolved organic carbon (DOC) (that portion of the TOC that passes through a 0.45-μm pore-size filter), particulate organic carbon (POC) (that portion of the TOC that is retained on the filter), BOD, and chemical oxygen demand (COD). These measures are indicators of treatment efficiency and water quality for many nonpotable uses of reclaimed water.

Organic compounds in wastewater can be transformed into DBPs where chlorine is used for disinfection purposes. There are strong associations between DBP exposure and bladder cancer among individuals who carry inherited variants in three genes (*GSTT1*, *GSTZ1*, and *CYP2E1*), the code for key enzymes that metabolize DBPs (Freeman et al, 2010; Cantor et al., 2010). In the past, most attention was focused on the trihalomethane (THM) compounds; a family of organic compounds typically occurring as chlorine or bromine-substituted forms of methane. Chloroform, a commonly found THM compound, has been implicated in the development of cancer of the liver and kidney. Haloacetic acids (HAAs) are another undesirable by-product of chlorination with similar health effects. Improved analytical capabilities to detect extremely low levels of chemical constituents in water have resulted in identification of several health-significant chemicals and DBPs in recent years. For example, the carcinogen NDMA is present in sewage and is also produced when reclaimed water is disinfected with chlorine or chloramines (Mitch et al., 2003). And because chlorination of wastewater is still the most commonly used form of wastewater disinfection, research to further address the challenge of DBP in *de facto* reuse is a critical need. In some planned reuse applications, the concentration of NDMA present in reclaimed water exceeds action levels set for the protection of human health in drinking water, even after RO treatment. To address concerns associated with DBPs and other trace organics in reclaimed water, several utilities in California have installed UV-AOP for treatment of RO permeate to address NDMA [US-CA-Vander Lans; US-CA-Orange County; US-CA-San Diego].

6.2.2.3 Trace Chemical Constituents

Sophisticated analytical instrumentation makes it possible to identify and quantify extremely low levels of individual inorganic and organic constituents in water. Examples include gas chromatography/tandem mass spectrometry (GC/MS/MS) and high-performance liquid chromatography/mass spectrometry (HPLC/MS). These analyses are costly and may require extensive and difficult sample preparation, particularly for nonvolatile organics. Advancements in these and other analytical chemistry techniques have enabled the quantification of chemicals in water at parts per trillion (ppt) and even parts per quadrillion levels. With further analytical advancements, nearly any chemicals will be detectable in environmental waters, wastewater, reclaimed water, and drinking water in the future, but the human and environmental health relevance of detection of diminishingly low concentrations remains a greater challenge to evaluate.

As analytical techniques have improved, a number of anthropogenic chemical compounds that are not commonly regulated have been detected in drinking water, wastewater effluent, or environmental waters, generally at very low levels. Detection of these compounds does not imply that they have been recently released to the environment—many have likely been in the environment for decades. This broad group of individual chemicals and classes of compounds present at trace concentrations is sometimes termed contaminants of emerging concern (CECs), TrOCs, or microconstituents. This broad group of CECs can include groups of compounds categorized by end use (e.g., pharmaceuticals, nonprescription drugs, personal care products, household chemicals, food additives, flame retardants, plasticizers, and biocides), by environmental and human health effect, if any (e.g., hormonally active agents, endocrine disrupters [EDs], or endocrine disrupting compounds [EDCs]), or by type of compound (e.g., chemical vs. microbiological, phenolic vs. polycyclic aromatic hydrocarbons). Contaminants under these sub-groupings that are not regulated under national drinking water standards may be on the Drinking Water Contaminant Candidate List (CCL), including some known EDCs, which include chemicals shown to disrupt animal endocrine systems, as well as those with adverse human health interactions. **Table 6-4** provides categories of compounds which may be detectable in reclaimed water.

Although trace chemical constituents are "pollutants" when they are found in the environment at concentrations above background levels, they are not necessarily "contaminants" (that is, found in the environment at levels high enough to induce ecological and/or human health effects). Experts have struggled to agree on a term that captures the range of constituents because the public often finds terms such as CEC confusing or alarming, as described in Chapter 6. However, describing the numerous constituents by sub-group or as individual chemicals can likewise cause confusion, because these are also not well understood by the general public. Debate and discussion is ongoing in the water community about how to discuss trace chemical compounds, including terminology and relative risk.

Removal of Trace Chemical Constituents. As reclaimed water is considered a source for more and more uses, including industrial process water or potable supply water, the treatment focus has expanded far beyond secondary treatment and disinfection to include treatment for other contaminants, such as metals, dissolved solids, and trace chemical constituents.

Chemical constituents are amenable to treatment depending on the physiochemical properties of the compounds and the removal mechanisms of particular treatment processes. EPA has released a report with results of an extensive literature review of published studies of the effectiveness of various treatment technologies for CECs (EPA, 2010). The results of this literature review are also available in a searchable database, "Treating Contaminants of Emerging Concern—A Literature Review Database" (EPA, 2010). EPA developed this information to provide an accessible and comprehensive body of historical information about current CEC treatment technologies.

Given the wide range of properties represented by trace chemical constituents, there is no single treatment process that provides an absolute barrier to all chemicals. To minimize their presence in treated water, a sequence of diverse treatment processes capable of tackling the wide range of physiochemical

Table 6-4 Categories of trace chemical constituents (natural and synthetic) potentially detectable in reclaimed water and illustrative example chemicals (NRC, 2012)

End use Category	Examples
Industrial chemicals	1,4-Dioxane, perflurooctanoic acid, methyl tertiary butyl ether, tetrachloroethane
Pesticides, biocides, and herbicides	Atrazine, lindane, diuron, fipronil
Natural chemicals	Hormones (17β-estradiol), phytoestrogens, geosmin, 2-methylisoborneol
Pharmaceuticals and metabolites	Antibacterials (sulfamethoxazole), analgesics (acetominophen, ibuprofen), beta-blockers (atenolol), antiepileptics (phenytoin, carbamazepine), veterinary and human antibiotics (azithromycin), oral contraceptives (ethinyl estradiol)
Personal care products	Triclosan, sunscreen ingredients, fragrances, pigments
Household chemicals and food additives	Sucralose, bisphenol A (BPA), dibutyl phthalate, alkylphenol polyethoxylates, flame retardants (perfluorooctanoic acid, perfluorooctane sulfonate)
Transformation products	NDMA, HAAs, and THMs

properties is needed (Drewes and Khan, 2010). Full-scale and pilot studies have demonstrated that this can be accomplished by combinations of different processes: biological processes coupled with chemical oxidation or activated carbon adsorption, physical separation (RO) followed by chemical oxidation, or natural processes coupled with chemical oxidation or carbon adsorption. The question is whether all of these technologies are necessary to assure health protection or whether a particular sequence is over-treatment, especially when the water will be returned to the environment via a reservoir or aquifer. The water, therefore, will likely be degraded to some degree prior to being withdrawn for further drinking water treatment.

A recent survey of the fate of pharmaceuticals and personal care products (PPCPs) in WWTPs revealed that many EDCs are present at mg/L concentrations and are not significantly removed during conventional wastewater treatment processes (Miège et al., 2008). Some removal or chemical conversion can be expected during drinking water disinfection (i.e., sulfamethoxazole, trimethoprim estrone, 17β-estradiol, 17α-ethinylestradiol, acetaminophen, triclosan, bisphenol A, and nonylphenol). Chlorine, chlorine dioxide, and ozone disinfection are oxidation processes (Alum et al., 2004; Huber et al., 2005); among the three oxidants, ozone is the most reactive with many trace organic chemicals.

Activated carbon adsorption can readily remove many organic compounds from water, with the exception of some polar water-soluble compounds, such as iodinated contrast agents and the antibiotic sulfamethoxazole (Adams et al., 2002; Westerhoff et al., 2005). Although they are very effective, AOP treatment processes are inefficient for oxidizing trace chemical constituents because they are energy intensive and involve random reactions with much of the TOC in addition to the target chemicals present in only minute quantities. Compared to ozone treatment alone, AOPs provide only a small increase in removal efficacy (Dickenson et al., 2009).

Low-pressure membranes, such as MF and ultrafiltration (UF), have pore sizes that are insufficient to retain trace chemical constituents; however, some hydrophobic compounds can still adsorb onto MF and UF membrane surfaces providing some short-term attenuation of the hydrophobic compounds and TOC. However, high-pressure membranes, such as RO and nanofiltration (NF), are very effective in the physical separation of a variety of pharmaceuticals and other organics and inorganics from water (Bellona et al., 2008). Low-molecular-weight organics are problematic for high-pressure membranes, and the disposal of the concentrate (brine) with elevated levels of trace chemical constituents can be an issue. Natural processes, such as riverbank filtration (RBF) and SAT, can be employed either as an additional treatment step for wastewater reclamation or as a pre-treatment to subsequent drinking water treatment (Amy and Drewes, 2007; Hoppe-Jones et al. 2010). RBF and SAT are very effective in attenuating a wide range of chemicals by sorption and biotransformation processes in the subsurface but are limited in attenuating refractory compounds, such as antiepileptic drugs or chlorinated flame retardants (Drewes et al., 2003).

AOP processes are being researched for their ability to remove organic compounds. For example, while UV photolysis is generally not an effective treatment option for removing organic compounds, UV photolysis in combination with H_2O_2 achieves high removal rates of a variety of potential EDCs, including bisphenol A, ethinyl estradiol, and estradiol (Rosenfeldt and Linden, 2004).

Table 6-5 presents a summary of indicative reductions of organic chemical concentrations. Data presented are intended to present relative removals but should not be used as a design or regulatory basis. Scheme proponents must validate the treatment technology for the specific application and operational conditions.

Risk Assessment of Trace Chemical Constituents. Because WWTPs using conventional treatment processes cannot remove trace organic chemicals completely, wastewater discharge can introduce some of these constituents into receiving environments. Thus, in *de facto* reuse, chemical constituents can be introduced into drinking water supplies (Benotti et al., 2009). Detection of trace chemical constituents in drinking water systems and environmental waters raise understandable concerns about the potential implications for public and ecological health. Research organizations around the world, including EPA, are exploring these implications and assessing the risks with respect to acute, chronic illness, and sequelae. Although a number of comprehensive studies have been conducted to address the concern about potential human health risks of unknown and unidentified trace level chemicals in reclaimed water (Nellor et al., 1984; Sloss et al., 1996; Anderson et al., 2010), there is currently no definitive documentation of risk with respect to trace chemicals for the use of reclaimed water to augment drinking water supplies. On the basis of available information, there is no indication that health risks from using highly-treated reclaimed water for potable purposes are greater than those from using existing water supplies (NRC, 2012).

A recent report by the Global Water Research Coalition (GWRC) synthesized results of nine recently published reports addressing the occurrence and potential for human health impacts of pharmaceuticals in the drinking water system (GWRC, 2009). The report concludes that there is no known impact on human health due to pharmaceutical exposure in drinking water, and that if a person consumed drinking water with the reported levels of pharmaceuticals, that person would consume only 5 percent (or less) of *one daily therapeutic dose* (i.e., a single pill) of an individual pharmaceutical over his or her whole lifetime. Further, a recent report from a WHO expert panel concluded that the risk of adverse human health effects from exposure to the trace levels of pharmaceuticals in drinking water is considered to be unlikely (WHO, 2011); this report did not assess nonpharmaceutical trace chemicals.

Public exposure to trace chemical constituents in water reuse for irrigation or other types of nonpotable reuse is negligible. In planned potable reuse, the treatment technologies employed in the United States ensure that concentrations of trace chemicals are at extremely low levels, often below analytical detection limits. And, in fact National Academy of Sciences 2012 Report on water reuse (*Water Reuse: Expanding the Nation's Water Supply Through the Reuse of Municipal Wastewater*) presented a risk comparison between potable reuse projects and *de facto* reuse scenarios (as described in Section 3.7), concluding that potable reuse scenarios have reduced risk of pathogen exposure and lower or equivalent risk of chemical contaminant exposure compared to existing water supplies (NRC, 2012).

While the risk associated with trace chemical constituents in drinking water is indeed very low, the water sector continues to investigate the issue and invest in precautionary treatment technologies. Because a human health risk of zero is not an achievable condition with exposure of any level, it is necessary to reach a consensus on upper bound *de minimis* risk goals that can be the basis for design and operation of planned potable reuse facilities.

The greater impact of trace chemical constituents may be the ecological effects from the presence of chemicals in wastewater discharges and stormwater runoff to surface waters. Recent concern over ecological effects of discharged chemical constituents is primarily from studies in the 1990s of surface waters receiving treated municipal wastewater where feral fish in proximity of the discharge were found to have altered reproduction strategies and high incidences of hermaphrodism (Sumpter and Johnson, 2008). When advanced wastewater treatment, which includes RO, is used, almost all microconstituents can be effectively removed, and the RO effluent poses no hormonal threat to tissue cultures and live fish (WRRF, 2010b). Thus, while many environmental monitoring programs are underway, toxicological studies conducted at environmentally relevant concentrations are not likely to provide much information due to the very low hypothetical risks at the trace concentrations that are detected, the difficulty in conducting chronic studies, and the large margins of exposures.

In response to uncertainties that may be associated with potential risks in potable reuse applications, adoption of appropriate treatment technologies has been employed to minimize exposure of humans to wastewater-derived trace chemical constituents. Many analytical studies have been conducted to identify the few residual chemicals that may pass through advanced treatment. Residual TOC levels, which can be considered a surrogate for trace chemical constituents in planned potable reuse finished water, are usually a fraction of a milligram per liter.

Additional information on guidance for developing monitoring programs that assess potential CEC threats from water reuse provided by the SWRCB is provided in the regulatory section that follows, **Section 6.3** (SWRCB, 2011; Anderson et al., 2010). Additional research on evaluating and explaining the relative human health risks related to the reuse of reclaimed water continue to be funded, and in 2012 the WRRF published a series of reports in which quantitative relative risk assessments were conducted at the Montebello Forebay [US-CA-Los Angeles County].

Table 6-5 Indicative percent removals of organic chemicals during various stages of wastewater treatment

Treatment	Percent Removal										
			Pharmaceuticals					Hormones			
	B(a)p	Antibiotics[1]	DZP	CBZ	DCF	IBP	PCT	Steroid[2]	Anabolic[3]	Fragrance	NDMA
Secondary (activated sludge)	nd	10–50	nd	–	10–50	>90	nd	>90	nd	50–90	–
Soil aquifer treatment	nd	nd	nd	25–50	>90	>90	>90	>90	nd	>90	>90
Aquifer storage	nd	50–90	10–50	–	50–90	50–90	Nd	>90	nd	–	–
Microfiltration	nd	<20	<20	<20	<20	<20	<20	<20	nd	<20	
Ultrafiltration/ powdered activated carbon (PAC)	nd	>90	>90	>90	>90	>90	nd	>90	nd	>90	>90
Nanofiltration	>80	50–80	50–80	50–80	50–80	50–80	50–80	50–80	50–80	50–80	
Reverse osmosis	>80	>95	>95	>95	>95	>95	>95	>95	>95	>95	25–50
PAC	>80	20–>80	50–80	50–80	20–50	<20	50–80	50–80	50–80	50–80	
Granular activated carbon		>90	>90	>90	>90	>90		>90		>90	>90
Ozonation	>80	>95	50–80	50–80	>95	50–80	>95	>95	>80	50–90	50–90
Advanced oxidation		50–80	50–80	>80	>80	>80	>80	>80	>80	50–80	>90
High-level ultraviolet		20–>80	<20	20–50	>80	20–50	>80	>80	20–50	nd	>90
Chlorination	>80	>80	20–50	–<20	>80	<20	>80	>80	<20	20–>80	–
Chloramination	50–80	<20	<20	<20	50–80	<20	>80	>80	<20	<20	

(Sources: Ternes and Joss, 2006; Snyder et al., 2010)

B(a)p = benz(a)pyrene; CBZ = carbamazepine, DBP = disinfection by-product; DCF = diclofenac; DZP = diazepam; IBP = ibuprofen; NDMA=N-nitrosodimethylamine; nd = no data; PAC = powdered activated carbon; PCT = paracetamol.

[1] erythromycin, sulfamethoxazole, triclosan, trimethoprim

[2] ethynylestradiol; estrone, estradiol and estriol

[3] progesterone, testosterone

The Montebello Forebay project is a potable reuse project that meets drinking water standards for chemical constituents. The second part of this research extended into identifying safe exposure concentrations for a broad range of chemicals of interest to the recycled water community based on published toxicity information; the final task of this work included identification of contaminants that would be a concern in 5 to 20 years (WRRF, 2010c, 2011 and 2012f). Results from this report point to the potential for a shift in the pharmaceutical industry to increase focus on research, development and production of more biodegradable pharmaceuticals.

Treatment technologies for producing reclaimed water are well documented to remove trace chemical constituents to very low concentrations, resulting in very low risks to human health. However, the continuous stream of reported detection of CECs in reclaimed water has led to public concern about their presence and the implications for adopting planned potable reuse. Better public education regarding the effectiveness of the available treatment technologies and the safety of highly treated reclaimed water, as described in Chapter 6, should be a high priority for scientists and regulators.

Potential Impact of Residual Trace Chemical Constituents. Most WWTPs and many water reclamation facilities are not designed for removal of TrOCs. As a result, residual antibiotics and metabolites are inadvertently released into the environment. This may lead to proliferation of antibiotic resistance (AR) in pathogenic or nonpathogenic environmental microorganisms (Pauwels and Verstraete, 2006). However, the proliferation of AR is not limited to the environment and may actually occur during therapeutic use, during which intestinal flora are exposed to high concentrations of antibiotics, or during wastewater treatment, particularly secondary biological processes (Clara et al., 2004; Dhanapal and Morse, 2009).

A 2000 WHO report identified AR as a critical human health challenge for the next century and heralded the need for “a global strategy to contain resistance” (WHO, 2000). According to the report, more than two million Americans are infected each year with antibiotic-resistant pathogens, and 14,000 die as a result. A potential source of this proliferation of AR is the use, whether for human health or animal husbandry, and subsequent release of antibiotics and metabolites into the environment. It is estimated that up to 75 percent of antibiotics are excreted unaltered or as metabolites (Bockelmann et al., 2009). And yet, few studies have attempted to identify processes contributing to the selection of AR bacteria. Such information will be critical in the development of treatment strategies to reduce the potential for AR proliferation in the environment.

There are several critical locations within a typical WWTP where AR may accumulate or develop. AR genes may already be present in raw sewage entering a WWTP, but there is also considerable evolutionary pressure within a WWTP to induce such changes. Specifically, the conventional activated sludge (CAS) and MBR processes may be a significant source of AR due to their continuous exposure of bacteria in ideal growth conditions to relatively high concentrations of antibiotics. Despite the direct correlation between solids retention time (SRT) and reductions in antibiotic concentrations, higher SRT also provides prolonged exposure of bacterial populations to relatively high concentrations of antibiotics present in primary effluent (Clara et al., 2005; Gerrity et al., 2012; Salveson et al., 2012). Some MBRs will operate at SRTs on the order of 50 days, while CAS processes may be operated in the range of 1 to 20 days, which is more than sufficient to allow for bacterial adaptation given their high growth rates. In both MBR and CAS configurations, AR bacteria may accumulate in biosolids and may also be discharged to the environment in finished effluent or reclaimed water.

To reduce the potential for AR proliferation, future research should target identification of the major source(s) of AR (i.e., raw sewage, biosolids, or treated effluent), determine treatment conditions that promote AR development, and characterize the persistence of AR in the environment. Ultimately, this knowledge will assist in developing mitigation strategies and alleviating environmental and public health concerns.

6.3 Regulatory Approaches to Establishing Treatment Goals for Reclaimed Water

Countless studies have provided information about the operating conditions of wastewater treatment processes; treatment efficacy; and pathogen and contaminant behavior, fate, and activity in the environment along with geological parameters necessary for developing and maintaining adequate processes to prevent contamination of groundwater and other water sources. Together, these studies established the role of each unit process in ensuring treatment efficiency. Many state guidelines and regulations emphasize the use of a multiple-barrier approach that combines several unit processes to ensure redundancy. Title 22 of the California Code of Regulations for Water Recycling Criteria (Title 22) (2008) and in Chapter 62-610 of the Florida Administrative Code for Reuse of Reclaimed Water and Land Application (2009) both require a multi-barrier approach.

6.3.1 Microbial Inactivation

With respect to understanding the human health impacts as a function of exposure to microbial contamination, it is useful to review historical work that was conducted and has been used as the basis for the EPA's Recreational Water Quality Criteria (RWQC). The criteria recommendations are for the protection of people using bodies of water for recreational uses, such as swimming, bathing, surfing, or similar water-contact activities, and are based on an indicator of fecal contamination, which is a pathogen indicator. The EPA RWQC may be used by states to establish water-quality standards that can provide a basis for controlling the discharge or release of pollutants from WWTPs. In many cases, individual states have used these criteria as the basis for development of microbial standards for some reuse. Interestingly, many of the states have used the EPA RWQC as the basis for reuse.

In December 2011, EPA released a new draft RWQC that recommended using the bacteria *enterococci* and *E. coli* as indicator organisms for freshwater. While the numeric criteria for the geometric mean of organisms are identical to the 1986 RWQC, there are also recommendations for how to address the maximum statistical values. It is unknown at this time what, if any, changes to the draft will be implemented before the new criteria are published as final.

The historical development of the EPA RWQC began in the 1960s, when the U.S. Public Health Service recommended using fecal coliform bacteria as the indicator of primary contact with fecal indicator bacteria. Studies showed that in surface waters impacted by wastewater discharges, there was a reported, detectable health effect when total coliform density was about 2,300 per 100 mL (Stevenson, 1953). In 1968, the National Technical Advisory Committee (NTAC) translated the total coliform concentrations to 400 cfu/100 mL based on a ratio of total coliform to fecal coliform, and then halved that number to 200 cfu/100 mL (EPA, 1986). The NTAC criteria for recreational waters were recommended again by EPA in 1976. In the late 1970s and early 1980s, EPA conducted a series of epidemiological studies to evaluate several additional organisms as possible indicators of fecal contamination, including *E. coli* and *enterococci*; these studies showed that *enterococci* are a good predictor of gastrointestinal illnesses in fresh and marine recreational waters and *E. coli* is a good predictor in freshwater (Cabelli et al., 1982; Cabelli, 1983; Dufour, 1984). The current 2012 draft RWQC now has acknowledged the use of quantitative real time polymerase chain reaction (qPCR) data for *enterococci* and set levels in recreational settings. The qPCR method was found to be superior to cfu in predicting illness (Wade et al. 2008), and acceptable risk levels of 8 illnesses per 1,000 exposures have been set. Thus, at the state level this allows discussion if these approaches and levels of risk could be appropriate for the various levels of use for reclaimed water.

Concurrently, several key studies were conducted that contributed significantly to understanding recycled water treatment processes, benefits of the multiple-barrier approach, and the long-term impacts of using recycled water. The Pomona Virus Study (Miele, 1977) was a landmark study that provided a database for wastewater-treatment unit process performances. The data could be used to make regulatory decisions regarding alternative treatment system variances of the California recycled water regulatory requirements (Title 22), at that time (California Administrative Code, 1978; Dryden et al., 1979; Miele, 1977). The study concluded that nearly complete virus removal is possible using additional filtration and disinfection steps and opened up the possibilities of wastewater reuse for various applications.

Since then, the potential health effects from long-term use of recycled water were evaluated in three epidemiological studies (Nellor et al., 1984; Sloss et al., 1996; Sloss et al., 1999). Almost 600 filtered effluent and groundwater well samples were analyzed for human viruses, and no viruses were found. Further, two additional studies were conducted to increase the understanding of the effectiveness of SAT processes for use in designing, operating, and regulating SAT systems, which are further discussed in Section 6.4.5.3 (Fox et al., 2001; Fox et al., 2006). In these studies, culturable human viruses were found in disinfected secondary effluents and downstream monitoring wells, indicating that SAT does not completely remove these viruses. However, where coagulation and filtration processes are added to the reclaimed water treatment process, the disinfected effluent samples and water associated with groundwater spreading operations does not contain culturable human viruses. These findings reiterate that plants with different levels of treatment produce different qualities of recycled water and that properly-designed treatment can remove viruses to below detection limits.

Thus, there is a substantial body of scientific evidence that most states use in development of microbiological criteria for reuse; and most states that have reuse rules or guidelines base their criteria on the removal of indicator organisms. Generally, reuse applications in which only specific applications with minimal human contact are allowed (e.g., irrigation of fodder crops for livestock use) do not require the same level of disinfection as applications in which human contact is more likely to occur (e.g., irrigation of landscaping or turf in a public area). A majority of states that allow and permit applications specify microbiological effluent quality and do not specifically require certain treatment technologies, with several notable exceptions (e.g., California, Washington, and Hawaii).

For example, North Carolina has recently produced reuse-quality specifications for two categories of reuse applications. The level of treatment required for the use with the highest potential for human contact includes criteria of 6-log (99.9999 percent) removal for *E. coli*, 5-log (99.999 percent) removal for coliphage, and 4-log (99.99 percent) removal for *Clostridium perfringens*. In California, the regulatory approach is based on treatment technology with specific performance requirements. The most stringent reclaimed water treatment uses in California include oxidation, sedimentation, coagulation, filtration, and disinfection (California Department of Health Services, 2001). Taken as a whole, these treatment strategies are useful for the removal and inactivation of pathogens to undetectable or very low levels in reclaimed water.

California's recycled water requirements were adopted from the guidelines developed for the SDWA requirements of 1974 and are currently the most protective requirements in the nation. For unrestricted public access, including edible crop irrigation and swimming, the California Title 22 requirements include specific filtration and disinfection criteria that are designed to remove and/or inactivate 5-log of viruses. The requirements also include monitoring limits for total coliform bacteria, while many states have less stringent limits based on fecal coliforms. Rigorous turbidity requirements that are a component of the California criteria are used as a surrogate measure of filtration performance, which, as described in Section 6.4.2, is an important factor in achieving the rigorous microbial inactivation requirements. Further, disinfection technologies that are approved for application in reuse projects must demonstrate the equivalent of 5-log reduction of poliovirus over a range of operating conditions.

More recently in California, new draft groundwater replenishment regulations have been discussed for indirect potable reuse by planned groundwater replenishment reuse projects (GRRP) that use highly treated municipal wastewater to replenish groundwater basins designated as potable water supplies by 2013 (CDPH, 2011). Draft provisions of the GRRP regulations would be based on reducing the risk of waterborne disease and would include pathogen controls requiring treatment systems to achieve 12-log virus reductions and 10-log reductions of the protozoan parasites *Cryptosporidium* oocysts and *Giardia* cysts through at least three treatment barriers. Up to 6-log removal credit would be allowed for surface and groundwater storage that is at least 6 months in duration. Treatment facilities that employ approved filtration and disinfection processes or an approved AOP process with at least 6 months of underground retention prior to use can obtain a 10-log removal credit for *Cryptosporidium* oocysts and *Giardia* cysts. Use of proven, CDPH accepted technology/treatment processes reduces the burden on utilities to pilot proven processes and to prove reduction of microbial contaminants through underground storage.

6.3.2 Constituents of Emerging Concern

The majority of wastewater-derived trace chemical constituents are not specifically regulated in the United States, although pretreatment requirements and effluent guidelines and secondary and advanced treatment are beneficial for reducing loadings of many chemicals. Moreover, with thousands of chemicals potentially present in reclaimed water, compiling a comprehensive list of chemicals that could be present in trace concentrations is not feasible. In fact, EPA considered a select number of trace chemical constituents on their most recent Candidate Contaminant List (CCL3) and the proposed Unregulated Contaminants Monitoring Rule 3 (UCMR3) for drinking water. In the absence of federal mandates, individual states may choose to regulate individual chemical constituents. The WHO concluded that WHO guidelines were not necessary for pharmaceuticals in water supplies, and it did not recommend general monitoring of water supplies for pharmaceuticals (WHO, 2011).

Extensive regulations for trace chemical constituents in recycled water for potable applications and drinking water are probably neither feasible nor necessary. Treatment specifications or guidelines for particular end uses, such is the approach for all U.S. drinking water supplies, may be useful. However, benchmarks for water quality composition are useful for decision-makers as well as public confidence. Development of benchmarks for specific chemicals, especially pharmaceuticals and pesticides, is feasible because they usually have very extensive databases developed as part of their registration or approval process, and margins of exposures are available relative to therapeutic or toxic doses (Bull, et al., 2011). Screening techniques, such as estimation of Thresholds of Toxicological Concern, are also available for use in prioritizing and reducing long lists of chemicals to those of potential greater interest (Cotruvo, 2011). These techniques could be applied rapidly and at relatively low cost. Another useful model for producing benchmarks for unregulated water contaminants would be like the nonregulatory EPA Drinking Water Health Advisories that were initiated more than 20 years ago (EPA, 2012b; Cotruvo, 2012).

While there are no specific regulations for CECs in reclaimed water as of 2012, further investigation is necessary before any final decisions can be made on the subject. While the application of reclaimed water for urban and landscape irrigation (i.e., lawns, golf courses, parks, non-food gardens, etc.) is thought to pose very low risk to humans in contact with the various plants/surfaces irrigated, recent research by Knapp et al. (2010) indicates that there may be indirect health effects resulting from use of reclaimed water in agricultural applications . In that study, changes in antibiotic resistance in soil bacteria in samples taken and archived in the Netherlands between 1940 (when antibiotic use was beginning to be widespread) until 2008 showed supported growing evidence that resistance to antibiotics is increasing both in benign and pathogenic bacteria, which could pose an emerging threat to public and environmental health (Knapp et al., 2010).

In order to understand these broader, indirect effects of CECs, one of the stated areas of priority for the USDA Agriculture and Food Research Initiative (AFRI) Program is to investigate the potential and relevance of bioaccumulation of CECs when recycled water is applied at typical irrigation rates. The USDA-AFRI is funding work to examine the potential for bioaccumulation of PPCPs by crops under irrigation with reclaimed water. This work is being conducted to help address the concerns over potential health risks posed by consuming raw food crops that may bioaccumulate these chemicals (Wu et al., 2010).

6.3.2.1 Example of California's Regulatory Approach to CECs

Over the years, the CDPH has developed a series of incremental draft criteria for the use of reclaimed municipal wastewater to recharge groundwater basins that are sources of domestic water supply (CDPH, 2008). These criteria were designed to ensure that groundwater supplies are augmented with reclaimed water that meets all drinking water standards, and other requirements.

In 2009, California's SWRCB adopted a new Recycled Water Policy that created a "blue ribbon" panel to guide future state actions relative to CECs by conducting a review of scientific literature related to use of reclaimed water and current knowledge on risks that might be posed by CECs and to make recommendations regarding monitoring for CECs (SWRCB, 2009). Background on the California Recycled Water Policy and CECs, including links to public hearings and reports, is available online (SWRCB, 2011). The Advisory Panel report *Monitoring Strategies for Chemicals of Emerging Concern (CECs) in Recycled Water – Recommendations of a Scientific Advisory Panel* was issued in June 2010 (Anderson et al., 2010).

The panel provided a conceptual framework for assessing potential CEC targets for monitoring and used the framework to identify a list of chemicals that should be monitored currently (Anderson et al., 2010). The panel also recommended that the prioritization process be reapplied on at least a triennial basis and that the state establish an independent review panel to periodically review CEC monitoring efforts. The CECs the panel recommended for monitoring currently are those found in recycled water at concentrations with human health relevance, as defined by the exposure screening approach recommended by the panel. Further, the panel recommends monitoring both the performance of treatment processes to remove CECs using selected "performance indicator CECs," and surrogate/operational parameters to verify that treatment units are working as designed. Surrogates include turbidity, DOC, and conductivity. Health-based CECs selected for monitoring included caffeine, 17β-estradiol, NDMA, and triclosan. Performance-based indicator CECs were selected by the panel, each representing a group of CECs: caffeine, gemfibrozil, n,n-diethyl-meta-toluamide (DEET), iopromide, NDMA, and sucralose. Caffeine and NDMA serve as both health and performance-based indicator CECs.

CDPH provided recommendations to the SWRCB specific to CECs and the CDPH monitoring requirements for surface spreading groundwater recharge projects (CDPH, 2010). CDPH recommendations were specific for chemicals on the current CDPH notification-level list, other chemicals, and chemicals specific to a new permit. CDPH notification-list chemicals to be monitored are boron; chlorate; 1,4- dioxane; nitrosamines (NDMA, NDEA, and NDPA); 1,2,3-trichloropropane; naphthalene; and vanadium, with initial quarterly testing that could be reduced to annual testing if the chemicals are not detected. Initial quarterly monitoring was also recommended for chromium-6, diazinon, and nitrosamines NPYR and N-Nitrosodiphylamine, with the ability to reduce to annual testing if the chemical is not detected. Three additional chemicals, bisphenol A, carbamazepine, and TCEP, were recommended for annual monitoring. CDPH also included a statement that it would consider source waters and treatment process when recommending project-specific monitoring requirements, such as monitoring for formaldehyde when an AOP process is used.

The most current draft regulations, issued in November 2011, are scheduled to be finalized in 2013 (CDPH, 2011). Other scientific oversight groups required by legislation for individual projects have recommended other performance-monitoring regimens to demonstrate the effectiveness of the treatment trains being employed. Very few chemicals are being detected, even at ppt levels, in fully-treated waters.

6.3.2.2 Example of Australia's Regulatory Approach to Pharmaceuticals

In 2008, Australia was the first country to develop national guidelines for potable reuse with the release of Phase 2 of the *Australian Guidelines for Water Recycling (AGWR): Augmentation of Drinking Water Supplies* (EPHC, 2008). The AGWR provide a risk management framework, rather than simply relying on end-product (reclaimed-water) quality testing as the basis for managing water recycling schemes. They include concentration-based numeric guidelines for at least 86 pharmaceuticals in reclaimed water. The guideline concentrations are based on application of a safety factor of 1,000 to 10,000 relative to a single therapeutic dose. These are not mandatory and have no formal legal status, but they were provided as nationally consistent guidance for those recycling projects. In general, the guideline concentrations are far higher than concentrations found in drinking water or reclaimed water.

While there is no definitive risk assessment tool for some types of trace chemical constituents in recycled water, the Australian guidelines do provide a methodology for evaluating the potential risk from known and emerging chemical constituents (NHMRC-NRMMC, 2004; EPHC, 2008; and Snyder et al., 2010).

6.4 Wastewater Treatment for Reuse

The level of wastewater treatment required for any project depends on the end use or discharge location, but in the United States, all wastewater is required to be treated to secondary levels, at a minimum. Secondary treatment is designed to achieve removal of degradable organic matter and suspended solids. Filtration and disinfection provide additional removal of pathogens and nutrients, and AOPs can target trace chemical constituents. Wastewater treatment from raw to secondary is well understood and covered in great detail in other publications, such as the WEF Manual of Practice (MOP) 8, *Design of Municipal Wastewater Treatment Plants* (WEF, 2010). The discussion here is limited to treatment processes with a particular application to water reuse and reclamation, which also includes source control.

For many uses of reclaimed water, appropriate water quality can be achieved through conventional, widely-practiced secondary, filtration and disinfection processes. However, as the potential for human contact increases, advanced treatment beyond secondary treatment may be required. As discussed in Section 1.5, the level of treatment and treatment processes to be employed for a reuse project should consider the end use to establish water quality goals and treatment objectives. Not all constituents have negative impacts for all uses. Nutrients, for example, can be beneficial when water is reused for agricultural irrigation, offsetting the need for supplementally applied fertilizers, and in these cases nutrient removal in treatment may not be helpful. On the other hand, where water is reused for environmental flows, nutrient removal could be critical to avoid overloading aquatic ecosystems with these nutrients. Likewise, nutrient removal would be targeted where reclaimed water would impact future drinking water sources, such as groundwater, as excess nutrients can be harmful to human health.

A summary of the level of treatment required for specific reclaimed-water end uses in 10 states is provided in Section 4.5.2. Three processes have seen significant technology advances since publication of the 2004 guidelines: filtration, disinfection, and advanced oxidation. The purpose of this section is to describe these processes and some of the recent technology advances, as well as highlight the increasingly important role of natural treatment systems, such as wetlands and SAT systems, for polishing or further treating the reclaimed water.

6.4.1 Source Control

A critical component of any water reuse program is to develop and implement an effective industrial source control program as the first barrier to preventing undesirable chemicals or concentrations of chemicals from entering the system. The pollutants in industrial wastewater may compromise municipal treatment processes or contaminate the treated effluent by pass-through. To protect municipal treatment plants and the environment, the CWA established the National Pretreatment Program, which requires industrial dischargers to use treatment and management practices to reduce or eliminate the discharge of harmful pollutants to sanitary sewers. The term “pretreatment” refers to the requirement that nondomestic sources discharging to publicly-owned treatment works control their discharges. EPA has established technology-based numeric effluent guidelines for 56 categories of industry, and the CWA requires EPA to annually review its effluent guidelines and pretreatment standards and to identify potential new categories for pretreatment standards; recommendations are presented in a Preliminary Effluent Guidelines Program Plan. The 2010 Plan included a strategy for the development of BMPs for unused pharmaceutical disposal at hospitals and other healthcare facilities that is intended to eliminate inconsistency in messages and policies regarding flushing of drugs to municipal sewer systems.

Wastewater management agencies are required to establish local limits for industries as needed to comply with NPDES permits and to prevent discharges into sewerage systems that inhibit or disrupt treatment processes, or the uses/disposal of treated wastewater. Generally, pollution prevention programs will be effective if certain conditions can be met:

- The pollutant can be found at measurable levels in the influent and collection system.
- A single source or group of similar sources accounting for most of the influent loading can be identified.
- The sources are within the jurisdiction of the agency to control (or significant outside support/resources are available).

Industrial sources are most easily controlled because industries are regulated and required to meet sewer-use permit requirements. If a pollutant source is a commercial product, such as mercury thermometers or lindane head lice remedies, it may not be within the local agency’s power to ban or restrict the use of the product; in such cases, to be effective, restrictions on product use must be enforced on a regional, statewide, or national basis, such as the ban on nonylphenol (a surfactant ingredient with endocrine disrupting properties) use in the European Union.

For agencies implementing IPR projects, source control programs may go beyond the minimum federal requirements. Many agencies have developed local or statewide “no drugs down the drain programs” and/or drug take-back programs. For example in Texas, SAWS has developed a collection program for unused medications. Other agencies have included additional program elements to enhance their pollution prevention efforts; the OCSD, which provides reclaimed water to the OCWD for the Groundwater Replenishment System Project in southern California, has instituted additional program elements that build on the agency’s traditional source control program. These elements include a pollutant prioritization scheme that includes chemical fate assessment for a broad range of chemicals; an outreach program for industries, businesses, and the public; and a toxics inventory that integrates a geographical information system and chemical fact sheets. The OCSD successfully used its source control program to reduce the discharge of NDMA and 1,4-dioxane from industries into its wastewater management system.

Oregon has passed rules that set trigger levels for pollutants, requiring municipal wastewater facilities to develop toxics reduction plans for listed priority persistent pollutants if any of the pollutants are found in their effluent above the trigger levels set by the rule (Oregon DEQ, n.d.). The rule includes numeric effluent concentration values for 118 priority persistent pollutants for which drinking water MCLs have not been adopted, but that the Oregon Environmental Quality Commission has determined should be included in a permitted facility’s toxic-pollutant reduction plan. The list includes pollutants that persist in the environment, and pollutants that accumulate in animals. All of the pollutants on the list have the potential to cause harm to human health or aquatic life; some are known carcinogens and others are believed to disrupt endocrine functions. The list includes both well-studied pollutants that people have worked to reduce for many years and others for which little information exists. Results of wastewater effluent monitoring will be compared against trigger levels, and where effluent concentrations exceed the trigger level, the facility will be required to develop a toxics reduction plan aimed at reducing levels of that pollutant in its discharge. The Oregon DEQ consulted with a Science Peer Review Panel to develop the list of pollutants and triggers.

6.4.2 Filtration

Filtration removes particulates, suspended solids, and some dissolved constituents, depending on the filter type. In addition, by removing particles remaining after secondary treatment, filtration can result in a more efficient disinfection process. While chemical or biophysical disinfection processes inactivate or destroy many classes of microorganisms, pathogens removed by filtration are removed by physical adsorption or entrapment. The ability of filtration to help reduce pathogens is a function of the pore size of the media, the size of the pathogen, and the impact of chemical addition, if used. Most types of filtration are able to remove some of the largest pathogens, such as protozoan cysts. Smaller pathogens, including bacteria or viruses, can be removed in filtration either through size exclusion by filters with very small pore sizes, or by filtering out larger particles to which the smaller pathogens are adsorbed. Because a large proportion of pathogens in treated wastewater prior to disinfection tend to be associated with particles, many states with reuse regulations also include requirements for removal of particles. The rationale of these requirements is that effective filtration, and thus particle removal, is part of a multiple-barrier treatment process. A second benefit is improvement in disinfection efficiency with fewer particles, lower turbidity, and higher transmittance.

Regulatory factors can affect the design of filtration, where required, for water reuse activities. For example, the regulatory requirements for water reuse filtration in California and Florida (the two states where the most water reuse occurs) are worth comparing. Florida does not stipulate the type of approved filters or loading rate to the filter as long as water quality requirements for TSS are satisfied. On the other hand, in California, the filtration technology must be conditionally accepted by the CDPH prior to its application for treatment of recycled water, in addition to meeting strict turbidity limits during performance. Many types of filtration, including depth filtration, surface filtration, and membrane filtration, have received approval from CDPH; the loading rate at which the conditionally-accepted filter can be operated is also specified. Both states require chemical feed facilities to improve filtration by first coagulating particles, but the chemical feed facilities can remain idle if the TSS or turbidity limits are satisfied.

In California, several conventional filtration technologies are approved for operation at 2 gpm/ft^2 (traveling bridge filters) and 5 gpm/ft^2 (mono-, dual-, or mixed-media filters), and disinfection with chlorine gas or sodium hypochlorite is allowed under stipulated conditions. All other filtration and disinfection technologies must undergo rigorous third-party testing and receive “conditional acceptance” from the CDPH prior to use. For filtration testing, this includes long-term performance demonstration for meeting turbidity criteria and other objectives.

In recent years, with increased emphasis on improving treatment for reuse, there have been many innovations in filtration, and today there are numerous types of commercially-available filtration technologies. Therefore, a brief discussion of recent advances in filtration technology as it relates to treatment of reclaimed water is merited. Regardless of the significant variations in configurations and characteristics of the filters, there are three types of commercially-available filtration technologies: depth filtration, surface filtration, and membrane filtration.

6.4.2.1 Depth Filtration

Depth filters have the longest history of use at WWTPs. Depth filters consist of a bed of noncompressible or compressible media. Noncompressible media, such as sand, anthracite, or garnet, is most commonly used. Depending on the type of filter (i.e., mono-, dual-, or mixed-media), the effective size of the media in noncompressible media filters varies between 0.0016 and 0.08 in (0.4 and 2.0 mm) in average diameter. Noncompressible media filters contain columns packed with several feet of media, and, depending on the filter configuration, utilize a continuous, semi-continuous, or batch backwash process. Utilities with existing depth filtration plants are also increasing their existing filtration capacity by conducting filtration studies to document the ability of their filters to operate at higher hydraulic loading rates. These advances in loading rates allow for substantial reduction in filtration costs.

In 2000, depth filters with synthetic compressible media became commercially available. These compressible-media filters utilize a synthetic medium that has a diameter of approximately 1.25 in (32 mm). During normal filtration, media in the compressible-media filters is compressed 15 to 40 percent, and filtration occurs. Backwashing occurs in a batch process, during which the media is uncompressed and then cleaned with an air scour and a hydraulic wash. The high porosity of the compressible media (around 88 percent) allows for higher hydraulic loading rates than other depth filter, while the backwashing continuously recharges the media surface to prepare it for another round of filtration so that filtration efficiency is not compromised. Conditional acceptance of this technology for water reuse applications was granted in 2003 by CDPH for hydraulic loading rates up to 30 gpm/ft^2 (1200 L/min/m^2), which is more than six times the approved filtration rate of conventional depth filters. More recent advances in this technology have resulted in the development of a modified compressible media that operates at even higher hydraulic loading rates (Caliskaner et al., 2011).

6.4.2.2 Surface Filtration

The main difference between surface and depth filters is the depth of the packed media and the media material. Depth filtration typically includes several feet of packed media, while surface filters are generally a fraction of a millimeter to several millimeters thick. Surface filters typically consist of screens or fabric manufactured from nylon, polyester, acrylic, and stainless steel fibers. Most surface filters are gravity fed, and backwashing is semi-continuous; however, for short periods of time it may be necessary to perform backwash in a continuous mode.

Manufacturers of disk filters, which are a type of surface filter with the filtration screen mounted on a series of disks, have made recent improvements in performance and efficiency; increasing numbers of disk filter configurations are gaining regulatory approval in California, where filter technologies must be approved. In 2001, the CDPH approved the first disk filtration technology for water reuse applications at hydraulic loading rates up to 6 gpm/ft^2 (230 L/min/m^2), and other disk filtration configurations have more recently received conditional acceptance at the same loading rate. A high-rate disk filter was granted conditional acceptance for loading rates up to 16 gpm/ft^2 (620 L/min/m^2), in 2009 (State of California, 2009). At least one manufacturer has received CDPH approval for a submerged, fixed cloth media, and there are several others that have applied for acceptance.

6.4.2.3 Membrane Filtration

A membrane may be defined as a thin film separating two phases and acting as a selective barrier to the transport of matter; detailed discussion of membrane filtration processes are provided in EPA’s *Membrane Filtration Guidance Manual* (EPA, 2005). For water to flow through a membrane there must be some type of driving force, and for reuse applications, membrane processes are typically pressure-driven processes. Some novel desalination approaches, which may gain application in reclamation of brackish waters, use osmotic gradients as the driving force. A summary of the driving force and nominal pore size is provided in **Table 6-6** for major, commercially-available filtration processes.

There are significant differences in the pore sizes of various filter types available (**Table 6-6**). The use of filters from the membrane group will result in a higher filter effluent quality than can be achieved by using either surface or depth filters. This higher effluent water quality with MF or UF membranes comes at a higher cost of 1.5 to 2 times that of depth or surface filtration systems because of energy and equipment costs. NF and RO costs are substantially higher, due to high energy costs and specialized equipment.

The capacity of a filtration system is usually evaluated based on filtration rate and the available surface area in the filtration system. Manufacturers are constantly developing new filtration technologies or modifying their established technologies to improve filter performance by increasing the hydraulic loading rates or increasing water quality, thus making their filters more economical or providing better value.

In San Ramon, Calif., the DSRSD provides filtration of secondary effluent using a continuous backwash sand filtration system in parallel with a 0.2 nominal pore size MF system for comparison of filtration efficiency [US-CA-San Ramon]. Studies conducted on this reuse system show that a higher level of particle rejection (which was achieved with the MF system) correlates with higher microorganism rejection (*Cryptosporidium*, *Giardia*, and total coliforms), and that the filtration system can be an important part of a multi-barrier approach to reclaimed water treatment (WRRF, 2012a). It is important to note that neither filtration system in this case study example was able to provide virus rejection. While smaller pore size membranes, such as UF, NF, and RO systems, can achieve virus removal when membranes do not have any flaws, chemical disinfection is needed for virus removal, which is why the multi-barrier approach is needed.

6.4.2.4 Biofiltration

Biological filtration or biofiltration is a treatment technique in which a granular media filter is allowed to be biologically active for the purpose of removing biodegradable constituents such as TOC. Most any granular media filter is capable of supporting microbial growth, assuming that the water being filtered does not have a disinfectant residual. As a result, the biological activity can improve treatment performance beyond particle removal such that water quality is improved with respect to a wide range of dissolved organic

Table 6-6 Summary of filter type characteristics[1]

Filter Type	Filtration Driving Force	Nominal Pore Size, *um*	Contaminants targeted for removal
Depth			
Non-Compressible Media	Gravity or pressure differential	60-300	TSS, turbidity, some protozoan oocysts and cysts
Compressible Media			
Surface Filtration			
Surface Filtration	Gravity	5-20	TSS, turbidity, some protozoan oocysts and cysts
Membrane[2]			
Microfiltration	Pressure differential	0.05	TSS, turbidity, some protozoan oocysts and cysts, some bacteria and viruses
Ultrafiltration	Pressure differential	0.002-0.050	Macromolecules, colloids, most bacteria, some viruses, proteins
Nanofiltration	Pressure differential	<0.002	Small molecules, some hardness, viruses
Reverse Osmosis	Pressure differential	<0.002	Very small molecules, color, hardness, sulfates, nitrate, sodium, other ions

[1] Information taken from California Department of Public Health (2009), Metcalf & Eddy (2003)
[2] Information from *Water Treatment Membrane Processes* (AWWA, 1996)

contaminants, including pesticides, EDCs, and pharmaceuticals, although the degree to which biological activity contributes to treatment performance varies (Bonne et al., 2006; Wunder et al., 2008; Van der Aa et al., 2003). Several types of biofiltration can be used, including slow sand, rapid-rate, and granular activated carbon (GAC) (Evans, 2010).

Depending on the pore size of the filter media, substantial removal of trace chemical compounds can be obtained. The mechanisms of physical removal include removal of particles with sorbed chemicals, removal of chemicals by sorption into media pores, or electrostatic repulsion (WRRF, 2012a; Kimura et al., 2003). Biofiltration, which is commonly used in potable reuse schemes, enhances the use of common physical and chemical means to remove contaminants through biodegradation. With increasing interest in obtaining higher quality reclaimed water, biofiltration, as part of a multi-barrier treatment process, could replace higher energy processes such as RO in certain applications (see sections 3.1 and 3.7 for the Namibia model for potable reuse).

Slow Sand Filtration. Slow sand filtration, along with natural filtration processes, such as SAT and riverbank filtration, which are discussed in Section 6.4.5, is actually one of the oldest drinking water treatment processes still being used today. Slow sand filtration uses small-diameter sand with low surface-loading rates without chemical coagulation. In slow sand biofiltration, the sand's top surface becomes coated with a biologically active layer called a schmutzdecke, which is periodically scraped off or harrowed to renew a system's hydraulic capacity. Although slow sand filtration primarily uses both physical and biological mechanisms to remove contaminants, the biological mechanism dominates.

Rapid-Rate Filtration. Rapid-rate filtration uses larger-diameter media, such as sand and anthracite, and surface loading rates about 100 times higher than slow sand filtration. A coagulant, such as ferric chloride or alum, is added upstream of the process to remove turbidity and organic matter. The filter must be backwashed periodically with chlorinated or nonchlorinated water. A preoxidation process that uses ozone, chlorine, chlorine dioxide, or permanganate is sometimes used, which can enhance biological activity by oxidizing complex organic matter into smaller, more biodegradable organic compounds that are readily removed by a rapid-rate filter.

GAC Filtration. When compared with sand or anthracite media, GAC has the additional property of adsorption and can accumulate greater microbial biomass (or biofilm) on activated carbon media. Biomass plays an important role in biodegrading contaminants and supplementing GAC filtration. GAC lifetime—the time between media replacements—can be extended by biological processes. Therefore, GAC filtration uses physical and biological processes for contaminant removal. Depending on contact time requirements to remove target contaminants, GAC filtration can be designed as a GAC rapid-rate filter, a mono-media deep-bed contactor, or a filter cap on top of a sand or anthracite filter bed. As with conventional rapid-rate filters, upstream coagulants and oxidants frequently are used to improve contaminant removal. Additionally, GAC's adsorptive properties aids in producing the desired filtered water quality through adsorption; thus, GAC must be regenerated periodically, particularly where adsorption may play a more dominant treatment role than the biological mechanism of contaminant removal.

6.4.3 Disinfection

Relative removal of microbial indicators and pathogens by various treatment stages is included in **Table 6-3**; however, in order to provide reclaimed water that meets the intended use, disinfection using one or more of these technologies is an important part of any reuse scheme. Disinfection is designed to inactivate microorganisms, including viruses, bacteria, protozoan oocysts and cysts, and helminthes; these pathogenic organisms and the associated health risks were discussed in Section 6.2.1. The most common reclaimed water disinfection method in use to date is chlorination. UV disinfection is a well-proven and commonly-used alternative to chlorine. Other disinfection alternatives are peracetic acid (PAA), ozone, pasteurization, and ferrate (WERF, 2008); PAA is not discussed further because no municipal reuse applications have been implemented in the United States, to date.

To date, California is the only state that has technology-based regulations for disinfection, although Florida references the NWRI UV Guidelines in its regulatory code as guidance for permitting reuse applications (NWRI, 2003). Thus, while there are many disinfection technologies that show promise for reuse applications, this section covers those technologies that have demonstrated pathogen reduction through rigorous research and have obtained "conditional acceptance" from the CDPH for use on reclaimed water treatment, with the exception of ferrate, which is also included. There are four technologies accepted by the CDPH: chlorination, UV disinfection, ozone, and pasteurization. Dose requirements for these disinfection technologies under California Title 22 are provided in **Table 6-7**, along with comparative dose requirements for reuse in Florida under FAC 62-610.

6.4.3.1 Chlorination

Chlorine disinfection may be accomplished using free chlorine or chloramines. Regardless of the mode of chlorination, the efficiency of chlorine disinfection depends on the water temperature, pH, degree of mixing, time of contact, presence of interfering substances, concentration and form of chlorinating species, and nature and concentration of the organisms to be destroyed. In general, bacteria are less resistant to chlorine than viruses, which, in turn, are less resistant than parasite ova and cysts.

Disinfection requirements often include monitoring of total chlorine (which includes free chlorine, chloramines, and other chlorine/organic compounds) remaining in the treated water after a certain contact time. When ammonia is present in wastewater, it will combine with free chlorine to form chloramines (typically monochloramine), which is less effective as a disinfectant than free chlorine and requires a disinfectant does an order of magnitude or more than free chlorine (WEF, 2010). Additionally, chlorine reacts with other organic constituents that remain in treated wastewater to form compounds that provide a measurable combined chlorine residual, but with a potentially low disinfection capability. The occurrence and effects of this phenomenon have been well documented (Black and Veatch, 2010; Szerwinski, et al., 2012).

Chlorine disinfection efficacy is typically measured as C_rT, which is the product of the total chlorine residual times the contact time. Methods of calculating C_rT can vary. The CDPH, for example, specifies the C_rT concept, with C_r being the total combined residual and T being the contact time at the point of measurement. C_rT can also be defined as the integration of the residual concentration of the disinfectant concentration C_rT over the measured contact time T. Depending on water quality and chemistry, there may be a significant chlorine demand that yields a difference in the applied and residual concentration at the required or recommended contact time. Because of the complications in wastewater, the chlorine C_rT values required for various rates of inactivation must be determined empirically. Many studies have shown that a C_rT for free chlorine outperforms the same C_rT for chloramines; however, the assumption that a lower dose may be required for disinfection using free chlorine is misleading, because achieving free chlorine residual in wastewater effluents can be challenging for the reasons given above. Planners and designers are cautioned to confirm the currently-accepted calculation approach for any specific project.

Table 6-7 California and Florida disinfection treatment-based standards for tertiary recycled water and high-level disinfection

Disinfection Process	California	Florida[2]
Chlorination	450 mg-min/L C_rT[1]	25 mg-min/L for fecal coliform <1,000 MPN/100 mL 40 mg-min/L for fecal coliform 1,000 to <10,000 MPN/100mL 120 mg-min/L for fecal coliform >10,000 MPN/100mL
UV	100 mJ/cm^2 following sand or cloth filtration; 80 mJ/cm^2 following MF or UF; 50 mJ/cm2 following RO	No uniform standard
Ozone	1 mg-min/L CT[1]	No standard
Pasteurization	10 second contact time at 179 degrees F	No standard

[1]CT is the multiplication of a measured modal contact time and oxidant residual at the end of the contact period. C_rT is the product of the total chlorine residual times the contact time.

[2]Florida's sliding disinfection standards for chlorination assume a direct correlation between fecal coliform concentrations and pathogen levels. Lower fecal coliform counts thus require less disinfection.

Free and combined chlorine have measurable differences in disinfection ability. Free chlorine is a rapid and effective viral disinfectant in wastewater, but a moderate concentration of ammonia results in a combined residual with reduced disinfection potential for poliovirus and MS2 coliphage (MS2) (Cooper, 2000). In California, for example, the C_rT of 450 mg-min/L is required for nonpotable water reuse applications with potential for direct public contact. At this dose, the CDPH assumes that disinfection will provide 4-log virus reduction for chlorine or chloramines. However, recent research has shown that in a high-quality nitrified effluent, a C_rT value of 50 mg-min/L or lower can meet the stringent "tertiary recycled water" disinfection quality for reuse in California (Maguin et. al., 2009).

Pathogenic protozoan parasites, such as *Giardia lamblia* and *Cryptosporidium parvum* and *hominis*, are found in the environment as cysts or oocysts, which protect them from environmental insults and inactivation by oxidants such as chlorine (EPA, 2004). In light of recent protozoan treatment goals, research, and publications, concerns over the use of chlorine for reclaimed water disinfection have been raised (Gennaccaro et al., 2003; Garcia et al., 2002). Gennaccaro et al. (2003) found infectious *Cryptosporidium* oocysts in 40 percent of final disinfected effluent samples in a survey of several reclamation facilities that used filtration and chlorination. Thus, *Giardia* and *Cryptosporidium* (some viable) have been documented in the literature to be found in reclaimed water effluents, the majority of which utilized chlorination. Some viable protozoan pathogens in reclaimed water disinfected with chlorine should be anticipated.

Because of the challenges of *Giardia* and *Cryptosporidium* inactivation, combining chlorine disinfectants with UV has recently attracted increasing attention, because of benefits such as disinfection of a wider range of pathogens, improved reliability through redundancy, reduced DBPs, and potential cost savings. A recent report showed that when chloramines were combined with UV, median total coliform levels below 2 cfu/100 mL and 5-log poliovirus inactivation can be achieved; however, free chlorine is still a more effective disinfectant than chloramines (WRRF, 2010d).

EPA specifies that in drinking water treatment engineers should only anticipate significant *Giardia* inactivation with free chlorine (3-log inactivation at a C_rT of 50 mg-min/L, depending on temperature and pH), as combined chlorine requires a C_rT of 1,000 mg-min/L for an equivalent level of treatment. For those states that dictate a required chlorine C_rT, regulatory compliance includes continuous monitoring and control of C_rT in conjunction with maintaining microbiological targets. Some states, such as California, require demonstration of minimum contact times upon completion of new chlorination facilities. And, for reclaimed water entering a reclaimed water distribution system, it is common to increase the chlorine residual based on time of travel and residual demand. If reclaimed water is released to a stream for flow augmentation and dechlorination is required, dechlorination can be provided as an end-of-pipe treatment.

6.4.3.2 Ultraviolet Disinfection

UV disinfection of reclaimed water is gaining in use due to increasingly energy-efficient and lower-cost UV technologies. Large systems are now successfully operating in cities such as Roseville, Calif. (45 mgd; 1,972 L/s), and Mesa/Gilbert, Ariz. (32 mgd; 1,402 L/s) [US-AZ-Gilbert]. As of 2012, UV is a well-proven and robust disinfection method; however, disinfection of treated wastewater by UV can be complicated by several factors. Most of these factors are governed by the level of treatment the utility has implemented prior to the UV disinfection reactor.

Two key water quality issues that can impact UV disinfection performance and efficiency are the presence of particle-associated microorganisms and the UV transmittance (UVT) of the wastewater. Particles can shade target microbes, shielding them from UV light; bacteria frequently become embedded in particulate matter, partially or wholly protecting them from the UV light (Paraskeva et al., 2002; Emerick et al., 1999). Particle size distribution may indicate the potential for UV disinfection efficiency, with smaller particles having less effect on UV efficiency than larger particles, as the shielding effect is reduced (Jolis et al., 2001); particles larger than 10 microns in size can shield microorganisms from disinfection by UV light. UV disinfection is enhanced by filtering water prior to disinfection, both by the reduction in particulates (a reduction in the number of large particles with embedded and shielded microorganisms) and by the increase in UVT (a reduction in smaller particulates that do not shield organisms but do reduce UVT and thus reduce UV efficiency).

Chevrefils et al. (2006) provide a thorough review of the literature on bacteria, virus, and protozoa disinfection with UV and clearly shows that UV is a powerful disinfectant for most microorganisms, including viruses such as poliovirus, calicivirus, reovirus, coxsackievirus, rotavirus, and hepatitis. Typically, UV systems are designed to meet regulations for bacterial indicator organisms; thus, total and/or fecal coliform bacteria are the primary regulatory targets. For instance, California's regulated total coliform level for "tertiary recycled water" reuse is 2.2 cfu per 100 mL of water (cfu/100 mL), which can be obtained at a relatively low UV doses (~35 to ~75 mJ/cm^2), but higher doses are required to meet the 5-log virus requirement (100 mJ/cm^2) (NWRI, 2003). UV dose is measured in millijoules seconds per cm^2 (mJ/cm^2) and is calculated by multiplying the UV intensity measured in mW/cm^2 and the exposure time in seconds.

One challenge with UV disinfection is the possibility that some organisms may undergo photoreactivation after UV exposure; this can occur when the microorganisms repair their DNA damaged by the UV light. Photoreactivation of disinfected organisms can occur when UV-damaged cells are exposed to light in the visible wavelength spectrum (310 to 480 nm) that prompts cell-initiated repair of damaged DNA (Harris et al., 1987; Ni et al., 2002). Photoreactivation can be a function of UV dose, the concentration of organisms, UV transmittance, and suspended solids concentration. But, Lindenauer and Darby (1994) found that photoreactivation of total coliforms in UV disinfected wastewater decreased with increasing UV dose. Thus, where treated water is stored in uncovered basins, the use of moderately higher UV dose values, such as the values required in California for "tertiary recycled water" (100, 80 or 50 mJ/cm^2 depending upon filtration technology) could be employed.

The UV industry has experienced substantial advances since implementation of the original systems that consisted of vast quantities of low pressure (LP), low intensity lamps, which had reasonable energy efficiency but maintenance challenges due to the large number of lamps that need to be replaced regularly. Medium pressure (MP) UV systems solved the problem of numerous lamps but resulted in three to four times the energy use of LP systems. The UV industry responded again by developing LP, high output (LPHO) UV systems, ranging in watts/lamp from 160 watts all the way to 1,000 watts of energy to individual lamps. One of the more innovative UV technologies to reach the mainstream marketplace is microwave UV systems, which utilize microwaves to generate UV light instead of the conventional voltage differential from electrode lamps. These innovations in LPHO and microwave technologies allow for lower-cost UV installation at reasonable energy use values. It is not uncommon for UV systems to have lower construction and operational costs compared to the costs for sodium hypochlorite.

For those states where UV dose is regulated (e.g., California, Washington, Hawaii), UV systems must be either pre-validated or undergo on-site validation after construction. The validation process consists of detailed third-party research of individual UV reactors over the range of potential operating conditions. For UV equipment that is to be used for reuse applications in California, validation must adhere to the requirements in Title 22 to receive conditional approval from the CDPH. The CDPH requires detailed testing and operation in accordance with the National Water Research Institute's (NWRI) Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse (NWRI UV Guidelines) (NWRI, 2003). The NWRI UV guidelines apply specifically to the disinfection of wastewater meeting the definition of "filtered wastewater" in California's Water Recycling Criteria (WRC), Title 22, Division 4, Chapter 3, of the California Code of Regulations. The NWRI UV Guidelines present guidance such that after disinfection, the disinfected filtered reclaimed water is essentially pathogen free, meeting the requirement of 5-log poliovirus inactivation and a 7-day median total coliform of 2.2 MPN/100 mL.

Additionally, the NWRI UV Guidelines was recently revised and its publication was announced in August 2012, during final preparation of this document. The key revisions with respect to reclaimed water incorporated into the 2012 version include (NWRI, 2012):

- All reclamation systems must undergo commissioning tests that demonstrate disinfection performance is consistent with design intent.
- Velocity profiles have been eliminated as an option for transferring pilot data to full-scale facility design.
- On-site MS-2 based viral assays are used for both the validation and commissioning test.
- A standard MS-2 dose-response curve is used to derive the reduction equivalent dose.
- The design equation is based on the lower 75-percent prediction interval for reclamation systems.
- Commissioning tests will require seven out of eight on-site measurements exceeding the operational design equation.
- Addition of an appendix to illustrate the computations involved in the application and evaluation of UV disinfection systems.

It is important to note that the NWRI UV Guidelines are applicable for specific reuse types, and there are other guidance documents available for low-dose applications. Other validation protocols for low-dose reuse applications have been recently published by Whitby et al. (2011).

6.4.3.3 Ozone

The detection of pharmaceutically active and EDCs in reclaimed water has resulted in an increased interest in the application of ozone disinfection. Ozone is a mature disinfection technology with secondary benefits of removal of CECs as well as color removal. Additional research funded by the WRRF under project WRF-08-05 on use of ozone for water reclamation is ongoing, and a report on contaminant oxidation in reclaimed water using ozone is scheduled for release in 2013. With respect to disinfection, the mechanism of microbial inactivation is similar to chlorine in that it is a chemical process that disrupts cell membranes and nucleic acids, altering transport across the membrane. This causes cell lysis, causing irreversible damage to the DNA. The high oxidation potential of ozone makes it suitable for oxidizing CECs and other compounds that can cause taste and odor issues in indirect potable applications. It also breaks down larger organic compounds that can act as precursors to chlorinated DBPs and bring about an increase in UVT, thus leading to more energy-efficient UV disinfection following ozonation (Kleiser and Frimmel, 2000).

While ozonation has substantial benefits, as of 2010, it was used at fewer than a dozen treatment plants in the United States, of which only two are specifically reuse applications: El Paso, Texas, and Gwinnett County, Ga. (Oneby et al., 2010). While ozone has been prevalent in the drinking water industry, it is important to recognize the growing body of ozone disinfection research in reuse, as documented in Ishida et al. (2008), which highlights novel approaches to the application of ozone for reclaimed water disinfection. The task of designing and operating ozone disinfection systems for wastewater reclamation may be approached in an alternative manner than utilized in the drinking water industry. Drinking water ozone disinfection is based on the traditional drinking water *Ct* concept, the product of contact time and ozone residual for dose determination (in mg-min/L). Application of the traditional drinking water *Ct* concept may be inappropriate for wastewater disinfection as significant bacterial reduction can be achieved prior to the appearance of an ozone residual, since ozone decays rapidly (Absi et al., 1993; Janex et al., 2000; Lazarova et al., 1998).

Bacterial inactivation by ozone in wastewater disinfection is highly dependent on effluent quality. Compared to drinking water applications, the process is less dependent on contact time than ozone concentrations, once an initial amount of ozone is transferred to the wastewater (Tyrrell et al., 1995; Janex et al., 2000; Ishida et al., 2008). Although this observation may be specific to the target microorganism, the presence or absence of readily oxidizable materials seems to determine the importance of contact time (Sommer et al., 2004). Detailed research on filtered wastewater has resulted in conditional acceptance of ozone by the CDPH for reclaimed water disinfection. For all test conditions, this research demonstrated that a *Ct* below 1 mg-min/L met nondetectable total coliform counts and provided the 5-log virus barrier required by CDPH; thus, CDPH has set an ozone minimum *Ct* requirement of 1 mg-min/L (Ishida et al., 2008). It should be noted that *Ct* values greater than 1.0 mg-min/L have been reported to meet various reclaimed water coliform standards (WRRF, 2012a).

The addition of hydrogen peroxide (H_2O_2) to ozone in wastewater has been shown to reduce bromate formation (Ishida et. al., 2008) where this is a concern due to the presence of bromide. Research reports conflicting results, and the reasons for these differences are not fully understood, although it is known to be related to water chemistry. Further, increasing the ozone contact time (while maintaining ozone residual) from 30 seconds to 120 seconds does not appear to substantially boost disinfection performance (WRRF, 2012a).

Because of improvements in ozone generation and dissolution technologies in recent years, which improve the economics of the process along with increasing interest in addressing CECs, several new ozone systems for wastewater disinfection are under design, under construction, and recently in operation. In Anaheim, Calif., a 0.1 mgd (4.4 L/s) pressurized ozone reactor (HiPOx by APTwater) will be in operation by 2012 (Robinson, 2011). This system was installed as part of a combined effort to produce high-quality reclaimed water and to educate the community. The Clark County Water Reclamation District has chosen to upgrade its treatment from sand filtration and UV to membrane filtration and ozone. The first 30 mgd (1,314 L/s) (average annual flow, peak flow of 45 mgd [1,972 L/s]) of this upgrade was under construction in 2012. A second upgrade of an additional 30 mgd (1,314 L/s) of average annual flow is under design (Drury, 2011).

6.4.3.4 Pasteurization

Pasteurization is a process of applying heat to a substance to inactivate pathogenic or spoilage microorganisms. The process was discovered by Louis Pasteur in 1864 and has since become standard practice in the food industry. Pasteurization has also become accepted practice in sewage sludge processing, with the goal of inactivating pathogens to achieve Class A Biosolids standards.

Thermal inactivation of microorganisms may depend on a number of factors: characteristics of the organism, stress conditions for the organism (e.g., nutrient limitation), growth stage, characteristics of the medium (e.g., heat penetration, pH, presence of protective substances like fats and solids, etc.), and temperature and exposure time combinations. In design of pasteurization systems, temperature and exposure time combinations are the dominant parameters (Moce´-Llivina et al., 2003; Salveson et al., 2011). Pasteurization has been demonstrated at the city of Santa Rosa's Laguna Wastewater Reclamation Plant, where validation testing was conducted as part of the CDPH program to review new technologies and provide conditional approval (often referred to as "Title 22" approval) (Salveson et al., 2007). Based upon this and other work, the CDPH approved pasteurization to meet the stringent "tertiary recycled water criteria" for specific minimum contact times and temperature.

The economic value of pasteurization is favorable when waste heat can be captured and transferred for disinfection. Heat exchangers can be used to recapture heat from hot disinfected water to preheat undisinfected water, also cooling the disinfected effluent to just a few degrees above the influent undisinfected water. Example sources of waste heat include exhaust heat from a turbine fueled by natural gas, digester gas, or hot water. Favorable economics for pasteurization has been demonstrated in Ventura, Calif., where a 400 gpm (25 L/s) demonstration system (**Figure 6-2**) has been constructed and is in continuous operation. Because of the high cost of power at this utility, pasteurization is projected to save several million dollars in lifecycle costs compared to UV disinfection (US-CA-Pasteurization).

Figure 6-2
Pasteurization demonstration system in Ventura, Calif.

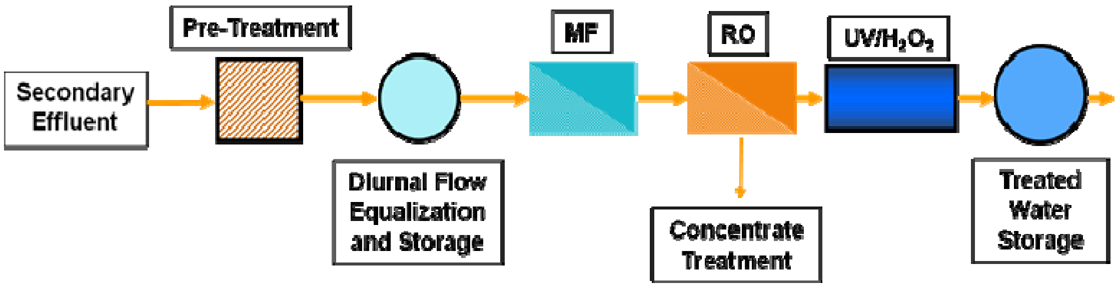

Figure 6-3
Example WRF treatment train that includes UV/H_2O_2 AOP

6.4.3.5 Ferrate

Ferrate was explored in the 1970s as a replacement chemical for chlorine, but prior synthesis methods made its utilization cost prohibitive. With recent advances in new on-site production methods of ferrate, it has the potential to be applied as an alternative to other widely-practiced oxidation and disinfection processes. Research has demonstrated that ferrate can be an extremely competitive oxidizing agent for disinfection processes, with the key benefit of minimizing by-product formation. Ferrate chemistry results from formation of iron in the plus 6 oxidation state, or Fe^{+6}, and is a powerful oxidant, depending upon the pH of the solution. As pH will dictate the stability and reactivity of ferrate in solution, testing is required to determine the conditions under which ferrate disinfection is feasible. There are many reports on the use of ferrate in wastewater disinfection, and an excellent summary of the most relevant literature has been provided in Skaggs et al. (2009 and 2008).

The on-site generation of ferrate requires bulk caustic, bulk ferric chloride, and bulk liquid sodium hypochlorite solutions. The components of a ferrate disinfection system are similar to that of a liquid hypochlorination system with the exception of the addition of an on-site generation system. Additional solids are produced in ferrate disinfection, so solids handling may be an additional component of a ferrate disinfection system. Site-specific testing must be conducted to determine the required disinfection dose.

While there have been numerous laboratory and pilot-scale investigations, the first full-scale installation of ferrate at the 100 mgd (4,400 L/s) East Bank treatment plant in New Orleans, La., is not anticipated to be implemented until after 2012. The technology was selected for this application due to its advantages over other technologies, including the fact that it can provide oxidation and disinfection in the same application, similar to ozone. This allows the disinfection process to also address EDCs, which were a concern for reuse of the water at the East Bank WWTP for wetlands restoration (AWWA, 2010).

6.4.4 Advanced Oxidation

AOPs are a class of water treatment technologies, including UV/H_2O_2, ozone/H_2O_2, ozone/UV, UV/TiO_2 (titanium dioxide), and a variety of Fenton reactions (Fe/H_2O_2, Fe/ozone, Fe/H_2O_2/UV) (Asano et al., 2007; Stasinakis, 2008; Munter, 2001) that can be added to the end of a treatment train, as shown in **Figure 6-3**. These technologies have a broad range of applications, from reducing the CECs and toxicity of industrial effluent and wastewater to finishing water for high-tech industries (Munter, 2001; WateReuse, 2012). This process is especially valuable for reclaimed water treatment for potable applications because of its ability to address PPCPs and EDCs that are not significantly removed during conventional wastewater treatment processes (Miège et al., 2009).

Although a variety of base treatment technologies can drive AOPs, each AOP is similar in that it is designed to generate highly reactive, nonspecific intermediate species (such as hydroxyl radicals and superoxide radicals) (Glaze et al., 1987). There are several technologies available for advanced oxidation that show promise for reuse applications. AOPs are designed to take advantage of the high electrochemical oxidation potential of radical species, combining parallel disinfection and oxidation processes as shown in **Table 6-8**.

The hydroxyl radicals formed in an AOP work in parallel to the primary disinfectant by breaking apart organic compounds, resulting in the transformation of toxic organic compounds into less-toxic daughter compounds (Stasinakis, 2008). Hydroxyl radical formation and availability is affected by pH, but only at pH extremes (Arakaki, 1999); at typical pH values, hydroxyl radical formation rates will not vary significantly (Watts et al., 1994). Free radicals quickly react with electron acceptors in water, and as a result wastewater has a high scavenging capacity (Rosario-Ortiz et al., 2010). Because of this, organic species present in treated wastewater can compete for hydroxyl radicals and it is less likely that the preferred reaction, the oxidation of TrOCs, will take place.

Table 6-8 Electrochemical oxidation potential (EOP) for several disinfectants (adapted from Tchobanoglous et al., 2003)

Oxidizing Agent	EOP [V]	EOP Relative to Chlorine
Hydroxyl Radical	2.80	2.05
Ozone	2.08	1.52
Peracetic Acid[1]	1.81	1.33
Hydrogen Peroxide	1.78	1.3
Hypochlorite	1.49	1.1
Chlorine	1.36	1
Chlorine Dioxide	1.27	0.93

[1] Peracetic acid data courtesy of Enviro-Tech Chemical Services Inc.

Advanced oxidation processes are most commonly used in potable reuse applications to address treatment objectives that include recalcitrant organic compounds, such as PPCPs, and a wide range of potential EDCs. Compared to other treatment alternatives, such as activated carbon, AOPs also disinfect a wide variety of microbial targets and result in an overall removal of pathogens and CECs (WateReuse, 2012), as opposed to simply sequestering compounds via adsorption or physical separation. UV-based AOPs are also frequently employed to destroy nitrosamines, particularly the carcinogenic DBP NDMA in potable reuse applications [US-CA-San Diego]. This is in response to regulations on NDMA in California, which is ahead of EPA in regulating this compound; EPA placed NDMA (and the other five nitrosamines) on its second Unregulated Contaminant Monitoring List (UCMR2) in 2006.

When the operational costs of advanced oxidation systems are compared to the total operational expenses of the treatment process for potable reuse applications, these costs are marginal. In a recent study from Australia, the electrical costs of running the UV system were only 3.5 percent of the total energy costs, and H_2O_2 costs made up only 4 percent of the total costs of the chemicals used on-site (Poussade et al., 2009). WRRF (2012a) demonstrated that the lowest-cost AOP process following media filtration, MF filtration, and UF filtration is ozone. More expensive technologies following media, MF, and UF filtration included UV/H_2O_2, ozone/H_2O_2, TiO_2/UV, peracetic acid with UV, and several other technologies. Following RO treatment, the optimum AOP system is dependent on the target compound. If NDMA destruction is the key target, UV/H_2O_2 will be the lowest-cost treatment; if an organic compound is the primary target, likely ozone/H_2O_2 or ozone will be the lowest-cost technology.

In some reuse scenarios, augmentation of existing potable water supplies is required. The practice of IPR continues to grow in acceptance and application. One of the main drivers for this acceptance is the growing public knowledge of water treatment, particularly the extensive treatment the wastewater undergoes before being considered safe for potable consumption. A vital component of the extensive treatment train in IPR is the combined use of UV light and H_2O_2. In IPR applications, UV/H_2O_2 not only provides disinfection, but also destroys CECs (Drewes et al., 2002). Examples include the OCWD and the WBMWD, whose IPR projects provide groundwater replenishment, and the community of Big Spring, Texas, which has begun a project that will purify wastewater to quality better than drinking water for the augmentation of local surface water. In these cases, an integrated membrane system (IMS) provides significant pretreatment to the UV/H_2O_2 AOP.

The full-scale Advanced Water Purification Facility at the OCWD's Groundwater Replenishment System, commissioned in 2008, uses filtered secondary wastewater effluent from a neighboring WWTP and treats it to water that meets all drinking water quality standards. The 70-mgd (3,100 L/s) system consists of MF, RO, and UV/H_2O_2. The UV/H_2O_2 treatment step at OCWD consists of a LPHO amalgam lamp UV system comprised of multiple parallel trains of stacked UV chambers (connected in series). To verify predicted NDMA reductions, this UV/H_2O_2 system was tested to demonstrate both NDMA destruction and microorganism disinfection, showing that the system was effective for both treatment objectives.

6.4.5 Natural Systems

Natural filtration processes take advantage of intrinsic characteristics of riverbanks, aquifers, and wetlands comprised of media—soil and plants—that can filter water and in some cases provide a surface for biofilm growth that can biologically oxidize or reduce contaminants. Two natural treatment approaches include wetlands and soil aquifer filtration (which also includes riverbank filtration for the purposes of this discussion). The principles of how these natural filtration processes can be used to confer additional treatment are described in the EPA *Process Design Manual for Land Treatment of Municipal Wastewater Effluents* (EPA, 2006).

6.4.5.1 Treatment Mechanisms in Natural Systems

Natural systems have the potential to reduce or remove pathogens, organic carbon, contaminants of concern, and nutrients during sub-surface transport. As reclaimed water filters through the subsurface, physical, biological, and chemical water quality improvement occurs during SAT where spreading basins are used (Section 2.3.3.2). During ASR, vadose zone injection, or direct injection, these mechanisms can also occur to a varying extent; this is especially true of ASR systems, in which sub-surface residence time can be highly variable.

Pathogens. Pathogens are a major concern in all reclaimed water systems, and the highest risk associated with pathogens is ingestion. Pathogen removal efficacy for SAT systems via filtration and disinfection is described in *Demonstration of Filtration and Disinfection Compliance through SAT* (WRRF, 2012). Pathogen removal during SAT is most efficient during unsaturated flow but the unsaturated zone is bypassed by direct injection into the aquifer during ASR. For ASR, treatment efficiency determination is site specific. Furthermore, pathogen removal during ASR is less efficient when non-porous media is present, for example, recharge into bedrock (e.g. basalt) rather than into granular aquifers (sand). Concerns over pathogens have resulted in the implementation of travel time requirements for environmental buffers in IPR systems. Travel times are average values and some groundwater takes a faster path and arrives sooner than average. Travel times are most accurately calculated for only porous media aquifers. In non-porous media aquifers, travel times are best determined using site specific field tracer tests. In either case, travel times are uncertain and are especially uncertain for non-porous media. In California, travel time requirements range from 6 to 12 months, depending on the percentage of reclaimed water in the IPR system. In 2009, Massachusetts adopted a 6-month travel time requirement for environmental buffers in IPR systems. The retention times required for environmental buffers ranges from 50 days to 12 months, and this has a major impact on design and implementation.

The AWWARF study titled “Water Quality Improvements during Aquifer Storage and Recovery” (2005) reported on extensive laboratory and field studies on the survival of the bacteria, *E. coli*, a nonpathogenic indicator. A summary of studies on *E. coli* decay rates revealed that most researchers found decay rates of 0.1/d or greater when studying the decay of *E. coli* in a sub-surface environment (Roslev et al., 2004). Many of these studies were conducted under controlled conditions in groundwater without the effects of straining and sorption (filtration). Therefore, decay alone may result in 5-log removal of *E. coli* in less than 20 days during sub-surface transport. However, *E. coli* decay rates do not inform pathogenic human viral or parasitic protozoan decay rates.

Concern over viruses has prompted continued research on virus transport and survival in environmental buffers. Soil saturation and aquifer flow type (porous or non-porous media), media composition, ground water pH, and virus strain all interact to affect the sorptive capacity and virus die-off rate in soils and aquifers. Because viral subsurface inactivation rates are an estimate, a second barrier with reliable, effective disinfection is recommended. Furthermore, virus removal by sorption is an active research area and remains difficult to predict in field studies. Similar concerns over protozoa have been raised because *Cryptosporidium* oocysts and *Giardia* cysts have been found in groundwater (Bridgman et al. 1995; Hancock et al. 1998) and in reclaimed water (Gennancaro et al., 2003; Huffman et al., 2006) including infectious *Giardia*. And, there have been *Cryptosporidium* and *Giardia* outbreaks, some associated with heavy rainfall (Bridgman et al. 1995; Willocks et al. 1998; Rose et al. 2000; Curriero et al. 2001), with research revealing that *Cryptosporidium* oocysts and *Giardia* cysts can be transported in the subsurface under normal conditions, soil, especially when preferential porous media flow paths exist

(Darnault et al. 2003 and Park et al., 2012). Additional research into the transport of protozoan pathogens is needed.

Organic Carbon. Residual organic carbon is a concern in IPR systems because these compounds are associated with a broad spectrum of potential health concerns (Asano, 1998). Three groups of residual organic chemicals require attention (Drewes and Jekel, 1998): 1) natural organic matter (NOM) present in most water supplies, 2) CECs added by consumers and generated as DBPs during the disinfection of water and wastewater, and 3) soluble microbial products (SMPs) formed during the wastewater treatment process and resulting from the decomposition of organic compounds. NOM and SMPs are mixtures of compounds that cannot be effectively measured individually. When NOM and SMPs are measured as a group, the concentrations of organic carbon are typically measured in the mg/L range; CECs are typically present in the µg/L to ng/L range. Most waters contain NOM, and reclaimed waters contain a mixture of NOM and SMPs (Drewes and Fox, 2000).

Most reclaimed waters used in managed aquifer recharge systems receive limited characterization of NOM and/or SMPs that comprise the bulk of the organic carbon compounds present. Typically, these compounds are quantified by DOC measurements and ultraviolet absorbance (UVA) (Fox and Drewes, 2001). Organic compounds are removed during sub-surface transport by a combination of filtration, sorption, oxidation/reduction, and biodegradation. Biodegradation is the key sustainable removal mechanism for organic compounds during sub-surface transport (Fox et al., 2005; AWWARF, 2001). The concentrations of NOM and SMPs are reduced during sub-surface transport as high molecular weight compounds are hydrolyzed into lower molecular weight compounds and the lower molecular weight compounds serve as substrate for microorganisms (Drewes et al., 2006). Synthetic organic compounds at concentrations too low to directly support microbial growth may be co-metabolized, as NOM and SMPs serve as the primary substrate for growth (Rausch-Williams et al, 2010, Nalinakumari et al, 2010).

During sub-surface transport, the transformation of organic compounds may be divided up into several different regimes defined as short-term transformations where relatively fast reactions occur and long-term transformations where recalcitrant compounds continue to transform at slower rates over time (Fox and Drewes, 2001). Easily biodegradable carbon is transformed within a time-scale of days. The environmental buffer of IPR systems typically contains much longer time-scale over which DOC can continue to be transformed.

Constituents of Concern. The removal of CECs in general tends to parallel the removal of DOC. Easily biodegradable constituents of concern, such as caffeine and 17β-Estradiol, tend to degrade on a time-scale of days while more refractory compounds, such as NDMA and sulfamethoxazole, tend to degrade over a time-scale of weeks to months (Dickerson et al., 2008). Persistent compounds, such as carbamezapine and primodone, can persist for months or years in an environmental buffer (Clara et al., 2004, Heberer, 2002). The transformation of organic constituents of concern can depend on the presence of biodegradable dissolved organic carbon (BDOC) because the concentrations of constituents of concern are very low and may not support growth (Rausch-Williams et al., 2010; Nalinakumari et al., 2010).

Nitrogen. Reclaimed water that has not been nitrified or denitrified may contain greater than 20 mg/L of ammonia-nitrogen, which can exert over 100 mg/L of nitrogenous oxygen demand. The majority of studies on the fate of nitrogen have been done in the vadose zone because wet/dry cycles can result in alternating aerobic/anoxic conditions (Miller et al., 2006). Alternating aerobic/anoxic conditions may facilitate nitrogen cycling, and greater than 70 percent nitrogen removal has been observed in the vadose zone at the Tucson Sweetwater Underground Storage and Recovery Facility. Other facilities have also sustained nitrogen removal in the vadose zone when alternating aerobic/anoxic conditions were maintained (Kopchynski et al., 1996). This mechanism for removal is not dependent on the retention time in the buffer zone but is a function of recharge basin operation. The aquifer below a vadose zone becomes anoxic when ammonia is present in recycled water at levels sufficient to deplete oxygen in percolating water (AWWARF, 2001). Reduction of nitrate will occur as a function of retention time under anoxic conditions as nitrate is used as the electron acceptor for organic compound transformations. If nitrate becomes depleted, more reduced conditions can develop, leading to reduced transformation of organic compounds and the release of soluble iron and manganese. Indirect potable reuse systems are not operated under these conditions because the produced water will require post-treatment. These conditions do occur in bank filtration systems in Europe, and post-treatment for iron and manganese is commonly practiced.

6.4.5.2 Wetlands

Wetland treatment technology has been under development, with varying success, for more than 40 years in the United States. A great deal of research has been performed documenting the ability of wetlands, both natural and constructed, to provide consistent and reliable water quality improvement. With proper execution of design and construction elements, constructed wetlands exhibit characteristics that are similar to natural wetlands in that they support similar vegetation and microbes to assimilate pollutants. In addition, constructed wetlands provide wildlife habitat and environmental benefits that are similar to natural wetlands. Constructed wetlands are effective in the treatment of BOD, TSS, nitrogen, phosphorus, pathogens, metals, sulfates, organics, and other toxic substances. There are hundreds of wastewater treatment wetlands operating in the United States today (Source: EPA832-R-93-005).

Water quality enhancement is provided by transformation and/or storage of specific constituents within the wetland. The maximum contact of reclaimed water within the wetland will ensure maximum treatment assimilation and storage. This is due to the nature of these processes. If optimum conditions are maintained, nitrogen and BOD assimilation in wetlands will occur indefinitely, as they are primarily controlled by microbial processes and generate gaseous end products. In contrast, phosphorus assimilation in wetlands is finite and is related to the adsorption capacity of the soil and long-term storage within the system. The wetland can provide additional water quality enhancement (polishing) to the reclaimed water product. A review of wastewater recycling and reuse alternatives performed by Carey and Migliaccio (2009) indicate that natural or constructed wetlands can, in certain instances, replace other advanced wastewater treatment processes, removing up to 79 percent of total nitrogen and 88 percent of total phosphorus concentrations.

In addition to our current state of knowledge on the design and performance of known pollutants in surface-flow and subsurface-flow constructed wetland systems, including BOD, TSS, nutrients, and pathogens, a description of removal of wastewater-derived organic compounds (WDOCs) is provided in *Evaluate Wetland Systems for Treated Wastewater Performance to Meet Competing Effluent Quality Goals* (WRRF, 2011b). This report provides identification of specific chemicals that best represent or act as surrogates for various classes of pollutants and WDOCs, which supports continuing consideration of constructed wetlands as an option for providing polishing treatment to protect aquatic ecosystems and potable water supplies.

A series of long successful examples of wetlands treatment projects are described in *Constructed Wetlands for Wastewater Treatment and Wildlife Habitat: 17 Case Studies* (EPA, 1993). More recently, constructed wetlands have been employed in Phoenix, Ariz., where in 1990 city managers were faced with needed improvements at the WWTP to meet new state water quality standards. After determining that upgrading the plant might cost as much as $635 million, managers looked for a more cost-effective solution to provide final treatment for discharge into the Salt River. A preliminary study suggested that a constructed wetland system would address discharge water quality requirements while supporting high-quality wetland habitat for birds, including endangered species, and protect downstream residents from flooding. These benefits would be achieved at a lower cost than retrofitting the existing treatment plant. As a result, the 12-acre Tres Rios Demonstration Project began in 1993 with assistance from the USACE, the BOR, and EPA's Environmental Technology Initiative. The Tres Rios treatment wetlands are currently the largest of their kind in Arizona. Highly-treated effluent from the 91st Avenue WWTP was first delivered to a 98-ac cell in July 2010 with discharges regulated under a NPDES permit overseen by EPA and an Aquifer Protection Permit as mandated by the ADEQ. The remaining two wetland cells are developing mature wetland vegetation and were brought online late in 2011. Treated water from the Tres Rios wetlands is reused to support approximately 137 ac of wetland and riparian habitat along the north bank of the Salt River while at the same time conveying water to satisfy contractual obligations to the Buckeye Water Conservation District. This site, which serves as a home for thousands of birds and other wildlife, will be open to the public and will serve as a platform for environmental education and passive recreation [US-AZ-Phoenix].

Thus, while in most reclaimed water wetland projects the primary intent is to provide additional treatment of effluent prior to discharge from the wetland, it is also important to consider the design considerations that will maximize wildlife habitats, and thereby provide important ancillary benefits, which are discussed in Section 3.4.1.1. With respect to constructed wetlands, there are some well-established types of treatment systems, including free water surface wetlands that have open water areas and emergent vegetation, and subsurface flow (SSF) wetlands in which water does not flow above the surface of the media. There are several key documents available that provide information that can be used to assist in the design of wetland treatment systems, including: *Treatment Wetlands, Second Edition; Treatment Wetlands; Small-scale Constructed Wetland Treatment Systems: Feasibility, Design Criteria, and O&M Requirements; Constructed Wetlands for Pollution Control: Process, Performance, Design and Operation*; *Water Environment Federation Manual of Practice FD-16*. Natural Systems for Wastewater Treatment, Chapter 9: Wetland Systems; and *Free Water Surface Wetlands for Wastewater Treatment*.

6.4.5.3 Soil Aquifer Treatment Systems

Essentially, SAT is a low-technology, advanced wastewater treatment system. The process is most commonly implemented at spreading basins (Section 2.3.3.2), where reclaimed water percolates into the soil, consisting of layers of loam, sand, gravel, silt, and clay. As the reclaimed water filters through the soil, these layers allow it to undergo further physical, biological, and chemical treatment through the SAT (WRRF, 2012g). SAT systems require unconfined aquifers, vadose zones free of restricting layers, and soils that are coarse enough to allow for sufficient infiltration rates but fine enough to provide adequate filtration. This process of filtration, in which the unsaturated or vadose zone acts as a natural filter and can remove essentially all suspended solids, biodegradable materials, bacteria, viruses, and other microorganisms, results in significant reductions in nitrogen, phosphorus, and heavy metals concentrations. Additional information on piloting and design of SAT systems is presented in *Soil Treatability Pilot Studies to Design and Model Soil Aquifer Treatment Systems* (AWWARF, 1998). Because the soil and aquifer are natural treatment systems, SAT systems have a positive impact on public acceptance.

6.4.6 Monitoring for Treatment Performance

Reliable monitoring to detect process failures and assess water quality in a reuse scheme have been recommended in several recent reference documents (NRC, 2012; WRRF, 2011c; Colford et al., 2009) and, in summary, should include:

1. A source control program documenting contaminant concentrations and diversion alternatives;
2. Individual evaluation of multiple barriers that mitigate pathogenic contaminants;
3. Robust study designs to determine contaminant fate e.g. biodegradation, sorption, photolysis, or health effects like gastrointestinal illness;
4. Documented travel time without short circuits;
5. Certified operators; and
6. Communication protocols for corrective actions.

While the appropriate monitoring parameters represent an ongoing subject of research, particularly for potable reuse applications, the selection of which biological and chemical constituents to monitor must be carried out as part of a larger QA/QC program, as described in Chapter 4. But, it is useful to highlight some case study examples of performance assessment and monitoring to demonstrate that the treatment practices described in this chapter have been shown to be effective for meeting the objectives for the specified end uses of the treated reclaimed water.

As part of the Montebello Forebay Groundwater Recharge Project, five studies were conducted following initial replenishment efforts in 1962: Pomona Virus Study, 1977; Health Effects Study, 1984; An Investigation of Soil Aquifer Treatment for Sustainable Water Reuse, 2006; Rand Study, 1996; and Rand Study, 1999 [US-CA-Los Angeles County]. These studies included flow modeling, virus monitoring, toxicology, and limited epidemiological studies and showed that the majority of CECs are effectively removed through SAT.

In King County, Wash. [US-WA-King County], all reclaimed water meets “Class A” standards and is safe to use for irrigating food crops. However, to both gain customer confidence and illustrate that local soil and reclaimed water characteristics are suitable for a range of crops, King County partnered with the University of Washington to conduct a greenhouse study and a field trial to test for the potential for pathogen transfer and metal uptake from reclaimed water to garden vegetables. Soils, water samples, and washed and unwashed edible portion of plant tissue were analyzed for bacterial indicators (total coliforms, fecal coliforms, and *E. coli*) and heavy metals. Metal concentrations in the reclaimed water were at least two orders of magnitude below EPA regulations for drinking water, and the bacteria tests were either negative or below the state regulatory limit of 2 cfu per 100 mL.

In Tossa de Mar, Costa Brava, Spain, the implementation of a reuse system that distributes reclaimed water for landscape irrigation in public spaces, fire hydrants, and wash-down water at a dog shelter included an extensive assessment of the overall human health infection risk and an ongoing monitoring program. The high quality of reclaimed water, the systematic follow-up studies, and the educational programs implemented have all contributed to assure a very positive public perception [Spain-Costa Brava].

6.4.7 Energy Considerations in Reclaimed Water Treatment

Conventional wastewater treatment is an energy-intensive process, and adding filtration and disinfection systems, which is a typical practice to upgrade WWTPs for water reclamation for nonpotable reuse, only adds to energy consumption. Overall, the energy use in this scenario is dominated by pumping, aeration, and disinfection. It is critical to note that the quality of the water being disinfected will dictate the energy requirements for this process. For instance, for UV disinfection, a nitrified filtered secondary effluent with a UVT of 70 percent will require about half as much energy to disinfect as a non-nitrified filtered secondary effluent with a UVT of 55 percent (WRRF, 2012h).

Treatment alternatives that lower energy requirements represent the future of reclaimed water treatment. A recent study by the WRRF examined processes that could provide dramatic energy savings. In general, new approaches are moving treatment process toward higher mechanical efficiency, decreased oxygen use, and more effective biochemistry. The tradeoff to these gains may be increased complexity and reliance on technology. The full evaluation of the costs and benefits of these technologies must be conducted for a specific site based on local power rates, but general trends in energy savings are presented in Challenge Projects on Low Energy Treatment Schemes for Water Reuse (WRRF, 2012h).

Disinfection processes can make up about a third of the total energy used at a WWTP, excluding pumping energy (WEF, 2009; EPRI, 2002). Novel approaches including pasteurization, UV disinfection using light emitting diodes (LEDs), and electrochemical reactors for combined coagulation/filtration/disinfection have potential to reduce this power demand. As discussed in Section 6.4.3.4, pasteurization has undergone rigorous testing, demonstrating near-zero energy input by capturing waste heat, and is now undergoing large-scale piloting. UV LEDs save energy through the use of a better UV dose distribution, but this technology is at the very early stages of development for wastewater disinfection.

As aeration is a key consumer of energy at WWTPs, significant research has gone into optimizing processes to minimize this requirement. A range of energy-saving technologies at different levels of development offer up to 50 percent energy savings through improvements in aeration or reduced aeration requirements, optimized microorganisms for nutrient removal processes, and novel anaerobic processes (WRRF, 2012h).

In typical nonpotable reuse applications, filtration makes up about 3 percent of the total energy use of a WWTP (WEF, 2009; EPRI, 2002). While representing a small percentage of the overall energy budget, improved filtration technologies that optimize filtration backwash modes or the type of filter media have demonstrated reduced energy use compared to conventional sand filtration (Parkson, 2011).

Natural treatment of reclaimed water in wetlands or through managed aquifer recharge systems are key treatment options for water reuse. These systems, in addition to potentially providing secondary environmental benefits such as enhanced stream flows, wildlife habitat, or a barrier from saltwater intrusion into groundwater, can also reduce the energy footprint of the overall treatment system, depending on the treatment application. Additional discussion of managed aquifer recharge is provided in Section 2.3.3; and a description of the treatment mechanisms through wetlands and SAT systems are provided in Section 6.4.5.

6.5 References

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CHAPTER 7
Funding Water Reuse Systems

This chapter provides an overview of the financial viability of reclaimed water and also includes resources for how to properly fund reclaimed water systems.

7.1 Integrating Reclaimed Water into a Water Resource Portfolio

Historically, wastewater utility systems have entered into long-term agreements with agricultural and golf course customers to deliver reclaimed water at little or no cost. Giving treated effluent away was viewed as mutually beneficial. Many of those original agreements for low cost reclaimed water have recently expired—or will soon expire—creating an opportunity to develop reasonable rates and charges for the value provided.

Reclaimed water is now widely recognized as a full-fledged component of integrated water resources planning. As a result, ensuring adequate funding for reclaimed water systems is not dissimilar from funding other water services. Developing and operating a sustainable water system requires the use of sound business decision-making processes that are closely tied to the system's strategic planning process. The underlying principles for a reclaimed water system's funding strategy should reflect the following:

1. Revenues from rates and charges should be sufficient to provide annual operating maintenance and repair expenses, capital improvements costs, adequate working capital, and required reserves.

2. Accounting practices should separate reclaimed water accounts from other governmental or entity operations for transparency and to prevent diversion of funds to uses unrelated to water services; this concept is typically reflected by use of an enterprise fund, which may be stand alone for the reclaimed water system, or combined with the utility's potable water and wastewater systems.

3. Accounting practices should adhere to generally accepted accounting principles and comply with applicable regulatory requirements.

4. Rates and fees should equitably distribute the cost of water service based on cost-of-service principles, compliance with legal requirements, and transparency of communication regarding non-quantifiable benefits to rate payers.

5. Budgeting should be adequate to support asset management, including planned and preventive maintenance, as well as infrastructure re-investment.

There are a number of existing resources to assist utilities in understanding and implementing these principles, including:

- *Principles of Water Rates, Fees, and Charges*, 5th Edition (AWWA, 2000)
- *Water Rates, Fees, and the Legal Environment*, 2nd Edition (AWWA, 2010)
- *Financing and Charges for Wastewater Systems*, (MOP 27) (WEF, 2004)
- *Governmental Accounting, Auditing, and Financial Reporting: Using the GASB 34 Model* (GFOA, 2005)
- *Water Reuse Rates and Charges, Survey Results*, (AWWA, 2008)

Nonetheless, utilities often set reclaimed water rates lower than potable water rates to promote customer conversion to reclaimed water use. In general, reclaimed water is priced from 50 percent to 100 percent of potable water with the median rate 80 percent of potable water rates (AWWA, 2008). This discount enables users to pay for retrofit costs, plus it serves as an incentive to use reclaimed water. There are some jurisdictions where reclaimed water is priced at full parity with potable water, especially where reclaimed water is not subject to the potable water use restrictions during droughts.

The initiation and maintenance of a sound funding strategy for reuse programs requires prudent financial decisions and accounting controls, as well as a comprehensive understanding of the technical, economic, and social factors that ultimately determine the sustainability of a system's water resource portfolio. A planning process referred to as "Integrated Resource Planning" is often used as a means of accruing information that is critical to a fiscally and socially sustainable water system.

A holistic planning process such as IRP sets the stage for clearly communicating an integrated funding strategy while characterizing and communicating both the costs and benefits of particular elements of the water resources management program. This comprehensive and transparent decision-making framework is critical to sustainable funding to ensure that water management meets a community's needs. In an uncertain business environment (e.g., economic volatility, climate change), sustainable water utility funding strategies are based on a combination of capital, operations and maintenance considerations, and revenue tools that provide the greatest value for the system and its customers, while minimizing the potential "regret" of making a poor investment.

A number of useful integrated planning resources have been published in recent years. The *Water Resources Planning, Manual of Water Supply Practices* (M50) (AWWA, 2007), *Evaluating Pricing Levels and Structures to Support Reclaimed Water Systems* (WRRF, 2009), *Water Reuse Economic Framework Workshop Report* (WRRF, 2004), *An Economic Framework for Evaluating Benefits and Costs of Water Reuse* (WRRF, 2006), and EPA's draft *Total Water Management* document (Rodrigo et al., 2010) provide specific guidance on incorporating reuse into water resources plans.

7.2 Internal and Debt Funding Alternatives

While there are several mechanisms for funding reclaimed water systems, utilities typically use internal funding and debt funding.

Internal funding is based on revenue generated from customers. The customers can be individual large-volume users or a wide network of users within the water reuse district or a region that has an agreement with the utility for taking and paying for the product. Large-volume customers, if available, can finance a significant portion of a project and may have well-defined water quality objectives that would impact the nature and character of the treatment and distribution system. They may, in fact, dictate these requirements to the utility and be willing to reserve reclaimed water for their operations. Typically these customers are industrial users, large-scale agricultural operations, or golf courses. The concern for the utility is the risk of losing the large-volume customer or the revenue from the service agreement. Protection for both parties should be incorporated into any service agreements that are based on revenue being generated from a small number of large customers. The utility will need to determine and weigh the risk of losing funding from this type of arrangement.

There are several forms of debt funding, including revenue bonds and low interest loans. The benefits of these funding instruments are that they are typically long-term with the funding received up-front from bondholders, in contrast to the project being funded internally through an agreement with a large customer where funding is obtained from rates over the life of the project.

Revenue bonds are supported by net operating income from recurring utility charges. These instruments are issued based on internal policy and financial standing through a bond counsel. The requirements include the assurance that the capital and operations and replacement costs are covered by the rates being charged with typically a 10 percent to 25 percent debt service coverage generation, depending on the bonding authority or other requirements.

7.2.1 State and Federal Financial Assistance

Where available, grant programs are an attractive funding source, but they require that the proposed system meets grant eligibility requirements. These programs reduce the total capital cost borne by system beneficiaries, thus improving the affordability and viability of the project. Some funding agencies have an increasingly active role in facilitating water reuse projects. In addition, many funding agencies are receiving a clear legislative and executive mandate to encourage water reuse in support of water conservation.

To be financially successful over time, a reuse program, however, must be able to "pay for itself." While grant funds may underwrite portions of the capital improvements necessary in a reuse project—and in a few states, state-supported subsidies can also help a program to establish itself in early years of operation—grant funds should not be used for funding needs associated with annual operating costs. In fact, most federally-funded grant and loan programs explicitly prohibit the funding of operation, maintenance, and replacement (OM&R) costs. Once the project is underway, the program should strive to achieve self-sufficiency as quickly as possible, meeting OM&R costs and debt service requirements of the local share of capital costs by generating an adequate stream of revenues through local sources.

7.2.1.1 Federal Funding Sources

The CWA of 1977, as amended, has supported water reuse projects through the following provisions:

- Section 201 of PL 92-500 was amended to ensure that municipalities are eligible for “201” funding only if they have “fully studied and evaluated” techniques for “reclaiming and reuse of water”. A 201 facility plan study must be completed to qualify for state revolving loan funds.
- Section 214 stipulates that the EPA administrator “shall develop and operate a continuing program of public information and education on water reclamation and reuse of wastewater…”
- Section 313, which describes pollution control activities at federal facilities, was amended to ensure that WWTFs will utilize “recycle and reuse techniques: if estimated life-cycle costs for such techniques are within 15 percent of the most cost-effective alternative.”

There are a number of federal sources that might be used to generate funds for a water reuse project. While there are many funding sources, only certain types of applicants or projects are eligible for assistance under each program, with annual funding dependent on congressional authorizations.

The USDA has several programs that may provide financial assistance for water reuse projects in rural areas, but the definition of a rural area varies depending upon the statutory language authorizing the program. Most of these programs are administered through the USDA Rural Development Office in each state.

Rural Utilities Service (RUS) offers funds through the Water and Waste Program, in the form of loans, grants, and loan guarantees. The largest is the Water and Waste Loan and Grant Program, with approximately $1.5 billion available nationwide per year. This program offers financial assistance to public bodies, eligible not-for-profits, and recognized tribal entities for development (including construction and non-construction costs) of water and wastewater infrastructure. Unincorporated areas are typically eligible, as are communities with less than 10,000 people. Grants may be available to communities meeting income limits to bring user rates down to a level that is reasonable for the serviced population. Interest rates for loan assistance depend on income levels in the served areas as well. The Rural Development offices act to oversee the RUS-funded projects from initial application until the operational stage.

The Rural Housing Service (RHS) also known as Rural Development Housing and Community Facilities Programs (HCFP) is a division within the USDA’s Rural Development agency that administers aid to rural communities. The HCFP may fund a variety of projects for public bodies, eligible not-for-profits, and recognized tribal entities where the project serves the community. The HCFP provides grants to assist in the development of essential community facilities in rural areas and towns of up to 20,000 in population.

The Rural Business-Cooperative Service offers the Rural Business Enterprise Grant (RBEG) program. The RBEG program is a broad-based program that reaches to the core of rural development in a number of ways. Examples of eligible fund use include: acquisition or development of land, easements, or rights of way; construction activities, pollution control; and abatement and project planning. Any project funded under the RBEG program should benefit small and emerging private businesses in rural areas. A water reuse system serving a business or industrial park could potentially receive grant assistance through this program. An individual eligible business could apply for loan guarantees through the Rural Business-Cooperative Service to help finance a water reuse system that would support the creation of jobs in a rural area.

Other agencies that have funded projects in cooperation with USDA may provide assistance for water reuse projects if eligibility requirements are met, include the Economic Development Administration, Housing and Urban Development (Community Development Block Grant), Appalachian Regional Commission, and the Delta Regional Commission.

Finally, USBR, authorized under Title XVI, the Reclamation Wastewater and Groundwater Study and Facilities Act; PL 102-575, as amended, Reclamation Recycling and Water Conservation Act of 1996; PL 104-266, Oregon Public Lands Transfer and Protection Act of 1998; PL 105-321, and the Hawaii Water Resources Act of 2000; PL 106-566, provides for USBR to conduct appraisal and feasibility studies on water reclamation and reuse projects. USBR can then fund construction of reuse projects after Congressional approval of the appropriation. This funding source is restricted to activities in the 17 western states unless otherwise authorized by Congress. Federal participation is generally up to 25 percent of the capital cost.

Information about specific funding sources can be found in the *Catalog of Federal Domestic Assistance*, prepared by the Federal Office of Management and Budget and available in federal depository libraries (CFDA, n.d.). It is the most comprehensive compilation of the types and sources of funding available.

7.2.1.2 State, Regional, and Local Grant and Loan Support

There are a number of sources for grant funding and loans for reuse projects. A summary of several state, regional, and local sources of grants and loans is provided in this section.

State Revolving Fund

State support is generally available for WWTFs, WRFs, conveyance facilities, and, under certain conditions, for on-site distribution systems. A prime source of state-supported funding is provided through State Revolving Funds (SRF) loans.

The SRF is a financial assistance program established and managed by the states under general EPA guidance and regulations and funded jointly by the federal government (80 percent) and state matching money (20 percent). It is designed to provide financial assistance to local agencies to construct water pollution control facilities and to implement non-point source, groundwater, and estuary management activities, as well as potable water facilities.

Under SRF, states make low-interest loans to local agencies. Interest rates are set by the states and must be below current market rates and may be as low as 0 percent. The amount of such loans may be up to 100 percent of the cost of eligible facilities. Loan repayments begin within 1 year of completion of the facility construction and are generally completely amortized in 20 years—although this differs from state to state. Repayments are deposited back into the SRF to be loaned to other agencies.

States may establish eligibility criteria within the broad limits of the Clean Water State Revolving Fund (CWSRF). Basic eligible facilities include secondary and advanced treatment plants, pump stations, and force mains needed to achieve and maintain NPDES permit limits. States may also allow for eligible new and rehabilitated collection sewers, combined sewer overflow correction, stormwater facilities, and the purchase of land that is a functional part of the treatment process. Water conservation and reuse projects eligible under the Drinking Water State Revolving Fund (DWSRF) include installation of meters, installation or retrofit of water efficient devices such as plumbing fixtures and appliances, implementation of incentive programs to conserve water (e.g., rebates, tax breaks, vouchers, conservation rate structures), and installation of dual-pipe distribution systems as a means of lowering costs of treating water to potable standards.

In addition to providing loans to water systems for water conservation and reuse, states can use their DWSRF set-aside funds to promote water efficiency through activities such as development of water conservation plans, technical assistance to systems on how to conserve water (e.g., water audits, leak detection, rate structure consultation), development and implementation of ordinances or regulations to conserve water, drought monitoring, and development and implementation of incentive programs or public education programs on conservation.

States select projects for funding based on a priority system, developed annually and subject to public review. Such priority systems are typically structured to achieve the policy goals of the state and may range from “readiness to proceed” to very specific water quality or geographic area objectives. Each state is allowed to write its own program regulations for SRF funding, driven by its own objectives with annual approval by EPA. Some states, such as Virginia, provide assistance based on assessing the community's economic health, with poorer areas being more heavily subsidized with lower interest loans. Further information on SRF programs is available from each state's water pollution control agency.

Additional Local Funding Sources

Although the number of states that have developed other financial assistance programs or reuse projects is still limited, there are a few examples. Texas has developed a financial assistance program that includes the Agriculture Water Conservation Grants and Loans Program, the Water Research Grant Program, and the Rural Water Assistance Fund Program. There is also a planning grant program—Regional Facility Planning Grant Program and Regional Water Planning Group Grants—that funds studies and planning activities to evaluate and determine the most feasible alternatives to meet regional water supply and wastewater needs.

Local or regional agencies, such as the regional water management districts in Florida, have taxing authority. In Florida, a portion of the taxes collected has been allocated to funding alternative water resources including reuse projects, which have a high priority, with as much as 50 percent of the transmission system eligible for grant funding. Various methods of prioritization exist, with emphasis on projects that are benefit to multi-jurisdictional users. The Southwest Florida Water Management District states:

> *"Our Cooperative Funding Initiative program has contributed to more than 300 reuse projects to help communities develop reclaimed water systems. Reuse grant funding since 1987 exceeds $343 million. Our Regional Water Supply Plan describes a District wide reclaimed water long-term goal of 75 percent utilization of all wastewater treatment plant flows and 75 percent offset efficiency of all reclaimed water used".*

The California SWRCB administers the Water Recycling Funding Program (WRFP). The mission of the WRFP is to promote the beneficial use of reclaimed water (water recycling) in order to augment freshwater supplies in California by providing technical and financial assistance to agencies and other stakeholders in support of water recycling projects and research. The Plan establishes a strategic goal, sets program objectives, and identifies specific measures and targets for tracking program performance. Currently, the WRFP administers 49 construction projects and 33 facilities planning studies.

In 2006, Proposition 84 (The Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act of 2006) passed for $5.4 billion. Proposition 84 funds water, flood control, natural resources, park, and conservation projects. The bonds would be used to fund various projects aimed at 1) improving drinking and agricultural water quality and management; 2) preserving, restoring, and increasing public access to rivers and beaches; 3) improving flood control, and 4) planning for overall statewide water use, conveyance, and flood control.

For example, the DSRSD received a $1.13 million grant for the Central Dublin Recycled Water project from the California Department of Water Resources Proposition 84 Integrated Regional Water Management Implementation Grant Program. The $4.6 million project will bring recycled water to irrigate Dublin's oldest neighborhoods, providing a rationing-resistant water supply for schools, parks, and other valuable public landscaping. New distribution pipelines in Central Dublin will connect to existing recycled water infrastructure that already serves other parts of the city.

In 2007, the state of Washington offered $5.45 million in grants to help local governments in the 12 Puget Sound counties reclaim water and help Puget Sound. The State Department of Ecology was responsible for carrying out the grant program under legislative directive to specifically aid Puget Sound. The highest funding priority was to be given to projects in water-short areas and where reclaimed water will restore important ecosystem functions in Puget Sound.

7.3 Phasing and Participation Incentives

Reclaimed water program phasing can account for the various limitations of the parties involved. Phasing is often necessary to extend capital expenditures over multiple years to better match the funding capacity of the water purveyor. Other limitations that may dictate a phased approach to reclaimed water programs include the impacts of establishing and connecting new services, evaluating whether existing potable water users can be feasibly connected, educating new users, and the ongoing costs of regulatory requirements, such as annual water quality and backflow prevention valve testing. Phasing may also be considered for agencies that have not yet verified technical and/or financial feasibility of the planned reclaimed water system. Once initial phases have proven successful, constructing additional phases can be considered. Phasing can also be beneficial from the perspective of the new reclaimed water customer. The benefits of reclaimed water may be more immediately apparent to some types of users, while others may be more inclined to implement reclaimed water only after its success has been fully demonstrated.

It is important to identify and obtain commitments from future reclaimed water customers before undertaking costs of design and construction. Those commitments will be critical to determining design capacity, facility sizing, and other decisions about future distribution branches. Securing these commitments often begins by conducting an initial survey in a service area, followed by a formal written agreement. These agreements may include a memorandum of understanding, particularly for customers with significant capacity requirements, such as golf courses, large industrial customers, or agricultural operations. These commitments assure the long-term viability and financially sustainability of the project.

A reclaimed water purveyor can employ participation incentives to help motivate users to convert to reclaimed water. Several variations of incentives have been used, including rate-based, capital-based, or subjective types of incentives. The rate structure for SAWS sets reclaimed water rates comparable to base potable water rates; however, incremental fees for water supply, stormwater, and aquifer management are not applied to the reclaimed water rate. For reclaimed water customers that transfer aquifer pumping rights to SAWS, that same volume of reclaimed water is priced at 25 percent of the basic reclaimed water rate. A combination of incentives can be used to entice the necessary users to convert to reclaimed water. Financial factors that should be considered may include the avoided or reduced costs of wastewater disposal, future expansion of potable treatment and/or storage facilities, and the higher costs of future potable supplies.

Rate-based incentives can emphasize either positive or negative reinforcements. For example, a positive incentive could include a lower rate (volumetric unit price) for reclaimed water, e.g., less than 100 percent of the current potable rate. A negative incentive could include conservation-based increasing block rates that effectively penalize customers that have the types of summer peak usage that would benefit from using reclaimed water.

Capital-based incentives include options to help pay for conversion costs. Some agencies in southern California have paid for and constructed on-site facility conversions, provided grants, or provided low or no-interest loans. At least one agency has used a surcharge that, in effect, sets the reclaimed water rate equal to the potable water rate until the loan is repaid. The Metropolitan Water District of Southern California's Local Resource Program case study provides an example of a capital-based incentive [US-CA-Southern California WMD].

Subjective incentives may have little cost impact to the reclaimed water purveyor but require effort to educate new reuse customers. Persuading them of the increased reliability and lower cost of reclaimed water is one approach. The increased nutrient levels that reclaimed water may provide are often important factors in obtaining commitments from agricultural customers. Most users can be convinced of the benefits of reclaimed water when there are no available potable supplies and reclaimed water is, therefore, their only option.

7.4 Sample Rate and Fee Structures

There are several types of rate and fee structures that have been used for the recovery of reuse costs, including a fixed monthly fee, volumetric rates, connection fees, impact fees, and special assessments. **Table 7-1** shows a comparison of rate types for a number of U.S. communities.

7.4.1 Service Fees

Service fees are typically charged to cover the cost of the meter or hose bib connection. The fee is typically related to the size of the meter or service line. Connection fees are also used as an incentive, with connection fees for those made in a specified time frame waived. The city of St. Petersburg Beach, Fla., charged a $250 connection fee that was waived if the connection was made within 1 year of availability.

Table 7-1 Comparison of reclaimed water rates

Community	Potable Water Rates First Tiers Only)		Reclaimed Water Rates		
	Rate per 1,000 gal	Use	Rate per 1,000 gal	Use	% of Potable Rate
Tucson, AZ	$2.19 $7.82	1 - 15 ccf 16 - 30 ccf	$2.45	Variable on all uses	112% 31%
Dublin San Ramon Services District, CA	$3.28 $3.48	Tier 1 Volume charge, first 22,440 gallons Tier 2 Volume charge, over 22,440 gallons	$3.19	Flat rate volume charge	97% 92%
Eastern Municipal Water District, CA	$2.07 $3.79	Tier 1 Indoor use Tier 2 Outdoor use	$0.80 $0.88	R-452 Non-Ag, Secondary, Disinfected-2009 R-462 Non-Ag, Tertiary, Disinfected, Filtered-2009	21% of Tier 2 23% of Tier 2
Glendale Water and Power, CA	$3.18	Commercial Rate	$2.39	Nonpotable purposes	75 %
Irvine Ranch Water District, CA[1]	$1.62 $3.34 $5.78	Residential Detached Base Rate 5-9 ccf Residential Detached Inefficient Rate 10-14 ccf Residential Detached Excessive Rate 15-19 ccf	$1.44 $3.01 $5.20	Landscape Irrigation Base Index 41-100% ET Landscape Irrigation Inefficient Index 101-110% ET Landscape Irrigation Excessive Index 111-120% ET	89% 111% 111%
Los Angeles Department of Water and Power, CA	$4.77	Schedule C-First Tier Jul-Sep High Season	1.42 1.76	Valley and Metro West Side and Harbor	30 % 37 %
Boca Raton, FL	$0.742	0 - 25,000 gal	$0.449	0 - 25,000 gallons Tiered rates per 1,000 gal	61%
Cape Coral, FL	$3.81	0 - 5,000 gal	$0.0012 $9.50 $0.50	Res per lot sq. ft. multi-family Fixed fee Non-Res - per 1,000 gal.	13%
Orange County, FL	$1.04 $1.39	0 - 3,000 gal 4,000 - 10,000 gal	$0.74	Variable on > 4,000 gal/month	71% 53%
St. Petersburg, FL	$3.45	0 - 5,600 gal	$17.63 $10.10 $0.50	Unmetered - First acre Unmetered > 1 acre Metered**	14%
City of Tampa, FL	$2.43 $2.82	0 - 5 ccf 6 - 13 ccf	$1.60	Variable on all uses	66% 57%
Cary, NC	$3.60 $5.79	0 - 5,000 gal 0 - 15,000 gal	$3.60	Variable on all uses	100% 62%
El Paso, TX	$1.94	Over 4 ccf	$1.24	Variable on all use	64%
Hampton Roads Sanitation District, VA	$4.00	Average rate for all uses	$1.50	Variable on all uses	38%
Loudoun Water, Loudoun County, VA	$1.82	Variable, non-peak rate	$1.28	Variable, non-peak rate	70 %
San Antonio Water System, San Antonio, TX	$1.09 $1.63	Base volume charge at 90 % annual average use Volume charge at 125 - 150% annual average use	$0.92 $0.99	Base Rate, first 748,000 gal Seasonal Rate, first 748,000 gal	84 % 61 %

ccf = 100 cubic feet

[1]Irvine Ranch Water District employs a steep inclined rate based on watering in excess of the evapotranspiration (ET) rate.

7.4.2 Special Assessments

Special assessments are established to defray the initial capital costs of a reuse system, primarily the distribution system. This type of assessment may be applied to those connecting to the reuse system or to all that have reuse system availability. Availability is typically defined as the distance to a nearby pipeline. The cities of Cape Coral and St. Petersburg, Fla., utilize special assessments for this purpose. Cape Coral has established service areas, with all of the residences within that area subject to a special assessment. St. Petersburg relies on a customer application process, with the majority of the owners in a specific area required to agree to the service. While many reuse systems are partially supported by their water or wastewater system revenues, the systems in these two communities are self-supporting.

7.4.3 Impact Fees

Impact fees have been used to recover the capital costs of water and wastewater systems from new customer connections. Included in the calculation of the impact fee are effluent disposal costs for wastewater, as well as the cost of the treatment system. A rational nexus is needed to justify the costs recovered from impact fees. A portion of the reuse system costs may be recoverable from either water or wastewater impact fees due to the ability to defer or reduce the costs of supplying water or wastewater service. Hillsborough County, Fla., has defined the benefit to water and wastewater systems in terms of additional capacity available due to the implementation of the reuse system. The decreased cost of capacity was estimated and identified as a revenue source for the reuse system (percent of impact fee).

7.4.4 Fixed Monthly Fee

Fixed monthly fees are used for a variety of purposes. In some cases, actual use is not metered, and the operation and maintenance costs and/or capital costs are collected from this fee. There are several methods used to establish these fees, such as a cost per acre, a cost per acre-foot, a cost per pervious square feet, a cost per equivalent residential connection, a cost per meter size, or a cost per customer. When there is a combination of a fixed monthly fee and a volumetric rate, the fixed monthly fee may include the costs of administration and customer service only, or this portion of the fee may also include a portion of capital costs. This approach could then base the fixed monthly fee on a per customer basis, per meter size, or per equivalent residential connection. When there is only a fixed monthly fee and no volumetric rate, there is generally a basis that attempts to relate an estimated use to the fee. The costs per acre, acre-foot, or pervious square foot all provide a means of establishing use without actually metering the use.

The city of St. Petersburg Beach, Fla., has a fixed monthly fee that is consistent for residential customers and a commercial fee that was calculated based on permeable acres. There is no volumetric metering. Another example of a fixed fee with volumetric rates is provided in the reuse rate study for Durham, N.C., where a combination of a fixed monthly fee and volumetric rates were recommended. The fixed monthly fee is designed to recover this wholesale reuse system's capital costs, with the costs allocated per estimated capacity for each of three customers.

7.4.5 Volumetric Rates

Volumetric rates may be the primary fee, with either operation/maintenance and/or capital costs recovered. These rates may be charged per thousand gallons or per hundred cubic feet. The actual volumetric rates may differ per phase of connection. Initial reuse systems may offer incentives for early connections. This is specifically true when reuse is the primary means of effluent disposal. Bulk users, such as agriculture, golf courses, and industrial applications, have benefited from these early connection rates. These large volume users may also need rates that are competitive with the costs of groundwater use rather than potable water. Lee County, Fla., has established user fee rates for their large customers on this basis.

Other variations on the volumetric rates exist when water is distributed in low versus high pressure systems. Such cases are typical for golf courses that utilize storage ponds, where the pipeline distributing reclaimed water does not require high pressure, since high pressure distribution systems also have higher pumping costs. Collier County, Fla. has rates that are set on this basis. Inclining blocks are also used to conserve a limited resource. Hillsborough County and Boca Raton, Fla., have established three tiers of inclining blocks.

7.5 Developing Rates

There are typically two methods used for developing reclaimed water rates. The rate either fully covers the cost of reclaimed water production, distribution, administration, and operation, or rates are lowered by subsidizing the cost from other sources.

Full cost recovery rates include the appropriate portion of capital and annual costs to plan, design, construct, administer, and operate a reclaimed water program. Capital costs include treatment, distribution, and possibly on-site facilities. The allocation of treatment facilities between reclaimed water and wastewater rates can be challenging, but it is generally accepted that facilities necessary for meeting NPDES discharge requirement levels are attributed to wastewater rates. Anything in addition to costs necessary to produce reclaimed water of a higher quality is attributed to reclaimed water rates.

The annual costs for reclaimed water rates include everything necessary for treatment (as allocated above) and operation of a reclaimed water distribution system. Costs necessary to meet regulatory requirements, such as annual testing and site monitoring, should not be overlooked. Estimating the operating cost of a reclaimed water system involves determining those treatment and distribution components that are directly attributable to the reclaimed water system. Direct operating costs involve additional treatment facilities, distribution, additional water quality monitoring, and inspection and monitoring staff.

Often the current costs of constructing reuse facilities cannot compete with the historical costs of an existing potable water system. Hence, a full cost recovery calculation frequently results in rates higher than potable water rates. As discussed in Section 7.1, reclaimed water rates have historically been expected to be lower than potable water to incentivize current potable water users to convert to reclaimed water. Therefore, reclaimed water rates are often subsidized to reduce the rate at or below the potable water rate. There are many opportunities in the rate calculation for subsidies from other sources, some of which are described below:

Potable water. Reuse reduces potable water demands, thereby allowing the deferral or elimination of developing new potable water supplies or treatment facilities. These savings can be passed on to the reuse customer.

Wastewater. Costs saved from effluent disposal may be considered a credit. Indirect costs include a percentage of administration, management, and overhead. Another cost is replacement reserve, i.e., the reserve fund to pay for system replacement in the future. In many instances, monies generated to meet debt service coverage requirements are deposited into replacement reserves.

General and administrative costs. These costs can also be allocated proportionately to all services, just as they would be in a cost-of-service allocation plan for water and wastewater service. In some cases, lower wastewater treatment costs may result from initiating reclaimed water usage. Therefore, the result may be a reduction in the wastewater user charge. In this case, depending on local circumstances, the savings could be allocated to the wastewater customer, the reclaimed water customer, or both.

Conservation. In California, replacement of potable water with reclaimed water can be applied toward the conservation goal of a 20 percent reduction by the year 2020. Therefore, funds set aside for a conservation program could be applied to the reuse program to subsidize the reclaimed water rate.

With more than one category or type of reclaimed water user, different qualities of reclaimed water may be needed. If so, the user charge becomes somewhat more complicated to calculate, but it is no different than calculating the charges for treating different qualities of wastewater for discharge. For example, if reclaimed water is distributed for two different irrigation needs with one requiring higher quality water than the other, then the user fee calculation can be based on the cost of treatment to reach the quality required. This assumes that it is cost-effective to provide separate delivery systems to customers requiring different water quality. Clearly this will not always be the case, and a cost/benefit analysis of treating the entire reclaimed water stream to the highest level required must be compared to the cost of separate transmission systems. Consideration should also be given to providing a lower level of treatment to a single reclaimed water transmission system with additional treatment provided at the point of use as required by the customer and consistent with local/state regulations.

7.5.1 Market Rates Driven by Potable Water

Reclaimed water rate structures and rate values are set by the utility through the utility's governing council or, in the case of private utilities, the public service commission. Reclaimed water and potable water variable rates are typically expressed as dollars per thousand gallons, dollars per 100 ft^3, or dollars per ac-ft. The dollar value of reclaimed water rates is typically based on the value of reclaimed water to those who have nonpotable water demands, such as for irrigation or industrial applications.

Reclaimed water rates are at their lowest values when the availability of freshwater and/or reclaimed water is significantly greater than demand. As fresh and reclaimed water supplies tighten relative to demand, there is pressure on the utility to raise reclaimed water rates to encourage reclaimed water conservation so that increasing demands can be supplied. In some cases, water conservation pricing is used to further encourage efficient reclaimed water use. In areas with sufficient freshwater supply but limited wastewater effluent disposal options, reclaimed water is produced and applied to constructed wetlands, pastures, and irrigated areas to reduce effluent discharges to surface waters or near shore coastal areas. The reclaimed water rates in these areas can be much lower than potable water rates and reclaimed water costs.

In some cases, reclaimed water is provided at no charge or at a nominal charge that does not recover its full costs. As a result, the full costs are recovered through wastewater customers, through water customers, or through state or federal subsidies. For many utilities, reclaimed water use provides significant benefits to other customers by providing an environmentally-safe alternative to wastewater effluent disposal, by reducing ground and surface water pumping, and/or by delaying the need for additional water supply well fields and water treatment plant facility capacity.

Nationally, reclaimed water rates as a percent of potable water rates range from 0 to at least 100 percent. According to a survey by AWWA, the median reclaimed water rate charged by sampled utilities in 2000 and 2007 was 80 percent of the potable water rate (AWWA, 2008). The median reclaimed water rate as a percent of the potable water rate did not change between the two survey years. However, the number of respondents in 2007 (30) was significantly lower than those in 2000 (109). Of the utilities surveyed in 2007, 42 percent set their reclaimed water rate to encourage reclaimed water use, and 11 percent based their reclaimed water rate on the estimated cost of service. The town of Cary, N.C., Reclaimed Water System case study is an example of setting reclaimed water rates at a level to compete favorably with potable water rates [US-NC-Cary].

Florida treats and uses more reclaimed water per day and per person than any state in the nation, with California running a close second (FDEP, 2011b). Florida has a long history of water reuse beginning with agricultural irrigation in Tallahassee in the mid-1960s and the development of the city of St. Petersburg system in the late-1970s (Toor and Rainey, 2009). Florida utilities charge a wide range of reclaimed water rates recovering from none to most of the reclaimed water costs, depending on the availability of freshwater supplies relative to demand. About 177 utilities provide irrigation water to residential and/or non-residential customers in Florida. Of these, 104 utilities provide reclaimed water use for residential irrigation; for 94 of these utilities, the reclaimed water rate was compared to the potable water rate. For brevity, the evaluation included only the water rates of residential single-family customers.

According to Florida's 2010 Annual Reuse Inventory, the median residential variable rate for reclaimed water was $0.80 per 1,000 gallons in 2010 for the 29 utilities that did not include a flat rate in their rate structures. For the 49 utilities that collected a flat rate, the median flat rate was $8.00 per month per account, and the median variable rate was $0.31 per 1,000 gallons. These utilities do not include the 16 that provided reclaimed water service to their residential customers at no charge.

For each of these 94 utilities, the ratio of the reclaimed water variable rate to the potable water variable rate times 100 was calculated to obtain a percentage comparison metric. The potable water variable rate chosen from each utility's inclining block rate structure was the rate at 10,000 gallons of water per month. For two of these utilities, the potable water rate at 10,001 gallons per month was used because it is the same rate as the reclaimed water rate. These rate values are thought to capture the cost of using potable water for irrigation. Potable water rates are those that were implemented in either 2010 or 2011. The distribution of these percentages among the 94 utilities is provided in **Table 7-2**.

Table 7-2 Utility distribution of the reclaimed water rate as a percent of the potable water rate for single-family homes in Florida

Percent Range	Number of Utilities	Percent of Utilities
0%	39	41%
1% to 5%	0	0%
6% to 10%	8	9%
11% to 20%	10	11%
21% to 30%	10	11%
31% to 40%	7	7%
41% to 50%	7	7%
51% to 60%	4	4%
61% to 70%	2	2%
71% to 80%	1	1%
81% to 90%	1	1%
91% to 99%	0	0%
100%	5	5%
Total	94	100%
Average percent	22%	
Median percent	10%	
Minimum percent	0%	
Maximum percent	100%	

(a) Reclaimed water rates for single-family residential customers by utility are from the Florida Department of Environmental Protection, “2010 Reuse Inventory,” Tallahassee, Fla., May 2011. Sources of utility potable water rates at 10,000 gallons per month for residential single-family customers: For utilities in the Southwest Florida Water Management District the source is in-house data provided by the district. For all other public utilities the sources are the individual utility web sites. For all other private utilities, the source is the Florida Public Service Commission, "Comparative Rate Statistics as of December 31, 2010". Potable water rates are those implemented in either 2010 or 2011.

The most common ratio of reclaimed water to potable water rates is 0 percent, with 41 percent of utilities levying either no charge or just a flat charge for residential reclaimed water use. The second most common reclaimed water rate as a percent of the potable water rate is in the range of 11 percent to 30 percent, and 20 utilities, or 22 percent, are in this category. Only 13 utilities, or about 13 percent, set their reclaimed water rate in the range of 50 percent to 100 percent of the potable water rate. About 5 percent of the utilities charge the same variable rate for reclaimed water as they do for potable water (100 percent). The average reclaimed water rate as a percent of the potable water rate is 22 percent and the median is 10 percent. All of these utilities collect a flat charge for potable water service that ranges from $2 to $25 per single-family connection per month. Of these utilities, 49 (or 52 percent) collect a flat charge for reclaimed water service that ranges from $2.50 to $25 per connection per month.

Given this comparison of flat and variable rates between residential potable water service and reclaimed water service, most Florida utilities designed their 2010 reclaimed water rates to significantly lower customer water bills when reclaimed water is used instead of potable water. Many nonpotable water users are not fully aware of the benefits that reclaimed water provides. User benefits of reclaimed water may include:

- Having a guaranteed and reliable water supply
- Ability to conserve fresh water for their other uses
- Ability to irrigate more frequently than if a traditional water source was used
- Ability to reduce fertilizer applications
- Ability to apply more water to the crop or landscape than with a traditional water source (Hazen and Sawyer, 2010)
- Typically costs less than potable water

As nonpotable water users begin to understand the benefits of reclaimed water to their household or business, the amount of money they are willing to pay for reclaimed water will increase along with reclaimed water demand.

7.5.2 Service Agreements Based on Take or Pay Charges

There are many types of reclaimed water service agreements with varying complexity, covenants, and restrictions. A survey by the AWWA (2008) indicated that most utilities either recovered less than 25 percent of their operating costs or they did not know how much they were recovering. Service agreements and cost recovery for utilities is a large part of the socio-economic balance that is required by utilities to properly value a reclaimed water product. The high cost of treating wastewater is one of the reasons that utilities have historically not wanted to pass the entire cost of a system onto their reclaimed water customers. This situation is also prevalent in the costs of potable water systems and is a water industry-wide concern for the future.

Service agreements can be relatively simple with a single rate, but normally they are complex and multi-tiered, depending on water quality, supply and demand, specialized reuse districts, and peaking factors. For example, the Irvine Ranch Water District's recovery costs include no less than nine different classes of commodity charges for nonpotable and reclaimed water. Service agreements that include full cost recovery for reclaimed water should be promoted because reclaimed water is a reclaimed and delivered product that inherently includes all the costs in the value chain, from point of water withdrawal to point of use. First and best use, in terms of a service agreement, is not a factor; all water is reclaimed, and reclaimed water performance should be rated on the basis of delivered water quality. Additionally, the service agreements can include cost recovery for meters, commodity charges, tiered rates, surcharges, seasonal use, and peaking factors, and may include a market analysis to assess supply and demand for a regional system. A schedule of rates for each service agreement should include terms and conditions, covenants and restrictions, water quality parameters, allocations by intended use or service sector, and a dispute resolution clause.

7.5.3 Reuse Systems for New Development

Similar to ordinances that require the installation of roads, water systems, and sewer systems, municipal ordinances can also require installation of reuse systems for new developments. Where new development occurs on sizeable tracts of open land, requiring the installation of a reuse system is an efficient method to provide for facilities to deliver reclaimed water. Examples exist in the southwest where reclaimed water systems were installed years prior to reclaimed water becoming available. Typically, such systems are designed to serve irrigation demands for the common areas of the new development, such as median strips, green belts, and parks. Under such an approach, developers incur the cost of constructing the reclaimed water delivery system. The installation of a reuse system before or during development will be less expensive than doing so afterwards or as a retrofit.

7.5.4 Connection Fees for Wastewater Treatment versus Distribution

Typically, connection fees for reuse systems are limited to recovering the costs of transmission and distribution. Treatment costs are generally the responsibility of the wastewater utility that provides reclaimed water; the wastewater utility and its customers assume financial responsibility for treating the wastewater to applicable standards, whether for discharge or reuse. Thus, the connection fee for a reclaimed water meter is often the same as the connection fee for a potable water meter because reclaimed water is considered a water resource and often is distributed by the water utility just like potable water. The cost of wastewater treatment would not be part of such a fee.

There are examples of utilities including the cost of reclaimed water treatment in their fees or splitting such costs with the wastewater utility. The reuse utility may be a separate agency that simply takes wastewater treated to discharge standards and provides the necessary extra level of treatment to produce reclaimed water. In that circumstance, connection fees would properly include treatment costs. Situations can also be found where treatment costs are split and any responsibility borne by the water utility could be included in the reuse connection fees. Each situation is unique, and various costs must be identified to be sure a nexus exists between the cost and the ultimate service being provided to end users.

The amount of the potable water connection fees must be considered when setting the reuse connection fees. If the reuse connection fee is higher than the potable water connection fee, there will be less incentive for a user to choose reclaimed water over potable water, unless the reclaimed water is priced at a discount to potable water. This is the same concept that applies to setting reclaimed water rates. Thus, while it may be possible to justify higher reuse fees, practical considerations may dictate that such fees are set below cost.

An excellent case study example of a city successfully expanding its reclaimed water system by managing customer concerns about connection fees is the city of Pompano Beach, Fla. [US-FL-Pompano Beach].

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CHAPTER 8
Public Outreach, Participation, and Consultation

This chapter provides an overview of key elements of public involvement, which is critical to success of any reuse program (WRA, 2009), as well as several case studies illustrating public involvement and/or participation approaches to support successful reuse programs

8.1 Defining Public Involvement

Public outreach, participation, and consultation programs work to identify and engage key stakeholder audiences on planned projects that directly impact the population. Generally, effective public participation programs invite two-way communication, provide education, and ask for meaningful input as the reuse program is developed and refined. Depending on the project, public involvement can involve a range of types and levels of outreach, participation, and consultation. Some projects require only limited contact with a number of specific users. Others take an expanded approach to include formation of a formal advisory committee or an extensive campaign with multiple methods of public engagement.

Regulatory agencies often require some level of public involvement in water management decisions, and stakeholders are increasingly vocal about being involved in those decisions. This is strikingly different from the past when members of the public were often informed about projects only after final decisions had been made. Today, responsible leaders recognize the need to inform and consult with the public to obtain their values and advice about science, technology, and legal aspects. Advancing the understanding of water issues can facilitate real, workable, and implementable solutions tailored to meet specific needs.

Public information efforts often begin by targeting the most impacted stakeholders. Over time, as an early education base is built among stakeholders, the education effort then broadens to include the public at large. Regardless of the audience, all public involvement efforts are geared to help ensure that adoption of a selected water reuse program will communicate benefits and fulfill real user needs and generally recognized community goals, including public health, safety, and program cost.

Two-way communication cannot be emphasized enough. In addition to building community support for a reuse program, public participation can also provide valuable community-specific information to reuse planners. Community residents may have legitimate concerns that quite often reflect their knowledge of detailed technical information. In reuse planning, especially, where one sector of the public comprises potential users of reclaimed water, this point is critical. Several case studies highlight how prompt and regular communication and a collaborative spirit between utilities, regulators, the general public, consultants, and contractors led to project success [US-CA-Southern California MWD], [US-FL-Orlando E. Regional], [US-NC-Cary].

8.1.1 Public Opinion Shift: Reuse as an Option in the Water Management Toolbox

Over the past decade, public dialogue about reuse has increased, particularly in communities of water scarcity, and there is greater general public knowledge about water reuse as an option. In cities in the states of Arizona, California, Florida, and Texas where water reuse is already occurring, a survey by the WRRF found that 66 percent of respondents knew what reclaimed or recycled water is, 23 percent were not sure, and 11 percent were unaware (WRA, 2009). Research has shown that public involvement for water reuse projects can result in a community having a more favorable collective attitude toward a project as its level of familiarity with water reuse increases (USBR, 2004). Proactive education and involvement programs that put water reuse into perspective and promote shared decision-making help to ensure that public understanding develops.

A study conducted by San Diego County Water Authority demonstrates a shift in public opinion about reuse in the community between 2004 and 2011 (**Figure 8-1**). The percentage of respondents who “strongly oppose” using advanced treated recycled water as an addition to drinking water supply dropped from 45 percent in 2004 to 11 percent in 2011 (San Diego County Water Authority, n.d.).

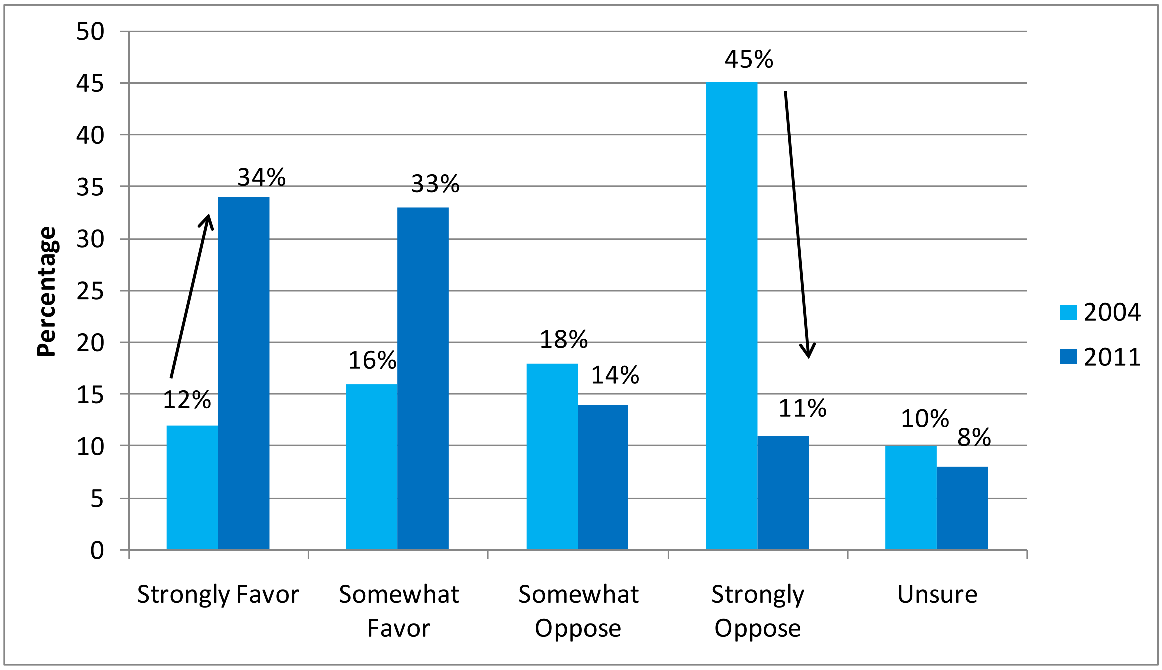

Figure 8-1
Survey results from San Diego: opinion about using advanced treated recycled water as an addition to drinking water supply (2004 and 2011) (SDWWA, 2012)

Media coverage of high-profile water reuse projects has taken center stage in television and national newspapers. In 2011, *USA Today* ran a cover story about potable reuse in Big Spring, Texas. In 2012, the *New York Times* published a front page story titled "As 'Yuck Factor' Subsides, Treated Wastewater Flows From Taps." By engaging with the media and larger communities, water utility public outreach campaigns have encouraged the dissemination of more science-based information about the risks and benefits of reuse.

8.1.2 Framing the Benefits

The process of public engagement begins with clearly defining the problem: *What is the driving reason for which people are being asked to make a change and investment? What are the options for solving it?* Equally important is discussion of the benefits: *What will the community and the individuals that comprise it gain from each of the solutions?* It is important to discuss how water reuse can be of value to the public and the contexts in which it can surpass other options for securing supply reliability and/or quality. Once the reuse options—including status quo—are fully explored, it is then appropriate to discuss the technologies at our disposal to address the potential risks associated with reuse. In the past, dialogue has focused on risks and the associated mitigating technologies rather than beginning from a collaborative problem-solving standpoint.

This focus on identifying benefits is stressed in the WRRF report "Best Practices for Developing Indirect Potable Reuse Projects" (Resource Trends, Inc., 2004). The report concludes that, "Although a compelling value may be created with products or services, the customer or audience must perceive that benefit. When a meaningful problem is solved, the perception will likely be that the state of affairs has improved. This goal is why clearly stating the problem is so important."

So what are the perceived benefits? In a 2009 survey conducted by the WRA in eight target U.S. cities, "Conserving water in my community" was the dominant benefit driver by a 4 to 1 margin (WRA, 2009). Other key benefits that were found to be strong motivators were "positive impact on wetland, streams, and wildlife habitat;" and "irrigating crops without wasting water." Other possible benefits ranked lower, e.g., "industrial/manufacturing use," "groundwater replenishment," and "conserving water in my workplace."

8.2 Why Public Participation is Critical

Over the past few decades people have come to expect or even demand information and engagement related to utility decision-making and initiatives. The intensity of people's interest in having a role in public decisions parallels the potential for impacts on their health, security, and quality of life. Water recycling in all its forms does or can be perceived to impact all of these factors; thus, public outreach and involvement have become key components in the success of water reuse programs.

Public participation begins with having a clear understanding of why reuse needs to be implemented, the water reuse options available to the community, and the potential concerns related to each option. Once an understanding of possible alternatives is developed, a list of stakeholders, including possible users, can be identified and early public contacts may begin. Why begin engaging stakeholders before a plan is in place? It is important to get early adopters that stakeholders can look to and even access for questions or concerns. These community resident stakeholders can provide early indications regarding acceptance of the reuse program and where management and other implementation team members may need to shore up or spend time on additional information and outreach components. Beyond that, informed residents can help identify and resolve potential problems before they occur and develop alternatives that may work more effectively for the community.

8.2.1 Project Success

Involvement of the public in each stage of project planning can be a critical step in achieving a successful project. Hundreds of water reuse projects have been undertaken in the last two decades; many have succeeded and others have failed. Economic, scientific, and technical soundness have not always translated into public support. Some projects failed after millions of dollars had already been spent for development, design, and community involvement, with opposition groups filing lawsuits as a means of stopping them. Public opposition, where present, has included concerns about potential or perceived risks to human health and the environment, economic concerns such as the cost to produce the water, population growth and development, environmental justice and equity, and competing water rights. In some cases, it has taken the form of general rejection of reuse except as an "option of last resort" (USBR, 2004). A 2001 AWWA Research Foundation Highlights Report, *Public Involvement – Making It Work*, stresses this approach: "Drinking water utilities must involve the public prior to implementing projects that affect the public. Understanding this principle will save utilities time and money through avoided litigation and project delays. It will also lay the foundations for establishing public trust and support for future projects" (CH2M Hill, 2001).

8.2.2 The Importance of an Informed Constituency

A public participation program can build an informed constituency that is comfortable with the concept of reuse, knowledgeable about the issues involved in reclamation/reuse, and supportive of program implementation. Ideally, community residents who have taken part in the planning process will be effective proponents of the selected plans. Having educated themselves on the issues involved in adopting reclamation and reuse, they will also understand how various interests have been accommodated in the final plan. Public understanding of the decision-making process will, in turn, be communicated to larger interest groups—neighborhoods, clubs, and municipal agencies—of which they are a part. Indeed, the potential reuse customer who is enthusiastic about the prospect of receiving service may become one of the most effective means of generating support for a program. This is certainly true with the urban reuse programs in St. Petersburg and Venice, Fla. In these communities, construction of distribution lines is contingent on the voluntary participation of a percentage of customers within a given area.

8.2.3 Building Trust

Trust lies at the core of people's understanding, support, and acceptance of reclaimed water as a supply alternative. Unfortunately, the current social and political environment has resulted in a general lack of trust and confidence in utility service providers; both public and private. Public involvement provides opportunities to build trust, not only by fully and truthfully informing individuals within the community, but ideally by engaging them to share information, provide feedback, or contribute to utility decisions. Trust is earned over time by actions and not just words, by taking risks and sharing power. Early public engagement and continuing participation throughout the project (and even beyond) provides greater opportunities to develop trusting relationships. "Trying to sell a completely designed project does not embrace the true spirit of the word *communicate*—coming to a common understanding" (AWWA, 2008; WEF, 2008).

The AWWA/WEF Special Publication *Using Reclaimed Water to Augment Potable Water Resources* provides a path through the process of fully engaging the public in exploring the needs and benefits of water recycling. While targeted at IPR, the ideas and processes in this publication are applicable to all forms of water reuse (AWWA, 2008).

8.3 Identifying the "Public"

Outreach and engagement regarding increased recycled water use must encompass a diverse cross-section of the communities that are impacted or who believe the project has some effect on their interests. Utilities with successful reuse initiatives identify these communities early on and develop a strategy to provide them with information in a format that adds to the credibility of the communication and to hear and address their ideas and concerns.

There is no such thing as "the general public." People belong to geographic, socio-economic, gender, and age groups. They belong to groups according to political ideology, social orientation, and recreation interests. From a marketing perspective, they are frequent fliers, homeowners, credit card holders, health food eaters, and vacation takers. The segmentation of America is prolific, so there are groups and magazines tailored to just about any issue or interest. When planning for public outreach related to reclaimed water use, this diversity needs to be considered.

Diversity should be considered from a variety of perspectives, including ethnic, demographic, geographic, cultural, professional, and political background. Outreach and engagement also should reach multi-cultural, multi-lingual, and multi-ethnic communities and organizations. Market research has shown that some ethnic groups mistrust the safety of water supplies and are wary of government much more than the general population. Working to build support within multi-cultural organizations that are already trusted in these communities can help build awareness and acceptance of a reuse project more effectively and quickly than doing so independently. Outreach to organized groups is as important as outreach to individuals, if not more so. Groups that are likely to have an interest in reclaimed water use include chambers of commerce and environmental organizations, as well as health advocacy groups, service organizations, homeowners associations, academia, and organized labor. Outreach and public participation could take significant effort and time upfront but will ultimately save time over the life of the project.

One particularly successful example of this inclusiveness is the diversity of outreach by the OCWD for its Groundwater Replenishment System. For several years, OCWD staff provided presentations to hundreds of community organizations and leaders in the diverse communities of Orange County before seeking their support. Sometimes this meant presenting to three or four groups in a single day. The process was rigorous and time consuming, but the utility was able to secure support from the majority of these organizations. Supporters were listed on the project website, in informational materials, and in other public forums. This far-reaching inclusiveness helped the Groundwater Replenishment System become a reality [US-CA-Orange County].

8.4 Steps to Successful Public Participation

From the experience of reuse projects over the past decade, it is possible to develop a core set of behaviors common to successful public engagement. Those actions include the steps presented in this section:

- Begin with an assessment of the community and of the utility itself.
- Determine early the level of public involvement that will be sought, including a preliminary list of potential stakeholders.
- Develop and follow a comprehensive strategic communication plan that presents information clearly and anticipates long-term implications of reuse messages.
- Gauge community and utility opinions and attitudes; assess trusted information sources and avenues for participation.

- Meet with community officials and leaders early and then regularly.
- Engage neutral, credentialed outside experts, as potential spokespeople or evaluators while establishing the utility as the primary, credible source of information.
- Engage the media, approaching every available information channel, including social media.
- Involve employees and ensure they are informed with accurate, timely information.
- Dialogue with the broader community of stakeholders directly through various means; understand opposition, and be proactive in responding.

A 2003 Water Environment Research Foundation (WERF) report outlines a framework to help water utilities engage constructively with the public on challenging, contentious issues. While outlining principles for success, the report stresses that no checklist of “to-do's” exists for establishing public confidence and trust. Quite the opposite, the research suggests that a one-size-fits-all model cannot work because the most appropriate steps must be tailored to the specific context. The report provides an analytical structure that utilities can use to assess the community and design an appropriate approach (Hartley, 2003).

Several case studies illustrate how public participation is tailored to meet the needs of the specific context, from formal outreach and involvement campaigns to simpler informational programs. In an environment of distrust in government, OCWD and the OCSD successfully partnered to build a potentially controversial 70 mgd (3,067 L/s) IPR project that garnered overwhelming public support and overcame the “toilet-to-tap” misperception [US-CA-Orange County].

In many communities, reclaimed water has been widely accepted with little to no opposition. In these contexts, public education may include tours and websites, but not require dedicated public relations staff or a formal public outreach and communication program [US-GA-Forsyth County]. In Big Spring, Texas, a new water reclamation plant was launched in 2010 that blends reclaimed water with raw water supplies. Open and proactive communications with state regulators and the public have been keys to the project’s success [US-TX-Big Spring].

Another example of public support of reuse comes from Virginia. Reclaimed water has been successfully augmenting the drinking water supply for over three decades at the Occoquan Reservoir in Northern Virginia near Washington, D.C. Though first unintended, a newly-conceived framework set in motion the intentional, planned use of reclaimed water for the purpose of supplementing a potable surface water supply. A number of hearings were conducted to explain what was to be implemented and to allow the public a venue to express their views. While the UOSA has had an active 30-year program to provide information on its website and tours to local students from grade school through college, a formal public outreach campaign has not been necessary [US-VA-Occoquan].

8.4.1 Situational Analysis

Planning for successful public outreach and engagement should begin with an assessment of the community and of the utility itself. While there are models of successful outreach for water reuse programs to emulate, the selection of specific public involvement approaches, strategies, and tools should be based on the specific attributes and conditions in a community. In combination, this is termed a “Situational Analysis.” In analyzing the community, it is important to assess factors such as:

- The current political environment in which the project will be implemented
- Economic, social, and environmental issues that might indirectly become part of the debate and communication platforms
- Public awareness and knowledge of water-related issues and how these issues may be interconnected
- The history and reputation of the utility, particularly related to trust
- Potential supporters and opponents
- What people currently are seeing and hearing in the media, particularly related to water quality and health

- The principal conduits people rely upon for information, and which of those they trust

Findings likely will vary among differing geographies and demographics within the community. It is important to tap into all of these using tools such as:

- A review of recent media coverage and social media content
- Interviews with elected and appointed officials
- Sit-down conversations with "inherent" community leaders who, though not titled, are respected and listened to by local constituents
- Discussions with customer service staff
- Public opinion surveys and focus groups

The WateReuse guidebook *Marketing Nonpotable Recycled Water* provides a strategic plan template for public outreach, as well as example market research results on the types of messages and modes of communication that would be most reassuring (Humphreys, 2006). As an example, the San Diego County Water Authority conducts annual surveys within its service area to measure public knowledge and opinions of water issues and share the results with the public (San Diego County Water Authority, 2012). Equally important is an inward assessment of the utility to understand factors such as:

- The amount of connectivity with the community and its values
- Openness to engaging people who may express varied perspectives of the project as well as of the utility and its leadership
- Willingness to share decision-making authority
- Willingness and capacity to sustain the hard work of going out to inform and engage the community, including making presentations to diverse and potentially adversarial groups
- Ability and willingness of management to support these efforts over time, including resource allocation

8.4.1.1 Environmental Justice

Environmental justice is of critical concern not only when planning a reuse project, but also while involving the community in the educational process. Environmental justice issues are a result of either procedural or geographic inequity. Procedural inequities occur when there is no "meaningful involvement" of community or stakeholder groups. EPA defines "meaningful involvement" as the seeking out and providing for the affected community an "appropriate opportunity" to participate in the decision-making process, as well as providing the opportunity for the community to have input that will be considered and has the potential to influence the decision-making process. Geographic inequity issues arise when one portion of the community perceives, rightly or wrongly, that it is required to share a majority, or disproportionate share, of the impact from project siting, ultimate water application location (where the water is ultimately used), or potential decreases in property values. Geographic inequity concerns arise primarily where projects are situated in economically or historically disadvantaged areas.

Respectfully and clearly acknowledging and addressing environmental justice issues is critical to success. The guiding principle of environmental justice is that no group of people should bear an unbalanced share of negative environmental impacts of a project or program, and all should have equal right to environmental protection. Insightful tools that can help utilities address the delicate and potentially volatile issues of environmental justice include EPA's Environmental Justice Web site, EPA *"Toolkit for Assessing Potential Environmental Justice Allegations"*, and Executive Order 12898, established during the Clinton administration (EPA, 2004). Questions to ask with regard to the potential for environmental justice issues related to a project are:

- Is each social group in the community being treated fairly or the same as others?
- Is everyone receiving equal access to safe, reliable drinking water?
- Is everyone protected equally from health risks?
- Is any social group bearing the burden of a negative aspect of this project or program?

Engagement of leaders in minority and under-served communities provides an opportunity to better understand their sense of the potential for environmental justice issues related to a water reuse project to arise, and establishes another forum for public outreach and involvement.

8.4.2 Levels of Involvement

It is important to understand and align community member expectations for public participation with what a utility, municipality, or agency is actually willing to commit to and able to deliver. If the two are aligned, public satisfaction with both the process and the outcome can be enhanced.

The appropriate scope, complexity, and content of public involvement will vary according to the type of reuse proposed, the nature of the community, and the magnitude of the project. A project for median irrigation or industrial uses, for example, is likely to directly touch far fewer individuals and evoke less opposition and controversy than a project involving playground irrigation or indirect potable reuse. (Metcalf & Eddy/AECOM, 2007). All reuse projects, however, warrant a thoughtful, targeted, transparent, and truthful public sharing of information with customers and stakeholders, as well as associated opportunities for participation.

The concept of varying levels of participation is captured by the "Spectrum of Public Participation" developed by the International Association of Public Participation (IAP2). The spectrum designates five levels of involvement ranging from *informing*, which provides balanced and objective information to help people understand the problem as well as alternatives for resolving it, to *empowering*, in which the utility turns over final decision making or a significant portion of it to the public or a representative unit of that public. The IAP2 spectrum articulates a "promise to the public" associated with each progressive level of participation. For example, *informing* promises that the utility will help the public understand, while *empowering* promises the utility will implement what the public decides (IAP2, 2007).

It is important to determine early the level of involvement that will be sought, keeping in mind the willingness and capacity of the utility (particularly its leadership) to broadly share the decision-making power. Once a level of involvement has been publicly promised, it can be more damaging to renege on that promise than to have no public involvement at all.

8.4.3 Communication Plan

Regardless of project scope, it is critical to develop at the earliest possible stage a comprehensive strategic communication plan that identifies how the utility will present information and solicit involvement of stakeholders. This plan should pre-identify and provide for training for those who will speak on behalf of the project, especially. The plan must consider consistent messaging, including the long-term implications of reuse messages. The various references at the end of this chapter may be useful planning tools.

8.4.3.1 The Role of Information in Changing Opinion

To communicate with the public in a way that fosters public understanding, utilities must consider carefully the way information is presented. Two recent WRRF projects provide valuable and surprising feedback for the water industry about public communication about potable reuse, but the lessons are applicable for any type of reuse project. *WRRF 07-03: Talking about Water; Images and Phrases that Support Informed Decisions about Water Reuse and Desalination* illustrates that while some staunch opponents are unlikely to change in opposition, a significant portion of community members may change their opinion to favor reuse when provided clear information (WRRF, 2011). **Figure 8-2** provides data from focus groups where individuals were noted as being of one of three mind-sets according to their responses about drinking reclaimed water: "minded a little," "don't mind at all," or "minded a lot" (WRRF, 2011). Participants were then provided information related to water reuse, including easy-to-understand technical details and graphics explaining the water purification process. Following this information sharing, most of those who had "minded a little," changed their opinion to "don't mind at all," though many had additional questions. Most who had indicated they "minded a lot" maintained that position.

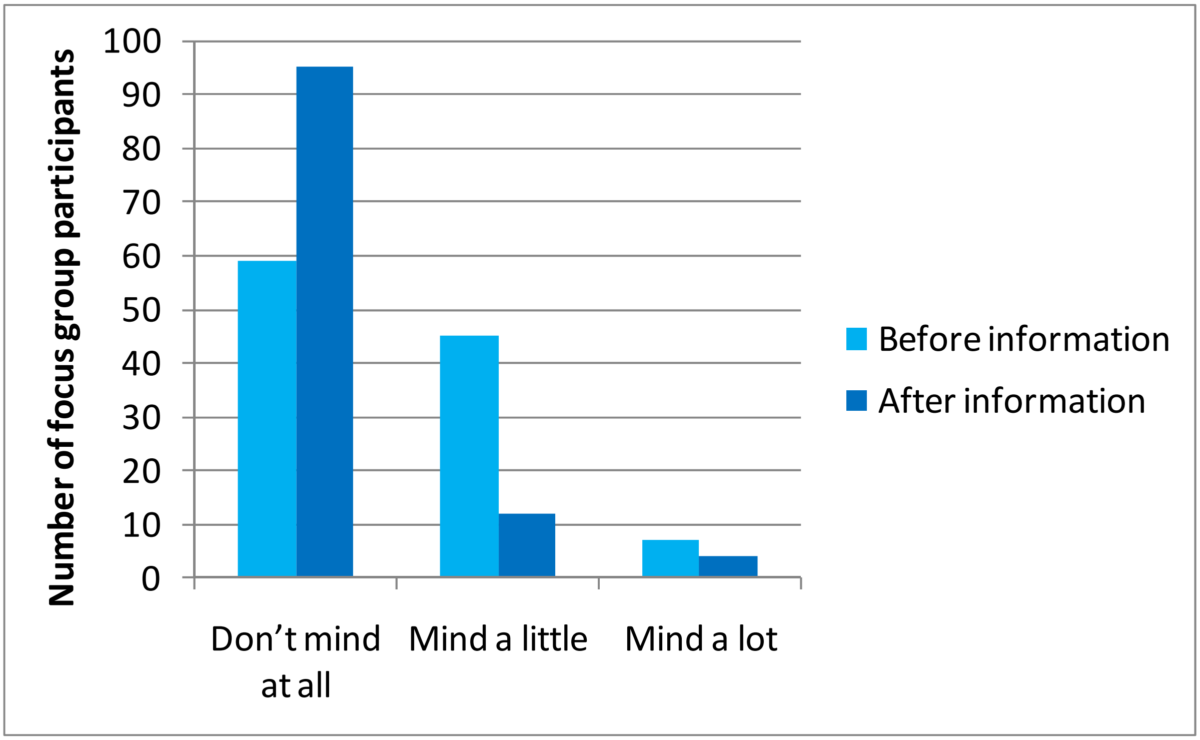

Figure 8-2
Focus group participant responses: before and after viewing information (Source: Adapted From WRRF, 2011)

This research led to the conclusions that information presented to the public needs to be simple enough to understand yet technical enough to trust and that public communications should be treated as a dialogue that avoids technical jargon and acronyms. An interactive web-based urban water cycle was developed to assist in explaining reuse to the public in the context of urban water management. While potential users *generally* know what flow and quality of reclaimed water are acceptable for different applications, it is critical to ensure a common baseline understanding among the community about local water cycle. A water cycle glossary and informational videos have been put together by the WRA to assist in a holistic and contextual understanding of water reuse (A Thirsty Planet, n.d.).

8.4.3.2 Words Count

WRRF 07-03 clearly demonstrated that the industry's vocabulary and means of communicating with the public are not well understood or well received, often resulting in confusion and contributing to public mistrust or lack of acceptance of water reuse projects. The terms to describe reclaimed water produced for augmentation of drinking water supply that survey respondents found the most reassuring all described the very high quality of the water, and did not include the "re" prefix (reuse, reclaimed, etc.), as summarized in **Figure 8-3**. On the other end of the spectrum, the terms found least reassuring are the terms most often used by the water industry (WRRF, 2011).

This study also found that most participants preferred that reclaimed water quality be described by the uses for which it is suitable, rather than a grading system, degree or type of treatment, or type of pollutants removed. Earlier research speaks of people's "visceral" aversion to human waste and the difficulty overcoming a perception of contamination (Rozin, 1987 and USBR, 2004). However, WRRF 09-01: *The Effect of Prior Knowledge of 'Unplanned' Potable Reuse on the Acceptance of 'Planned' Potable Reuse* demonstrated that when reuse options are placed into context of the water cycle's *de facto* "unplanned potable reuse," there is higher acceptance of "planned potable reuse" (WRRF, 2012). When compared to the IPR options of continuing to use the current water supply ("business as usual"), blending reclaimed water in a reservoir, and discharging treated water upstream of a drinking water treatment facility, direct potable reuse was judged to produce the safest drinking water by 41 percent of focus group participants (**Figure 8-4**).

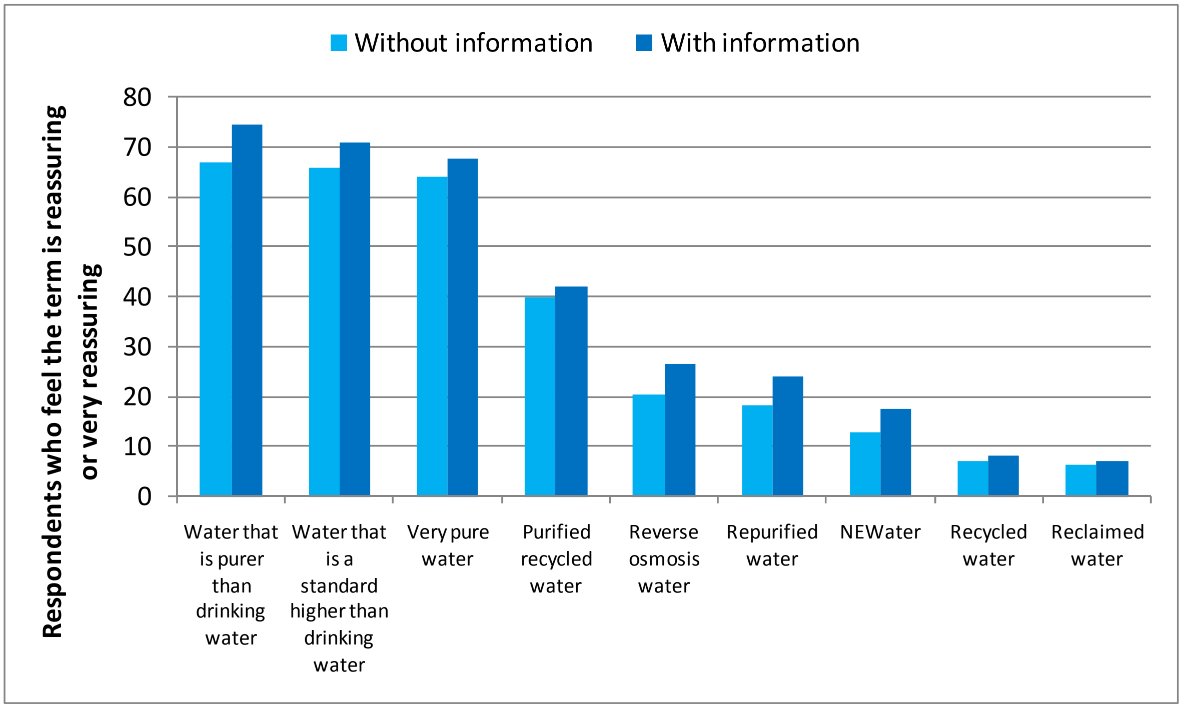

Figure 8-3
Water reclamation terms most used by the water industry are the least reassuring to the public. (Selected data from WRRF 07-03 – refer to the report for the complete list of terms studied.)

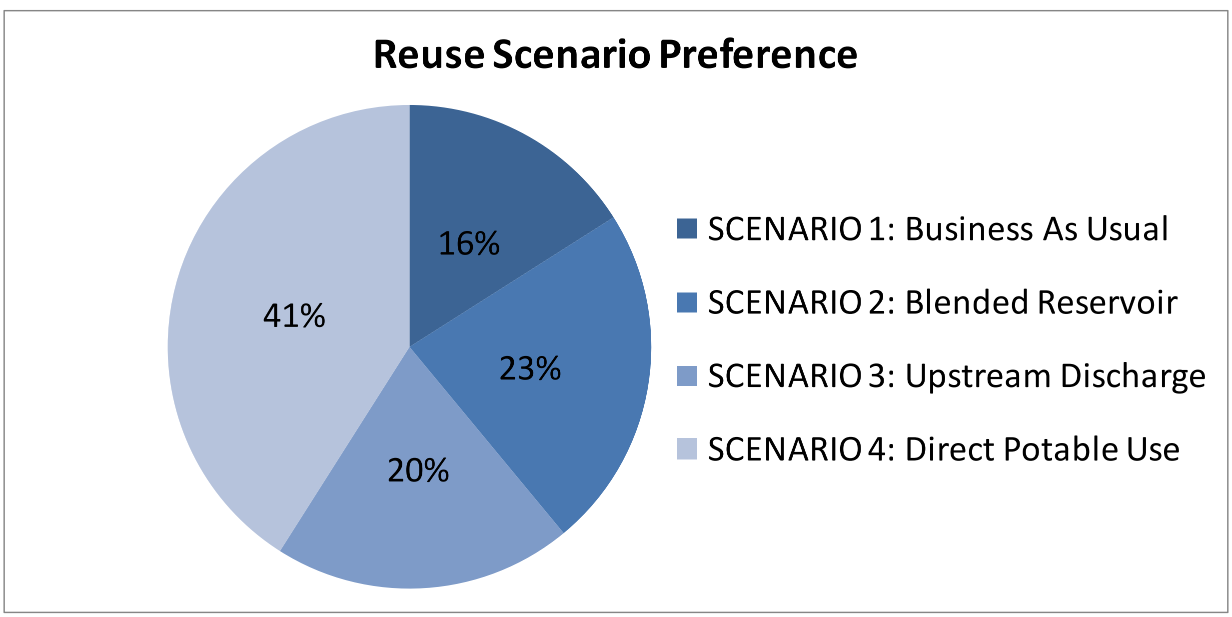

Figure 8-4
Focus group participants preferred "direct potable use" over "business as usual," "blended reservoir," or "upstream discharge" IPR options (WRRF 09-01)

The study suggests that the public is less concerned about the source of the drinking water supply than about monitoring and reliability of the safety and taste of their drinking water. Additionally, positive terminology leads to early acceptance of reuse. The water purification plant described in the study appeared to strongly influence people's preference.

A 2010 WRRF study titled *The Psychology of Water Reclamation and Reuse: Survey Findings and Research Road Map* found that only 13 percent of respondents said they would be unwilling to drink certified safe recycled water. In this study, messages of *"recycled water is safe"* and *"all water has the properties of recycled water"* were tested—each showed an increase in willingness to drink certified safe recycled water [US-CA-Psychology Survey] (WRRF, 2010a).

Taken together, this research emphasizes the importance of language in setting the context for people's perceptions about reclaimed water. Outcomes of the studies include recommendations for practices and terminology related to water reuse that will facilitate rather than erode people's ability to understand and accept reused water as a safe and reliable water supply option. These include:

- **Facilitate Understanding:** Focus groups demonstrated that simple and easy-to-understand information results in increased knowledge and acceptance of water reuse. At the same time, materials should not be overly simplistic. People want more in-depth information about water, as opposed to general information (WRRF, 2011). This result supports the benefit of informing people early in a reuse initiative, with information specific to the project being proposed.
- **Forget the Past:** Reclaimed water is best presented in terms of its suitability for specific uses, rather than its source.
- **Emphasize Purity:** The word "pure" and its derivatives help reassure people that the water is safe.
- **Show that it is Integral to the Cycle:** Water reuse is best presented in the context of the complete water cycle, setting the framework for people to understand the truth that *all water is recycled*.
- **Avoid Jargon:** Many terms common to water utility professionals (flocculation, primary treatment, effluent) are obscure to most people. It's important to explain the purification process and its outcomes in clear, readily-understandable terms. Some people perceive highly technical terminology as an attempt at obfuscation, which serves to erode rather than engender trust.
- **Use Pictures:** Graphics and pictures that clearly (and even cleverly) illustrate the technical steps of the water treatment process help people to understand and believe in the technology behind water purification.
- **Present Analogies:** Comparisons can help people better understand and evaluate risk. Examples given include the explanation that "Wastewater is mostly water—a 53-gallon drum of it contains only about one tablespoon of dirt." Similarly, researcher Shane Snyder noted in a Congressional hearing, "The highest concentration of any pharmaceutical compound in U.S. drinking waters is approximately 5 million times lower than the therapeutic dose and that …one could safely consume more than 50,000 8-ounce glasses of this water per day without any health effects." (Snyder, 2008). Another useful study is *WRRF 09-07 - Research Update: Risk Assessment Study of PPCPS in Recycled Water to Support Public Review* (WRRF, 2010b).
- **Tell It Like It Is:** Terminology commonly used by the industry can get in the way of public understanding and acceptance of reclaimed water. The terms "constituents of emerging concern," "trace organic compounds," and "microconstituents," are alternative terms to identify a number of anthropogenic chemical compounds that have been detected in water or wastewater, generally at very low levels, but that are not commonly regulated. While experts struggle to identify this category of constituents with an accurate term (as described in Chapter 6), these terms can be confusing or alarming to the public. The term "emerging" is likely to increase a person's sense of worry, connoting this not only exists, but is prone to become larger or more virulent. Use of the word "concern" expresses that this is something that

should be a cause for apprehension. Alternative terms have been proposed, categorizing them by end use (e.g., pharmaceuticals, personal care products, flame retardants), by environmental and human health effect, if any (e.g., hormonally active agents or endocrine disrupting compounds), or by type of compound (e.g., chemical vs. microbiological, phenolic vs. polycyclic aromatic hydrocarbons). The sheer array of different types of compounds can likewise cause confusion and are not well understood by the general public.

The term *endocrine disruptors* can be misinterpreted as having proven implications for human endocrine systems, whereas current evidence is limited to disruptions in frogs and fish. A report by WERF, *Communication Principles and Practices, Public Perception and Message Effectiveness* provides guidance on effective risk communication practices, particularly around TrOC (Deeb, 2010). The report suggests a less stigmatizing term for most of these constituents is “pharmaceuticals and personal care products” with the added words “and other unregulated constituents” to broaden the term to be inclusive of a wider array of constituents.

Common terms like “toilet-to-tap” tend to resurface in people’s minds the link between reclaimed water and wastewater. Still, perpetuation of such words and phrases often is beyond the control of those proposing reuse projects; it is, in fact, in the control of those most commonly perpetuating the words and phrases, namely the media and project opponents. The utility should be prepared and ready (and willing) to clarify the inaccuracy of “toilet-to-tap” and similar terms, either by explaining that reuse is but one segment of the ongoing water cycle or by stressing the multiple intervening treatment steps between toilet and tap.

While a great deal is now understood around how to build public understanding and involvement in reuse, some questions remain, and are described in the case study [US-CA-Psychology Survey] originally reported by WRRF (2010).

8.4.3.3 Slogans and Branding

As emphasized in the previous section, the choice of slogan for a reuse campaign must be easy to understand and must communicate the benefits that resonate most with the target audience. WRRF found that *“Water… it’s too valuable to be used just once”* was the branding statement that was preferred by more than a 2 to 1 margin over all alternatives in their eight-city stakeholder survey (WRA, 2009). Since public understanding and attitudes about water reuse varies greatly by location and is dynamic, it is important to understand and stay current on stakeholder attitudes and beliefs about key benefits in a given location.

8.4.3.4 Reclaimed Water Signage

One undervalued, and often overlooked, method for communicating the benefits of water reuse to the public is the posted signage provided to reclaimed water irrigation customers. As just described, the terminology presented on the sign can convey the message of the benefits of reuse, while properly advising the community on the type of water being used for irrigation. Many states still require a symbol with drinking glass and a slash with text “Do Not Drink,” but also allow the inclusion of more positive language as shown in the adjacent signage example.

Some states have specific requirements for reuse signage. An additional discussion on signage is provided in Chapter 2. An example of terminology used by the Cucamonga Valley Water District, Calif., (CVWD) is shown in **Figure 8-5**. The signage emphasizes the benefits of using recycled water for irrigation (i.e., supporting conservation) through the use of large centered text. The advisory language, shown in smaller text on the lower right hand corner, is still present but is not the focus of the sign. This simple choice in word selection and imaging results in a positive message being conveyed to the audience and eases public concerns.

Figure 8-5
CVWD encourages its wholesale customers to promote the notification of water reuse benefits (Photo credit: Miguel Garcia)

8.4.4 Public Understanding

To build an informed constituency, pre-conceived notions about reclaimed water and its risks must be identified and addressed. In water reuse, a challenge may lie in the difference between the technical experts' understanding and the lay public's perceptions of water reuse projects.

8.4.4.1 Perception of Risk

In general, the public tends to perceive risks differently than scientists schooled in the statistical analysis of risk. A growing body of research is examining the factors that explain the public's perceptions of risk and thus influence decision-making and project implementation. Researchers in this area of study are finding that the range of factors that underlie the public's perception of risk is very large. Technical information and public participation can influence the public's response to those factors, but it is only one influence and may not be sufficiently persuasive on its own. Other factors that influence the public's perception of risk associated with water reuse include:

- The cluster of mental pictures or associations that follow mention of the words "wastewater," "reclaimed water," or "reuse water"
- The way in which different groups within the general public rank and evaluate other risks relative to water reuse, such as sunbathing, caffeine, a poor diet, or driving without a seatbelt
- The baseline knowledge that different groups already possess about causality or different risk factors associated with disease-specific outcomes
- The level of trust in which the public holds the agency or body responsible for managing a risk

Given the importance of each of these variables to understanding perceptions of different health and environmental risks and to communicating effectively about reuse, public information campaigns must consider:

- Perceived risk
- Effect and image
- Language and stigma
- Mental and cultural models (context)
- Trust

As previously mentioned, a useful study is *WRRF 09-07 - Research Update: Risk Assessment Study of PPCPS in Recycled Water to Support Public Review* (WRRF, 2010b).

8.4.4.2 Trusted Information Sources

Survey research conducted by individual utilities continues to indicate that the public has a greater level of trust in opinions about potable reuse projects provided by scientific experts. A WRRF research study found that independent (e.g., university-affiliated) scientists are the most credible source of information on recycled water, followed by state and federal government scientists (WRRF, 2010a). Hired actors, neighbors, and employees of private water-related companies are least credible, according to this study [US-CA-Psychology Survey]. The WRRF 09-01 study (WRRF, 2012) resulted in slightly different conclusions about which sources of information about reuse the public trusts most to provide information about reuse (**Table 8-1**).

In this study, respondents from the United States and, to an even greater degree, from Australia, identified regulators as the most trustworthy source of reclaimed water information. Regulators were chosen by more people than consultants, professors, doctors, and local water agency spokespeople.

Table 8-1 Focus group participant responses – most trusted sources (Source: Adapted from WRRF, 2012)

Source	U.S. Respondents (n=302)		Australia Respondents (n=349)	
	Number	Percentage	Number	Percentage
Regulators	130	43%	215	62%
Consultants	27	9%	13	4%
University professors	42	14%	36	10%
Medical doctors	56	19%	48	14%
Local water agency spokesperson	47	16%	37	11%

Because trusted sources can vary from community to community, state to state, and country to country—as evidenced when comparing the WRRF (2010) and WRRF 09-01 results—it is best to conduct a public opinion survey in each community where water reuse is being considered.

8.4.5 Community Leaders

Public involvement early in the planning process, even as alternatives are beginning to be identified, allows ample time for the dissemination and acceptance of new ideas among the constituents. Public involvement can even expedite a reuse program by uncovering any opposition early enough to adequately address concerns and perhaps modify the program to better fit the community. As mentioned previously, engagement of leaders in groups with specific interests or from under-served communities provides opportunities to understand the needs and concerns of the community as a whole.

Further, because many reuse programs may ultimately require a public referendum to approve a bond issue for funding reuse system capital improvements, diligently soliciting community viewpoints and addressing any concerns early in the planning process can be invaluable in garnering support. Engaging policy makers, educating them on the facts about reuse, and gaining their acceptance can be a critical component to public involvement. By providing policy makers with proper education on reuse, they will be prepared with facts and tools should stakeholders call them or their representatives with questions or concerns.

8.4.6 Independent Experts

To demonstrate that the utility is seen as taking community concerns seriously and as the primary, credible source of information, the outreach program can target the use of stakeholder advisory groups or neutral experts to inform the planning and evaluation process.

8.4.6.1 Advisory Groups

Making decisions about recycled water projects, especially potable reuse projects, can be challenging when different interest groups are involved. One way to address those challenges, as well as to ensure that community values and diverse opinions are considered, is to establish an advisory group or taskforce composed of representatives of the range of perspectives in the community. The community advisory group provides a forum to enable stakeholders to enter into a dialogue with each other and even develop recommendations related to a specific project. There is one key element to consider before deciding whether a community advisory group should be established: early agreement on the group's role in the decision-making process and/or work product. An advisory group should clearly understand what they are being asked to do in context of the project, and each group should have and agree to a mission statement and principles of participation. This ensures the group members, as well as utility staff and decision-makers, clearly understand what is expected of the group. Further it is critical to make sure that human and financial resources are available to support the group process, an independent facilitator is retained to guide the group process and ensure its independence, group participants are selected to represent various community perspectives needed by the project team, and also that adequate time is allocated for the group to meet and develop recommendations and input.

There are several benefits that can accrue from a properly designed and administered community advisory group:

- All stakeholders can gain an understanding of each other's perspectives.

- Stakeholders can develop a better understanding of the decision-makers' dilemma in trying to satisfy groups holding differing positions.
- Meetings of the group allow time for members to gain a deeper understanding about technical, fiscal, and community issues that must be considered.
- Participating in a series of meetings on a specific topic can help build trust and also result in ownership of recommendations by the group members.
- The group itself, or its individual members, can become a legitimate voice in the community for supporting a decision.

At the University of California, Santa Cruz campus, future enrollment growth will result in a 25 percent increase in water demand. A campus workshop involving faculty was held to rank a range of potential reuse projects. Steps are now in place to help offset the potential increase in demand [US-CA-Santa Cruz].

8.4.6.2 Independent Advisory Panels

Another important group to consider is an independent advisory panel composed of science, health, water quality, and other technical experts. Such independent advisory panels have multiple benefits for utilities seeking to implement or expand water recycling. Panel members provide access to a broad range of worldwide technical and scientific expertise. They offer an unbiased review of proposed actions and activities, advancing sound public-policy decisions. And, relative to public outreach and information, the panels offer highly expert and impartial validation of the project's soundness and safety.

Utilities can use a number of independent research organizations to convene and manage an independent advisory group, which further validates their independent evaluation of the project. The utility should recognize from the start that engagement of the panel and work to support its studies is likely to add to the time commitment and cost of the project. Like all aspects of public engagement, it is a matter of weighing costs and benefits. The utility will want to carefully outline the purpose and specific focus areas of the panel, which will help to establish its membership, guide its work, and avoid unnecessary costs.

Reports from independent advisory panels can serve many purposes, including suggesting technical enhancements to the project design; identifying cost-saving measures; serving as a focal point for public information; providing independent corroboration of the project's validity and safety, particularly to skeptics; and serving as a resource to regulators and oversight agencies. While the independent advisory panel's report will be technical in nature and will be read in its entirety by the project team and those with technical interests, developing an accompanying executive summary is recommended, so that technical findings are accessible and easily understood by a lay audience.

8.4.6.3 Independent Monitoring and Certification

Several reuse projects have benefitted from the use of monitoring and certification programs to build public trust. The city of Tucson has augmented its reuse water service inspection program to build public trust. The program includes testing for cross-connections, ordinances, and inspector training and certification programs [US-AZ-Tucson]. Tossa de Mar in Spain is one of the leading cities in Costa Brava to recognize the benefits of turning wastewater into reclaimed water after the region suffered from a prolonged drought. The water supply and sanitation agency promoted a high-quality branding through their website, the municipality website, and Facebook [Spain-Costa Brava].

King County, Wash., is constructing a new WWTF designed to produce Class A reclaimed water, which is safe to use for irrigating food crops. To gain customer confidence and to confirm suitability to end users, King County partnered with the University of Washington to conduct research on the safety and efficacy of Class A reclaimed water use [US-WA-King County].

As customers connect to the reclaimed water system, outreach is undertaken to inform users of safe and proper applications of reclaimed water. Many states, such as Florida, include customer education as a reuse permit requirement.

8.4.7 Media Outreach

Local media play an integral role in shaping public opinion about projects. Numerous case studies demonstrate the value of media as an outreach conduit regarding water reuse, with the added credibility of originating from a neutral third party. To establish effective media relations, several BMPs will help to create a positive working environment.

- Identify specific reporters who will likely cover the topic on a regular basis and take time to provide them with background information when they are not facing a deadline in order to develop longstanding relationships and foster more accurate reporting.
- Identify, internally, who will speak regularly with the media and provide them with training on how to explain the project in concise, easy-to-understand statements that will, in turn, become good quotes.
- Determine local media preferences for communication and make use of the preferred resources, including formal news releases, Twitter, Facebook, email, phone, fax, and in-person communication.
- Identify local newspaper editorial boards and begin to educate them on the benefits of reuse early on. These are different individuals than the news reporters.
- Be responsive and direct in answering media questions. A reporter who knows that he/she can come to a source for direct answers, even to difficult questions, will develop a respectful relationship with that source.
- Think about ways to help reporters tell the story visually; consider illustrations or props and plan for short-term successes (i.e., landscaped medians) that can be showcased. Many media outlets can take files directly from an in-house graphic artist.
- Humanize the story rather than presenting all details on a clinical level. This also helps to humanize the organization. Reporters will also look for other third-party sources to interview. Be ready to suggest positive interview candidates and story ideas.
- If something negative happens with a project, consider the facts that are most likely to go public and be direct, never evasive, in presenting the facts.

Media coverage of the city of San Diego's Water Purification Demonstration Project with the potential for reservoir augmentation is a prime example of how a utility can work with the media to present more accurate information about a reuse project. In the late 1990s, the San Diego *Union-Tribune*, San Diego's largest regional newspaper, editorialized against water reuse in any form, particularly potable reuse. The city of San Diego conducted the Water Reuse Study, which resulted in a community group endorsing the concept of reservoir augmentation as the most sensible use of the recycled water the city plants were producing. This study laid the groundwork for providing more factual information to reporters, culminating in an article by a *Union-Tribune* writer that very accurately described the purification processes that would be used at the city's Advanced Water Purification Facility, the cornerstone of the Demonstration Project. Four months later, the paper published an editorial titled "The Yuck Factor – Get Over It." Thanks also to the progress made on the potable reuse project in Big Spring, Texas, television and national newspapers began to cover the topic in a more factual way during 2011, including a cover story in *USA Today*. In 2012, the *New York Times* published a front-page story titled "As 'Yuck Factor' Subsides, Treated Wastewater Flows From Taps." Many hard-working water utility public outreach staffers have spent countless hours talking to reporters and encouraging more science-based information about potable reuse, a trend that will hopefully continue.

8.4.7.1 New Media Outreach Methods – Social Networking

In today's dynamic environment, it is important that utility professionals use the most effective and dynamic communication tools available to connect with stakeholders and communities on an ongoing basis. In a 2012 paper titled "Social Media Demonstrates Their Worth for Utilities and Their Stakeholders," the authors present the value that social media can provide as a utility communication tool and describe how D.C. Water has completely integrated social media elements into a larger communications strategy (Peabody et al., 2012).

Social media should not be ignored. In today's dynamic environment, social media can provide interesting insights into the stakeholder population, can offer early alerts to opposition, and can provide direct contact to stakeholder groups. A caution, though, is the reality that effective use of social media requires commitment of staff resources and time that is continuous and can become significant, particularly if there is controversy or opposition surrounding a project. Ignoring or failing to keep current with the flow of conversation in such circumstances can be detrimental to the project and the organization's reputation.

8.4.8 Involving Employees

Employees comprise another often-overlooked but highly important component of the public. People working for the utility (as well as for associated organizations, such as departments within the same city) often are questioned by family and neighbors and are seen as a reliable source of information about projects and initiatives. Special, targeted efforts to inform and engage this specialized audience is a way to ensure they have accurate, timely information to convey to others. It also provides the opportunity for them to bring back ideas and concerns they hear from others.

8.4.9 Direct Stakeholder Engagement

As described in Section 8.1, public involvement often begins by targeting the most impacted stakeholders, with the outreach effort broadening to include the public at large over time. For instance, a community may work closely with golf course owners and superintendents to introduce reclaimed water as a resource to keep the golf course in prime condition, even at times when other water supplies are low. This small, informed constituency can then provide the community with a lead-in to other reclaimed water options in the future. Golf course superintendents spread the word informally, and, as golfers see the benefits, the earliest of education campaigns has subtly begun. Later, the same community may choose to introduce an urban system, offering reclaimed water for irrigation use.

8.4.9.1 Dialogue with Stakeholders

A broad range of involvement techniques are available for direct dialogue with stakeholders, including: surveys, public information programs, public meetings, workshops, interviews with key stakeholders, community events, presentations, and regular e-updates (Metcalf & Eddy/AECOM, 2007). It is critical that language translation of informational materials is incorporated into the outreach strategy to ensure that all stakeholders within the utility's diverse community of interests will benefit from outreach and public participation opportunities.

8.4.9.2 Addressing Opposition

Opposition frequently is aroused by prospects of water reuse, most often when a project involves children and/or use of reclaimed water as a potable source. As part of public involvement, it is critical to anticipate and be prepared to address opposing viewpoints. In developing groups for public involvement, it is preferable for the utility to include opponents as part of the mix of participants. This will help bring to the surface issues that need to be addressed and also may help to make the opposing individuals more informed and more comfortable with reuse.

People voicing opposition to reclaimed water projects most often cite health concerns, though sometimes there are other underlying drivers of opposition. For example, opposition to urban growth or specific political agendas has underlying factors masked in health-issue opposition to projects. A 2011 WRRF study conducted in Arizona (WRRF 06-016-01) found that survey respondents' views on the acceptability of reclaimed water for various uses was influenced by their perception of the desirability of growth in their community (WRRF, 2011).

Opposition can surface at any point in the project's lifecycle. In Pompano Beach, objections to development were one source of opposition to reuse [US-FL-Pompano Beach]. The potential for political opportunism during an election cycle underscores the importance of developing a public engagement program where community and stakeholder involvement occurs at all stages of the project so that stakeholders are involved in the decision-making process and the community and politicians know about and accept the project. Project timing must be considered in the broader sense to avoid political opportunism, if possible (USBR, 2004). When met with opposition, it is important to:

- Include both individuals who might support the utility's position as well as those who might oppose it when forming participation groups.

- Be prepared to respond promptly and calmly to misinformation.
- Be prepared to address opposition with clear, readily-comprehensible information and illustrations.
- Get support in writing if someone voices such support.

8.5 Variations in Public Outreach

Public outreach can vary, depending on the project itself and/or the community it will serve. Decision-makers may choose to test a novel approach (whether technological or regulatory) through demonstration projects, in order to demonstrate reliability to constituencies. While demonstration projects can add time to the overall implementation schedule of a reuse project, public buy-in may be enhanced if participation is built from the demonstration phase and an appropriate, tailored solution can be constructed from all available approaches, rather than succumbing to the temptation to simply copy existing 'proven' approaches (e.g., the treatment train of Orange County). In some cases, a demonstration project may be an appropriate step prior to setting new regulation, rather than the reverse.

In the case of King County, Wash., in addition to sharing data with the public on the quality of the reclaimed water and the crops irrigated by it, luncheons and tastings were held at the end of each year's research. The staff of the King County Wastewater Treatment division, potential reclaimed water customers, members of the community, and other stakeholders were invited, as shown in **Figure 8-6** [US-WA-King County].

Figure 8-6
A luncheon was held in King County, Wash. to present data on reclaimed water used for irrigation, along with lunch featuring crops and flowers from the reuse irrigation study. (Photo courtesy of Jo Sullivan).

In San Diego, Calif., public demonstration is a major phase of the reuse project. In 2004, the city embarked on its Water Reuse Program with the goal of maximizing water reuse, either through nonpotable market expansion, potable reuse, or a combination of the two. IPR through reservoir augmentation was chosen as the preferred strategy and is currently being evaluated in the Water Purification Demonstration Project (anticipated completion in 2013).

A successful public outreach and education program is attributed for a recent shift in perception about IPR in San Diego, cited earlier in this chapter. Aggressive outreach to community leaders and the media, public tours of the Advanced Water Purification demonstration facility, and project presentations to interested groups throughout the community helped to increase public understanding of the processes involved in providing safe reclaimed water [US-CA-San Diego]. At the Denver Zoo, where reclaimed water is used for animal habitats, animal health and public relations experts have ensured and communicated the safety and beneficial aspects of water reuse through education and outreach efforts [US-CO-Denver Zoo].

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CHAPTER 9
Global Experiences in Water Reuse

9.1 Introduction

This chapter provides an overview of global experiences in water reuse. The primary objectives of this chapter are to 1) review a range of drivers, barriers, benefits, and incentives for water reuse and wastewater use outside of the United States; 2) outline the state of, and geographic variation in, water reuse and wastewater use; and 3) review paths for expanding the scale of safe and sustainable water reuse and wastewater use in different contexts. Discussion is provided to address these objectives; it draws on experiences from more than 40 global case studies that provide an array of approaches to safe and sustainable water reuse. While EPA guidelines focus on water reuse, the global abundance of wastewater use and the gray lines dividing water reuse and wastewater use have led the contributors to broaden the scope of this chapter to discuss both water reuse and wastewater use outside of the United States.

The planning, technical, institutional, and socio-economic settings in which water reuse is practiced varies both among and within countries as a function of specific geographic and economic conditions. As a result, it is important to define the context of these practices, as well as provide case study examples of these practices.

9.1.1 Defining the Resources Context

As this chapter examines water reuse across a spectrum of resource contexts, it is necessary to draw a distinction between resource-endowed and the resource-constrained countries. For the purposes of this chapter, the term "resource-endowed" countries or settings will refer to locations in high-income or "developed" countries, and "resource-constrained" countries or settings will refer to locations in low-income or "developing" countries. Locations in middle-income countries or settings may fall into either category depending on the context.

Most resource-endowed countries have established human health risk guidelines or standards that involve high-technology/high-cost approaches. This enables the institution of practices that extend beyond protecting human health to providing environmental protection and restoration. Many resource-constrained countries have considered adopting an approach to protecting human health based on the WHO's recommendations in the WHO *Guidelines for the Safe Use of Wastewater, Excreta, and Greywater*, which usually entail a fit-for-purpose, gradational process toward reducing health risks (WHO, 2006).

9.1.2 Planned Water Reuse and Wastewater Use

For this chapter especially, it is necessary to make a distinction between water reuse and wastewater use. As defined in Chapter 1, water reuse, for the purposes of this document, is the use of treated municipal wastewater. Globally, water reuse occurs both in resource-constrained settings using low-cost methods (as illustrated in case studies [Palestinian Territories-Auja] and [Philippines-Market]), as well as in resource-endowed settings, where the more typical high-tech applications are seen (as illustrated in case studies: [China-MBR], [India-Bangalore], [Japan-Building MBR], [South Africa-eMalahleni Mine], and [Spain-Costa Brava]).

Wastewater use is the intentional or unintentional use of untreated, partially treated, or mixed wastewater that is not practiced under a regulatory framework or protocol designed to ensure the safety of the resulting water for the intended use. This practice does not occur in the United States, as wastewater treatment is ubiquitous. Wastewater use occurs mainly for agricultural irrigation, and often it is officially prohibited, yet unofficially tolerated (informal irrigation sector), because many people derive their livelihoods from access to untreated or partially treated wastewater. Wastewater use may occur, for example, where wastewater is knowingly taken from outfall pipes or drainage canals because it is easily accessible at no cost or can confer benefit over other sources because of its high nutrient content when water is used for irrigation. Wastewater use can also occur where water is taken from natural stream or river channels that contain large loads of untreated wastewater mixed with freshwater. It should be noted that these definitions do not include any judgment about water quality and related health risks. In resource-constrained countries, for example, the quality of "treated" wastewater in a planned reuse project can be worse than that of untreated, but diluted, wastewater collected from streams.

Although wastewater use can have various livelihood benefits and support food security, it presents serious risks to human health from a range of pathogens that may be contained in the wastewater, as described in Chapter 6. In addition, where urban or agricultural runoff or industrial wastes impact wastewater, chemical pollutants may also be present. Exposure to untreated wastewater is a likely contributor to the burden of diarrheal disease worldwide (WHO, 2004). Epidemiological studies suggest that the exposure pathways to the use of wastewater in irrigation can lead to significant infection risk for the following groups:

- **Farmers and their families**—Several epidemiological investigations have found excess parasitic, diarrheal, and skin infection risks in farmers and their families directly in contact with wastewater. There is, in particular, a high prevalence of hookworm disease and ascariasis infections among those who do not use protective gear as the organisms that cause those infections (hookworm and roundworm) are common in hot climates (WHO, 2006).

- **Populations living near wastewater irrigation sites, but not directly involved in the practice**—Populations, particularly children, living within or near wastewater irrigation sites using sprinklers may be exposed to aerosols from untreated wastewater and at risk of bacterial and viral infections (Shuval et al. 1989).

- **Consumers of raw produce irrigated with wastewater**—Excess diarrheal diseases and cholera, typhoid, and shigellosis outbreaks have been associated with the consumption of wastewater-irrigated vegetables eaten uncooked (WHO, 2006). In Ghana, for example, a burden of disease of 12,000 disability-adjusted life years (DALY) annually, or 0.017 DALY per person per year was estimated, which represents nearly 10 percent of the WHO-reported DALYs occurring in urban Ghana due to various types of water- and sanitation-related diarrhea (Drechsel and Seidu, 2011). The contribution of wastewater use, and in particular its impact on consumer food safety, has not been quantified so far at larger scale.

In cases where wastewater treatment prior to use is not possible, alternative strategies for protecting human health need to be evaluated and applied (Scott et al., 2010; Amoah et al., 2011). In such cases, guidelines for the development, contracting, and implementation of water reuse can facilitate the transition from wastewater use to planned reuse systems.

9.1.3 International Case Studies

A broad range of global water reuse practices are discussed in this chapter and in accompanying case studies. The geographic location and reuse application associated with each case study is displayed in **Figure 9-1**. As a group, the case studies illustrate water reuse experiences in a variety of contexts and demonstrate the possibilities for expanding the scale of safe and sustainable water reuse practices across geographies and resource settings. Throughout the text, the case studies are referenced by a code name in brackets. In the pdf version of this document, hyperlinks will direct the reader to the international case studies, which are located in Appendix E. A table with links to international regulatory websites is also provided in Appendix E.

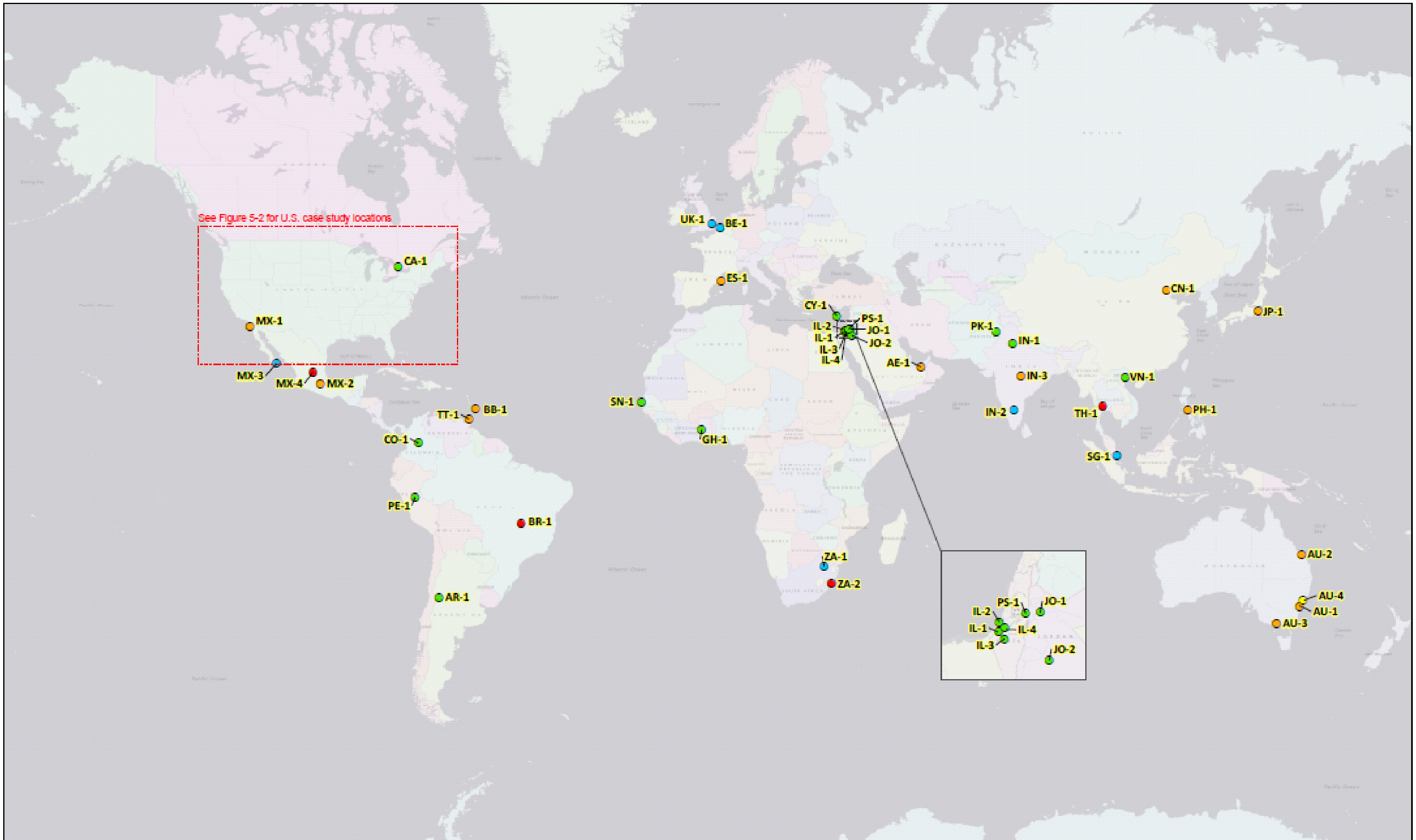

Figure 9-1
Geographic Display of International Water Reuse Case Studies Categorized by Application

Figure 9-1 Legend

Map code	Text code	Case Study Name
AR-1	Argentina-Mendoza	Special Restricted Crop Area in Mendoza, Argentina
AU-1	Australia-Sydney	Sewer Mining to Supplement Blackwater Flow in a Commercial High-rise
AU-2	Australia-Graywater	Retirement Community Graywater Reuse
AU-3	Australia-Victoria	End User Access to Recycled Water via Third Party-Owned Infrastructure
AU-4	Australia-Replacement Flows	St Marys Advanced Water Recycling Plant, Sydney
BB-1	Barbados-Economic Analysis	Economic Analysis of Water Reuse Options in Sustainable Water Resource Planning
BE-1	Belgium-Recharge	Water Reclamation for Aquifer Recharge in the Flemish Dunes
BR-1	Brazil-Car Wash	Car Wash Water Reuse - A Brazilian Experience
CA-1	Canada-Nutrient Transfer	Water Reuse Concept Analysis for the Diversion of Phosphorus from Lake Simcoe, Ontario, Canada
CN-1	China-MBR	Water Reuse in China
CO-1	Colombia-Bogotá	The Reuse Scenario in Bogotá
CY-1	Cyprus-Irrigation	Water Reuse In Cyprus
GH-1	Ghana-Agriculture	Implementing Non-conventional Options for Safe Water Reuse in Agriculture in Resource Poor Environments
IN-1	India-Delhi	Reuse Applications for Treated Wastewater and Fecal Sludge in the Capital City of Delhi, India
IN-2	India-Bangalore	V Valley Integrated Water Resource Management: the Bangalore Experience of Indirect Potable Reuse
IN-3	India-Nagpur	City of Nagpur and MSPGCL Reuse Project
IL-1	Israel/Jordan-Brackish Irrigation	Managing Brackish Irrigation Water with High Concentrations of Salts in Arid Regions
IL-2	Israel/Palestinian Territories/Jordan-Olive Irrigation	Irrigation of Olives with Recycled Water
IL-3	Israel/Jordan-AWT Crop Irrigation	Advanced Wastewater Treatment Technology and Reuse for Crop Irrigation
IL-4	Israel/Peru-Vertical Wetlands	Treatment of Domestic Wastewater in a Compact Vertical Flow Constructed Wetland and its Reuse in Irrigation
JP-1	Japan-Building MBR	A Membrane Bioreactor (MBR) Used for Onsite Wastewater Reclamation and Reuse in a Private Building in Japan
JO-1	Jordan-Irrigation	Water Reuse and Wastewater Management in Jordan
JO-2	Jordan-Cultural Factors	Cultural and Religious Factors Influence Water Reuse
MX-1	Mexico-Tijuana	Water, Wastewater, and Recycled Water Integrated Plan for Tijuana, Mexico
MX-2	Mexico-Mexico City	The Planned and Unplanned Reuse of Mexico City's Wastewater
MX-3	Mexico-Ensenada	Maneadero Aquifer, Ensenada, Baja California, Mexico
MX-4	Mexico-San Luis Potosi	Tenorio Project: A Successful Story of Sustainable Development
PK-1	Pakistan-Faisalabad	Faisalabad, Pakistan: Balancing Risks and Benefits
PS-1	Palestinian Territories-Auja	Friends of the Earth Middle East's Community-led Water Reuse Projects in Auja
PE-1	Peru-Huasta	Assessing Water Reuse for Irrigation in Huasta, Peru

Figure 9-1 Legend

Map code	Text code	Case Study Name
PH-1	Philippines-Market	Wastewater Treatment and Reuse for Public Markets: A Case Study in Sustainable, Appropriate Technology in the Philippines
SN-1	Senegal-Dakar	Use of Wastewater in Urban Agriculture in Greater Dakar, Senegal: "Adapting the 2006 WHO Guidelines"
SG-1	Singapore-NEWater	The Multi-barrier Safety Approach for Indirect Potable Use and Direct Nonpotable Use of NEWATER
ZA-1	South Africa-eMalahleni Mine	Turning Acid Mine Drainage Water into Drinking Water: The eMalahleni Water Recycling Project
ZA-2	South Africa-Durban	Durban Water Recycling Project
ES-1	Spain-Costa Brava	Risk Assessment for *Legionella* sp. in Reclaimed Water at Tossa de Mar, Costa Brava, Spain
TH-1	Thailand-Pig Farm	Sam Pran Pig Farm Company: Using Multiple Treatment Technologies to Treat Pig Waste in an Urban Setting
TT-1	Trinidad and Tobago-Beetham	Evaluating Reuse Options for a Reclaimed Water Program in Trinidad, West Indies
UK-1	United Kingdom-Langford	Langford Recycling Scheme
AE-1	United Arab Emirates-Abu Dhabi	Water Reuse as Part of Holistic Water Management in the United Arab Emirates
VN-1	Vietnam-Hanoi	Wastewater Reuse in Thanh Tri District, Hanoi Suburb, Vietnam

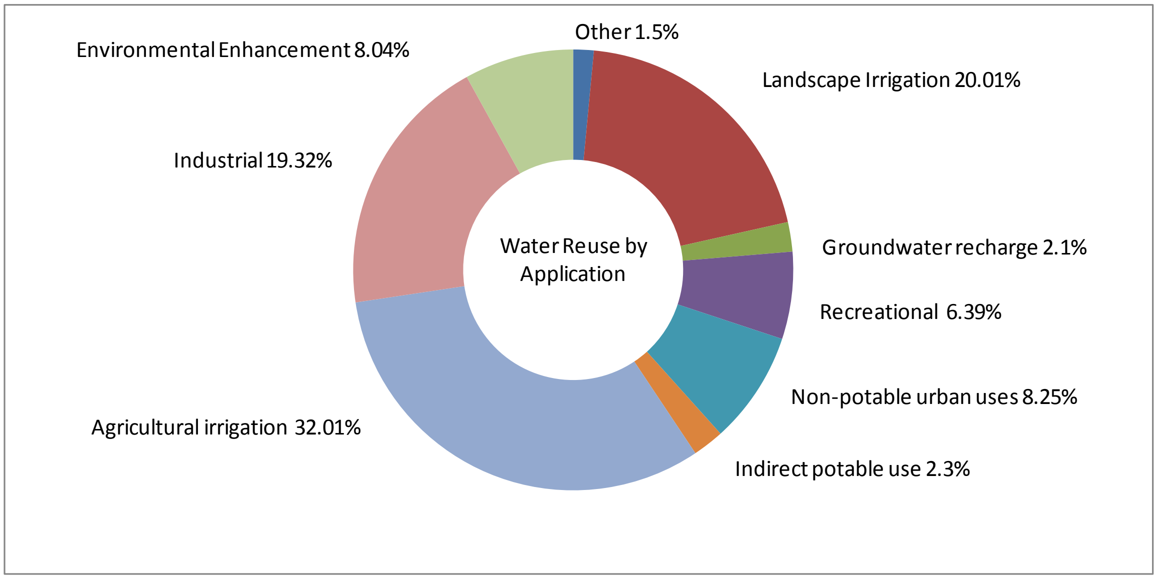

Figure 9-2
Global water reuse after advanced (tertiary) treatment: market share by application (Figure taken from *Municipal Water Reuse Markets 2010* from the publishers of Global Water Intelligence)

9.2 Overview of Global Water Reuse

This section provides an overview of the global status of water reuse, and the case studies illustrate the diverse range of water reuse applications worldwide.

9.2.1 Types of Water Reuse

Water is reused worldwide for agriculture, aquaculture, industry, drinking water, nonpotable household uses, landscape irrigation, recreation, and groundwater recharge. Note that these uses are described in greater detail in Chapter 3, as they are likewise practiced in the United States. **Figure 9-2** shows types of reuse after advanced (tertiary) treatment, which describes only a portion of the actual reuse practiced worldwide.

9.2.1.1 Agricultural Applications

Consistent with the high proportion of fresh water use in the agricultural sector, most reclaimed water used globally serves crop production. Many of the case studies describe applications of using reclaimed water or wastewater for irrigation or other agricultural applications, such as projects highlighted in the following case studies from around the world. In Victoria, reclaimed water is used to irrigate vineyards, tomatoes, potatoes, and other crops in addition to traditional landscape irrigation [Australia-Victoria]. Citrus and olive trees and fodder crops use approximately 90 percent of the available reclaimed water on Cyprus [Cyprus-Irrigation]. Constructed vertical wetlands are being tested and applied for irrigation of fruit trees and gardens in decentralized treatment systems [Israel/Peru-Vertical Wetlands]. In Mexico City, nearly 46 mgd or reclaimed water is used for irrigation of green areas, recharge of recreational lakes and agriculture [Mexico-Mexico City]. Fodder crop irrigation predominates in Jordan with some application for irrigation of date palms and olives [Jordan-Irrigation].

9.2.1.2 Urban and Industrial Applications

Technology-driven approaches that promote advanced reuse include the NEWater project in Singapore [Singapore-NEWater], sensitive manufacturing operations [South Africa-Durban], high-rise office treatment and recycling in Sydney [Australia-Sydney], retirement center toilet flushing and landscape irrigation [Australia-Graywater], and in high-rise buildings in Japan [Japan-Building MBR], other industrial reuse including vehicle washing ([Brazil-Car Wash] and [Mexico-Mexico City]), and cooling for manufacturing operations or energy production as demonstrated in several case studies throughout the world ([Jordan-Irrigation], [Trinidad and Tobago-Beetham], [Mexico-Mexico City], [India-Delhi], and [India-Nagpur]). In the Philippines, reclaimed water from a satellite plant serving the produce market is used for toilet flushing, street washing and plant watering [Philippines-Market]. Reclaimed water is used in Spain for traditional nonpotable irrigation, street washing, fire hydrants, and washdown at the community dog shelter [Spain-Costa Brava]. A wide variety of industries, including commercial laundries, vehicle-washing establishments, pulp and paper industries, steel production, textile manufacturing, electroplating and semiconductor industries, boiler-feed water, water for gas stack scrubbing, meat processing industries, brewery and beverage industries, and power plants, have the capability to use reclaimed water in their operations (Jimenez and Asano, 2008). In the food and beverage industry, reclaimed water is used for cooling and site amenities. Internal process water may also be recirculated or reused with appropriate treatment. Urban amenities, such as stream restoration and other features, may involve reclaimed water, thus representing elements of "cities of the future" visions for sustainable cities (Jimenez and Asano, 2008). In the case study from Barbados, the economic, environmental, and social trade-offs of various reuse schemes were considered [Barbados-Economic Analysis].

9.2.1.3 Aquifer Recharge

Groundwater or aquifer recharge, both planned and *de facto,* is likewise practiced globally (Jimenez and Asano, 2008). Documented cases of aquifer recharge are reported in Israel, South Africa, Germany, Belgium [Belgium-Recharge], Australia, Namibia, India, Italy, Mexico, China, Barbados [Barbados-Economic Analysis], and Cyprus [Cyprus-Irrigation]. Indirect potable recharge following advanced treatment has been studied in Tijuana but not yet implemented [Mexico-Tijuana]. Planned recharge with reclaimed water provides subsurface storage and can enable additional treatment, as discussed in Chapters 3 and 6. In addition to storage for nonpotable reuse (e.g., for agricultural or landscape irrigation, industrial use, etc.) or IPR, replenishment of aquifers experiencing higher rates of withdrawal than natural recharge can prevent saltwater intrusion in groundwater supply in coastal areas and supplement groundwater base flows to promote ecosystem health. On a global scale, wastewater-impacted aquifer recharge is widespread. Often highly polluted and only partially treated (if at all), wastewater drains to rivers or drainage canals connected to underlying unconfined aquifers that may be used for drinking water.

Regardless of the type of reuse application, water quality issues are an important dimension. Ideally, the wastewater source and type of treatment should be matched to the eventual reuse application, also known as "Fit for Purpose," as described in Chapter 1. Reclaimed water suppliers may need to be certified and provide proof of compliance with water quality specifications before they are allowed to supply water to consumers, and systems should be in place to store and retreat water that fails to meet standards and to avoid cross-connection between the distribution systems for reclaimed water and potable drinking water. The planning and management of water reuse is described in Chapter 2.

9.2.2 Magnitude of Global Water Reuse

The total volume of domestic wastewater generated in the world every day is estimated to be between 180 and 250 billion gallons (680 and 960 million m^3), as shown in **Table 9-1** (GWI, 2010; FAO, 2010). The current global capacity to treat wastewater to advanced levels (like tertiary treatment) is approximately 8 billion gallons per day (32 million m^3/day), or only 4 percent of the total volume of wastewater that is generated (GWI, 2010). The volume of wastewater treated beyond secondary treatment for reuse has grown by an average of 500 mgd (2 million m^3/day) each year since 2000, allowing a greater proportion of water to be safely reused (GWI, 2010). Wastewater production is likely to increase with population growth; with expanded sewerage networks there is great potential for expanding the magnitude of global water reuse, especially for high-end usages.

Table 9-1 Global domestic wastewater generated and treated (in billion gallons per day and million cubic meters per day)

	Volume (billion gallons per day)	Volume (million m^3/day)
Total volume of domestic wastewater generated as of 2009	180-250	680-960
Current global capacity to treat wastewater to advanced levels as of 2009	8	32
Total volume of domestic wastewater that is not treated to advanced levels as of 2009	172-242	648-928
Growth in global capacity to treat wastewater to advanced levels (per year since 2000)	0.5	2

Sources: GWI, 2010; FAO, 2010

There is limited reliable data documenting quantities of water reuse and wastewater use in the agricultural sector. The limited evidence that does exist, which is not geographically comprehensive, suggests that the area of land irrigated with untreated wastewater is more than 10 times as great as the area irrigated with reclaimed water (Scott et al., 2010). Rough estimates suggest that about 20 million ha of agricultural land is irrigated with mostly untreated wastewater globally (**Figure 9-3**), and crops produced from such irrigation comprise 10 percent of global agricultural production from irrigation (Scheierling et al., 2010; Drechsel et al., 2010). As such, the proportion of wastewater used in agriculture may be far greater than that shown in **Figure 9-3**, which only summarizes documented cases.

Growth in the global water reuse sector is expected to migrate from being dominated by agricultural reuse toward higher-value applications, mostly in municipal applications, such as potable, industrial, and landscape irrigation reuse. China, the United States, Spain, Mexico, India, Australia, Israel, Kuwait, Japan, and Singapore lead the world in total installed advanced water reuse capacity to date (GWI, 2010). GWI projects that global capital expenditure in advanced water reuse is expected to grow 19.5 percent annually between 2009 and 2016 (GWI, 2010). The countries that are projected to add the greatest additional advanced water reuse are shown in **Table 9-2**. Many of these countries have recently completed major investments in desalination and are now turning to growth in the water reuse sector to meet needs, particularly in growing urban populations.

Table 9-2 Projected reuse capacity in selected countries (data taken from *Municipal Water Reuse Markets 2010* from the publishers of Global Water Intelligence)

Country	Additional advanced reuse capacity (2009-2016)	
	Billion gallons per day	Million m^3/day
USA	2.8	10.7
China	1.6	5.9
Saudi Arabia	0.9	3.5
Australia	0.7	2.5
Spain	0.6	2.1
Mexico	0.6	2.1
United Arab Emirates	0.5	1.9
Oman	0.4	1.6
India	0.3	1.2
Algeria	0.3	1.1

Source: GWI, 2010

DPR and planned IPR still account for a minor proportion of water reuse worldwide (2.30 percent), but the proportion is growing. Of all advanced reuse, approximately 2.3 percent is potable reuse (GWI, 2010). Growth in potable reuse applications is driven by pressures on water supply, along with increased public acceptance because of successful records of performance demonstrated by notable installations in the United States, Namibia, South Africa, and Singapore (GWI, 2010, NRC, 2012). A table summarizing a sampling of IPR installations (and potable in Namibia) is provided in Chapter 3 to illustrate that this practice occurs worldwide, at both very small and very large scales. Singapore has made water reuse a national priority, as described in a case study [Singapore-NEWater]. Decision-makers in Bangalore, India, are developing plans to include IPR as part of an overall approach to narrow gaps between water supply and the demands of a growing population [India-Bangalore]. And in South Africa, a novel partnership between a mining company and a township is turning acid mine drainage into drinking water [South Africa-eMalahleni Mine]. Note that countless other planned IPR applications exist where reclaimed water is deliberately recharged to a groundwater aquifer using rapid infiltration basins or injection wells or to a drinking water reservoir. A representative example of this is from Wulpen, Belgium, where reclaimed water is returned to the aquifer before being reused as a potable water source [Belgium-Recharge]. An example of *de facto* IPR comes from Langford, UK, where reclaimed water is returned upstream to a river that is the potable water source [United Kingdom-Langford].

9.3 Opportunities and Challenges for Expanding the Scale of Global Water Reuse

While the opportunities for expanding reuse are quite significant, there are some challenges related to the country-specific drivers, the regional variation of climate, social acceptance, and financial resources. While some of these factors are barriers to reuse, the benefits of expanding the water reuse will likely outweigh the challenges, ultimately paving the way for reuse to become an ever-growing part of the global water resource/water supply solution.

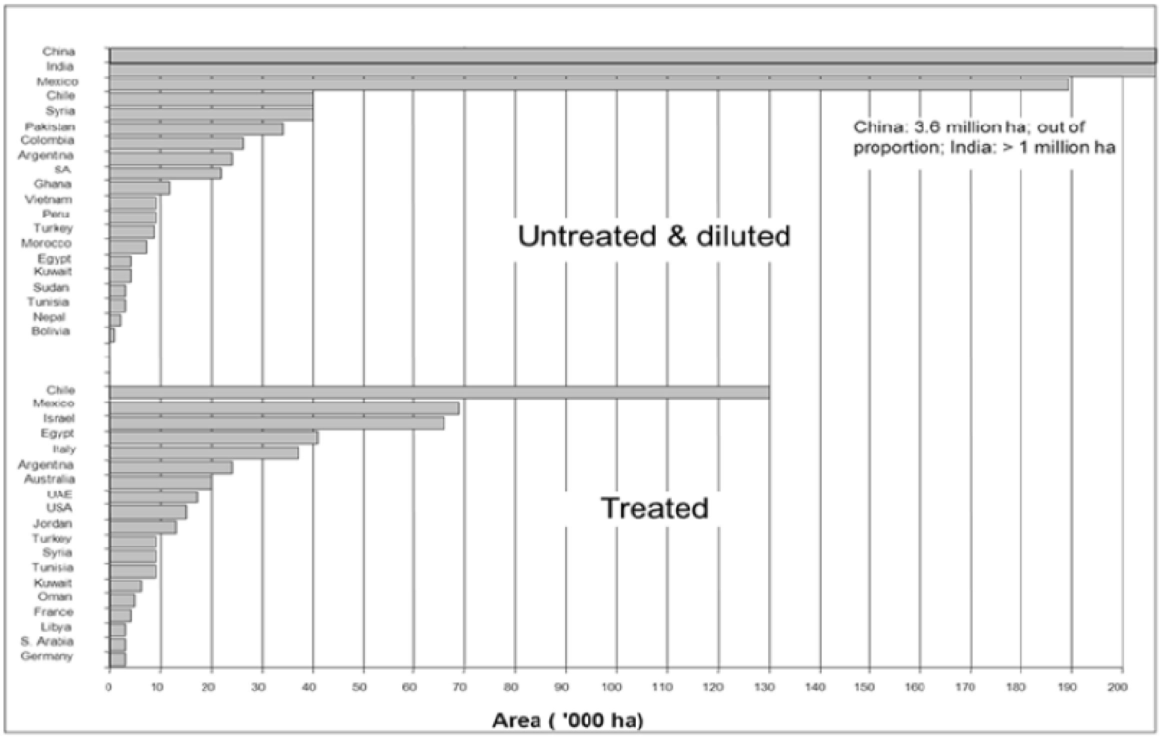

Figure 9-3
Countries with greatest irrigated areas using treated and untreated wastewater (Adapted from Scott et al., 2010).

9.3.1 Global Drivers

Global water reuse is primarily driven by two main factors. First, reuse is a response to rising demand for water and limitations on freshwater availability. Second, water reuse is driven by a desire to capture and harness the economic benefits of wastewater. Wastewater use, on the other hand, is usually driven by the lack of wastewater collection and/or treatment facilities, resulting in untreated wastewater being discharged into the environment where, especially in urban and peri-urban areas of resource-constrained settings, safer water sources are difficult to find (Jimenez et al., 2010; Scott et al., 2010).

The first group of drivers for water reuse typically catalyzes reuse in areas of physical water scarcity, such as the Middle East and North Africa region, Australia, Singapore, and parts of southern Africa. Thus, poor water resources management and climate change may exacerbate conditions of scarcity in some countries and create conditions of scarcity in others. In resource-endowed settings, a desire to protect freshwater resources has fostered the creation of environmental regulations that limit the quantity of water available for human use and uphold standards for the quality of effluent resulting from such use. Application of these regulations has, in turn, promoted greater reuse of existing water rather than development of new water sources.

Economic considerations are also beginning to drive water reuse in high-resource contexts, as the possibility of marketing reclaimed water as a commodity holds the promise of partial return on investment for wastewater treatment (Jimenez et al., 2010). Trends in resource-endowed settings are moving toward the use of treated water at increasingly higher water quality standards for higher-value uses, such as industrial and municipal uses. The prospect of water scarcity begins to discourage lower-value uses, such as agricultural irrigation and aquifer recharge and free or heavily-subsidized use of reclaimed water (GWI, 2010). Economic benefits associated with formal water reuse projects are more likely to be achieved over longer timeframes compared to shorter-term gains from transporting water from distant sources, groundwater mining, and reservoir construction (GWI, 2010).

Wastewater use is often driven by resource constraints and high rainfall variability; wastewater may constitute a large proportion or even all of the flow in water bodies during the dry season. Scarcity of safe water due to the pollution of water resources with wastewater is common in low-resource contexts across any climate, leading to wastewater use. Indeed, in resource-constrained settings, untreated wastewater can serve as an economic resource for poor urban and peri-urban farmers. In many instances, these farmers have no viable alternative to the use of wastewater for their livelihood needs, yet use of such wastewater or polluted stream water often poses a significant threat to the public health of producers and consumers of farm products if not appropriately addressed. An interesting case of wastewater use comes from Pakistan, where local farmers, following extensive legal cases and now with permission from the local water and sanitation authority, have installed a permanent conveyance of untreated wastewater to their irrigation networks. While there is an existing WWTP (a waste stabilization pond), farmers have been opposed to using treated effluent, as it was much lower in nutrients and much higher in salinity (as a result of massive evaporation from the waste stabilization pond) than untreated wastewater [Pakistan-Faisalabad].

9.3.2 Regional Variation in Water Reuse

Factors affecting the regional dynamics of water reuse include economic development priorities, water management options, environmental and climatic factors, social acceptance, and availability of financial resources. Water reuse in the Middle East and North Africa region is typically driven by water scarcity. Some high-income countries in the region use desalination to meet drinking water supply needs and use reclaimed water for agricultural and landscape irrigation using standards based on California Title 22. Middle- and low-income countries in the region use partially-treated or untreated wastewater primarily for specific restricted types of agricultural irrigation and utilize the previous WHO (1989) guidelines to inform approaches to improve human health and safety of water reuse practices (Jimenez and Asano, 2008).

Analysis of reuse patterns in sub-Saharan Africa is hampered by a lack of reliable data. Limited existing evidence suggests that water reuse is driven by water scarcity (Jimenez et al., 2010). In this region, wastewater serves as a reliable water supply for multiple uses and as a source of high nutrient content for agricultural irrigation. Although much of the wastewater use in this region is informal and occurs in the agricultural sector, one of the most high profile and pioneering examples of potable water reuse is a 40-year ongoing project in Namibia involving direct human consumption of highly-purified reclaimed water.

In northern Europe, water reuse is practiced primarily for environmental and industrial applications, whereas in southern Europe, environmental and agricultural applications dominate. Practices generally follow the WHO (1989) guidelines or regulations that closely emulate California Title 22 standards.

Across Central and South America, water reuse is driven by water scarcity and by a desire to recycle wastewater nutrients in areas of poor soil quality. But lack of sanitation is also leading to some of the largest areas of wastewater use, like in Mexico and Chile. Water scarcity is the main driver for planned reuse in the drier areas of the Caribbean islands, Mexico, and Peru. Agricultural irrigation is the primary application. Wastewater use dominates, although there are many documented cases of planned reuse projects. WHO (1989) guidelines are used to improve the safety of reuse practices, but implementation is not universal.

The situation in Asia varies among its subregions. While China and India show significant progress in high-quality reuse (GWI, 2010), both countries are still among the global leaders of unplanned use of wastewater (**Figure 8-3**), often via contaminated streams. Poor sanitation is also driving wastewater use across Central Asia and, to an even greater degree, Southeast Asia, where, in addition to agriculture, wastewater-fed aquaculture is also common.

Reuse in Australia is driven by both water scarcity and high environmental standards. Key applications include industrial mining, agricultural irrigation, and recreation. National coordinated water policies have incentivized expansion of water reuse practices, and regulations recognize a combination of natural treatment and advanced technology approaches.

9.3.3 Global Barriers to Expanding Planned Reuse

From a technical standpoint, water reuse is a logical part of the overall water supply and water resources management solution. However, there are often projects that are technically feasible but do not get implemented. In these cases, the barriers to implementing reuse are often institutional, economic, organizational, or related to public perception/ education. Thus, a discussion of these non-technical barriers to expanding planned reuse is provided in this section.

9.3.3.1 Institutional Barriers

A basic driver of wastewater use—and barrier to wastewater treatment and planned reuse—in much of the world is the dearth of effective collection and treatment systems for fecal matter and sewage (**Table 9-3**). In resource-endowed urban areas, comprehensive sewer system coverage serves as a conduit for wastewater to be channeled to treatment plants in order to be safely released or reused. In resource-constrained settings, however, such infrastructure often either does not exist or does not terminate in functional treatment plants. While developing an extensive sewerage network is often a recommended step toward improving water reuse, it is important to recognize that improvements in on-site sanitation systems and related collection services can also significantly reduce the environmental burden and health risks associated with wastewater management.

It is worth noting that China has made a strong emphasis on installing urban wastewater treatment over the past decade. As of 2010, 75 percent of Chinese cities are now connected to wastewater treatment, according to official governmental estimates (Xinhua, 2011).

While lack of appropriate infrastructure poses a constraint on water collection, treatment, and safe reuse in some areas, there are at least two broader barriers to planned water reuse. They are 1) limited institutional capacity to formulate and institutionalize enabling legislation and to subsequently conduct adequate enforcement and monitoring of water reuse activities, and 2) lack of expertise in health and environmental risk assessment and mitigation. One limiting factor is a lack of political will to formalize an existing use of untreated or partially treated wastewater due to the institutional and enforcement hurdles that must be put in place to support planned reuse. Governments may feel they lack the capacity and budget to adequately implement these necessary reforms and thus risk causing farmers to lose access to existing sources of irrigation water. An underlying basis for these barriers, in turn, has been a funding bias towards conventional infrastructure investments, which may not always be fit-for-purpose (Nhapi and Gijzen, 2004; Murray and Drechsel, 2011). A critical issue, highlighted in subsequent sections, is adapting regulations and institutional capacities to local contexts to achieve the achievable rather than adopting over-ambitious policies that spur few sustainable, on-the-ground improvements. Australia has provided technical guidance to providers and users in designing agreements that address the legal and technical aspects of reuse and, therefore, allow providers to better control their costs (Wintgens and Hochstrat, 2006).

Table 9-3 Percent of urban populations connected to piped sewer systems in 2003-2006 (regional averages)

Region	Number of countries with available data	Connected urban population (%)
United States and Canada	2	94
European Union*	18	90
Australia*	1	87
Central Asia	5	83
Middle East and North Africa	7	83
Namibia, South Africa, Zambia, Zimbabwe	4	68
Latin America and the Caribbean	21	64
China	1	56
South Asia	6	31
Sub-Saharan Africa **	24	9
South-East Asia	5	3

Source (all countries except United States): Modified after Evans et al. 2012; based on Joint Monitoring Programme, 2012; United Nations Department of Economic and Social Affairs, 2011; United Nations Statistics Division, 2011; and Eurostat, 2006. US data: GWI, 2010 (population served in 2004) and JMP, 2012 (population in 2004).

* Rural and urban population
** Excluding Namibia, South Africa, Zambia, Zimbabwe
Note: Sewer connection does not automatically imply wastewater treatment.

9.3.3.2 Public Perception/ Educational Barriers

Additional barriers include public perceptions that may drive fear of the dangers of consuming food irrigated with reclaimed water, spurring a preference for use of freshwater. Concerns about the failure of conventional treatment technologies to remove TrOCs, such as pharmaceuticals and endocrine disruptors, are also an impediment to reuse for drinking water supply purposes (GWI, 2010). However, successful potable reuse projects and increased familiarity with advanced treatment technologies, such as UF, RO, and UV disinfection, signal a possibility that public discomfort with potable reuse may be declining (GWI, 2010). As described in Chapter 8, public outreach programs to build awareness and involve community members in planning can change resistance to reuse. Singapore has carried out an impressive public awareness program to build a national commitment to water reuse [Singapore-NEWater]. In the city of San Diego, Calif., intense public opposition to water reuse changed over a period of many years, largely because of public outreach and stakeholder involvement, in addition to the economic driver of local water scarcity [US-CA-San Diego].

In resource-constrained settings, public attention to risks of using untreated wastewater has not reached the level of attention as in resource-endowed settings. However, public attitudes are subject to change, particularly in response to real or perceived failures or contamination events and associated media attention (Wintgens and Hochstrat, 2006). Establishing a regulatory framework for water reuse practices and health- or environmental-based standards or guidelines, ideally based on internationally-recognized guidelines, should be a first step (Jimenez and Asano, 2008). To promote risk awareness and behavior change, educational campaigns and social marketing techniques will be required where obvious benefits are not perceived (Karg and Drechsel, 2011)

As discussed in Chapter 8, proper use of language that does not stigmatize reclaimed water is also quite important when water professionals communicate water reuse ideas to the public. Words such as “wastewater reuse,” “reuse water,” etc., are stigmatizing and negative to the public while “water recycling,” “new water,” “purified water”—and to a lesser extent “reclaimed water”—are more appealing and likely to promote public acceptance (Macpherson, 2012). To clarify the appropriateness of reclaimed water to the faithful, certain Muslim scholars have issued Fatwas declaring that reclaimed water is clean enough for ablution and other purposes, as long as technical experts attest to its purity and safety for such uses. Examples of these Fatwas can be viewed in original Arabic and in English translation and are described in a case study from Jordan [Jordan-Cultural Factors] (Senior Scholars Board in the City of Taif, 1978; Abu Dhabi Islamic Court, 1999).

9.3.3.3 Economic Barriers

The long-term economic viability of reuse projects also represents an important barrier to water reuse. Reclaimed water is often priced just below the consumer cost of drinking water to make it more attractive to potential users, but this may also affect the ability to recover costs (Jimenez and Asano, 2008). Distortion in the market for drinking water supply complicates the pricing of reclaimed water, as does the lack of accounting for externalities, including water scarcity and social, financial, and environmental burdens of effluent disposal in the environment (Wintgens and Hochstrat, 2006; Sheikh et al., 1998). Although there is a movement towards increased or even full operations and maintenance cost recovery in the large market of agriculture water reuse (Morocco, Tunisia, Jordan), this is still the exception among many state-run service providers. There may, however, be opportunities to set different tariff levels for different classes or types of users, thus subsidizing the resource for the poor while recovering costs from groups that are able to pay. Finally, financing of up-front costs remains an important barrier to introducing new reuse programs and often requires government intervention in the form of grants or subsidies combined with eventual revenues.

9.3.3.4 Organizational Barriers

Fragmentation of responsibilities for and authority over different parts of the water cycle is another impediment that must be overcome before water reuse projects can go forward. In many regions the authority over the water supply sector resides in an entirely different organization than that over wastewater management. This separation of powers leads to long periods of inaction, stalemate, disagreement, negotiation, and complex interagency agreements that make the resulting water reuse project far more costly and complex than need be. Regions where the same authority manages water, wastewater, stormwater, and the watershed are far more nimble, implementing their water reuse projects quickly, efficiently, and at much lower cost (Sheikh, 2004).

9.3.4 Benefits of Expanding the Scale of Water Reuse

Similar to the factors driving current levels of water reuse, a range of incentives for increasing, especially, planned water reuse in the coming years appear to exist. Indeed, there are at least several economic, environmental, and social benefits that can be achieved through expanding safe and sustainable reuse of water.

First, there is an opportunity to increase water availability and reliability without tapping new water sources, which either may not exist or may carry adverse consequences. For example, as there has been increased opposition on environmental grounds to dam-building projects, new desalination plants, and groundwater mining as a means of securing new water supplies, water reuse has emerged as a viable and more environmentally-sound alternative (GWI, 2010). Water reuse also avoids environmental pollution caused by releasing wastewater, treated or not, to receiving streams. Reclaimed water is available continuously, even during drought periods, and is produced where people live. Additionally, the use of reclaimed water may augment natural flows in surface waters (with cascading positive effects on ecosystem health and biodiversity) and may contribute to rising groundwater tables where reclaimed water is used for crop or landscaping irrigation, as has been documented in parts of Mexico (IWMI and Global Water Partnership, 2006).

Second, reuse provides opportunities to recover valuable resources, including water, energy, and nutrients. Third, expanding safe and sustainable water reuse helps reduce the human health costs associated with unplanned wastewater use. Finally, increasing water availability through reuse may help to reduce conflicts over water due to scarcity or resource limitations.

Some benefits are specific to or more commonly occur in resource-endowed or resource-constrained settings. For example, recreational (contact or non-contact) or aesthetic benefits may be experienced in resource-endowed settings when water is reused in urban water features and stream restoration projects. Other benefits that are more likely to occur in resource-endowed contexts include partial recovery of treatment costs; savings on production costs in industrial reuse scenarios; and cost savings when treatment is matched to eventual reuse applications. In resource-constrained settings, likely benefits include increased nutrition, food security, and income (Keraita et al., 2008) for farmers, as well as other groups along the urban/peri-urban agricultural value chain, including women who are often traders of urban agricultural products in Sub-Saharan Africa (IWMI and GWP, 2006).

9.4 Improving Safe and Sustainable Water Reuse for Optimal Benefits

There are different options for optimizing benefits of safe and sustainable water reuse. In areas where wastewater use is currently being practiced, there are ways to reduce the risks associated with it without treating wastewater prior to use. It may also be possible to begin transitioning to wastewater treatment and water reuse when certain factors are present, as described in Section 9.4. Finally, in areas where water reuse is currently occurring, there are ways to optimize benefits of reuse by transitioning to higher-value uses and imposing stricter regulations for environmental conservation.

Importantly, the sheer scale of the opportunity (or challenge) for increasing safe and sustainable water reuse may call for use of any combination or all of these approaches. There is indeed tremendous potential to increase the scale of safe and sustainable water reuse, for at least two reasons. First, as highlighted above, only a small proportion of wastewater that is currently generated is used in a planned context for high-value applications. Second, given trends in population growth and urbanization, the quantity of wastewater generated is likely to increase substantially in the future.

9.4.1 Reducing Risks of Unplanned Reuse: The WHO Approach

Improving safe and sustainable water reuse in areas of currently unplanned practice has been greatly influenced by the WHO guidelines (1989, 2006). In 2006 the WHO released a four-volume report titled *Guidelines for the Safe Use of Wastewater, Excreta and Greywater*. The first volume focuses on policy and regulatory aspects of wastewater, excreta, and graywater use; the second volume focuses on use of wastewater in agriculture; the third volume focuses on wastewater and graywater use in aquaculture; the fourth volume focuses on excreta and graywater use in agriculture. The discussion in the WHO guidelines is limited to wastewater, excreta, and graywater from domestic sources that are applied in agriculture and aquaculture.

Rather than relying on water quality thresholds as in past editions (WHO, 1989), the most current WHO guidelines (2006) adopt a comprehensive risk assessment and management framework. This risk assessment framework identifies and distinguishes among vulnerable communities (agricultural workers, members of communities where wastewater-fed agriculture is practiced, and consumers) and considers trade-offs between potential risks and nutritional benefits in a wider development context. As such, the WHO approach recognizes that conventional wastewater treatment may not always be feasible, particularly in resource-constrained settings, and offers alternative measures that can reduce the disease burden of wastewater use. The specific approach utilized by the WHO (2006) guidelines is to 1) define a tolerable maximum additional burden of disease, 2) derive tolerable risks of disease and infection, 3) determine the required pathogen reduction(s) to ensure that the tolerable disease and infection risks are not exceeded, 4) determine how the required pathogen reductions can be achieved, and 5) put in place a system for verification monitoring.

Table 9-4 presents an overview of selected treatment and non- or post-treatment health protection measures in agricultural water reuse and their potential to reduce pathogen loads (WHO, 2006; Amoah et al., 2011). While each of the risk mitigation measures can be employed in isolation, comprehensive risk reduction is best achieved when measures are used in combination—the multi-barrier approach. To protect farmers themselves, awareness campaigns on the invisible risk of pathogens should accompany the promotion of protective clothing (boots, gloves, etc.), hygiene, and where possible, a shift to irrigation methods that minimize human exposure, like drip irrigation. Compared to conventional wastewater treatment, on- and off-farm risk mitigation measures are usually cheaper and more cost-effective, indicating suitability for resource-constrained contexts. For example, estimates from Ghana show that some of these measures can avert up to 90 percent of the estimated disease burden related to wastewater irrigation at a cost-effectiveness below $100 per averted DALY [Ghana-Agricultural] (Drechsel and Seidu, 2011). The case study from Senegal illustrates how unsafe wastewater use can be tied up in complex political factors. In Dakar, Senegal, urban farmers divert wastewater from sewage pipes to irrigate their small plots. As these plots are often seized for housing, farmers choose to grow short-rotation crops such as lettuce. If farmers were guaranteed a more formalized land tenure status, they might be willing to make longer-term investments in on-site water treatment approaches or switch crop choices to those that grow slower (with similar overall profit), but are not eaten raw [Senegal-Dakar]. The health protection measures listed in **Table 9-4** could be implemented to improve the unsafe use of diluted wastewater for vegetable production pictured in **Figure 9-4**.

The most effective health protection recommendation is the production of crops not eaten raw. However, this option requires appropriate monitoring capacity and viable crop alternatives for farmers. Other options include on-farm treatment and application techniques, as well as the support of natural die-off as described in two Africa case studies, [Ghana-Agricultural] and [Senegal-Dakar], and natural attenuation in non-edible aquatic plants lining irrigation canals [Vietnam-Hanoi] (Amoah, et al., 2011). There is reported success of blending of wastewater with higher-quality water to make it more suitable for production ([Vietnam-Hanoi], [Senegal-Dakar], [India-Delhi], [Jordan-Irrigation], and [Israel/Palestinian Territories/Jordan-Olive Irrigation].

In addition to the risks from pathogen contamination, wastewater may have chemical contaminants from industrial discharges or stormwater runoff. The WHO (2006) guidelines provide maximum tolerable soil concentrations of various toxic chemicals based on human exposure through the food chain. For irrigation water quality, WHO refers to the FAO guidelines, which focus on plant growth requirements and limitations (Ayers and Westcot, 1985; Pescod, 1992). The guidelines do not specifically address how to reduce chemical contaminants from wastewater for use in irrigation. Resource-constrained countries may have historically been less prone to heavy metal contamination that is usually localized and associated with industrial activities, but where industries are emerging, industrial source control measures are required to avoid potential contamination in food crops.

Likewise, where required, stormwater should be diverted and treated to remove pollutants. Alternative options for low-income countries to reduce the potential risk of chemical contamination, like through phytoextraction, crop selection, and soil treatment are limited (Simmons et al., 2010).

Table 9-4 Selected health-protection measures and associated pathogen reductions for wastewater reuse in agriculture

Control measure	Pathogen reduction (log units)	Notes
A. Wastewater treatment	1−6	Pathogen reduction depends on type and degree of treatment technology selected.
B. On-farm options		
Alternative land and water source	6-7	In Ghana, authorities supported urban farmers using wastewater by drilling wells. In Benin, farmers were offered alternative land with access to safer water sources.
Crop restriction (i.e., no food crops eaten uncooked)	6−7	Depends on (a) effectiveness of local enforcement of crop restriction, and (b) comparative profit margin of the alternative crop(s).
On-farm treatment:		
(a) Three-tank system	1−2	One pond is being filled by the farmer, one is settling and the settled water from the third is being used for irrigation
(b) Simple sedimentation	0.5−1	Sedimentation for ~18 hours.
(c) Simple filtration	1−3	Value depends on filtration system used
Pathogen die-off (fecal sludge)	in line with WHO 2006	Raw fecal sludge used in cereal farming in Ghana and India should be dewatered on-farm for ≥ 60 days or ≥ 90 days depending on the application method (spread vs. pit) to minimize occupational health risks.
Method of wastewater application:		
(a) Furrow irrigation	1−2	Crop density and yield may be reduced.
(b) Low-cost drip irrigation	2−4	2-log unit reduction for low-growing crops, and 4-log unit reduction for high-growing crops.
(c) Reduction of splashing	1−2	Farmers trained to reduce splashing when watering cans used (splashing adds contaminated soil particles on to crop surfaces which can be minimized).
Pathogen die-off (wastewater)	0.5−2 per day	Die-off support through irrigation cessation before harvest (value depends on climate, crop type, etc.).
C. Post-harvest options at local markets		
Overnight storage in baskets	0.5−1	Selling produce after overnight storage in baskets (rather than overnight storage in sacks or selling fresh produce without overnight storage).
Produce preparation prior to sale	1−2	(a) Washing salad crops, vegetables and fruit with clean water.
	2−3	(b) Washing salad crops, vegetables and fruit with running tap water.
	1−3	(c) Removing the outer leaves on cabbages, lettuces, etc.
D. In-kitchen produce-preparation options		
Produce disinfection	2−3	Washing salad crops, vegetables and fruit with an appropriate disinfectant solution and rinsing with clean water.
Produce peeling	2	Fruits, root crops.
Produce cooking	6−7	Option depends on local diet and preference for cooked food.

Sources: EPHC, NRMMC, and AHMC, 2006; WHO 2006; Amoah et al. 2011; modified from Mara et al., 2010

Figure 9-4
Reducing the pathogenic health risks from unsafe use of diluted wastewater
(Pictured left) The use of diluted untreated wastewater is prevalent in vegetable production in West Africa, such as here from a wastewater canal (Photo credit: IWMI). In the absence of wastewater treatment, possible pathogenic health risks from unsafe wastewater use could be reduced by implementing on-farm, post-harvest, and in-kitchen protection measures. (Pictured right) One on-farm option is the use of settling basins prior to irrigation. Comprehensive risk reduction is best achieved when multiple measures are used in combination. (Photo credit: Andrea Silverman)

9.4.2 Expanding and Optimizing Planned Water Reuse

As countries or municipalities in resource-constrained settings build operational and financial capacity, reuse safety should progress incrementally from on-farm and off-farm safety options to centralized or decentralized wastewater treatment, while establishing sound regulatory and monitoring protocols (Von Sperling and Fattal, 2001; Drechsel and Keraita, 2010; and Scheierling et al., 2010). This step-wise approach, recommended by WHO (2006), provides local public health risk managers with flexibility to address wastewater irrigation risks with locally viable options matching their capacity within a multi-barrier framework (**Figure 9-5**), instead of struggling to achieve water quality threshold levels as the only regulatory option (Von Sperling and Chernicharo, 2002). When treatment capacity has increased and irrigation water quality can be managed, the introduction of water quality standards should follow a similar incremental approach. The shift from water quality standards (WHO, 1989) to health-based targets (WHO, 2006), has helped to support a much broader range of measures for improving safe water reuse.

Reuse schemes often evolve from household and decentralized systems to eventual centralized urban systems (Scheierling et al., 2010). However, it is important to remember that household and decentralized schemes may continue to be desirable in high-resource settings for some applications, such as graywater reuse for toilet flushing and sewer mining ([Palestinian Territories-Auja] and [Australia-Graywater]). The regulatory framework for reuse in these contexts should continue to support small-scale and potentially low-cost options where appropriate and where health and environmental risks can be minimized.

Wastewater quality regulations and standards from 28 countries are compiled by GWI (2011). Common challenges associated with establishing and implementing standards, especially in countries with limited resources, are summarized in **Table 9-5**, along with recommendations to overcome these challenges.

Appropriate technologies and practices for wastewater treatment for agricultural reuse are one way to reduce risks to public health where direct wastewater use is prevalent. There is a wide range of wastewater treatment options for safe water, nutrient recovery, and irrigation with particular relevance for resource-constrained countries. Many experts in the field have summarized appropriate treatment options, including Mara (2004), Laugesen et al. (2010), Von Sperling and Chernicharo (2005), and Scheierling et al. (2010). As advances are made to drive down the cost of centralized and decentralized treatment technologies in resource-endowed contexts, some of the "high-tech" technologies, including MBR, may be adapted to lower-resource settings. Advances in decentralized wastewater treatment technologies and schemes may be particularly relevant in rapidly growing urban contexts where installation of centralized collection and treatment infrastructure is not cost-effective ([Japan-Building MBR] and [Australia-Graywater]). However, decentralized systems are not a panacea where institutional capacities are generally low (Murray and Drechsel, 2011).

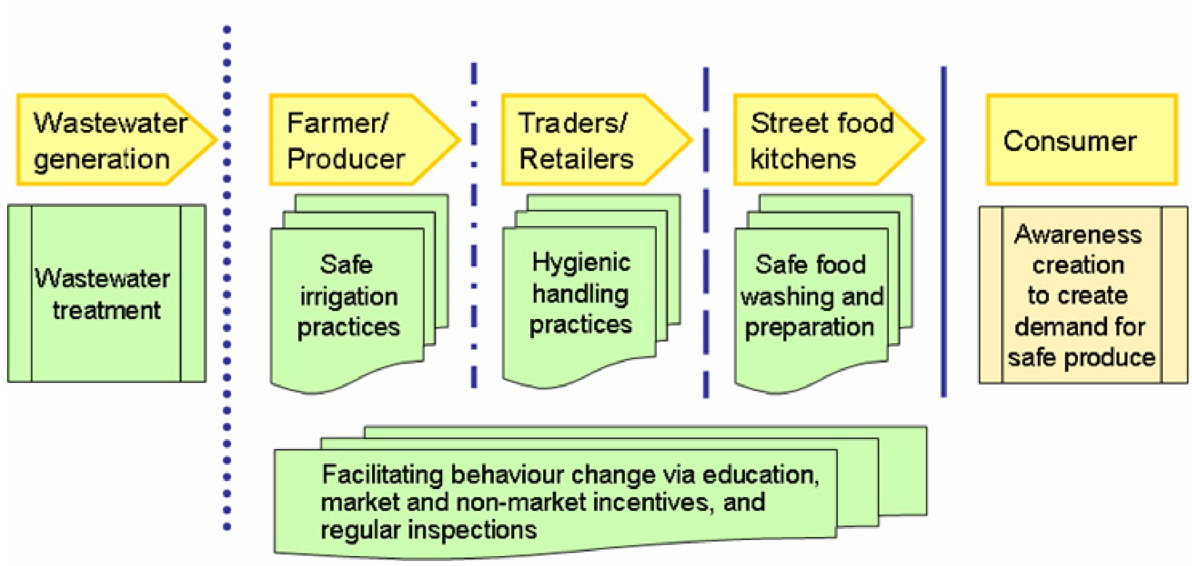

Figure 9-5
Multi-barrier approach to safeguard public health where wastewater treatment is limited (Amoah et al., 2011)

Table 9-5 Challenges and solutions for reuse standards development and implementation

Observation	Recommendation
Guidelines, frequently copied from developed countries, are directly adopted as national standards.	Each country should adapt the guidelines, based on local conditions, and derive the corresponding national standards. In developed countries, these resulted from a long period of investment in infrastructure, during which standards were progressively improved. Cost and maintenance implications of too strict standards in the short term should be taken into account.
Guideline values are treated as absolute values, and not as target values.	Guideline values should be treated as target values, to be attained on a short, medium or long term, depending on the country's technological, institutional or financial conditions.
Treatment plants that do not comply with global standards do not obtain licensing or financing.	Environmental agencies should license and banks should fund control measures which allow for a stepwise improvement of water quality, even though standards are not immediately achieved. However, measures should be taken to effectively guarantee that all steps will be effectively implemented.
There is no affordable technology to lead to compliance of standards.	Control technologies should be within the countries' financial conditions. The use of appropriate technology should always be pursued.
Standards are not actually enforced.	Standards should be enforceable and actually enforced. Standard values should be achievable and allow for enforcement, based on existing and affordable control measures. Environmental agencies should be institutionally well developed in order to enforce standards.
Discharge standards are not compatible with water quality standards.	In terms of pollution control, the true objective is the preservation of the quality of the water bodies. Discharge standards should be based on practical (and justifiable) reasons, assuming a certain dilution or assimilation capacity of the water bodies.
Number of monitoring parameters are frequently inadequate (too many or too few).	The list of parameters should reflect the desired protection of the intended water uses and local laboratory and financial capacities, without excesses or limitations.
There is no institutional development that could support and regulate the implementation of standards.	The efficient implementation of standards requires an adequate infrastructure and institutional capacity to license, guide, and control polluting activities and to enforce standards.
Reduction of health or environmental risks due to compliance with standards is not immediately perceived by decision makers or the population.	Decision makers and the population at large should be well informed about the benefits and costs associated with the maintenance of good water quality, as specified by the standards.

When transitioning from wastewater use to planned reuse, it is important to consider a country or city's readiness to sustain investments in wastewater collection and treatment and the value added by treatment versus risk reduction through non-treatment barriers. There is no shortage of sanitation infrastructure that has fallen into disrepair, for example, and restrictions associated with reuse of treated wastewater has at times caused farmers to return to using untreated wastewater (Scheierling et al., 2010). It is therefore necessary to move toward planned reuse in a circumspect, phased approach whereby initial implementation is monitored for efficacy and sustainability before a larger-scale initiative is undertaken. Moving from wastewater use toward planned reuse requires a context-specific approach in light of institutional limitations and resource constraints. The following lessons of transitioning to wastewater collection, treatment, and reuse can be drawn from global experiences:

Consider overall infrastructure needs. In many cities of the world without functioning wastewater collection systems, stormwater and wastewater flow through unlined engineered or natural drainage paths. The cost of upgrading or constructing a collection system must be considered.

Consider local capacities. A key consideration in choosing appropriate treatment technologies is operator capacity. If a water reuse scheme is being planned and institutionalized at the municipality level, as exemplified in several case studies from India ([India-Nagpur], [India-Delhi], and [India-Bangalore]), as opposed to a community or small institution scale ([Palestinian Territories-Auja], [Israel/Peru-Vertical Wetlands], and [Peru-Huasta]), a different set of technologies and practices will be appropriate and perhaps required in consideration of differing operator capacity, sophistication, and resource levels. Treatment and reuse schemes should therefore be designed to align with the social, environmental, technological, and economic circumstances of the target location/operator to achieve maximum sustainability (Von Sperling and Chernicharo, 2002; Nhapi and Gijzen, 2004).

Match treatment approach with reuse application at design stage. Several considerations should be taken into account when choosing an appropriate set of technologies to incorporate into the design of a planned reuse scheme. The treatment approach should be chosen to match the intended reuse application at the design stage rather than retrofitted after construction (Huibers et al., 2010; Murray and Buckley, 2010). This approach may represent a departure from conventional approaches that treat wastewater immediately to meet water quality standards for discharge to receiving waters. This goal may not be achievable where there is an existing WWTP and no capability to convey treated wastewater directly to the reuse application. It also may not apply where the reuse application can only absorb a small amount of the discharged wastewater. However, where there is an opportunity to design a new facility with a reuse component, there is potential to achieve significant cost and energy savings by matching the level of treatment (and thus the investment in treatment technology and construction) to the intended reuse, as water quality standards for uses such as irrigation of forest plantations and cooling water for industrial processes may be much lower than standards for aquatic discharge. Also, for some irrigation applications it is necessary to reduce fertilization rates based on the increased nutrient content found in reclaimed water. Where possible, it will be important to implement a design flexible enough to accommodate future increases in demand for reclaimed water for the same application, as well as additional applications. This may require a phased approach to constructing treatment capacity and a design that does not preclude potential future treatment processes required for a broader range of water reuse applications.

Consider overall costs and benefits. As highlighted in the Hyderabad Declaration of 2002, wastewater irrigation can have significant positive livelihood implications for poor smallholder farmers (EPA, 2004). These cost benefits can be considerable—even where wastewater is used without ideal treatment, especially in a low-resource context where households are facing multiple health risks. These economic benefits might outweigh health risks to the farmer and his/her family. Overly strict standards in these circumstances might be counterproductive, even for public health. In Ouagadougou and Lima, for example, farmers are not allowed to use treated wastewater as it does not meet ideal standards. As a result, farmers continue using untreated wastewater for crop production.

Resource Recovery and Reuse: a Strategic Research Portfolio

An international research program addressing water reuse—Resource Recovery and Reuse (RRR) Strategic Research Portfolio—was recently launched by the Consultative Group on International Agricultural Research (CGIAR). The RRR research is part of the CGIAR's strategic objective to enhance sustainable management of the natural resource base supporting agriculture to feed a rapidly growing global population. The first three-year budget (2011–13) is estimated at US$ 7 million and is coordinated by IWMI, a CGIAR center. USAID is one of several major donors to the CGIAR system.

The research under this theme will look at how to enhance the recovery of water, nutrients, organic matter, and energy from otherwise wasted resources for use in agriculture, serving two critically important goals. First, more nutrients and water will be available for use in agriculture even as the natural stocks of nutrients, such as phosphorus, become more expensive to mine. Second, the research will engage the private sector to identify opportunities for generating revenue that will support the sanitation service chain for the benefit of those exposed to poor sanitation and unsafe food.

The research will explore existing, emerging, and potential business models; provide scientific guidance; and make policy recommendations to maximize the untapped potential for recovering water, essential nutrients, and biogas. At the same time, the research will promote safer and healthier practices when reusing waste materials on farms and when processing crops for consumption in local markets.

Critically, the research will contribute to notable gains in food security by helping to alleviate water scarcity and restore nutrient losses on agricultural lands.

For more information, see IWMI's website on the research program: <www.iwmi.org/Topics/RRR>

Where planned reuse is already being undertaken, there are at least two ways to strengthen its safety and sustainability for optimal benefits:

1. Transition to higher-value planned water reuse
2. Give greater consideration to environmental protection

Both options for strengthening planned water reuse imply moving beyond the WHO guidelines focus on protecting human health. The first point above calls for a shift from viewing treatment of wastewater as an obligation, either to protect human health or to satisfy environmental regulations, to viewing it as an opportunity to exploit a valuable economic resource. There is, indeed, growing recognition on the part of governments, from Arizona to Saudi Arabia, that the sale of treated wastewater can generate valuable revenues (GWI, 2010).

However, the greatest revenues come almost entirely from advanced water reuse applications, which require more advanced treatment and as such are better suited to applications other than agriculture. A major constraint to unlocking the market potential of water reuse are policies in many countries that force utilities to provide treated wastewater—even wastewater treated to an advanced level—to the agriculture sector. A major key to tapping the high value potential of water reuse, therefore, is overcoming strict government regulations and the public perceptions that often drive them, in order to open the domestic and industrial sectors to greater use for treated water (GWI, 2010).

It should be noted that liberalizing the allocation of reused water could result in a greater proportion of wastewater allocation to high-value, non-agriculture uses, possibly resulting in less water for agriculture. However, it is important to remember that this is not a zero-sum game. As highlighted above, there are large quantities of wastewater that are currently untreated and/or unused. It may very well be possible with treatment of growing volumes of wastewater, for example, to continue to provide reclaimed water to agriculture in addition to fostering increased reuse for higher-value applications, such as industrial and municipal applications.

Nonetheless, transitioning to higher-value uses can be hampered by the often low, subsidized price of drinking water, which drives down the sale price of recycled water, as well as the subsidized cost of sanitation and treatment services (Jimenez and Asano, 2008). Water pricing policies may need to be adopted that promote total water management, cost recovery of treatment, and service provision as a means of incentivizing water reuse. Comparing the cost of highly-treated recycled water with the price of highly-subsidized potable or irrigation water is an economic fallacy. This common comparison ignores both the numerous benefits inherent in water reuse and externalized costs of potable water under nearly all circumstances. The more appropriate comparison takes into account both sets of economic values and services using sophisticated quantification methods that go beyond simplistic benefit/cost ratios or price-versus-cost comparisons.

In addition to transitioning to higher-value uses, a second way to strengthen the safety and sustainability of planned water reuse is to give greater consideration to environmental protection, enhancement, and restoration. Indeed, countries may decide to graduate from the WHO model and address environmental concerns along with public health issues. In particular, water quality standards and guidelines for environmental flows may be instated to promote a desired level of treatment and volumes to divert for reuse. Standards are often set to reflect the degree of pathogen and contaminant removal possible with best-available treatment technologies. An overall regulatory strategy for water reuse is typically driven by the economics of treatment and monitoring, as well as enforcement capacity (Jimenez and Asano, 2008). In the agricultural sector, water quality standards for water reuse on export crops may also be influenced by standards required by the importing countries or regions. These improvements would build on previous low-cost steps to reduce public health risks and toxic contamination at the source, as outlined in the Hyderabad Declaration (IWMI and International Development Research Centre, 2002).

9.5 Factors Enabling Successful Implementation of Safe and Sustainable Water Reuse

Global experiences have demonstrated that choosing an appropriate set of technologies or regulations is not in itself sufficient to ensure the safety and sustainability of a given water reuse project, especially under resource-constrained conditions. A set of factors must be established to support the long-term functioning of the water reuse program to achieve sustainability. Some of these factors are discussed in this section.

Stakeholder process. Although participatory processes can take more time compared with less-participatory approaches, risk of failure will be reduced by explicit integration of all relevant institutions and stakeholders in the planning and design phases of water reuse schemes. This applies in particular to water reuse in agriculture, which links different sectors (sanitation, agriculture, health, and environment). While regulatory frameworks that govern wastewater treatment and reuse schemes are typically crafted at the national or regional level of government, it is usually the responsibility of local or municipal institutions to implement the programs, including long-term financing, cost recovery, operations and maintenance, and performance monitoring. In the case of Ghana, for example, treatment plants at universities, hospitals, and military camps were operated by the Ministries of Education, Health, and Defense, respectively (Murray and Drechsel, 2011). This places a significant responsibility on local institutions without ensuring their improved capacities. National-level frameworks are indeed a key enabling factor, as illustrated in the Nagpur, India case study [India-Nagpur].

Another critical element of the multi-stakeholder planning process is involving the end users in the planning and design phases. If end-user preferences for reclaimed water volumes and quality are not taken into account during the planning phase, the end users may not be able to make full use of the provided water or may refuse to pay for the service. Also, the treatment technology selected for the project should consider local experience in what works and what does not. Involving representatives from the communities that both supply and use the treated water will facilitate negotiations and "water swaps." For example, farmers may be willing to transfer a portion of their freshwater allocations to meet urban water demand if they are provided access to treated, nutrient-rich, and reasonably-priced reclaimed water for agricultural activities (Winpenny et al., 2010; Huibers et al., 2010). Transitioning from a traditional top-down approach to a user-centered approach for planning and design has the potential to achieve more sustainable outcomes. This approach is described further in Chapter 8.

Sustainable Financial and Institutional Capacity Management. Forward-minded consideration of financing and capacity building is critical to sustainability. Operation and maintenance costs are often underestimated, and high staff turnover is a key challenge of public sector projects such as those related to water reuse. These factors often drive a run-to-failure trajectory (Murray and Drechsel, 2011). Development of a longer-term strategy and/or involvement of the private sector could help avoid such an outcome. Although WWTPs are often publicly financed, the public-private partnership model is being piloted (e.g., Scheierling et al., 2010; Murray et al., 2011). An example of cost-recovery is the use of treatment ponds for aquaculture in Ghana (Waste Enterprisers, 2012).

Public Outreach. A successful and sustainable water reuse program must integrate a public involvement campaign, particularly where the involved public will be consumers of the reclaimed water or the product developed using the reclaimed water. This is described further in Chapter 8. Just as a water reuse project may fail due to a lack of early stakeholder involvement, failure to garner public acceptance of water reuse through a well-conceived and implemented communication campaign can limit market demand for the product. There are several good examples of public acceptance campaigns for water reuse associated with potable reuse [Singapore-NEWater] and [India-Bangalore], irrigation [Spain-Costa Brava], [Palestinian Territories-Auja], [Israel/Peru-Vertical Wetlands], and industrial reuse [India-Nagpur]. Public outreach will be more challenging where risk awareness is low or hazards of multiple origins (water-borne, food-borne) affect households, such as in many low-resource settings. In these circumstances, a significant investment in risk education is required. Lessons can be learned from hand-washing campaigns.

9.6 Global Lessons Learned About Water Reuse

There are key themes emerging in the global dialogue on water reuse that are of relevance to the United States and that merit discussion; regardless of the context of reuse, there are common challenges.

We have a common challenge. Pressure on the world's water resources has been growing dramatically, and climate change is accentuating patterns of droughts and floods. Water scarcity is affecting communities around the world, presenting an incredible opportunity for collaboration. And as solutions are developed in one context, they can be adapted to new contexts. For example, the U.S. is one of the world's leaders in advanced water reclamation technologies and stands to benefit from taking advantage of low-cost, low-energy solutions being demonstrated as described in several case studies from outside of the U.S. [Brazil-Car Wash], [Israel/Peru-Vertical Wetlands], [Philippines-Market]. Likewise, advances in salinity management and drip irrigation in agricultural reuse is a key topic for scientific exchange between the United States and countries in the Middle East and other arid regions. The world has learned a great deal from Singapore's advanced reuse technology as well as its leadership in integrated management and holistic planning under its long-term water supply strategy called "Four National Taps." Regulators in the United States have gained insight from the experience of other countries setting national guidelines and regulations, notably Australia. Current challenges in reuse, including economic models for partial or full cost recovery and technical challenges in nutrient recovery and energy efficiency, are also opportunities for international exchange.

Multi-purpose reuse. Some of the reuse projects described in the international case studies are multi-purpose programs, where reclaimed water within one system is treated to different water quality standards to supply reclaimed water to an array of end uses. In contrast, most water reuse applications in the United States are designed for water reuse for a singular purpose. Multi-purpose systems may be more robust and adaptable than single-use applications, and new installations in the United States might take note from successes in other regions of the world.

Fine tuning the treatment. The concept of "fit-for-purpose" is illustrated dramatically in many of the international reuse case studies ([Australia-Replacement Flows], [Brazil-Car Wash], [Colombia-Bogota], [India-Nagpur], [South Africa-eMalahleni Mine], and [South Africa-Durban]). In these reuse installations, careful study was conducted to ensure that the water produced would have the appropriate water quality for the intended use. Water reuse market growth is projected to take this approach—designing reuse for a specific purpose to achieve economic efficiency. Both high- and low-tech solutions are imminently relevant to tuning our approaches, and as mentioned above, multiple endpoints may be appropriate for multi-purpose systems. Global experiences can help reuse planners answer the following questions: *Are we choosing the easiest solution or the best solution? How carefully have the options been weighed?*

Increasing dialogue about water reuse in all corners of the world. Confidence in water and wastewater treatment technologies has grown among scientists and engineers, regulators, and increasingly, the general public such that the public and the decision-makers have security in the safety of reclaimed water. As the market grows, public awareness will increase, which has been shown to improve acceptance of and investment in reuse. Countries with only emerging wastewater collection and treatment systems will benefit from this dialogue if their opportunities and constraints are taken into account. The case studies show an encouraging spectrum of options where increased sanitation and wastewater management efforts in resource-constrained countries can move unplanned wastewater use to planned reuse, while taking advantage of modern treatment and non- or post-treatment options for safeguarding public health. With increasing population pressures for more available water resources, increasing recovery of the water resource from wastewater can help in meeting the total water needs of many nations.

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APPENDIX A
Funding for Water Reuse Research

A.1 Federal Agency Reuse Research

Several federal agencies provide funding for various aspects of water reuse research, including EPA, USAID, U.S. Bureau of Reclamation (USBR), USDA, U.S. Geological Survey (USGS), the Centers for Disease Control and Prevention (CDC), the Department of Energy (DOE), and the National Science Foundation (NSF). The only agency with a specific directive driving research in water reuse is USBR, which is focused mainly on water quantity. EPA's research looks at water quality, while DOE's research examines the energy requirements of water reuse. USDA focuses on the benefits of water reuse in agriculture. USDA, CDC, and USGS fund research examining public health and water reuse. USAID's research targets water reuse as a component of sustainable development in developing countries and as a collaboration tool for developing peace and security between nations. NSF funds water reuse research around the themes of water treatment technology and infrastructure renewal.

A.1.1 EPA

Water reuse is relevant to the water elements of EPA's 2011-2015 Strategic Plan (EPA, N.D.), which include strengthening water quality standards, adoption of sustainable management practices, and promoting innovative, cost-effective practices to protect water quality. EPA has many ongoing efforts related to water reuse, with no single lead office on the topic. Research that supports water reuse includes EPA's program on human health effects of chemicals (using screening and laboratory studies) and pathogens (using epidemiological data). Advances in analytical methods and monitoring are supported through research with the Unregulated Contaminant Monitoring Rule (UCMR) program. The program also collects and analyzes data on the occurrence of endocrine-disrupting chemicals in the environment to better understand human health and environmental effects (NRC, 2012).

A.1.2 USAID

USAID has a major programmatic focus on integrated water resources management and in water and sanitation for health in developing countries. USAID has sponsored projects to implement nonpotable water reuse projects in India, Jordan, Morocco, Philippines, Thailand, and West Bank/Gaza, as illustrated in several case studies.

USAID also provides some funding for water reuse research in three different programmatic areas. First, USAID supports the Consultative Group on International Agricultural Research (CGIAR), which is global partnership that unites organizations engaged in research for sustainable development. Part of the CGIAR research portfolio includes research in the area of water reuse and resource recovery. This research is described further in Chapter 9 in the text box "Resource Recovery and Reuse: a Strategic Research Portfolio."

USAID's Middle East Research Cooperation Program (MERC) was created in 1979 to promote Arab-Israeli cooperation through joint applied research projects; and to contribute to the peace process through the establishment of cooperative relationships that will last beyond the life of the projects. As part of its portfolio of research, MERC has funded peer-reviewed cooperative projects in the areas of agriculture, health, environment, economics, and engineering, including wastewater treatment and water reuse. Case studies from Israel, Jordan, and West Bank/Gaza include examples of MERC-funded projects [Israel/Jordan-AWT Crop Irrigation; Israel/Palestinian Territories/Jordan-Olive Irrigation; Israel/Jordan-Brackish Irrigation].

USAID's U.S.-Israel Cooperative Development Research (CDR) Program was created in 1985 to support joint research projects between Israeli (and U.S.) scientists with their counterparts in developing countries around the globe to address problems facing the developing-country partners. Each project's budget is spent primarily on capacity-building measures in the participating developing country such as student training, essential equipment and outreach. As part of its portfolio of research, CDR has funded peer-reviewed cooperative projects in the areas of agriculture, health, and environment, including wastewater treatment and water reuse. CDR is, however, presently closed to new applications. A CDR case study from Israel and Peru is included [Case study: Israel/Peru - Vertical Wetlands].

A.1.3 USBR

The only federal agency with a directive to fund water reuse research is USBR. The USBR water reclamation and reuse program is authorized by the Reclamation Wastewater and Groundwater Study and Facilities Act of 1992 (Title XVI of Public Law 102-575) (USBR, 2009). Also known as Title XVI, the act directs the Secretary of the Interior to undertake a program to investigate and identify opportunities for water reclamation and reuse of municipal, industrial, domestic and agricultural wastewater, and naturally impaired ground and surface waters, and for design and construction of demonstration and permanent facilities to reclaim and reuse wastewater. It also authorized the Secretary to conduct research, including desalting, for the reclamation of wastewater and naturally impaired ground and surface waters. Currently, funding is used for demonstration and desalination projects and the WateReuse Research Foundation. Reclamation's partnership with the WateReuse Research Foundation funds applied research in the areas of water reclamation, reuse and desalination. Both solicited and unsolicited projects are funded for cutting edge research that expands the water and wastewater communities knowledge in a wide range of subjects, which include: chemistry and toxicology; desalination and concentrate management; microbiology and disinfection; natural systems, groundwater recharge, storage; policy, social sciences, and applications; treatment technologies. The Foundation is funded primarily by a group of subscribers, which typically include: water and wastewater utilities, consulting firms, equipment suppliers and other organizations. Reclamation's financial contributions supplement these subscriber funds.

Active reclaimed water research funded by the 2008 National Irrigation Water Quality Program (NIWQP) of USBR sought to develop tools and guidelines for risk management decisions based on the microbial monitoring of surface derived irrigation water and assessing potential risks from using treated effluent for irrigation of food crops in the Lower Colorado River Basin. Project directors are finalizing the determination of the variation and environmental factors affecting the microbial risks from reclaimed irrigation water, identifying relationships among total fecal coliform, generic *E. coli*, and *E. coli* O157:H7 in irrigation water and corresponding levels found in irrigated vegetables, shaping criteria needed to estimate cumulative risk of reclaimed irrigation water followed by appropriate testing and decision tools, assess the microbial risk, and conduct an aggressive outreach program to implement irrigation water risk assessment management practices.

A.1.4 USDA

USDA has interest in water reuse as an alternative reliable supply of water for irrigation. USDA currently funds research on the potential health and agricultural sector effects of using reclaimed water for crops. USDA/NIFA has made funding for water reuse research, education, and extension one of its priorities. As a result of the 2005 Agricultural Water Security Listening Session (Dobrowolski and O'Neill, 2005), NIFA (formerly the Cooperative State Research, Education and Extension Service, CSREES) chose to develop three research, education, and extension themes. These three themes—biotechnology, conservation, and reclaimed water—fit within the research and education challenges (water availability, quantity and quality, water use, and water institutions) described by the National Research Council (2004). Subsequent to the 2005 session, NIFA sponsored two specialty conferences in 2007 and 2008 in partnership with the WateReuse Association titled "Water Reuse in Agriculture Opportunities and Challenges" and "Water Reuse in Agriculture Ensuring Food Safety." The purpose of the conferences is to provide a forum for discussion, collaboration, and coordinated funding in reclaimed water among USDA agencies and others. More recently, the Research, Education, and Economics mission area of USDA drafted a Strategic Action Plan with water as a sub-goal and recycled water in agriculture as an action item for both research agencies. This included a commitment to invest in research, development, and extension of new irrigation techniques and management of limited water resources, including strategies for water reuse. NIFA-funded research includes studies on impacts of reclaimed water on plants and soils, treatment methods to prevent impacts to soils, long-term effects of irrigating with reclaimed water, minimizing food safety hazards, and fate of pharmaceuticals and hormones in agricultural production.

USDA/NIFA's Agriculture and Food Research Initiative (AFRI) Foundational program in 2010 funded six projects currently investigating the bioaccumulation and potential contamination of reclaimed water constituents applied at typical irrigation rates used exclusively or through blending with surface and ground water sources. NIFA awarded these projects competitively, evaluated by peer-review panels. Scientists focused their studies on six issues:

- The bioaccumulation of pharmaceutical and personal care products (PPCPs) by common vegetables and fruit (lettuce, cabbage, bell pepper, tomato, carrot, parsley, radish, and strawberry) in both field and greenhouse hydroponic experiments irrigating with treated wastewater.
- The dose-dependent bioaccumulation of chemicals of emerging concern (CEC) assessed in both laboratory and field studies with reclaimed water fortified with CECs; subsequent studies will examine the effects of soil organic matter and cumulative use of recycled water on selected crops eaten fresh.
- The uptake of reclaimed water chemicals from irrigation of commonly grown vegetable crops with water containing several isotopically labeled chemicals, using a range of irrigation regimens to simulate varying degrees of water stress.
- The integration of hydroponic, column, and greenhouse studies to evaluate bioaccumulation of antimicrobials by food crops with fate modeling and risk assessment to determine relevance; with results synthesized into an assessment of health risk from antimicrobial exposure through food, water, and reclaimed water use.
- The minimization of antibiotic resistant (ABR) Salmonella in vegetables irrigated with reclaimed water; identifying the fate of ABR Salmonella in soil and lettuce after irrigation, and developing best management practices both lowering pathogen levels through blending water source and avoiding using reclaimed water at critical stages of plant growth, to minimize accumulation in lettuce.
- The clear understanding of the fate and potential bioaccumulation of estrogenic chemicals (endocrine disrupting compounds, EDCs) within the edible portion of crop plants through root and foliar exposure followed by sap flow and plant extraction methodologies; results will be useful for predicting bio-concentration potential, potential dietary intake, and risks to human health.

NIFA also collects annual information on the extent of the use of reclaimed water in irrigation in an annual inventory of farms conducted by its National Agricultural Statistics Service (NRC, 2012). This research will provide a more in-depth understanding of the impacts of long-term water reuse on the nation's agricultural sector.

A.1.5 USGS

USGS supports water reuse research through its Water Census, aquifer storage and recovery (ASR) program, and program on the occurrence of human-use compounds in the nation's surface waters. The Water Census is nation-wide accounting of water supplies and water use in the United States, which is cited in Chapter 5 for each region of the United States. The ASR research program looks at how geochemistry changes with subsurface storage of water. USGS's surface water program has also conducted extensive research on the occurrence, pathways, uptake, and effects of these human-derived contaminants, including from wastewater (NRC, 2012).

A.1.6 CDC

The CDC has supported research on water reuse as a means to protect human health during drought conditions and a research project to enhance capacity to investigate links between wastewater, groundwater contamination, and human health (NRC, 2012).

A.1.7 DOE

As part of DOE's National Energy Technology Laboratory's efforts to reduce water demands in energy production, DOE is conducting research on the technical, financial, and long-term challenges and benefits associated with using reclaimed wastewater for power plant cooling (NRC, 2012).

A.1.8 NSF

NSF sponsors one fifth of the water resources research in the United States (NRC, 2004), but does not have a specific funding emphasis on water reuse. Water reuse is a consideration under many of the urban/suburban focused "Water Sustainability and Climate" grants, a new NSF initiative. The goal of these grants is to assess the overall impact of decisions about water resources, including downstream impacts on water quality. An NSF-funded center on water treatment technology (the Center of Advanced Materials for the Purification of Water with Systems (WaterCAMPWS) includes research related to water reuse technologies (NRC, 2012). Another NSF-funded engineering research center ReNWUIt brings together environmental engineering, earth sciences, hydrology, ecology, urban studies, economics, and law to address the nation's urban water infrastructure.

A.2 Non-Governmental Organization (NGO)-Sponsored Research

Several U.S.-based and international NGOs sponsor research in water reuse.

A.2.1 Global Water Research Coalition (GWRC)

The GWRC is a collaboration between 12 research organizations around the globe, with partnership from EPA. The GWRC aims to leverage funding and expertise toward water quality research of global interest (NRC, 2012).

A.2.2 National Water Research Institute

The National Water Research Institute (NWRI) supports research and outreach related to ensuring clean and reliable water. NWRI was founded in 1991 and has six member organizations, all based in Southern California. NWRI has invested over $17 million in research, largely focused on water reuse since its member organizations have strong interest in sustainable water solutions. Research has included disinfection guidelines for water reuse, the fate and transport of trace organic contaminants, subsurface transport of bacteria and viruses, and use of bioassays and monitoring to assess trace contaminant removal in water reuse (NRC, 2012).

A.2.3 Water Environment Research Foundation

The Water Environment Research Foundation (WERF) is a subscriber-based organization that funds wastewater- and stormwater-related research. WERF's areas of active water reuse research include:

- Advanced wastewater treatment processes for removal of trace organic compounds
- Fate and transport of trace organic chemicals in treated municipal wastewater used for turf irrigation
- Demonstration of membrane zero liquid discharge technologies as a long-term solution for concentrate disposal following municipal wastewater treatment
- Demand, waste and cost estimation tools for urban water management
- Source separation of household graywater from blackwater for graywater reuse
- Fate and transport of chemical and pathogen constituents in household graywater used for landscape irrigation
- Technologies and practices for sustainable stormwater reuse

A.2.4 WateReuse Research Foundation

The WateReuse Research Foundation is an educational, nonprofit public benefit corporation that serves as a centralized organization for the water and wastewater community to advance the science of water reuse, recycling, reclamation, and desalination. The Foundation funds research covering a broad spectrum of issues, including chemical contaminants, microbiological agents, treatment technologies, salinity management, public perception, economics, marketing, and industrial reuse.

The Research Foundation's primary sources of funding are its subscribers and its funding partners, which include the Bureau of Reclamation, the California State Water Resources Control Board, and the California Energy Commission. The Foundation's subscribers include water and wastewater agencies and other interested organizations. The Foundation is committed to pursuing new partners to collaborate on research and leverage resources.

Full reports are available for purchase through the WateReuse Research Foundation website (http://www.watereuse.org/foundation/publications).

A.2.5 Water Research Foundation

The Water Research Foundation (formerly known as the American Water Works

Association Research Foundation) supports applied research related to drinking water. The Water Research Foundation is a subscriber-based organization. Water reuse-related research has included research on soil aquifer treatment and on trace organic contaminants in drinking water, including assessment of exposure, improvements in analytical methods, and improved frameworks for risk communication for utilities (NRC, 2012).

A.3 Research Funding Outside the U.S.

This section describes government initiatives in Australia, Egypt, and Qatar to fund water reuse research. Though this is not meant to be comprehensive of global efforts; instead it illustrates the interest in water reuse by many countries around the world.

A.3.1 Australian Federal Funding

In Australia, water reuse (generally referred to as water recycling in Australia) has been growing at around 10% per year over the past 5 years. Rapidly growth in investment in reuse began in the mid 2000s, partially in response to a dry period from 2001 to 2009. For urban areas the greatest value of water reuse is attached to replacement of potable demand. Concurrent with the rapid investment in water reuse projects, state and federal government agencies, water utilities, research institutions and the broader water sector embarked upon a rapid increase in water reuse research. There were two major driving forces behind this increased research investment.

First, national health and environmental guidelines were developed for potable and non-potable water reuse. In response to conservative targets based on existing data, regulators and utilities soon identified a range of research needs to manage and reduce treatment costs while ensuring that risk management and prevention remained the critical underpinning of water reuse projects.

Second, politics around potable reuse drove investments in research. In a referendum in Toowomba, Queensland in 2006, the community voted against potable reuse to alleviate their water supply problems. This highlighted the need for greater community engagement and how political water decisions could be. Just a few years later, having spent billions on an indirect potable reuse scheme in South East Queensland, elected officials decided at the last minute to set very conservative requirements to introduce highly purified water into the local surface reservoirs that would not be reached for many years and beyond the subsequent few electoral cycles. Again, potable reuse had been stymied by politics.

This background leads to the current state of water reuse research in Australia which is well funded and is addressing the highest priority issues:

1. The Federal Government has provided $20 million dollars (over 5 years) to develop a Centre of Excellence. The Australian Water Recycling Centre of Excellence is now half way through its term and has 4 major research goals encompassing community and stakeholder acceptance of potable reuse, developing a national framework for validation of treatment technologies, a program of projects dedicated to understanding and measuring the sustainability of water recycling, and development of skills and capability in managing the complexity of water reuse projects from a planning, technological and operational perspective.

2. Water utilities have had an ongoing research program working both collaboratively through Water Services Association of Australia, Water Quality Research Australia and through local and state based Research collaborations including the Smart Water Fund in Victoria and the Urban Water Security Research Alliance in Queensland. These collaborative research programs continue to generate highly valued research in water quality, health and ecosystem protection and sustainability analysis. Water utilities also undertake their own research on water reuse covering issues such as treatment technology and validation and customer and community research.

3. More recently, the Federal Government has provided multi million dollars of funding over 8 years to a Cooperative Research Centre on Water Sensitive Cities which, inter alia, will be addressing the next frontier of water reuse, the safe and sustainable use of storm water harvesting. This large national collaboration

brings together researchers, industry, governments and utilities to research approaches to urban water management that encompass traditional water supplies, water reuse from sewage, graywater and storm water and the integration of desalinated supplies.

Other research entities funding water reuse research in Australia include the National Groundwater Centre of Excellence and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia's national science agency. These entities undertake water reuse research under contract or through strategic partnerships. In addition, in 2012 the Australian Water Recycling Centre of Excellence (AWRCE) announced Aus$ 3 million (US$ 3 million) for a research project to investigate and address the barriers to public acceptance of reusing water for augmenting drinking water supplies.

A.3.2 Egypt National Water Research Center (NWRC)

Egypt's NWRC funds research on drainage water reuse that is conducted by the Drainage Research Institute (one of the NWRC twelve institutes), through its governmental budget. Research areas under this topic include drainage water quantity and quality monitoring and assessment and simulation of national drainage water reuse policy in the context of integrated water resources management of the Nile Delta. The NWRC also provides guidelines for drainage water reuse in irrigating old and newly reclaimed lands.

A.3.3 Qatar National Research Fund (QNRF) and Qatar Water Sustainability Center

The purpose of the Qatar National Research Fund (QNRF) is to foster a research culture in Qatar. Water reuse is one of the research areas identified as relevant to Qatar's national needs, based on an internal study commissioned by Qatar Foundation after consultation with a variety of relevant stakeholders in Qatar. The Global Water Sustainability Center will work with industrial and municipal organizations in Qatar to promote water recycling and reuse.

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National Research Council (NRC). 2012. *Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater.* The National Academies Press: Washington, D.C.

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APPENDIX B
Inventory of Recent Water Reuse Research Projects and Reports

Project Number	Publication Date	Title	Organization
-	2009	*Sustainable Wastewater Management in Developing Countries : New Paradigms and Case Stories from the Field*	American Society of Civil Engineers
-	2009a	Planning for the Distribution of Reclaimed Water	AWWA
-	2012 (pre-publication)	Assessment of Water Reuse as an Approach for Meeting Future Supply Needs	AWWA
-		Advanced Oxidation of Pharmaceuticals and Personal Care Products: Preparing for Indirect and Direct Water Reuse	AWWA
-	2008	Survey of High Recovery and Zero Liquid Discharge Technologies for Water Utilities	AWWA
-	2008	Regional Solutions for Concentrate Management	AWWA
-	2008	The Impacts of Membrane Process Residuals on Wastewater Treatment: Guidance Manual	AWWA
-	2011	Membrane Treatment of Impaired Irrigation Return and Other Flows: Creating New Sources of High Quality Water	AWWA
-		Research Strategy for Water Reuse Workshop	AWWA
-	2008	Inland Membrane Concentrate Treatment Strategies for Water Reclamation Systems	AWWA
-	2008	Design, Operation and Maintenance for Sustainable Underground Storage Facilities	AWWA
-	2007	Comparing Nanofiltration and Reverse Osmosis for Treating Recycled Water	AWWA
-	2009	Water Quality Changes During Aquifer Storage and Recovery	AWWA
-	2006	Organic Nitrogen in Drinking Water and Reclaimed Water	AWWA
-	2004	Industrial Water Quality Requirements for Reclaimed Water	AWWA
-	2005	Water Quality Improvements During Aquifer Storage and Recovery	AWWA
-	2003	ASR in Wisconsin Using the Cambrian-Ordovician Aquifer	AWWA
-	2003	Comparison of Alternative Methods of Recharge of a Deep Aquifer	AWWA
-	1996	Aquifer Storage and Recovery of Treated Drinking Water	AWWA
-	2002 & 2006	Investigation of Soil-Aquifer Treatment for Sustainable Water Reuse	AWWA
-	1998	Issues with Potable Reuse: The Viability of Augmenting Drinking Water Supplies with Reclaimed Water	AWWA
-	2004	Industrial Water Quality Requirements for Reclaimed Water	AWWA Research Foundation

Project Number	Publication Date	Title	Organization
-	2007	Removal of EDCs and Pharmaceuticals in Drinking and Reuse Treatment Processes	AWWA Research Foundation
-	2006	Characterizing and Managing Salinity Loadings in Reclaimed Water Systems	AWWA Research Foundation
94-PUM-1CO	1998	Soil Treatability Pilot Studies to Design and Model Soil Aquifer Treatment Systems	AWWA/WERF
-	2010	Whitepaper on Graywater	AWWA/WERF/WateReuse Foundation
-	2009	Technical Memorandum on Gray Water	Black and Veatch
-	2005	*Water Reuse for Irrigation: Agriculture, Landscapes, and Turf Grass*	Chemical Rubber Company Press
-	2006	*Growing Crops with Reclaimed Wastewater*	CSIRO Publishing
-	2009	*Sustainable Water for the Future, Volume 2: Water Recycling Versus Desalination*	Elsevier, Amsterdam Netherlands
-	2010	Municipal Water Reuse Markets 2010	Global Water Intelligence
-	2012b	*Water-Energy Interactions in Water Reuse*	International Water Association
-	2008	*Water Reuse: An International Survey of Current Practice, Issues and Needs*	International Water Association
-	2012	*Sustainable Treatment and Reuse of Municipal Wastewater for Decision Makers and Practicing Engineers*	International Water Association
-		Milestones in Water Reuse: The Best Success Stories	International Water Association
-	2006	*Water Reuse : Issues, Technologies, and Applications*	McGraw-Hill
-	2012a	Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater	National Research Council
-	2011	*Water Recycling and Water Management (Water Resource Planning, Development and Management)*	Nova Science Publishers
-	2011	Onsite Residential and Commercial Water Reuse Treatment Systems	NSF
-	January 2012	Direct Potable Reuse: Benefits for Public Water Supplies, Agriculture, the Environment, and Energy Conservation	NWRI
-	April 2010	Regulatory Aspects of Direct Potable Reuse in California	NWRI
-	2008	*Efficient Management of Wastewater: Its Treatment and Reuse in Water-Scarce Countries*	Springer-Verlag, Berlin Germany
-	2011	*Waste Water Treatment and Reuse in the Mediterranean Region*	Springer-Verlag, Berlin Germany
-	2009	Development of Indicators and Surrogates for Chemical Contaminant Removal During Wastewater Treatment and Reclamation	Water Environment Research Foundation
-	2006	Advances in Soil Aquifer Treatment Research for Sustainable Water Reuse	Water Environment Research Foundation
-	2007	Towards an Innovative DNA Array Technology for Detection of Pharmaceuticals in Reclaimed Water	Water Environment Research Foundation
-	2005	Membrane Treatment of Secondary Effluent for Subsequent Use	Water Environment Research Foundation
-	2006	Long-Term Effects of Landscape Irrigation Using Household Graywater	Water Environment Research Foundation
-	2011	Guidance Manual for Separation of Graywater from Blackwater for Graywater Reuse	Water Environment Research Foundation

Project Number	Publication Date	Title	Organization
-	2004	Evaluation of Microbial Risk Assessment Techniques and Applications	Water Environment Research Foundation
-	2008	*Using Reclaimed Water to Augment Potable Water Resources*	Water Environment Research Foundation
92-WRE-1	-	Water Reuse Assessment	Water Environment Research Foundation
92-HHE-1-CO		Use of Reclaimed Water ad Sludge in Food Crop Production	Water Environment Research Foundation
97-IRM-6	-	Non-Potable Water Reuse Management Practices	Water Environment Research Foundation
98-CTS-1	-	Research Needs to Optimize Wastewater Resource Utilization	Water Environment Research Foundation
98-CTS-5	-	Feasibility and Application of Membrane Bioreactor Technology for Water Reclamation	Water Environment Research Foundation
98-HHE-1	-	Cryptosporidium in Wastewater Occurrence, Removal and Inactivation	Water Environment Research Foundation
98-PUM-1CO	-	A Comparative study of Physiochemical Properties and Filtration of Several Human and Bacteria Viruses: Implication for Groundwater Recharge	Water Environment Research Foundation
99-HHE-1	-	Effects of Wastewater Disinfection on Human Health	Water Environment Research Foundation
99-HHE-4ET	-	Handheld Advanced Nucleic Acid Analyzer (HANNA) for Waterborne Pathogen Detection	Water Environment Research Foundation
99-HHE-5-UR	-	Development of Molecular Methods for Detection of Infectious Viruses in Treated Wastewater	Water Environment Research Foundation
99-PUM-4	-	Impact of Surface Storage on Reclaimed Water: Seasonal and Long Term	Water Environment Research Foundation
99-WWF-6	-	Online Monitoring of Water Effluent Chlorination Using ORP vs. Residual Chlorine Measurement	Water Environment Research Foundation
00-CTS-8	-	Membrane Technology: Feasibility of Solid/Liquid Separation in Wastewater Treatment	Water Environment Research Foundation
00-CTS-11	-	Membrane Technology: Pilot Studies of Membrane-Aerated Bioreactors	Water Environment Research Foundation
00-CTS- 14-ET	-	A Novel Membrane Process for Autotrophic Denitrification	Water Environment Research Foundation
00-HHE-2A	-	Overcoming Molecular Sample Processing Limitations: New Platform Technologies	Water Environment Research Foundation
00-HHE-2C	-	Overcoming Molecular Sample Processing Limitations: Quantitative PCR	Water Environment Research Foundation
00-HHE-7-CO	-	Endocrine Disruptors and Pharmaceutically Active Chemicals in Drinking Water	Water Environment Research Foundation
00-HHE-2C	-	Overcoming Molecular Sample Processing Limitations: Fiber Optic Biosensors	Water Environment Research Foundation
00-PUM-1	-	Water Reuse: Understanding Public Perception and Participation	Water Environment Research Foundation
OO-PUM-2T	-	Reduction of Pathogens, Indicator Bacteria, and Alternative Indicators by Wastewater Treatment and Reclamation Processes	Water Environment Research Foundation
00-PUM-3	-	Evaluation of Microbial Risk Assessment Techniques and Applications	Water Environment Research Foundation
00-WSM-6	-	Strategies for Sustainable Water Resource Management	Water Environment Research Foundation
00-WSM-6A	-	Moving Towards Sustainable Water Resources	Water Environment

Project Number	Publication Date	Title	Organization
		Management: A Framework and Guidelines for Implementation	Research Foundation
01-CTS-6 & 01-CTS-6A	-	Membrane Treatment of Secondary Wastewater Effluent for Subsequent Use	Water Environment Research Foundation
01-CTS-19-UR	-	Effects of Biosolids Properties on Membrane Bioreactors and Solids Processing	Water Environment Research Foundation
01-CTS-31-ET	-	Dynamic Medialess Microfiltration for Membrane Prefiltration	Water Environment Research Foundation
01-HHE-1	-	Applications of DNA Microarray Technology for Wastewater Analysis	Water Environment Research Foundation
01-HHE-2A	-	Molecular Alternatives to Indicator and Pathogen Detection: Real-Time PCR	Water Environment Research Foundation
01-HHE-4A	-	Online Methods of Evaluating the Safety of Reclaimed Water	Water Environment Research Foundation
02-CTS-4 & 02-CTS-4A	-	Membrane Bioreactors for Anaerobic Treatment of Wastewaters	Water Environment Research Foundation
03-CTS-17cCO	-	Impacts of Membrane Process Residuals on Wastewater Treatment	Water Environment Research Foundation
03-CTS-18C0	-	Long-Term Effects of Landscape Irrigation Using Household Graywater	Water Environment Research Foundation
03-CTS-22-UR	-	Fate of Pharmaceuticals and Personal Care Products through Wastewater Treatment Processes	Water Environment Research Foundation
04-SW-1	-	Using Rainwater to Grow Livable Communities	Water Environment Research Foundation
04-HHE-3	-	Microbial Risk Assessment Interface Tool and User Documentation Guide	Water Environment Research Foundation
06-CTS-1C0	-	Long-Term Study on Landscape Irrigation using Household Graywater- Experimental Study (Phase 2)	Water Environment Research Foundation
DEC3R06	-	When to Consider Distributed Systems in an Urban and Suburban Context	Water Environment Research Foundation
-	2007	Dewatering Reverse Osmosis Concentrate from Water Reuse Applications Using Forward Osmosis	WateReuse Foundation
-	2009b	How to Develop a Water Reuse Program : Manual of Practice	WateReuse Foundation
-	2010	Reaction Rates and Mechanisms of Advanced Oxidation Processes (AOP) for Water Reuse	WateReuse Foundation
-	2005	Irrigation of Parks, Playgrounds, and Schoolyards with Reclaimed Water: Extent and Safety	WateReuse Foundation
-	2006	Rejection of Wastewater-Derived Micropollutants in High-Pressure Membrane Applications Leading to Indirect Potable Reuse: Effects of Membrane and Micropollutant Properties	WateReuse Foundation
-	2009	The Psychology of Water Reclamation and Reuse : Survey Findings and Research Roadmap	WateReuse Foundation
-	2006	Marketing Nonpotable Recycled Water	WateReuse Foundation
-	2004	Water Reuse Economic Framework Workshop Report	WateReuse Foundation
-	2011	Talking About Water : Vocabulary and Images That Support Informed Decisions About Water Recycling and Desalination	WateReuse Foundation
-	2006	An Economic Framework for Evaluating the Benefits and Costs of Water Reuse	WateReuse Foundation
-	2004	Best Practices for Developing Indirect Potable Reuse Projects: Phase 1 Report	WateReuse Foundation

Project Number	Publication Date	Title	Organization
-	2008	The Impacts of Membrane Process Residuals on Wastewater Treatment Guidance Manual	WateReuse Foundation
-	2011	Optimization of Advanced Oxidation Processes for Water Reuse : Effect of Effluent Organic Matter on Organic Contaminant Removal	WateReuse Foundation
-	2010	Low-Cost Treatment Technologies for Small-Scale Water Reclamation Plants	WateReuse Foundation
-	2011	Direct Potable Reuse : A Path Forward	WateReuse Foundation
-	2010	Oxidative Treatment of Organics in Membrane Concentrates	WateReuse Foundation
WRF-01-001	Dec-05	Alternative Methods for the Analysis of NDMA and Other Nitrosamines in Water and Wastewater	WateReuse Foundation
WRF-01-002	May-06	Removal and/or Destruction of NDMA in Wastewater Treatment Processes	WateReuse Foundation
WRF-01-004	Jun-05	Best Practices for Developing Indirect Potable Reuse Projects: Phase 1 Report	WateReuse Foundation
WRF-01-005	May-06	Characterizing and Managing Salinity Loadings in Reclaimed Water Systems (AWWARF 91009)	WateReuse Foundation
WRF-01-006	May-06	Characterizing Microbial Water Quality in Reclaimed Water Distribution Systems (AWWARF 91072F)	WateReuse Foundation
WRF-01-007	2006	Removal of Endocrine Disrupting Compounds in Water Reclamation Processes (WERF 01HHE20T)	WateReuse Foundation
WRF-01-008	2007	Innovative DNA Array Technology for Detection of Pharmaceutics in Reclaimed Water (WERF 01HHE21T)	WateReuse Foundation
WRF-02-001	May-06	Rejection of Wastewater-Derived Micropollutants in High-Pressure Membrane Applications	WateReuse Foundation
WRF-02-002	Jun-06	Investigation of NDMA Fate and Transport	WateReuse Foundation
WRF-02-003	Aug-11	Filter Loading Evaluation for Water Reuse	WateReuse Foundation
WRF-02-004	Nov-08	National Database on Water Reuse Facilities - Summary Report	WateReuse Foundation
WRF-02-006a	Aug-08	Survey of High Recovery and Zero Liquid Discharge Technologies for Water Utilities	WateReuse Foundation
WRF-02-006b	Sep-06	Beneficial and Non-Traditional Uses of Concentrate	WateReuse Foundation
WRF-02-006c	Jul-08	The Impacts of Membrane Process Residuals on Wastewater Treatment	WateReuse Foundation
WRF-02-006d	Aug-08	Regional Solutions for Concentrate Management	WateReuse Foundation
WRF-02-007	2003	Using Surfactants in Optimizing Water Usage on Turf Grasses	WateReuse Foundation
WRF-02-008	Mar-09	A Reconnaissance-Level Quantitative Comparison of Reclaimed Water, Surface Water, and Groundwater	WateReuse Foundation
WRF-02-009	Aug-12	Study of Innovative Treatment on Reclaimed Water	WateReuse Foundation
WRF-02-011	2005	Framework for Developing Water Reuse Criteria with Reference to Drinking Water Supplies (UKWIR 05/WR/29/1)	WateReuse Foundation
WRF-03-001	2007	Pathogen Removal and Inactivation in Reclamation Plants - Study Design	WateReuse Foundation
WRF-03-005	Sep-06	Marketing Nonpotable Recycled Water: A Guidebook for Successful Public Outreach & Customer Marketing	WateReuse Foundation
WRF-03-006-01	2004	Water Reuse Economic Framework Workshop Report	WateReuse Foundation
WRF-03-006-02	Sep-06	An Economic Framework for Evaluating Benefits and Costs of Water Reuse	WateReuse Foundation

Project Number	Publication Date	Title	Organization
WRF-03-009	Aug-07	Reclaimed Water Aquifer Storage and Recovery: Potential Changes in Water Quality	WateReuse Foundation
WRF-03-010	2004	Water Reuse Foundation's Water Reuse Research Needs Workshop	WateReuse Foundation
WRF-03-011	2004	Research Needs Assessment Workshop on Integrating Human Reactions to Water Reclamation into Reuse Project Design	WateReuse Foundation
WRF-03-012	Aug-08	Salt Management Guide	WateReuse Foundation
WRF-03-013	2008	Rejection of Contaminants of Concern by NF and ULPRO Membranes for Treating Water of Impaired Quality	WateReuse Foundation
WRF-03-014	Dec-08	Development of Indicators and Surrogates of Chemical Contaminants and Organic Removal in Wastewater and Water Reuse	WateReuse Foundation
WRF-04-001	2008	Prospects for Managed Underground Storage of Recoverable Water	WateReuse Foundation
WRF-04-002	May-06	Effects of Recycled Water on Turfgrass Quality Maintained Under Golf Course Fairway Conditions	WateReuse Foundation
WRF-04-003	2008	Toxicological Relevance of Endocrine Disruptors & Pharmaceuticals in Drinking Water (AWWARF 91238)	WateReuse Foundation
WRF-04-004	Jan-09	Honolulu Membrane Bioreactor Pilot Study	WateReuse Foundation
WRF-04-005	Mar-12	Use of Recycled Water for Community Gardens	WateReuse Foundation
WRF-04-006	2005	Irrigation of Parks, Playgrounds, and Schoolyards with Reclaimed Water: Extent and Safety	WateReuse Foundation
WRF-04-007	2005	GWRC Water Reuse Research Strategy	WateReuse Foundation
WRF-04-008	Dec-09	The Psychology of Water Reclamation and Reuse: Survey Findings and Research Roadmap	WateReuse Foundation
WRF-04-009	Aug-12	Reclaimed Water Inspection and Cross Connection Control Guidebook	WateReuse Foundation
WRF-04-010	Nov-07	Extending the IRP Process to Include Water Reuse and Other Non-Traditional Water Sources	WateReuse Foundation
WRF-04-011	Nov-07	Application of Microbial Risk Assessment Techniques to Estimate Risk Due to Exposure to Reclaimed Waters	WateReuse Foundation
WRF-04-012	Aug-09	Exploring, Interpreting, and Presenting Microbial Data Associated with Reclaimed Water Systems: A Guidance Manual	WateReuse Foundation
WRF-04-013	Aug-10	Improved Sample Collection and Concentration Method for Multiple Pathogen Detection	WateReuse Foundation
WRF-04-014	Apr-09	Decision Support System for Selection of Satellite vs. Regional Treatment for Reuse	WateReuse Foundation
WRF-04-016	Jun-09	A Protocol for Estimating Potential Water Quality Impacts of Recycled Water Projects	WateReuse Foundation
WRF-04-017	Mar-10	Reaction Rates and Mechanisms of Advanced Oxidation Processes (AOP) for Water Reuse	WateReuse Foundation
WRF-04-018	2009	Contributions of Household Chemicals to Sewage and Relevance to Municipal Wastewater Systems and the Environment (WERF 03CTS21UR)	WateReuse Foundation
WRF-04-019	Apr-09	Methods for the Detection of Residual Concentrations of Hydrogen Peroxide in Advanced Oxidation Processes	WateReuse Foundation
WRF-04-021	Dec-09	Selecting Treatment Trains for Seasonal Storage of Reclaimed Water	WateReuse Foundation

Project Number	Publication Date	Title	Organization
WRF-05-001	Nov-09	Evaluating Pricing Levels and Structures to Support Reclaimed Water Systems	WateReuse Foundation
WRF-05-002	Jan-10	Microbiological Quality/Biostability of Reclaimed Water Following Storage and Distribution	WateReuse Foundation
WRF-05-004	Nov-11	Development of Surrogates to Determine the Efficacy of Soil Aquifer Treatment Systems for the Removal of Organic Chemicals	WateReuse Foundation
WRF-05-005	Aug-10	Identification of PPCPs for Screening Based on Persistence through Treatments used for Indirect Potable Reuse and Toxicity	WateReuse Foundation
WRF-05-006	Jan-11	Evaluate Wetland Systems for Treated Wastewater Performance to Meet Competing Effluent Quality Goals	WateReuse Foundation
WRF-05-007	Jun-09	Selection and Testing of Tracers for Measuring Travel Times in Groundwater Aquifers Augmented with Reclaimed Water	WateReuse Foundation
WRF-05-008	Sep-09	The Effect of Salinity on the Removal of Contaminants of Concern during Biological Water Reclamation	WateReuse Foundation
WRF-05-009	Aug-07	Dewatering Reverse Osmosis Concentrate from Water Reuse Applications Using Forward Osmosis	WateReuse Foundation
WRF-05-010	May-10	Oxidative Destruction of Organics in Membrane Concentrates	WateReuse Foundation
WRF-05-011	Aug-09	Formation and Fate of Chlorination Byproducts in Desalination Systems	WateReuse Foundation
WRF-06-001	Nov-08	Conduct Survey Research to Obtain Information/Data from all Water Recycling Facilities in CA	WateReuse Foundation
WRF-06-002	Jan-09	Developing a Pragmatic Research Agenda for Examining the Value of Water Supply Reliability	WateReuse Foundation
WRF-06-003	Expected Oct-12	The Occurrence of Infectious Cryptosporidium Oocysts in Raw, Treated and Disinfected Wastewater	WateReuse Foundation
WRF-06-004	Aug-12	Identifying Health Effects Concerns of the Water Reuse Industry and Prioritizing Research Needs for Nomination of Chemicals for Research	WateReuse Foundation
WRF-06-005	Dec-09	Leaching of Metals from Aquifer Soils during Infiltration of Low-Ionic-Strength Reclaimed Water: Determination of Kinetics and Potential Mitigation Strategies	WateReuse Foundation
WRF-06-006	Expected Mar-13	Comparisons of Chemical Composition of Recycled and Conventional Waters	WateReuse Foundation
WRF-06-007	Mar-12	Investigation of Membrane Bioreactor Effluent Water Quality and Technology	WateReuse Foundation
WRF-06-008	Jul-10	Low-Cost Treatment Technologies for Small-Scale Water Reclamation Plants	WateReuse Foundation
WRF-06-009	Expected Jan-13	Predictive Models to Aid in Design of Membrane Systems for Organic Micropollutants Removal	WateReuse Foundation
WRF-06-010a	Expected Oct-12	State of the Science Review of Membrane Fouling: Organic, Inorganic, and Biological	WateReuse Foundation
WRF-06-010b	Expected Sep-12	Feasibility Study of Offshore Desalination Plants	WateReuse Foundation
WRF-06-010d	Expected Dec-12	Consideration for the Co-Siting of Desalination Facilities with Municipal and Industrial Facilities	WateReuse Foundation
WRF-06-010e	Expected Jan-13	Development of Selective Recovery Methods for Desalination Concentrate Salts	WateReuse Foundation
WRF-06-010f	2010	Post Treatment Stabilization of Desalinated Water (WaterRF 4079)	WateReuse Foundation

Project Number	Publication Date	Title	Organization
WRF-06-010g	2011	Assessing Seawater Intake Systems for Desalination Plants (WaterRF 4080)	WateReuse Foundation
WRF-06-011	Expected Jan-13	Enhanced Disinfection of Adenoviruses with UV Irradiation	WateReuse Foundation
WRF-06-012	May-11	Optimization of Advanced Oxidation Processes (AOP) for Water Reuse	WateReuse Foundation
WRF-06-013	Expected Oct-12	Investigating the Feasibility of MBR to Achieve Low Nitrogen Levels for Water Reuse	WateReuse Foundation
WRF-06-014	Dec-11	Characterization of US Seawaters & Development of Standardized Protocols for Evaluation of Foulants in Seawater RO Desalination	WateReuse Foundation
WRF-06-015	Dec-10	Sequential UV and Chlorination for Reclaimed Water Disinfection	WateReuse Foundation
WRF-06-016	Jul-11	Guidance on Links between Water Reclamation and Reuse and Regional Growth	WateReuse Foundation
WRF-06-017	May-12	Water Reuse in 2030: Identifying Future Challenges and Opportunities	WateReuse Foundation
WRF-06-018	Apr-11	Development and Application of Tools to Assess and Understand the Relative Risks of Regulated Chemicals in Indirect Potable Reuse Projects - Tasks 1-3	WateReuse Foundation
WRF-06-018	Nov-10	Tool to Assess and Understand the Relative Risks of drugs and Other Chemicals in Indirect Potable Reuse Water: Development and Application	WateReuse Foundation
WRF-06-018	Expected Oct-12	Tool to Assess and Understand the Relative Risks of drugs and Other Chemicals in Indirect Potable Reuse Water: Executive Summary	WateReuse Foundation
WRF-06-019	May-10	Monitoring for Microcontaminants in an Advanced Wastewater Treatment Facility and Modeling Discharge of Reclaimed Water to Surface Canals for Indirect Potable Use	WateReuse Foundation
WRF-06-020	Sep-11	Attenuation of Emerging Contaminants in Streams Augmented with Recycled Water	WateReuse Foundation
WRF-06-021	Jun-12	Interagency Partnerships to Facilitate Water Reuse	WateReuse Foundation
WRF-07-01	Expected Nov-12	Validation of Microbiological Methods for Use with Reclaimed Waters	WateReuse Foundation
WRF-07-02	Expected Oct-12	Development of a Knowledge Base on Concentrate and Salt Management Practices	WateReuse Foundation
WRF-07-03	Jul-11	Talking About Water: Vocabulary and Images that Support Informed Decisions about Water Recycling and Desalination	WateReuse Foundation
WRF-07-04	Expected Oct-12	Evaluation of Impact of Nanoparticle Pollutants	WateReuse Foundation
WRF-07-05	Expected Oct-12	Membrane Distillation using Nanostructured Membranes	WateReuse Foundation
WRF-07-06	Expected Oct-12	Recycled Water Use in Zoo/Wildlife Facility Settings	WateReuse Foundation
WRF-08-01	Nov-10	Assessment of Approaches to Achieve Nationally Consistent Reclaimed Water Standards	WateReuse Foundation
WRF-08-02	Dec-12	Attenuation of PPCP/EDCs through Golf Courses using Reuse Water (WERF1C08)	WateReuse Foundation
WRF-08-04	Expected Jan-13	Approaches to Maintain Consistently High Quality Reclaimed Water in Storage and Distribution Systems	WateReuse Foundation
WRF-08-05	Expected Feb-13	Use of Ozone in Water Reclamation for Contaminant Oxidation	WateReuse Foundation

Project Number	Publication Date	Title	Organization
WRF-08-06	Expected Jan-13	Evaluation of Alternatives to Domestic Ion Exchange Water Softeners	WateReuse Foundation
WRF-08-07	Expected Nov-12	Disinfection Guidelines for Satellite Water Recycling Facilities	WateReuse Foundation
WRF-08-08	Expected Apr-13	Pilot-Scale Oxidative Technologies for Reducing Fouling Potential in Membrane Systems	WateReuse Foundation
WRF-08-09	Expected Oct-12	Value of Water Supply Reliability in Residential Sector	WateReuse Foundation
WRF-08-10	Dec-11	Maximizing Recovery of Recycled Water for Groundwater Recharge	WateReuse Foundation
WRF-08-11	Expected Jul-13	Process Optimization, Monitoring and Control Strategies, and Carbon and Energy Footprint UV/H2O2	WateReuse Foundation
WRF-08-12	Expected Dec-12	Assess water use requirements and establish water quality criteria	WateReuse Foundation
WRF-08-13	Expected Oct-12	Renewable energy, peak power management, and optimization of advanced treatment technologies	WateReuse Foundation
WRF-08-14	Expected Oct-12	Evaluation and optimization of existing and emerging energy recovery devices	WateReuse Foundation
WRF-08-15	Expected Sep-12	Evaluating Emergency Planning under Climate Change Scenarios	WateReuse Foundation
WRF-08-16	Aug-12	Implications of Future Water Supply Sources on Energy Demands	WateReuse Foundation
WRF-08-17	Feb-12	Reclaimed Water Desalination Technologies: Performance/Cost Comparison EDR & MF/RO	WateReuse Foundation
WRF-08-18	Mar-12	Infectivity Assay for *Giardia lamblia* Cysts	WateReuse Foundation
WRF-08-19	Expected Mar-13	Investigation of Desalination Membrane Biofouling	WateReuse Foundation
WRF-09-01	Expected Dec-12	The Effect of Prior Knowledge of ‘Unplanned’ Potable Reuse on Acceptance of ‘Planned’ Potable Reuse	WateReuse Foundation
WRF-09-02	Expected Jun-13	Develop a Framework to Determine When to Use Indirect Potable Reuse Systems vs. Dual Pipe	WateReuse Foundation
WRF-09-03	Expected Apr-13	Utilization of HACCP Approach for Evaluating Integrity of Treatment Barriers for Reuse	WateReuse Foundation
WRF-09-04	Expected Apr-13	The Value of Water Supply Reliability in the CII Sector	WateReuse Foundation
WRF-09-05	Expected Sept-12	Case Studies of Seasonal Storage of Reclaimed Water for Discharge into Surface Waters	WateReuse Foundation
WRF-09-06a	Expected Mar-13	Develop New Techniques for Real-Time Monitoring of Membrane Integrity	WateReuse Foundation
WRF-09-06b	Expected Mar-13	Develop New Techniques for Real-Time Monitoring of Membrane Integrity	WateReuse Foundation
WRF-09-07	May-12	Risk Assessment Study of PPCPs in Recycled Water to Support Public Review - Toolkit	WateReuse Foundation
WRF-09-07	Expected Oct-12	Risk Assessment Study of PPCPs in Recycled Water to Support Public Review - Main Report	WateReuse Foundation
WRF-09-08	Expected Feb-13	Evaluation of Potential Nutrient Impacts Related to Florida's Water Reuse Program	WateReuse Foundation
WRF-09-09	Expected Sep-12	Pilot Testing Pre-Formed Chloramines as a Means of Controlling Biofouling in Seawater Desalination	WateReuse Foundation
WRF-09-10	Feb-13	Use of UV & Fluorescence Spectra as Surrogate Measures for Contaminant Oxidation and Disinfection in Ozone/Peroxide Advanced Oxidation Processes	WateReuse Foundation
WRF-09-11	Expected Feb-14	Development of New Tracers for Determining Travel Time Near MAR Operations	WateReuse Foundation
WRF-09-12	Expected Nov-12	Continuous Flow Seawater RO System for Recovery	WateReuse Foundation

Project Number	Publication Date	Title	Organization
		of Silica Saturated RO Concentrate	
WateReuse-10-01	Expected May-14	Fit for Purpose Water: The Cost of "Over-Treating" Reclaimed and other Water	WateReuse Foundation
WateReuse-10-02	Expected Mar-13	Treatment, Public Health, and Regulatory Issues Associated with Graywater Reuse	WateReuse Foundation
WateReuse-10-03	Expected Jun-13	Regulatory Workshop on Critical Issues of Desalination Permitting	WateReuse Foundation
WateReuse-10-04	Expected Jul- 2013	Improvements to Minimize I&E of Existing Intakes	WateReuse Foundation
WateReuse-10-05	Expected Nov-14	Role of Retention Time in the Environmental Buffer of Indirect Potable Reuse Projects	WateReuse Foundation
WateReuse-10-06a	Aug-13	Lower Energy Treatment Schemes for Water Reuse, Part A	WateReuse Foundation
WateReuse-10-06b	Expected Aug-2013	Lower Energy Treatment Schemes for Water Reuse, Part B	WateReuse Foundation
WateReuse-10-06c	Expected May-2013	Lower Energy Treatment Schemes for Water Reuse, Part C	WateReuse Foundation
WateReuse-10-06d	Expected Aug-2013	Lower Energy Treatment Schemes for Water Reuse, Part D	WateReuse Foundation
WateReuse10-06 II	TBD	Lower Energy Treatment Schemes for Water Reuse - Phase II	WateReuse Foundation
WateReuse-10-07	Expected May-14	Bio-analytical Techniques to Assess the Potential Human Health Impacts of Reclaimed Water	WateReuse Foundation
WateReuse-10-08	Expected Feb-13	Guidance for Implementing Reuse in New Buildings & Developments to Achieve LEED/Sustainability Goals	WateReuse Foundation
WateReuse-10-09	Expected Apr-13	Guidance for Selection of Salt, Metal, Radionuclide, and other Valuable Metal Recovery Strategies	WateReuse Foundation
WateReuse-10-10	Expected Nov-12	Demonstration of Filtration and Disinfection Compliance through SAT	WateReuse Foundation
WateReuse-10-11	Expected Jul-13	Ozone Pretreatment of Non-Nitrified Secondary Effluent before Microfiltration	WateReuse Foundation
WateReuse-10-12	Expected May-13	Feasibility Study on Model Development to Estimate/Minimize GHG Concentrations and Carbon Footprint of WateReuse and Desalination Facilities	WateReuse Foundation
WateReuse-10-13	Expected Nov-12	Review of Nano-Material Research and Relevance for Water Reuse	WateReuse Foundation
WateReuse-10-14	Expected Nov-12	Future of Purple Pipes: Exploring best use of non-potable recycled water in diversified urban water systems	WateReuse Foundation
WateReuse-10-15	Expected Oct-13	Establishing Nitrification Reliability Guidelines for Water Reuse	WateReuse Foundation
WateReuse-10-16	Expected Oct-13	Enzymes: The New Wastewater Treatment Chemical for Water Reuse	WateReuse Foundation
WateReuse-10-17	Expected Jul-13	Understanding the Influence of Stakeholder Groups on the Effectiveness of Urban Recycled Water Program Implementation	WateReuse Foundation
WateReuse-10-18	Expected Dec-13	Regulated and Emerging Disinfection by-Products during the Production of High Quality Recycled Water	WateReuse Foundation
WateReuse-11-01	Expected Mar-16	Monitoring for Reliability and Process Control of Potable Reuse Applications	WateReuse Foundation
WateReuse-11-02	Expected Jul-15	Equivalency of Advanced Treatment Trains for Potable Reuse	WateReuse Foundation

Project Number	Publication Date	Title	Organization
WateReuse-11-03	Expected Sep-14	Develop Best Management Practices to Control Potential Health Risks and Aesthetic Issues Associated with Storage/Distribution of Reclaimed Water	WateReuse Foundation
WateReuse-11-04	Expected Mar-15	Emerging Desalination Technologies for Energy Reduction	WateReuse Foundation
WateReuse-11-05	Expected May-14	Demonstrating the Benefits of Engineered Direct versus Unintended Indirect Potable Reuse Systems	WateReuse Foundation
WateReuse-11-06	Expected Oct-13	Real Time Monitoring for Microbiological Contaminants in Reclaimed Water: State of the Science Assessment	WateReuse Foundation
WateReuse-11-07	Expected Jan-15	Application of the Bioluminescent Saltwater Assimilable Organic Carbon Test as a Tool for Identifying and Reducing Reverse-Osmosis Membrane Fouling in Desalination	WateReuse Foundation
WateReuse-11-08	Expected Oct-14	Formation of Nitrosamines and Perfluorochemicals during Ozonation in Water Reuse Applications	WateReuse Foundation
WateReuse-11-09	Expected Jan-14	Desalination Concentrate Management Policy Analysis for the Arid West	WateReuse Foundation
WateReuse-11-10	Expected Dec-13	Evaluation of Risk Reduction Principles for Direct Potable Reuse	WateReuse Foundation
WateReuse-12-01	TBD	Desalination Facility Guidelines (Scoping Study)	WateReuse Foundation
WateReuse-12-02	TBD	Development of Public Communication Toolbox for Desalination Projects	WateReuse Foundation
WateReuse-12-03	TBD	Analysis of Technical and Organizational Issues in the Development and Implementation of Industrial Reuse Projects	WateReuse Foundation
WateReuse-12-05	TBD	Management of *Legionella* in Water Reclamation Systems	WateReuse Foundation
WateReuse-12-06	TBD	Guidelines for Engineered Storage Systems	WateReuse Foundation
WateReuse-12-07	TBD	Standard Methods for Integrity Testing of NF and RO Membranes	WateReuse Foundation
WateReuse-12-08	TBD	Public Acceptance Clearinghouse of Information for Website	WateReuse Foundation
WateReuse-12-10	Expected Sept-13	Demonstrating an Innovative Combination of Ion Exchange Pretreatment and Electrodialysis Reversal for Reclaimed Water RQ Concentrate Minimization	WateReuse Foundation

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APPENDIX C
Websites of U.S. State Regulations and Guidance on Water Reuse

The WateReuse Association will maintain links of the state regulatory sites containing water reuse regulations as links and current regulations are subject to change by the states. Readers may access the state regulations link at https://www.watereuse.org/government-affairs/usepa-guidelines.

State	Title of Regulations or Guidelines	Link to State Reuse Regulations or Guidance	Alternate Link to Reuse Fact Sheet or Report
Alabama	Guidelines and Minimum Requirement for Municipal, Semi-Public and Private Land Treatment Facilities	http://adem.alabama.gov/alEnviroRegLaws/default.cnt	
Alaska	Alaska Administrative Code, Title 18 – Environmental Conservation, Chapter 72 - Wastewater Disposal	http://dec.alaska.gov/commish/regulations/pdfs/18%20AAC%2072.pdf	
Alaska - additional		http://dec.alaska.gov/water/wwdp/index.htm	
Arizona	Arizona Administrative Code - Title 18, Environmental Quality	http://www.azsos.gov/public_services/Title_18/18_table.htm	http://www.azdeq.gov/environ/water/permits/reclaimed.html
Arkansas	40 CFR 257, 40 CFR 503, and guidance from NRCS (for animal wastes)	http://www.adeq.state.ar.us/water/regulations.htm	
California	Title 22 California Code of Regulations	http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Lawbook.aspx	http://www.waterboards.ca.gov/water_issues/programs/grants_loans/water_recycling/directory.shtml
California - additional		http://www.cdph.ca.gov/HealthInfo/environhealth/water/Pages/Waterrecycling.aspx	
Colorado	Water Quality Control Commission: Regulation No. 84 - Reclaimed Water Control Regulation (effective 9/30/07)	http://www.cdphe.state.co.us/regulations/wqccregs/	
Colorado - additional		http://www.cdphe.state.co.us/regulations/wqccregs/100284wqccreclaimedwater.pdf	
Commonwealth of the Northern Mariana Islands	Commonwealth of the Northern Mariana Islands Wastewater Treatment and Disposal Rules and Regulations	http://www.deq.gov.mp/artdoc/Sec6art32ID130.pdf	
Connecticut	No regulations or guidelines at this time	http://www.ct.gov/dep/cwp/view.asp?a=2709&q=324216&depNav_GID=1643	
Delaware		http://www.dnrec.delaware.gov/wr/Information/regulations/Pages/GroundWaterDischargesRegulations.aspx	
Delaware - additional		http://www.dnrec.state.de.us/water2000/Sections/GroundWat/Library/ReclaimedWaterFactSheet.pdf	
District of Columbia	The District of Columbia currently does not have any regulations or guidelines addressing water reuse but considers projects on a case-by-case basis. The city is currently developing rules and		

State	Title of Regulations or Guidelines	Link to State Reuse Regulations or Guidance	Alternate Link to Reuse Fact Sheet or Report
	water quality requirements for stormwater use.		
Florida	Chapter 62-610 of the Florida Administrative Code "Reuse of Reclaimed Water and Land Application; Section 403.064 of the Florida Statutes	http://www.dep.state.fl.us/water/reuse/apprules.htm	
Georgia	Guidelines for Water Reclamation and Urban Water Reuse; Georgia Guidelines for Reclaimed Water Systems for Buildings; Constructed Wetlands Municipal Wastewater Treatment Facilities Guidelines; Guidelines for Slow-Rate Land Treatment of Wastewater Via Spray Irrigation (LAS Guidelines)	http://www.gaepd.org/Files_PDF/techguide/wpb/reuse.pdf	
Georgia - additional		http://www.gaepd.org/Documents/techguide_wpb.html	
Guam		http://epa.guam.gov/rules-regs/regulations/water-pollution-regulations/	
Hawaii	Guidelines for the Treatment and Use of Recycled Water	http://hawaii.gov/wastewater/pdf/reuse-final.pdf	
Hawaii - additional		http://hawaii.gov/dlnr/cwrm/planning_augmentation.htm	
Idaho	Idaho Administrative Code, Tittle 01, Chapter 17, IDAPA 58.01.17 - Recycled Water Rules	http://adminrules.idaho.gov/rules/current/58/0117.pdf	
Idaho - additional		http://adminrules.idaho.gov/rules/current/58/index.html	
Illinois	Title 35 Illinois Administrative Code Part 372 - Illinois Design Standards for Slow Rate Land Application of Treated Wastewater	http://www.ipcb.state.il.us/documents/dsweb/Get/Document-12046/	http://www.ilga.gov/legislation/ilcs/fulltext.asp?DocName=007023050K7
Indiana	Article 6.1 "Land application of Biosolid, Industrial Waste Product, and Pollutant-bearing Water" of Title 327 Water Pollution Control Board, Indiana Administrative Code.	http://www.in.gov/idem/4877.htm	http://www.in.gov/legislative/iac/title327.html
Iowa	Iowa Administrative Code Chapter 62: Effluent and Pretreament Standards: Other Effluent Limits or Prohibitinos	http://www.iowadnr.gov/InsideDNR/RegulatoryWater/NPDESWastewaterPermitting/NPDESRules.aspx	http://www.iowadnr.gov/portals/idnr/uploads/water/wastewater/dstandards/chapter21.pdf?amp;tabid=1316
Kansas	-	http://www.kdheks.gov/water/download/28_16.pdf	http://www.kwo.org/Kansas_Water_Plan/KWP_Docs/VolumeIII/LARK/Rpt_LARK_BPI_Role_Reuse_KWP2009.pdf
Kentucky	No regulations or guidelines at this time	Web Address could not be located at time of publication.	
Louisiana	No regulations or guidelines at this time	Web Address could not be located at time of publication.	
Maine	No regulations or guidelines at this time	Web Address could not be located at time of publication.	
Maryland	Environment Article, Title 9, Subtitle 3; COMAR 26.08.01through 26.08.04 and 26.08.07.	http://www.mde.state.md.us/assets/document/MDE-WMA-001%20%28land-	http://www.mde.state.md.us/programs/Permits/WaterManagementP

State	Title of Regulations or Guidelines	Link to State Reuse Regulations or Guidance	Alternate Link to Reuse Fact Sheet or Report
		treatment%20Guidelines%29.pdf	ermits/Documents/www.mde.state.md.us/assets/document/permit/MDE-WMA-PER014.pdf
Maryland - additional		http://www.mde.state.md.us/programs/Permits/WaterManagementPermits/WaterDischargePermitApplications/Pages/Permits/WaterManagementPermits/water_permits/index.aspx	
Massachusetts		http://www.mass.gov/dep/service/regulations/314cmr20.pdf	http://www.mass.gov/dep/water/wastewater/wrfaqs.htm#permit
Massachusetts - additional		http://www.mass.gov/dep/service/regulations/314cmr05.pdf	
Michigan		Web Address could not be located at time of publication.	
Minnesota		http://www.pca.state.mn.us/index.php/view-document.html?gid=13496	
Mississippi		http://www.deq.state.ms.us/newweb/MDEQRegulations.nsf?OpenDatabase	
Missouri		http://www.sos.mo.gov/adrules/csr/current/10csr/10csr.asp#10-20	http://www.dnr.mo.gov/env/wpp/permits/index.html
Montana		http://deq.mt.gov/wqinfo/pws/docs/deq2 revisions.pdf	
Nebraska	Title 119, Chapter 12 - Land Application of Domestic Effluent, Land Application of Single Pass Noncontact Cooling Water and Disposal of Domestic Biosolids	http://www.deq.state.ne.us/RuleAndR.nsf/pages/119-Ch-12	http://www.deq.state.ne.us/RuleandR.nsf/Pages/Rules
Nebraska - additional		http://www.deq.state.ne.us/RuleAndR.nsf/23e5e39594c064ee852564ae004fa010/97c32c5cd6c1802d8625674b006da528?OpenDocument	
Nebraska - additional		http://www.deq.state.ne.us/RuleAndR.nsf/23e5e39594c064ee852564ae004fa010/235cf139930e82d08625674b006e0738?OpenDocument	
Nebraska - additional		http://www.deq.state.ne.us/RuleAndR.nsf/23e5e39594c064ee852564ae004fa010/6fc9b4ab05f90c8e8625674b006fa9ab?OpenDocument	
Nevada	Nevada Administrative Code, Chapter 445A, Sections 274 - 280; WTS-1A General design criteria for reclaimed water irrigation use; WTS-1B General design criteria for preparing an effluent management plan; WTS-3 Guidance Document For An Application For Rapid Infiltration Basins; WTS-7 Guidance Document for Reclaimed Water Storage Ponds	http://www.leg.state.nv.us/nac/nac-445a.html#NAC445ASec275	http://ndep.nv.gov/bwpc/fact01.htm
Nevada - additional		http://ndep.nv.gov/admin/nrs.htm	
New Hampshire	No regulations or guidelines at this time	http://des.nh.gov/organization/commissioner/legal/rules/index.htm#water	
New Jersey		http://www.state.nj.us/dep/dwq/714a.	http://www.state.nj.us/d

State	Title of Regulations or Guidelines	Link to State Reuse Regulations or Guidance	Alternate Link to Reuse Fact Sheet or Report
		htm	ep/dwq/techmans/reuseman.pdf
New Mexico	NMED Ground Water Quality Bureau Guidance: Above Ground Use of Reclaimed Domestic Wastewater	http://www.nmenv.state.nm.us/gwb/documents/NMED_REUSE_1-24-07.pdf	http://www.rmwea.org/reuse/NewMexico.html
New Mexico - additional		http://www.nmenv.state.nm.us/gwb/NMED-GWQB-Regulations.htm	
New York		Web Address could not be located at time of publication.	
North Carolina	15A North Carolina Administrative Code Subchapter 02U – Reclaimed Water	http://reports.oah.state.nc.us/ncac.asp?folderName=\Title%2015A%20-%20Environment%20and%20Natural%20Resources\Chapter%2002%20-%20Environmental%20Management	http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environment%20and%20natural%20resources/chapter%2002%20-%20environmental%20management/subchapter%20u/subchapter%20u%20rules.html
North Dakota	Criteria for Irrigation with Treated Wastewater; Recommended Criteria for Land Disposal of Effluent	http://www.ndhealth.gov/WQ/	
Ohio		http://www.epa.state.oh.us/portals/35/rules/42-13.pdf	http://www.epa.state.oh.us/portals/35/rules/42-13_factsheet_feb08.pdf
Ohio - additional		http://www.epa.state.oh.us/dsw/pti/index.aspx	
Oklahoma	OAC 252:656 "Water Pollution Control Construction Standards; OAC 252:627 Operation and Maintenance of Water Reuse; These regulaitons OAC 252:656 Subchapter 27 and OAC 252:627 are proposed.	http://www.deq.state.ok.us/rules/656.pdf	http://normantranscript.com/x1552633625/City-of-Norman-considers-using-reclaimed-water-for-purposes
Oklahoma - additional		http://www.deq.state.ok.us/rules/627.pdf	
Oregon	Oregon Administrative Rules, Division 55 - Recycled Water Use	http://arcweb.sos.state.or.us/pages/rules/oars_300/oar_340/340_055.html	http://www.deq.state.or.us/wq/reuse/reuse.htm
Pennsylvania	Manual for Land Treatment of Wastewater; Reuse of Treated Wastewater Guidance Manual	http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-88575/385-2188-002.pdf	http://www.elibrary.dep.state.pa.us/dsweb/View/Collection-10105
Puerto Rico		Web Address could not be located at time of publication.	
Rhode Island		http://www.dem.ri.gov/programs/benviron/water/permits/wtf/pdfs/reusegyd.pdf	
South Carolina	Section 67.300 of South Carolina Regulation 61-67, Standards for Wastewater Facility Construction "State Land Application Permit"	http://www.scdhec.gov/environment/water/landpage.htm	
South Dakota		http://www.denr.sd.gov/des/sw/documents/DesignCriteriaManual.pdf.	
South Dakota - additional		http://legis.state.sd.us/statutes/DisplayStatute.aspx?Type=StatuteChapter&Statute=34A-2	
Tennessee		www.tn.gov/environment/permits/wqo	

State	Title of Regulations or Guidelines	Link to State Reuse Regulations or Guidance	Alternate Link to Reuse Fact Sheet or Report
		perm.shtml	www.tn.gov/environment/wpc/publications/#tech
Tennessee - additional		http://denr.sd.gov/des/sw/eforms/D0449V1-a_potw_appl.pdf	
Texas		http://www.tceq.texas.gov/rules/indxpdf.html#210	
US Virgin Islands		Web Address could not be located at time of publication.	
Utah	Reuse requirements moved to UCA R317-3-11 (from UCA R317-1-2).	http://www.rules.utah.gov/publicat/code/r317/r317-001.htm#T4	http://www.rules.utah.gov/publicat/code/r317/r317-003.htm#T11
Vermont	Environmental Protection Rules, Chapter 14, Indirect Discharge Rules	http://www.anr.state.vt.us/dec/ww/rules.htm#os	http://www.anr.state.vt.us/dec/ww/Rules/IDR/Adopted-IDR-4-30-03.pdf
Virginia	Virginia Administrative Code Agency 25, Chapter 740 - Water Reclamation and Reuse Regulation	http://lis.virginia.gov/000/reg/TOC09025.HTM#C0740	
Washington	Chapter 90.46 Revised Code of Washington - Reclaimed water use	http://apps.leg.wa.gov/rcw/default.aspx?cite=90.46&full=true	http://www.ecy.wa.gov/programs/wq/reclaim/index.html
West Virginia	Title 64 Series 47 Chapter 16-1 Sewage Treatment and Collection System Design Standards	http://apps.sos.wv.gov/adlaw/csr/ruleview.aspx?document=2802	
Wisconsin	Domestic Wastewater to Subsurface Soil Absorption Systems Permit (WI-0062901-2)	http://dnr.wi.gov/org/water/wm/ww/stauth.htm	
Wyoming	Chapter 21 Water Quality Rules - Standards for the Reuse of Treated Wastewater	http://soswy.state.wy.us/Rules/RULES/2804.pdf	http://deq.state.wy.us/wqd/WQDrules/index.asp

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APPENDIX D
U.S. Case Studies

List of Case Studies by Title and Authors[1]

Page No.	Text code	Case Study Title	Authors
D-5	US-AZ-Gilbert	Town of Gilbert Experiences Growing Pains in Expanding the Reclaimed Water System	Guy Carpenter, P.E. (Carollo Engineers)
D-7	US-AZ-Tucson	Tucson Water: Developing a Reclaimed Water Site Inspection Program	Karen Dotson (Retired, Tucson Water)
D-10	US-AZ-Sierra Vista	Environmental Operations Park	Kerri Jean Ormerod (University of Arizona)
D-12	US-AZ-Phoenix	91st Avenue Unified WWTP Targets 100 Percent Reuse	Steve Rohrer, P.E. and Tim Francis, P.E., BCEE (Malcolm Pirnie, the Water Division of ARCADIS); Andrew Brown, P.E. (City of Phoenix)
D-14	US-AZ-Blue Ribbon Panel	Arizona Blue Ribbon Panel on Water Sustainability	Channah Rock, PhD (University of Arizona); Chuck Graf, R.G. (Arizona Department of Environmental Quality); Christopher Scott, PhD (University of Arizona); Jean E.T. McLain, PhD (USDA-Agricultural Research Service, U.S. Arid Land Agricultural Research Center); and Sharon Megdal, PhD (University of Arizona)
D-18	US-AZ-Prescott Valley	Effluent Auction in Prescott Valley, Arizona	Christopher Scott, PhD (University of Arizona)
D-20	US-AZ-Frito Lay	Frito-Lay Process Water Recovery Treatment Plant, Casa Grande, Arizona	Al Goodman, P.E. (CDM Smith)
D-22	US-CA-Psychology	The Psychology of Water Reclamation and Reuse Survey: Findings and Research Roadmap	Brent M. Haddad, MBA, PhD (University of California, Santa Cruz)
D-24	US-CA-San Ramon	Managing a Recycled Water System through a Joint Powers Authority: San Ramon Valley	David A. Requa, P.E. (Dublin San Ramon Services District)
D-27	US-CA-San Diego	City of San Diego – Water Purification Demonstration Project	Marsi A. Steirer; Amy Dorman, P.E.; Anthony Van; and Joseph Quicho (City of San Diego Public Utilities Department)
D-30	US-CA-Orange County	Groundwater Replenishment System, Orange County, California	Mike Markus, P.E., D.WRE; Mehul Patel, P.E.; William Dunivin (Orange County Water District)
D-33	US-CA-North City	EDR at North City Water Reclamation Plant	Eugene Reahl and Patrick Girvin (GE)
D-35	US-CA-Santa Cruz	Water Reuse Study at the University of California Santa Cruz Campus	Tracy A. Clinton, P.E. (Carollo Engineers)
D-38	US-CA-Monterey	Long-term Effects of the Use of Recycled Water on Soil Salinity Levels in Monterey County	B.E. Platts (Monterey Regional Water Pollution Control Agency)
D-40	US-CA-Southern California MWD	Metropolitan Water District of Southern California's Local Resource Program	Raymond Jay (Metropolitan Water District)

[1] To search for case studies by region or by category of reuse, please refer to Figure 5-2.

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Page No.	Text code	Case Study Title	Authors
D-42	US-CA-Los Angeles County	Montebello Forebay Groundwater Recharge Project using Reclaimed Water, Los Angeles County, California	Monica Gasca, P.E. and Earle Hartling (Los Angeles County Sanitation Districts)
D-46	US-CA-Elsinore Valley	Recycled Water Supplements Lake Elsinore	Ronald E. Young, P.E., DEE (Elsinore Valley Municipal Water District)
D-48	US-CA-Temecula	Replacing Potable Water with Recycled Water for Sustainable Agricultural Use	Graham Juby, PhD, P.E. (Carollo Engineers)
D-51	US-CA-Santa Ana River	Water Reuse in the Santa Ana River Watershed	Celeste Cantú (Santa Ana Watershed Project Authority)
D-53	US-CA-Vander Lans	Leo J. Vander Lans Water Treatment Facility	R. Bruce Chalmers, P.E. (CDM Smith) and Paul Fu, P.E. (Water Replenishment District)
D-55	US-CA-Pasteurization	Use of Pasteurization for Pathogen Inactivation for Ventura Water, California	Andrew Salveson, P.E. (Carollo Engineers)
D-57	US-CA-Regulations	California State Regulations	James Crook, PhD, P.E., BCEE (Water Reuse Consultant)
D-61	US-CA-West Basin	West Basin Municipal Water District: Five Designer Waters	Shivaji Deshmukh, P.E. (West Basin Municipal Water District)
D-63	US-CO-Denver Zoo	Denver Zoo	Abigail Holmquist, P.E. (Honeywell); Damian Higham (Denver Water); and Steve Salg (Denver Zoo)
D-65	US-CO-Denver	Denver Water	Abigail Holmquist, P.E. (Honeywell); Mary Stahl, P.E. (Olsson Associates); and Steve Price, P.E. (Denver Water)
D-68	US-CO-Denver Energy	Xcel Energy's Cherokee Station	Abigail Holmquist, P.E. (Honeywell) and Damian Higham (Denver Water)
D-70	US-CO-Denver Soil	Effects of Recycled Water on Soil Chemistry	Abigail Holmquist, P.E. (Honeywell) and Damian Higham (Denver Water)
D-73	US-CO-Sand Creek	Sand Creek Reuse Facility Reuse Master Plan	Bobby Anastasov, MBA and Richard Leger, CWP (City of Aurora)
D-76	US-CO-Water Rights	Water Reuse Barriers in Colorado	Cody Charnas (CDM Smith)
D-77	US-DC-Sidwell Friends	Smart Water Management at Sidwell Friends School	Laura Hansplant, RLA, ASLA, LEED AP (Andropogon Associates [formerly] and Roofmeadow) and Danielle Pieranunzi, LEED AP BD+C (Sustainable Sites Initiative)
D-80	US-FL-Miami So District Plant	South District Water Reclamation Plant	R. Bruce Chalmers, P.E. (CDM Smith) and James Ferguson (Miami Dade Water and Sewer Department)
D-83	US-FL-Pompano Beach	City of Pompano Beach OASIS	A. Randolph Brown and Maria Loucraft (City of Pompano Beach)
D-85	US-FL-Orlando E. Regional	Eastern Regional Reclaimed Water Distribution System	Victor J. Godlewski Jr. (City of Orlando); Greg D. Taylor, P.E. and Karen K. McCullen, P.E., BCEE (CDM Smith)
D-87	US-FL-Economic Feasibility	Economic Feasibility of Reclaimed Water to Users	Grace M. Johns, PhD (Hazen and Sawyer) and C. Donald Rome, Jr. (Southwest Florida Water Management District)
D-90	US-FL-Reedy Creek	Reuse at Reedy Creek Improvement District	Ted McKim, P.E., BCEE (Reedy Creek Improvement District)
D-93	US-FL-Marco Island	Marco Island, Florida, Wastewater Treatment Plant	Jennifer Watt, P.E. (General Electric); Solomon Abel, P.E. (CDM Smith); and Rony Joel, P.E., DEE (AEC Water)

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Page No.	Text code	Case Study Title	Authors
D-96	US-FL-Everglade City	Everglade City, Florida	Rony Joel, P.E., DEE (AEC Water)
D-98	US-FL-Orlando Wetlands	City of Orlando Manmade Wetlands System	Mark Sees (City of Orlando)
D-99	US-FL-SWFWMD Partnership	Regional Reclaimed Water Partnership Initiative of the Southwest Florida Water Management District	Alison Ramoy (Southwest Florida Water Management District)
D-102	US-FL-Altamonte Springs	The City of Altamonte Springs: Quantifying the Benefits of Water Reuse	David Ammerman, P.E. (AECOM)
D-104	US-FL-Clearwater	Evolution of the City of Clearwater's Integrated Water Management Strategy	Laura Davis Cameron, BSBM; Tracy Mercer, MBA; Nan Bennett, P.E.; and Rob Fahey, P.E. (City of Clearwater Public Utilities)
D-107	US-FL-Turkey Point	Assessing Contaminants of Emerging Concern (CECs) in Cooling Tower Drift	James P. Laurenson (HEAC) and Edward L. Carr (ICF International)
D-110	US-GA-Clayton County	Sustainable Water Reclamation Using Constructed Wetlands: The Clayton County Water Authority Success Story	Veronica Jarrin, P.E. and Jim Bays, P.W.S (CH2M HILL); Jim Poff (Clayton County Water Authority)
D-113	US-GA-Forsyth County	On the Front Lines of a Water War, Reclaimed Water Plays a Big Role in Forsyth County, Georgia	Daniel E. Johnson, P.E. (CDM Smith)
D-115	US-GA-Coca Cola	Recovery and Reuse of Beverage Process Water	Dnyanesh V Darshane, PhD, MBA; Jocelyn L. Gadson, PMP; Chester J. Wojna; Joel A. Rosenfield, Henry Chin, PhD; Paul Bowen, PhD (The Coca-Cola Company)
D-118	US-HI-Reuse	Reclaimed Water Use in Hawaii	Elson C. Gushiken (ITC Water Management, Inc.)
D-121	US-MA-Southborough	Sustainability and LEED Certification as Drivers for Reuse: Toilet Flushing at The Fay School	Mark Elbag (Town of Holden)
D-123	US-MA-Hopkinton	Decentralized Wastewater Treatment and Reclamation for an Industrial Facility, EMC Corporation Inc., Hopkinton, Massachusetts	Mike Wilson, P.E. (CH2M Hill)
D-124	US-MA-Gillette Stadium	Sustainability and Potable Water Savings as Drivers for Reuse: Toilet Flushing at Gillette Stadium	Mike Wilson, P.E. (CH2M Hill)
D-126	US-ME-Snow	Snowmaking with Reclaimed Water	Don Vandertulip, P.E., BCEE (CDM Smith)
D-129	US-MN-Mankato	Reclaimed Water for Peaking Power Plant: Mankato, Minnesota	Mary Fralish (City of Mankato) and Patti Craddock (Short Elliott Hendrickson Inc.)
D-132	US-NC-Cary	Town of Cary, North Carolina, Reclaimed Water System	Leila R. Goodwin, P.E. (Town of Cary) and Kevin Irby, P.E. (CDM Smith)
D-134	US-NY-PepsiCo	Identifying Water Streams for Reuse in Beverage Facilities: PepsiCo ReCon Tool	Liese Dallbauman, PhD (Pepsi-Co Global Operations)
D-136	US-PA-Kutztown	The Water Purification Eco-Center	Jeff Moyer and Christine Ziegler Ulsh (Rodale Institute)
D-139	US-PA-Mill Run	Zero-Discharge, Reuse, and Irrigation at Fallingwater, Western Pennsylvania Conservancy	Mike Wilson, P.E. (CH2M Hill)
D-141	US-TN-Franklin	Franklin, Tennessee Integrated Water Resources Plan	Jamie R. Lefkowitz, P.E. and Kati Bell, PhD, P.E. (CDM Smith); and Mark Hilty, P.E. (City of Franklin)

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Page No.	Text code	Case Study Title	Authors
D-145	US-TX-San Antonio	San Antonio Water System Water Recycling Program	Pablo R. Martinez (San Antonio Water System)
D-148	US-TX-Big Spring	Raw Water Production Facility: Big Spring Plant	David W. Sloan, P.E., BCEE (Freese and Nichols)
D-150	US-TX-Landscape Study	Site Suitability for Landscape Use of Reclaimed Water in the Southwest	Seiichi Miyamoto, PhD and Ignacio Martinez (Texas A&M Agrilife Research Center at El Paso)
D-152	US-TX-NASA	U.S. Water Recovery System on the International Space Station	J. Torin McCoy (NASA Johnson Space Center)
D-154	US-TX-Wetlands	East Fork Raw Water Supply Project: A Natural Treatment System Success Story	Ellen T. McDonald, PhD, P.E. and Alan H. Plummer, Jr., P.E., BCEE (Alan Plummer Associates Inc.) and James M. Parks, P.E. (North Texas Municipal Water District)
D-157	US-VA-Occoquan	Potable Water Reuse in the Occoquan Watershed	Robert W. Angelotti (Upper Occoquan Service Authority) and Thomas J. Grizzard, PhD, P.E. (Virginia Tech)
D-160	US-VA-Regulation	Water Reuse Policy and Regulation in Virginia	Valerie Rourke, CPSS, LPSS, CNMP (Virginia Department of Environmental Quality)
D-163	US-WA-Sequim	City of Sequim's Expanded Water Reclamation Facility and Upland Reuse System	Chad Newton, P.E. (Gray & Osborne, Inc.)
D-166	US-WA-Regulations	Washington State Regulations	Chad Newton, P.E. (Gray and Osborne, Inc.) and Craig Riley, P.E. (Washington State Department of Health)
D-169	US-WA-King County	Demonstrating the Safety of Reclaimed Water for Garden Vegetables	Sally Brown, PhD (University of Washington)
D-172	US-WA-Yelm	City of Yelm, Washington	Shelly Badger (City of Yelm)

Town of Gilbert Experiences Growing Pains in Expanding the Reclaimed Water System

Author: Guy Carpenter, P.E. (Carollo Engineers)

US-AZ-Gilbert

Project Background or Rationale

The Town of Gilbert, population 208,453, is a 73 mi^2 (190-km^2) city located in the Phoenix, Arizona, metropolitan area. By 1986, and with a population of over 11,000, Gilbert's rudimentary sewage treatment system was replaced by a facility that produced reclaimed water of sufficient quality for open access urban irrigation. While Gilbert had a water resources portfolio sufficient to meet near-term water demands, there were a number of drivers for Gilbert to implement reuse.

First, Gilbert is several miles away from any possible discharge outfall to receiving waters (such as a river or lake), so there was no cost effective disposal option for treated wastewater. Second, the State of Arizona Groundwater Management Act's stringent water conservation requirements (which regulate all sources of water, not just groundwater) encourage the use of reclaimed water to maintain compliance with the act. The Act was adopted in 1980 to stop the rapid decline of aquifer water levels and for Arizona to receive congressional approval to build the Central Arizona Project, the 336-mile (540 km) canal that brings Colorado River water to Arizona's largest urban and agricultural centers. These factors encouraged town leaders to install a reclaimed water distribution system with connections required for new development, thereby ensuring a systematic and cost-effective expansion of the system.

Reclaimed water is an important element of the town's ability to demonstrate a 100-year assured water supply (a requirement of the act), a designation without which the town would be subject to a state-imposed growth moratorium.

Capacity and Type of Reuse Application

Gilbert operates two WRFs that treat produce A+ quality reclaimed water, with a loss of approximately 8 to 10 percent of the influent total to solids treatment. The Neely Water Reclamation Facility (WRF) has a treatment capacity of 11 mgd (482 L/s). The Greenfield WRF is a joint facility operated in partnership with the city of Mesa and the town of Queen Creek. The plant capacity is currently 16 mgd (700 L/s), with 8 mgd (350 L/s) of capacity available to Gilbert, and is planned to be expanded to treat up to 42 mgd (1840 L/s), with Gilbert's share of the capacity at 16 mgd (700 L/s).

Reclaimed water was initially used by a single customer, the town parks and recreation department. Over the past two decades, with rapid population growth, the system has expanded to include a distribution system throughout newly developed areas, the Riparian Preserve at Water Ranch, the South Recharge facilities, and eight facilities. The town of Gilbert now has over 60 miles (96 km) of reclaimed water transmission mains and approximately 37 reclaimed water customers.

In addition to reclaimed water distribution, because Gilbert is committed to 100 percent reuse, reclaimed water that is not used in the distribution system is recharged for the purpose of accumulating Long Term Storage Credits, which are utilized to offset current and future groundwater pumping, as well as to firm up the Assured Water Supply. Recharge facilities consist of percolation basins and injection wells.

Initial Phase of Implementation

In 1986, the new reclamation facility provided water to the Town's first regional park, Freestone Park, which is approximately two miles east of the Neely WRF. Freestone Park is a 60-acre (24 hectares) multi-use park with two attractive, non-recreational lakes out of which reclaimed water is pressurized and distributed throughout the park for spray irrigation.

Soon after the construction of the Neely WRF, a rapid increase in population growth and lack of additional reclaimed water customers forced Gilbert to look at alternatives. The evaporation ponds that were constructed to receive reclaimed water that was not otherwise used by the park were under capacity.

Because evaporating the unused reclaimed water did not meet the objectives of the Groundwater Management Act, the evaporation ponds on 35 ac (14 ha), adjacent to the Neely WRF were converted to recharge basins in 1989.

Growing Pains and Lessons Learned

As the town continued to grow, additional reclaimed water customers eventually responded to the availability of the inexpensive and continuous supply of reclaimed water. Additionally, recharge basins were expanded by another 40 ac (16 ha) and in response to suggestions by the public, the recharge facility was enhanced to include habitat for native and migratory birds.

At the time of the town's implementation of the reclaimed water system, there were no state, county, regional, or local construction standards specifically for reclaimed water systems. Several design issues caused operational problems. Basic, regional potable water system construction standards were used for expansion of the reclaimed water system, but valve spacing was allowed to be greater than that in the potable system. Thus, when breaks occurred, draining the lines for repair took significant time and reclaimed water cannot be drained to a retention basin without a permit, so management of a break was a labor and administrative intensive effort. Other challenges were related to developer-installed reclaimed water pipeline additions which often had valve boxes of the same specification as the potable water system. This caused confusion for operators and utility locators attempting to respond to system breaks and water delivery changes; incorrect valves were opened and closed due to the lack of differentiating features. This was also problematic from a health and safety standpoint.

Positive changes also occurred at this time, such as reclaimed water identification standards. To ensure compliance with its reuse permit through the state, and to provide limited system design guidance to developers, the town developed a reclaimed water user's manual. Along with the manual, each customer, except Gilbert Parks and Recreation, was required to enter a reclaimed water use agreement stipulating requirements and an annual volume of water that must be taken by the customer.

In 1999, in response to increasing conservation requirements, the mayor formed an "ad hoc" water conservation committee made up of the mayor, two council members, landowners, developers, engineers, and the large untreated water providers whose service areas overlapped the town of Gilbert water service area. Accurate information regarding the complexities of water resource management was conveyed and understood by stakeholders and the attitude of "disposing" reclaimed water was effectively overcome, and the importance of reclaimed water was finally understood.

Also in 1999, and in response to the need to recharge water to offset groundwater pumping debits and to manage "excess" reclaimed water associated with seasonal demand fluctuations, a second basin recharge facility was constructed on 120 ac (49 ha). Following the success of the original recharge facility's habitat enhancements, the new facility (called the Riparian Preserve at Water Ranch) was designed as an open-access, passive recreation park, in addition to a fully functional recharge facility (**Figure 1**).

Figure 1
Reclaimed water sustains a diverse wildlife habitat at the Gilbert Riparian Preserve, while replenishing the regional aquifer (Photo credit: Patty Jordan, Town of Gilbert)

Expansion

In 2005, the South Recharge Facility was constructed to accommodate increases in wastewater flows from the Greenfield Water Reclamation Plant, which began operation in 2005. In 2006, the Town's integrated water resources master plan was updated to guide the allocation of reclaimed water to ensure a long-term water supply.

Tucson Water: Developing a Reclaimed Water Site Inspection Program

Author: Karen Dotson (Retired, Tucson Water)

US-AZ-Tucson

Project Background or Rationale

The city of Tucson is part of a metropolitan area of over 1 million people in the northern semi-arid reaches of the Sonoran Desert in eastern Pima County, Arizona. The City owns and operates Tucson Water, the largest regional municipal water utility in the area. Tucson Water provides potable water to about 75 percent of the metropolitan area's population and non-potable reclaimed water service in the City and three other governmental jurisdictions. Recognizing the importance of maintaining public safety, protecting the quality of water supplies, and fostering a positive public perception of reclaimed water for non-potable purposes, Tucson Water developed a program to periodically inspect all sites having reclaimed water service. This program includes training and certification for staff conducting testing at reclaimed water sites.

Capacity and Type of Reuse Application

Until 1993, when Colorado River water was introduced as part of the potable water supply, the Tucson area relied exclusively on pumped groundwater. Today, Colorado River water makes up over half of Tucson Water's potable supplies –approximately 98,000 ac-ft/yr (121 MCM/yr) as of 2010. In 2010, 15,000 ac-ft (18.5 MCM) were delivered to over 900 reclaimed water customers – water that would otherwise have been drawn from the potable water system of Tucson Water or another water provider. Fifty-six percent of the deliveries went to 18 golf courses; another 17 percent was delivered to parks. The remainder was delivered to schools (8 percent), other water providers (13 percent), and single family, agriculture, commercial, multi-family, and street landscape irrigation (6 percent).

Reuse Treatment Technology

Since 1984, Tucson Water has operated its reclaimed water system while systematically expanding it to accommodate areas of growing customer demand. Today, the system has more than 160 miles (257 km) of pipeline and 15 million gallons (57,000 m^3) of surface storage. Reclaimed water is produced is produced in three ways and depending on the demand, water from a combination of the sources below is delivered through the Reclaimed Water System:

1. Secondary effluent from Pima County's Roger Road WWTP that receives additional filtration and disinfection at Tucson Water's Filtration Plant
2. Secondary effluent from Pima County's Roger Road WWTP that is recharged in constructed basins or the Santa Cruz River and later recovered and disinfected
3. Tertiary effluent from Pima County's Randolph Park WWTP

The average daily delivery of reclaimed water is 13.5 mgd (657 L/s), and the summer peak delivery is approximately 31 mgd (1358 L/s).

Project Description

1. Until 2010, Tucson Water only inspected sites with reclaimed water service once (prior to the initiation of service). At these inspections, a Tucson Water cross-connection control specialist checked the site for compliance with state and local regulations and conducted a dye test (**Figure 1**) to identify cross-connections. A manual was developed to guide cross-connection control specialists step-by-step through the dye test procedure (Tucson Water, 2010). The Reclaimed Water Site Inspection Program was implemented in phases:
2. Adoption of an ordinance requiring periodic reclaimed water site inspections
3. Development of a Reclaimed Water Site Testers Certification Program and training manual for Reclaimed Water Site Testers

4. Development of a training program

5. Inspection of reclaimed water sites

The first phase of implementation of the Reclaimed Water Site Inspection Program was the adoption of a 2010 ordinance requiring all reclaimed water sites to be inspected periodically, with provisions including the following:

- Annual inspections for schools, parks, and commercial sites
- Residential site inspections once every five years
- Inspection of non-residential sites by a private sector certified Reclaimed Water Site Tester beginning in 2015

The second phase included development of a reclaimed water site database and Reclaimed Water Site Testers certification program. Tucson Water's backflow prevention online database was modified to allow the addition of reclaimed water site information and the results of Reclaimed Water Site Testers' site inspections the same way that the annual backflow prevention assembly tests are entered.

The Reclaimed Water Site Testers certification program requires attendance at an eight-hour class instructed by Tucson Water, and a passing score on a written examination. Re-certification is required every three years. Because the site inspection program focused heavily on prevention and identification of cross-connections, Tucson Water required that a current certification as a Backflow Prevention Tester from a recognized agency, (e.g. AWWA or American Backflow Prevention Association), would be required.

The Tucson Water Cross-connection Control Specialists developed a training manual that includes chapters addressing: Tucson Water's reclaimed water system, Tucson Water's responsibilities, reclaimed water customers' responsibilities, and reclaimed water site testers' responsibilities; concepts addressed include:

- Ensuring that reclaimed water sites comply with state and local regulations
- Visiting a reclaimed water site and hands on experience conducting pressure tests
- Reporting cross-connections to Tucson Water and the customer
- Entering test results online into Tucson Water's database

Tucson Water conducts Reclaimed Water Site Tester classes several times a year and has certified more than 30 Reclaimed Water Site Testers. The initial classes were attended by cross-connection control specialists from Tucson Water and the Peoria, Arizona Public Works Utilities Department, and backflow prevention testers from the City of Tucson Parks and Transportation Departments, Pima County Natural Resources and Transportation Departments, Tucson Unified School District, the University of Arizona, and the Arizona Department of Environmental Quality (ADEQ). The ADEQ has approved the class for eight hours of professional development credit.

The Tucson Water Cross-connection Control Specialists are now working closely to mentor newly certified Reclaimed Water Site Testers as they begin inspecting schools, parks, and street medians. The mentoring program provides confidence that sites are being correctly inspected and tested and gives the new Site Testers a positive environment in which to ask questions. In 2013 Tucson Water Site Testers will begin inspecting residential sites.

Project Funding and Management Practices

The Reclaimed Water Site Inspection Program was developed by existing staff from the Backflow Prevention/Reclaimed Water Section. The only new expense for the Program's development was $10,000 for consultant services to modify the backflow prevention database to accommodate reclaimed water site information. When the program was implemented, a fifth cross-connection control specialist was hired and the total recurring annual cost for this position, including benefits, is $72,000. There was also a one-time $37,000 expense, including a vehicle, equipment, and training for the new specialist.

Successes and Lessons Learned

Development of the Reclaimed Water Site Inspection Program took more than 5 years from conception to implementation. Although the importance of the program was recognized, competing priorities often overshadowed implementation efforts. Ultimately, the program was implemented as the result of a project "champion" within Tucson Water and support from the Southern Arizona Office of the ADEQ. Once the commitment to implement the program had been made, strict adherence to the schedule made its completion a reality.

Tucson Water's Reclaimed Water Site Inspection Program is the first of its type in Arizona and will hopefully be used as a model for other programs and a template for State certification of Reclaimed Water Site Testers.

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City of Tucson. 2010. *Mayor and Council Ordinance: Requiring Inspections*. Available from <http://cms3.tucsonaz.gov/sites/default/files/water/docs/backflow-ordinance.pdf>.

Tucson Water. 2010. *A Training Manual for Reclaimed Water Site Testers*. Available at <http://cms3.tucsonaz.gov/files/water/docs/recl-train-1-2.pdf>.

Environmental Operations Park

Author: Kerri Jean Ormerod (University of Arizona)

US-AZ-Sierra Vista

Project Background or Rationale

The key water management challenges in Arizona are increasing demands for water, fully allocated existing water resources, and groundwater depletion. Groundwater depletion, or overdraft, is a result of excessive groundwater pumping and is problematic for numerous reasons, including its environmental impacts. Groundwater sustains rivers, streams, lakes, and wetlands providing the riparian habitat for wildlife. In the 19th century, wetlands, marshlands or cienegas, were common along rivers in Arizona; however, heavy pumping of groundwater beginning in the mid-20th century led to dewatered rivers and streams and loss of riparian ecosystems (Glennon, 2002).

Recently, artificially constructed wetlands have been designed to simultaneously provide natural wastewater treatment and enhance wildlife habitat. Environmental Operations Park (EOP) in southern Arizona serves as a case study, where water from the wastewater reclamation facility is polished in constructed wetlands and recharged to the local aquifer in order to mitigate the adverse impacts of continued groundwater pumping in the San Pedro River system.

The EOP is operated by the city of Sierra Vista, Arizona, in Cochise County in the southeastern corner of the state. Sierra Vista is adjacent to the upper San Pedro River and the U.S. Army's Fort Huachuca. The city and surrounding communities in Cochise County are experiencing rapid growth and subsequent increases in water demand. The addition of over 13,500 new residents between 2000 and 2010 represented a 12 percent change in population (U.S. Census Bureau, 2010) and by 2025 an estimated 7,000 ac-ft (8.6 MCM) will be necessary to serve the projected population (Glennon, 2002). Cochise county communities rely on the groundwater resources in the Sierra Vista sub-watershed, part of the bi-national San Pedro Watershed. Within the watershed, the San Pedro River flows north from Mexico into Arizona. The river is distinct as the last free-flowing undammed river in Arizona, which supports a unique desert riparian ecosystem. The wells supporting Sierra Vista and Fort Huachuca have created cones of depression that threaten the surface flow of the river (Glennon, 2002). While there is technically sufficient groundwater to sustain the rising population in and around Sierra Vista, a significant drop in the water table will reduce the amount of water available to the river and its riparian vegetation. Ecological considerations, including the protection of endangered species, prompted the decision to recharge available reclaimed water supplies to the underlying aquifer.

The ecological importance of Arizona's San Pedro River was recognized by Congress in 1988 when it established the San Pedro Riparian National Conservation Area with the explicit mission to protect approximately 40 miles (64 km) of the river and its riparian habitat. The San Pedro River system provides habitat for over two-thirds of all bird species in North America and is an internationally renowned attraction for birders (Glennon, 2002; Sprouse, 2005). In addition to the hundreds of bird species, the San Pedro provides habitat 82 mammals, 43 reptiles, including seven federally recognized endangered species (Sprouse, 2005).

In Sierra Vista, reclaimed water functions solely as a water supply for aquifer recharge. The artificial recharge occurs a couple miles from the San Pedro River with the ultimate goal of safe yield (balance between water withdraw and natural and artificial recharge). The immediate goal of the recharge is to mitigate groundwater pumping by creating a mound between the existing cone of depression and the San Pedro River in order to protect baseflow of the river.

Capacity and Type of Reuse Application

The Sierra Vista EOP was established as a multi-use center. The park spans 640 ac (260 ha) and includes 30 open basins that recharge nearly 2,000 ac-ft (2.5 MCM) of reclaimed water to the aquifer on an annual basis, 50 ac (20 ha) of constructed wetlands, nearly 200 ac (81 ha) of native grasslands, and an 1,800 ft^2 (170 m^2) wildlife viewing facility. The reclamation facility includes a 10-ac (4-ha) complete mix/partial mix lagoon system. The constructed wetlands provide numerous beneficial services, including filtering and improving water quality as plants take up available nutrients. In the EOP wetlands secondary treated effluent is treated to tertiary standards naturally.

The primary purpose of EOP is to offset the effects of continued groundwater pumping that negatively impact the river and protect the habitat for native and endangered species. The present volume of wastewater generated from the EOP treatment plant is 2.5 mgd (110 L/s). The facility system capacity is 4 mgd (175 L/s). Over 11,000 ac-ft (13.5 MCM) of water have been recharged since opening in 2002. The recharge facility is permitted and monitored by Arizona Department of Water Resources, the agency responsible for protecting water quality in the state.

Project Funding and Management Practices

The $7.5 million reclamation project at EOP was funded through a cooperative agreement with the City of Sierra Vista and the Bureau of Reclamation with assistance from Arizona Water Protection Fund Program and Department of Housing and Urban Development. Per the Bureau of Reclamation funding, the City of Sierra Vista is required to recharge all wastewater at the EOP facility until 2022.

Institutional/Cultural Considerations

In response to growing environmental concerns, considerable collaborative community effort has been made to protect the region's assets, including the watershed, endangered species, and the continued presence of Fort Huachuca—the region's biggest employer. The most influential group is the Upper San Pedro Partnership, a consortium of interested parties including federal, state, and local agencies, development groups, and environmental organizations committed to actively protecting the river and the fort.

Successes and Lessons Learned

Reclaimed water is utilized in Sierra Vista to protect the San Pedro River from the principal threat of increased groundwater pumping associated with population growth. The primary benefits reclaimed water provides to the region are recreational and economic. In addition to providing wastewater treatment, the wetlands, foot trails, trees, native grasses and animals at EOP are recognized as a community amenity. Recharge of reclaimed water within the watershed assists in sustaining the baseflows of the river and mitigating the damaging effects of continued groundwater pumping, helping to maintain essential migration corridors for wildlife and protect the habitat for endangered species. Nonetheless, future development and its associated increase in water demand are expected to exacerbate the environmental impacts of groundwater overdraft in the region (Glennon, 2002).

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91st Avenue Unified Wastewater Treatment Plant Targets 100 Percent Reuse

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US-AZ-Phoenix

Introduction

The 91st Avenue Wastewater Treatment Plant (WWTP) treats wastewater from the cities of Glendale, Mesa, Phoenix, Scottsdale, and Tempe, Arizona, which together constitute the Sub-Regional Operating Group (SROG), formed in 1979 and jointly owns the WWTP. The 230 mgd (10,100 L/s) facility uses nitrification/denitrification in treating municipal and industrial wastewater from the SROG cities. The WWTP is one of the largest water reclamation facilities in the country. Currently, the plant processes approximately 158,000 ac-ft/year (195 MCM/yr), of which approximately 60 percent is reused; 67,700 ac-ft/yr (83.5 MCM/yr) is delivered to a nuclear, power-generating station for cooling tower makeup water, 1,400 ac-ft/yr (1.7 MCM/yr) is delivered to new constructed wetlands, and 28,200 ac-ft (34.8 MCM/yr) is delivered to an irrigation company for agricultural reuse. The remaining effluent is discharged to the dry Salt River riverbed that bisects the SROG communities.

The 91st Avenue WWTP

The original 5 mgd (219 L/s) WWTP was built in 1958 near 91st Avenue and the Salt River in Phoenix. This plant was later replaced with a 45 mgd (1,970 L/s) plant that was subsequently expanded throughout the years. The plant initially discharged secondary treated wastewater to the dry Salt River, but in 2000, the SROG developed a 25-year Facility Master Plan that envisioned a unified plant concept for all future expansions. The first project under this plan, the Unified Plant 2001 (UP01), was designed in 2001 and completed in September 2008, increasing plant capacity to 204 mgd (8,900 L/s). The second plant expansion project, UP05, was completed in October 2010 and increased the capacity to the current 230 mgd (10,100 L/s).

The unified plant concept consists of process units that operate as part of an integrated system. Flow from each process is combined into a common channel so that the following process can be fed to any of the subsequent process units. One of the major advantages of the unified plant concept is that, in the event of a process upset or a scheduled maintenance event, a single process unit can be taken out of service while maintaining the treatment capacity in adjacent and follow-on process areas. Process units have been sized with built-in redundancy such that follow-on process units with slightly decreased influent quality can still satisfy the plant's permit water quality requirements, thus maintaining reliable reclaimed water production.

91st Avenue WWTP Water Reuse Program

The 25-Year Master Plan considered the likelihood of future advanced treatment that may be required as the result of evolving regulations or customer requirements. It is estimated that, by 2025, up to 60 mgd (2630 L/s) of the WWTP effluent could be allocated to end uses that require advanced treatment and the SROG envisions a Market Resource Center on the WWTP site that could include membrane filtration and reverse osmosis systems. As a result, planning estimates for the development area include space on the plant site for advanced treatment systems. Currently, the reuse program includes several agreements for delivery of the reclaimed water, including consideration for future uses of the resource.

Cooling Tower Use at the Palo Verde Nuclear Generating Station. SROG's original water pact with the Palo Verde Nuclear Generating Station (PVNGS) was signed in 1973 and water deliveries under that agreement began in 1985 when the facility's Unit 1 began operations. Because of its desert location, the PVGNS is the only nuclear power plant in the world that uses treated effluent for cooling tower use. Treated effluent is piped from the 91st Avenue WWTP a distance of 36 miles (58 km) to the PVNGS site, where it is further treated to meet the nuclear energy plant's cooling needs.

The original agreement required SROG to set aside 105,000 ac-ft/yr (130 MCM/yr) for the PVNGS. And, although the plant used considerably less water than this, SROG was required to maintain this capacity under the terms of the contract. In early 2010, SROG and owners of PVNGS renegotiated a new, comprehensive water contract which calls for an annual allotment of 80,000 ac-ft (98.7 MCM/yr) through 2050, freeing up an annual volume of 25,000 ac-ft (30.8 MCM) for other SROG uses.

Tres Rios Constructed Wetlands. The SROG worked with the U.S. Army Corps of Engineers to develop the Tres Rios Constructed Wetlands Project along the Salt River downstream of the 91st Avenue WWTP. The project will restore eight miles of unique riparian habitat near the confluence of the Salt, Gila and Agua Fria Rivers using reclaimed water from the 91st Avenue WWTP. In addition to meeting water quality and supply objectives, the project is intended to restore habitats for threatened and endangered fish and wildlife species, reduce potential for flood damage, and provide public recreation opportunities. The wetlands were constructed and put into operation in 2010 and are currently receiving 1,400 ac-ft/yr (1.7 MCM/yr) of reclaimed water. It is projected that the wetlands can accept 19,000 to 23,000 ac-ft (23 to 28 MCM) annually as it matures and operations are stabilized.

Buckeye Irrigation Company Agricultural Irrigation. Buckeye Irrigation Company (BIC) has a service area located approximately 20 miles (32 km) west of the 91st Avenue WWTP. The company got its start in 1907 after many periods of drought, floods, economic downturns, changing land and water policies, and fiscal uncertainties. Currently, some of BIC's water supply is purchased reclaimed water; BIC operates a diversion structure downstream from the plant, capturing and diverting reclaimed water discharged from the WWTP and/or the Tres Rios Constructed Wetlands into agricultural canals. BIC, by agreement, can take up to 20,000 ac-ft/yr (25 MCM/yr) of effluent through the year 2015, with options to extend to 2030.

Potential Future Reuses. Critical riparian and wetland habitats along the Salt, Gila and Agua Fria Rivers have been lost because of water resources development in the Phoenix metropolitan area. In addition to the Tres Rios Constructed Wetlands project, the SROG cities have evaluated other major groundwater recharge and habitat restoration projects near these three rivers. The projects will play significant roles in the transformation of the 91st Avenue WWTP, and likely other area WWTPs, in becoming major providers of reclaimed water.

Summary

The 91st Avenue WWTP currently delivers 60 percent of its reclaimed water produced to industrial, wetlands and irrigation uses. If current reuse customers take their full allotments, the effective reuse rate could be as high as 80 percent of the current plant production. In addition to increasing deliveries to the wetlands and continuing deliveries to the other reclaimed water customers, the SROG cities envision implementing other regional groundwater recharge and environmental and riparian habitat restoration projects. These projects, along nearby riverbeds, could accept all the remaining reclaimed water that would otherwise be discharged to the riverbed. This would effectively make the 91st Avenue WWTP the largest water reclamation facility in the country whose effluent is 100 percent reused.

Arizona Blue Ribbon Panel on Water Sustainability

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US-AZ-Blue Ribbon Panel

Background or Rationale

In response to the pressure of population growth coupled with an arid environment, Arizona has conventionally addressed water challenges by increasing supply. This case study demonstrates how decision-makers are reconsidering the other side of the equation—alleviating water demand, especially through conservation, recycling, and reuse. In particular, the expanding practice of water reuse has become the centerpiece of efforts to achieve sustainability.

Blue Ribbon Panel on Water Sustainability

In 2009, Arizona Governor Jan Brewer announced formation of the Blue Ribbon Panel on Water Sustainability (BRP) to focus on water conservation and recycling as strategies to improve water sustainability in Arizona. The BRP was jointly chaired officials responsible for regulation and management of water resources: Ben Grumbles, Director, Arizona Department of Environmental Quality (ADEQ); Herb Guenther, Director, Arizona Department of Water Resources (ADWR); and Kris Mayes, Chairperson, Arizona Corporation Commission (ACC), Arizona's constitutionally established regulatory body for privately owned utilities. Additionally, 40 members representing diverse water interests in Arizona were appointed to the BRP, including representatives of large and small cities, counties, agriculture, industry, Indian Tribes, environmental interests, universities, legislative leaders, and other experts. The BRP held its first meeting in January 2010 and was challenged to identify and overcome obstacles to increase water sustainability. The initial goal was to agree upon a succinct purpose statement:

To advance water sustainability statewide by increasing reuse, recycling, and conservation to protect Arizona's water supplies and natural environment while supporting continued economic development and to do so in an effective, efficient and equitable manner.

Members agreed to provide recommendations on statute, rule, and policy changes that, by the year 2020 in Arizona, would significantly;

1. Increase the volume of reclaimed water reused for beneficial purposes in place of raw or potable water
2. Advance water conservation, increase the efficiency of water use by existing users, and increase the use of recycled water for beneficial purposes in place of raw or potable water
3. Reduce the amount of energy needed to produce, deliver, treat, and reclaim and recycle water by the municipal, industrial, and agricultural sectors
4. Reduce the amount of water required to produce and provide energy by Arizona power generators
5. Increase public awareness and acceptance of reclaimed water uses and the need to work toward water sustainability

BRP Working Groups

Five working groups were formed, chaired by BRP members, with participation open to the public, to facilitate discussion of issues and involve broadest broad spectrum of stakeholders and technical expertise. Working groups were chaired by Arizona representatives from Pima County Regional Wastewater Reclamation; WateReuse Association; Arizona WateReuse Association; Arizona Municipal Water Users Association; and Pinal County to explore:

- Public perceptions related to reclaimed water reuse quality
- Regulatory and policy changes to further promote reuse and recycling
- Reclaimed water infrastructure and retrofit best practices
- Conservation/efficiency and energy/water nexus issues
- Economic and funding opportunities, including both public and private mechanisms

The chairs and working group participants accomplished substantial work from January through November 2010. Cumulatively, 58 meetings were held, involving some 320 individuals. The working groups identified 40 separate issues, which the BRP condensed and prioritized. The working groups were directed to write "white papers" analyzing these challenges and provided recommendations based on the analyses. Priority issues included a diversity of subjects, including public perception, education, research needs, regulatory impediments, efficient use of water supplies, expanded use of rainwater and storm water, the interface between water and energy, funding and incentives.

BRP White Papers

Subsequent panel meetings were used to provide an overview of the 26 issues and to present the recommendations developed in the white papers. The BRP reviewed recommendations and consolidated them into categories: 1) education/outreach, 2) standards, 3) information development and research agenda, 4) regulatory improvements, and 5) incentives.

BRP Final Report and Recommendations

Although the final report contains too many recommendations to summarize here, several involving data collection and management stand out because they cross all three agencies chairing the BRP. Accurate information is essential to promoting a common understanding of Arizona's water supplies and the extent to which water sustainability is achieved. Development of rational policies and regulations that encourage use of recycled water while protecting public health and safety, and fostering public confidence depends on appropriate, timely, and accurate data. In addition to data management, a few select recommendations of the Panel, relevant to reuse are presented.

Data Management. Most generators and end users of reclaimed water submit data manually, which is time-consuming and often involves more than one permit or application. Data may be submitted to one agency and the same data or data in a slightly different form may be required by another report or agency. Agencies store this information in paper files and multiple electronic databases, which are hard to access and often difficult to compare. This creates administrative complexity and added costs for both the regulatory agencies and the regulated community, and is not conducive to expanding the use of recycled water in Arizona.

The BRP recommended streamlining data submission and management as a means of reducing administrative burden and improving data quality. ADEQ and ADWR would initiate a process to review and revise permit and non-permit data submittal requirements for frequency, consistency, and relevance. Electronic data submittal should be standard, and agencies should develop common data management systems available to regulators, permittees, contractors, and the public. The system also should incorporate data needs of the ACC in support of their application and review process. The BRP also recommended that agencies utilize expertise of independent information technology professionals and share costs of developing data management system(s).

Regulatory Programs. Ultimately, the BRP recommended no new regulatory programs for reuse and water sustainability or major reconstruction of existing programs. Instead, less dramatic adjustments to Arizona's existing toolbox of water management, education, and research capabilities are highlighted. The BRP concluded that current programs administered by ADWR, ADEQ, and the ACC constitute an exceptional framework within which water sustainability and reuse can be pursued.

No major new programs were recommended for addressing reuse; this reflected the success of transformative rule changes adopted by ADEQ in January, 2001. At that time, following more than two years of stakeholder involvement, ADEQ adopted rules for reclaimed water permits for end users, reclaimed water conveyances, and reclaimed water quality standards. Simultaneously, ADEQ adopted rules requiring modern, high-performance, tertiary treatment for new or expanding wastewater treatment plants (WWTPs) under BADCT (Best Available Demonstrated Control Technology) provisions of its Aquifer Protection Permit program. The BADCT requirements provide that the high-quality, reclaimed water produced is suitable for reuse. This allows the permitting program for end users to be simple, concentrating on operation, maintenance and reporting matters, because end users are delivered high quality reclaimed water. Arizona's modern approach to wastewater treatment, combined with comprehensive but relatively simple requirements, has incentivized reuse throughout the state. Arizona's rules governing reclaimed water and prescribing high-performance WWTPs constitute a framework for regulating reclaimed water that can be used as a model for other states developing their own regulatory programs.

Reclaimed Water Infrastructure Standards. ADEQ adopted criteria for reclaimed water distribution systems in 2001 for both pipeline and open water conveyances; however, these criteria, which pertain to design and construction, are quite limited. For example, they do not address retrofit situations, including conversions of drinking water system piping to reclaimed water or vice versa. They insufficiently address cross connection control and do not address augmentation of the reclaimed water system with other sources, such as pumped groundwater. The BRP recommended convening a stakeholder group to compile a matrix of state, regional and local specifications and infrastructure standards to identify similarities, inconsistencies, and gaps and develop recommendations on a suite of standards to provide a common foundation of safety and good engineering practices.

Indirect Potable Reuse (IPR) Guidelines. Recognizing trends in other states, the BRP saw a need to develop definitions and guidance for IPR to clarify and facilitate drinking water source approval and local and state agency permitting requirements. The BRP believed that IPR guidance would facilitate a standardized and efficient approach to design, permitting and operation of advanced treatment operations with the intent of IPR and suggested that regulations be established to address water quality standards (regulated and unregulated constituents), hydro-geological circumstances of recharge and recovery, and multiple/engineered barriers needed to obtain approval. Thus, the BRP recommended creation of an IPR Multi-Agency Steering Committee comprised of diverse membership with the mission to develop approaches to streamlining agency reviews, incorporating new technologies, and devising a statewide policy on IPR. The policy would define the objectives of IPR; clarify how recharged reclaimed water can become acceptable for potable purposes; and outline the process for issuing approvals for IPR facilities.

Next Steps

Each BRP recommendation can be moved forward by the Governor, Legislature, the ACC, ADEQ, and ADWR. However, many recommendations involve implementation by ADEQ and ADWR, which will be a challenge in light of budget cuts that have reduced staff and program capabilities. Accordingly, agency efforts have recently focused on recommendations with university involvement to increase collaboration and move forward some of the research issues identified by the BRP, ranging from investigations in public perception to determinations of the linkages, if any, between residual trace organic compounds in treated wastewater effluents and impacts on the environment and human health.

Although implementation will take time, a clear punch list exists. As the agencies begin work, resulting progress in water conservation and reuse will benefit all the citizens of Arizona and stand as a tribute to the dedication and intellect of the participants who contributed long hours to the BRP process.

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Effluent Auction in Prescott Valley, Arizona

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US-AZ-Prescott Valley

Background

Arizona and other areas of the Southwest are experiencing rapid growth in population and water demand (Eden and Megdal, 2006). Despite the economic and real estate downturn that began in 2007, future demands for water and the resulting need for wastewater reclamation and reuse are expected to continue to grow (Scott et al., 2011), especially in Arizona's urban corridor stretching from Flagstaff and Prescott in the north, through Phoenix, and to Tucson and Nogales in the south (Morrison Institute, 2008). This region has a semiarid to arid climate with warm, mostly dry winters, and hot summers. Rainfall primarily occurs in convective thunderstorms that characterize the North American monsoon. Surface waters are subject to increased climate change and variability, exerting ever-greater pressure on groundwater and effluent as sources of supply (e.g., Tucson Water, 2008).

Arizona formed Active Management Areas (AMAs) under the Groundwater Management Act of 1980 in order to address long-term water sustainability and as a *quid pro quo* to secure federal funding for the Central Arizona Project aqueduct and canal system. Among other stipulations, the Act requires that assured water supply for 100 years be demonstrated for any new growth that is planned in the AMAs. In a process regulated by the Arizona Department of Water Resources (ADWR), jurisdictions have thus far exclusively relied on surface water or groundwater to meet assured water supply rules.

In a first-of-its-kind, in Arizona and the nation, the Town of Prescott Valley in 2006 made the case, in physical-hydrological terms and according to institutional and administrative rules, that effluent recharged into aquifers within town limits could be used to meet future water demands. As a result, in 2007, Prescott Valley auctioned rights to its future effluent to the highest bidder, allowing real estate interests to continue development that could otherwise have been restricted due to water scarcity. The bidder would receive credits to extract groundwater to be used to satisfy the assured water supply requirement. Prescott Valley intended to use the proceeds to help pay its share of the costs of a pipeline to move water from the Big Chino ranch to Prescott and Prescott Valley, both part of the Prescott AMA. The prospect of receiving water in the future from this pipeline was deemed to be uncertain by ADWR in 2006, and therefore was disallowed as a source of assured water supply for Prescott Valley.

This case study describes the Prescott Valley effluent auction and demonstrates that a) specific institutional conditions were necessary to allow the effluent-rights transfer to occur, b) effluent is a marketable commodity that benefits a specific set of interests, and thus requires further scrutiny to ensure broader, beneficial outcomes, and c) policy choices favoring effluent for growth must consider environmental uses and in-stream flows. These observations have implications for water reuse within Arizona, across the Southwest, and beyond.

Effluent Auction: Water Resources and Regulatory Considerations

Prescott Valley offered for auction the right to 2,724 ac-ft (3.36 MCM) of effluent on an annual basis. By Arizona's assured water supply rules, this would provide the buyer the right to use the effluent for 100 years. The initial auction in 2006 failed, bringing only one bid that did not conform to the conditions established. Subsequently, the Town entered into an agreement with Nebraska-based Aqua Capital Management, which provided a floor-price guarantee at a pre-negotiated price of $19,500 per ac-ft ($15.80/m^3). This left the Town the option to auction the effluent for a better price, but by doing so, it would pay a contract breakup penalty. In 2007, WestWater Research coordinated the auction, which brought in three bids. Water Asset Management through its subsidiary Water Property Investors, LLC offered the highest bid at $24,650/ac-ft ($19.98/m^3) for a total of $67 million.

There is extensive U.S. and international experience with marketing effluent pollution credits. However, the Prescott Valley case has set precedent in creating marketable rights for effluent as a commodity (Scott and Raschid-Sally, 2012). This was only possible with prior institutional and legal arrangements, briefly summarized here.

Effluent from Growth, Effluent for Growth

Effluent, and reclaimed water of other qualities suitable for a range of uses, is generated as a result of urban growth. Under conditions of water scarcity such as those in Arizona, effluent is viewed as a resource to meet growth-related water demands. This is increasingly the case in the context of regulatory limits on new surface water diversions and additional groundwater pumping. At the same time, climate change and variability, which water managers in the region address as “extended drought,” make effluent an integral part of water supply planning—an attractive alternative to conventional supplies.

Two features of the Prescott Valley case are especially interesting. First, the Town chose not to retain the rights to its effluent and instead used it as a financial mechanism to secure other, more conventional, water supplies from the Big Chino ranch. Second, the purchaser of the effluent, Water Property Investors, was not an Arizona developer but instead a holding company – essentially a speculator in effluent – that subsequently sold portions of the effluent rights it had purchased at auction. In 2009, developer John Crowley II of Denver, Colorado, purchased 200 ac-ft (0.25 MCM) and Cavan Real Estate Investments of Scottsdale, Arizona purchased 700 ac-ft (0.86 MCM) – both for undisclosed amounts price. These aspects of the effluent sale have important management and policy implications for water use, real estate growth, and environmental quality in Prescott Valley and more broadly.

According to the town manager, the auction process that resulted in the transfer of water credits to developers heightened competition in water markets with resulting financial benefits for local residents. The water resources manager of Prescott Valley observed that: a) existing infrastructure and available effluent were necessary, b) effluent rights needed to be eligible under assured water supply rules, and c) partnering with the private sector was necessary in order to navigate water markets and to structure financial risks allowing the town to auction its effluent.

Conclusions and Lessons Learned

It appears inevitable that markets for effluent as a resource will expand. The Prescott Valley case is likely the first of many such transactions. Markets in effluent as a resource require regulatory oversight of the actual sale process and the transfer of water rights. In July 2006 Prescott Valley was granted by ADWR, a Physical Availability Demonstration of 2,724 ac-ft (3.36 MCM) of effluent (that meets water quality criteria) for 100 years. In addition, Prescott Valley applied for a certificate to utilize the effluent on 14,000 ac (5670 ha) of land within the Prescott Valley Water District. This required a Notice of Intent to Serve, Verification of Construction Assurance, and evidence of financial capability. However, the environmental impacts of allocating effluent flows to real estate development were not required under the regulatory process. Effluent that is released to local streams plays an important role in sustaining riparian vegetation. In many instances, effluent is the primary source of water in streams that have been diverted for use in agriculture and urban areas. The quality of riparian vegetation is not simply a habitat and biodiversity issue—which are important in their own right; it also has implications for recreation, the attractiveness of local surroundings and indirectly for the value of real estate.

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Frito-Lay Process Water Recovery Treatment Plant, Casa Grande, Arizona

Author: Al Goodman, P.E. (CDM Smith)

US-AZ-Frito Lay

Project Background

PepsiCo and Frito-Lay, a key brand within PepsiCo, are proud to be reducing the effect of their operations on the environment. Since 1979, Frito-Lay has implemented conservation programs to shrink its overall environmental footprint as part of its snack food production. Frito-Lay's manufacturing plant in Casa Grande, Arizona, makes snacks including corn and potato products (Lay's, Ruffles, Doritos, Tostitos, Fritos and SunChips). In the arid region of the southwest U.S., Frito-Lay completed a project with the ambitious goal to run the plant almost entirely on renewable energy and reclaimed water while producing nearly zero waste—something the company refers to as "Near Net Zero." Major environmental projects implemented at the facility to achieve "Near Net Zero" included: process water recovery and reuse, use of renewable solar energy, generating steam from a renewable biomass boiler, and zero landfill waste projects.

Frito-Lay sought to integrate state-of-the-art technology and best practices from other Frito-Lay plants for a Process Water Recovery Treatment Plant (PWRTP). This PWRTP allowed the previous wastewater treatment system (which used land application of treated effluent) to be decommissioned, allowing those fields to be repurposed for solar energy production. The PWRTP system recycles up to 75 percent of the facility's process water—enabling Frito-Lay to reduce its water use by 100 million gallons (380,000 m^3) annually. An aerial view of the PWRTP is shown in **Figure 1.**

Production at the facility is a 24 hours/day, 7 days/week opeartion, requiring the PWRTP to be robust, reliable, and cost efficient. Design/build of the facility began in August 2009 with startup in June 2010.

Figure 1
Aerial View of PWRTP (Photo credit: Frito-Lay)

Capacity, Water Quality Standards, and Type of Reuse

The average daily design flow of the PWRTP is 0.648 mgd (28 L/s) from the production facility; characteristics of the influent are biochemical oxygen demand of 2,006 mg/L and total dissolved solids of 2,468 mg/L. All sanitary wastes (i.e. bathroom connections) are segregated and discharged to the city sanitary sewer for conventional treatment at the City of Casa Grande Wastewater Treatment Plant.

The reuse quality established by Frito-Lay/PepsiCo required the water to meet EPA primary and secondary drinking water standards. The process water that is used to move and wash potatoes and corn, clean production equipment, and for other in-plant cleaning and production needs, is reclaimed for reuse in the process. The reclaimed water quality from the PWRTP is of higher quality than the local potable water supply in terms of alkalinity, arsenic, and silica. A photo of the reclaimed water at various stages of the treatment process is shown in **Figure 2**.

Figure 2
Water at Various Stages of the Treatment Process (Photo credit: Frito-Lay)

Treatment Technology

The treatment train at the PWRTP is depicted in **Figure 3**. Oily wastewater (from specific production processes) is segregated to minimize adverse effects on the membrane bioreactor (MBR) and low pressure reverse osmosis (LPRO) processes; it is collected by separate drains and a free oil recovery sump. In addition, the plant recovers starch from specific production steps to recover resources for cost recovery and reduce nutrient loads on the PWRTP.

The treatment process includes: internal-feed rotary drum screening, equalization with pH adjustment using carbon dioxide, primary clarification/sedimentation, activated sludge with biological nutrient (nitrogen) removal in concentric steel bioreactor tanks, MBR, granular activated carbon (GAC), UV disinfection, LPRO, and chlorine disinfection prior to reuse. Treated water is stored in a 200,000 gallon storage tank. The GAC system was added in 2011 to enhance treatment for additional recovery and to further protect the LPRO membranes; the system uses lead-lag parallel carbon vessels. Reject water from the LPRO is discharged to the city of Casa Grande Wastewater Treatment Plant.

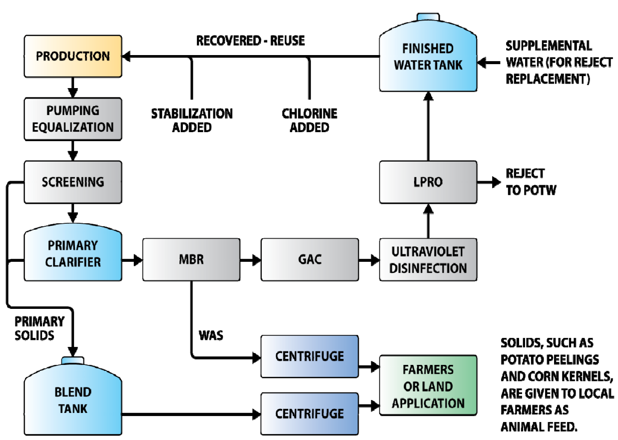

Figure 3
PWRTP process flow diagram

Solids generated from the screening (corn and potato wastes) are collected and combined with the primary clarifier sludge for dewatering by centrifuge and is used as animal feed. The waste activated sludge is dewatered by a dedicated centrifuge and disposed by land application.

Providing MBR equipment outdoors, in pre-engineered vessels, using factory-mounted skids enabled faster installation and startup, helped control costs, and reduced ventilation challenges in the control building. The prepackaged GAC filters and LPRO membranes are housed in an isolated room with that are visible from the control room. A laboratory, conference room and offices are provided within an 8,000+ square foot control building and visitors center. All PWRTP systems are SCADA monitored and controlled.

Project Funding and Management Practices

The project was fully funded by PepsiCo and Frito-Lay; project costs are confidential. A staff of six full-time operators is contracted by Frito-Lay to operate and maintain the PWRTP.

Public Considerations

Frito-Lay and PepsiCo have received the several state and national awards for this facility and include: WateReuse Association Small Plant Award (2011); Clean Water America Alliance U.S. Water Prize (2012); 2009 BE Inspired Award in the “Innovation in Water and Wastewater Treatment Plants” category, Plant-of-the-Year Award by *Food Engineering* magazine.

In October 2009, Frito-Lay Casa Grande became the first snack food manufacturing facility to be certified LEED 2.0 Existing Building Gold in the company, the state of Arizona, and the United States.

Successes and Lessons Learned

The project provides better water quality than initially targeted by designers, and has enabled Frito-Lay to install 5 megawatts of solar photovoltaic and Sterling dish technology on land previously used for land application of treated wastewater effluent.

The Psychology of Water Reclamation and Reuse: Survey Findings and Research Roadmap

Brent M. Haddad, MBA, PhD (University of California, Santa Cruz)

US-CA-Psychology

Project Background

The primary message of this report is the U.S. public is open to considering water reclamation and reuse for both potable and non-potable uses. Surveys were taken from 2695 respondents in five locations (San Diego, San Jose, Philadelphia, Oregon, and Phoenix) in 2006-2007. Surveys used the term "certified safe recycled water" as a term that would have meaning to the lay public although it does not correspond to any regulatory category of reclaimed water.

Survey Results

There were no significant regional or demographic differences in willingness to drink reclaimed water. And, other key findings included:

- Only 13 percent of respondents said they would be unwilling to drink certified safe recycled water.
- Roughly 26 percent of respondents do not believe that treatment systems can bring recycled water to a state of purity at which they would want to use the water. These respondents generally expressed a preference for natural treatment over technological treatment of water.
- Independent (e.g., university-affiliated) scientists are the most credible source of information on recycled water. State and federal government scientists are also credible. Hired actors, neighbors, and employees of private water-related companies are least credible.
- 30 percent of respondents are not interested in technical explanations of the water's safety as long as they have credible and trustworthy assurances of its safety.
- Systems that include natural barriers such as groundwater recharge or reintroduction to a river are slightly more trustworthy compared to systems without these features.
- In the short run (long run was not tested), exposure to information about the safety of reclaimed water has an effect on willingness to use it, even those initially fully opposed to drinking certified safe recycled water. Both the approach of *recycled water is safe* and *all water has the properties of recycled water* (i.e., no such thing as pure or pristine water) were tested and each showed an increase in willingness to drink certified safe recycled water.
- Although the statistical relationships are often weak, the person most likely to reject certified safe recycled water has the following characteristics:
  - Highly concerned about and easily disgusted by the presence of potential contagions in many settings (not just water-related)
  - Self-identified as not politically moderate
  - Less trusting in government institutions and science
  - Less favorable toward technology in general
  - Less impressed by successively more effective water treatment technologies
  - More interested in knowing about the history of one's drinking water
- Individuals most likely to accept and use certified safe recycled water have the following characteristics:
  - They have been exposed to the idea that all water is used

   - They have been exposed to statements about the purity of certified safe recycled water
   - They are confident they will get used to drinking certified safe recycled water over time if it is introduced

- Reclaimed water intended for drinking is least likely to be rejected by individuals if it is:
   - Certified safe by scientists
   - Extensively treated prior to use
   - Used in some natural way (river, lake, groundwater replenishment) prior to it being directly reintroduced to the drinking water system

Future Research Needs

The study identified research needs in the following areas:

- Fundamental research on human reactions to water quality, including demographic factors; psychological attributes; beliefs about hydrology, geology and water technology; and beliefs about natural systems and hybrid natural-engineered water treatment systems. Insights would inform agency-public communication strategies and regulatory reform.
- Research into modes of introduction of reclaimed water. Two approaches include slow, incremental introduction versus rapid, complete introduction. Each has general strengths and weaknesses when used in other contexts of introducing new technologies. Insights would inform how agencies introduce water reuse to their service territories.
- Research into opposition and opponents of water reuse. Insights could inform the public decision-making process and other modes of agency-public communication and decision-making that may be unnecessarily fueling the stridency of opposition.
- Research into the relationship between understanding water treatment technology and public acceptance of recycled water. How do images and statements about water treatment technology found in mailers, facility tours, public meetings, and websites influence the public? Results could help water agencies communicate with the public.

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Managing a Reclaimed Water System through a Joint Powers Authority: San Ramon Valley

Author: David A. Requa, P.E. (Dublin San Ramon Services District)

US-CA-San Ramon

The Dublin San Ramon Services District (DSRSD) and the East Bay Municipal Utility District (EBMUD) formed a joint powers authority to develop and manage the San Ramon Valley Reclaimed Water Program. Despite differences in size, structure, and culture, the two California agencies have successfully used the joint powers model to plan a system that serves both newly built and retrofitted neighborhoods, to work through multiple phases of construction, and to coordinate distribution and customer service.

Project Background

DSRSD and EBMUD have delivered potable water to adjacent communities since 1967. Although they rely on different water sources, both agencies face supply constraints in dry years; as a result, both agencies have long supported water recycling to increase reliability of potable water supplies. The DSRSD and EBMUD service areas and recycled water system are shown in **Figure 1**.

In the early 1990's DSRSD agreed to provide water for major new developments approved by the two cities in its service area. Its water service plans were predicated upon requiring customers to use reclaimed water to irrigate large landscapes. DSRSD had an available supply of secondary effluent from its own wastewater treatment plant, and in 1993 obtained a state permit to distribute reclaimed water. EBMUD had developed reclaimed water projects in other parts of its service area, but in the San Ramon Valley it lacked a local source of effluent. A reclaimed water partnership was a cost-effective solution for both agencies. As a much larger agency, EBMUD also could provide the financial and political base to support the program and better obtain grant funding.

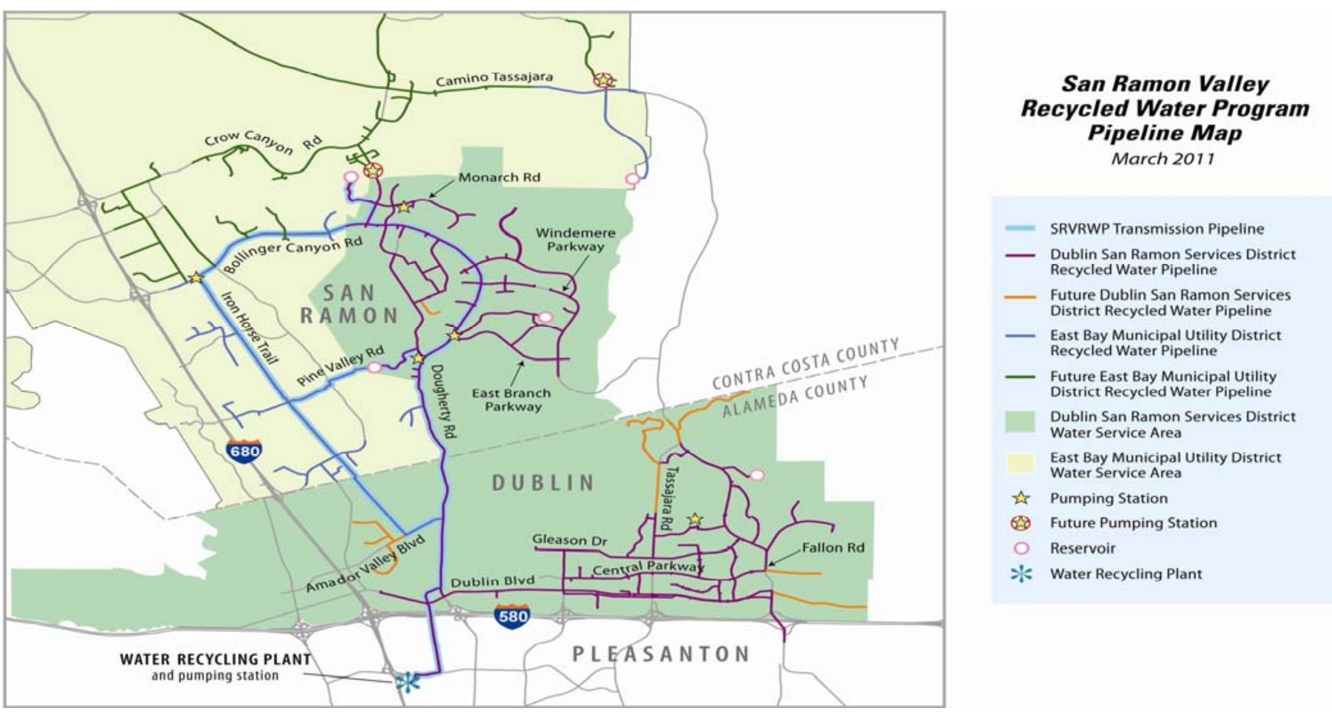

Figure 1
San Ramon Valley reclaimed water system (March 2010)

Management Practices

In 1995, the two agencies formed the DSRSD-EBMUD Reclaimed Water Authority (DERWA) to plan, build and operate the new program. DERWA is a wholesale entity with two retail customers—EBMUD and DSRSD. It is governed by a four-member Board of Directors comprised of two board members from each partner. Day-to-day operations are handled by an authority manager, who is a part-time contract employee.

The program is designed to ultimately deliver 6,420 ac-ft/yr (7.9 MCM/yr)—3,730 ac-ft/yr (4.6 MCM/yr) to DSRSD customers and 2,690 ac-ft/yr (3.3 MCM/yr) to EBMUD customers (DERWA 2003). The DERWA system consists of a sand filtration/UV disinfection (SFUV) treatment facility, a microfiltration/UV disinfection (MFUV) system used as backup and during the winter, three pump stations, two reservoirs, and 16 miles (26 km) of main transmission pipeline.

EBMUD and DSRSD designed and constructed the parts of the system to operate with minimal DERWA staffing (one part-time administrator to assist the authority manager). Ownership and labor are divided as follows:

- DSRSD owns the treatment plant and an initial high-lift pumping station at the plant.
- DERWA owns two pumping stations, two reservoirs, and the backbone transmission pipelines.
- Under contract to DERWA, DSRSD operates and maintains the entire system.
- EBMUD provides the DERWA treasurer and manages financial matters.
- Each agency owns and operates its distribution system and interacts with its own customers.

Funding

DSRSD and EBMUD divided $82 million dollars in DERWA capital costs based upon the benefit received from each facility or reach of pipeline. The resulting cost-share—52 percent DSRSD and 48 percent EBMUD—also was applied to grants and loans that DERWA obtained to build joint-use facilities (DSRSD, 2011b). These included $5 million in grants from the California State Water Resources Control Board (SWRCB), $14.5 million in grants from the U.S. Army Corps of Engineers, and $25 million in SWRCB low-interest loans. EBMUD and DSRSD provided remaining funding from internal sources. DERWA divides the annual cost of operation between DSRSD and EBMUD in proportion to the amount of reclaimed water delivered by each agency during the year.

The backbone of the system was completed in stages, from 1998 to 2010. DSRSD's initial customers were located in newly developed areas, where reclaimed water use is mandated by ordinance. DSRSD is building its reclaimed water distribution systems at the same time as other infrastructure in those areas develop. EBMUD has the more difficult task of connecting existing customers to its reclaimed water distribution system. In addition to managing complex infill construction, EBMUD must work with customers to retrofit their irrigation systems.

Water Quality and Treatment Technology

In 2010, the partnership produced 2,174 ac-ft (2.68 MCM) of reclaimed water that meets California Title 22 standards for unrestricted non-potable reuse (DSRSD, 2011c). When irrigation demand is high, SFUV facilities produce up to 9.7 mgd (425 L/s); during the winter, MFUV is typically used to produce smaller, intermittent deliveries up to 3 mgd (131 L/s). The redundant treatment systems increase reliability and operational flexibility. The two systems may also be operated in parallel to produce up to 12.7 mgd (556 L/s). A planned future expansion will increase the SFUV capacity to 16.5 mgd and the total treatment capacity to 19.5 mgd (854 L/s) (DSRSD, 2011a).

Institutional/Cultural Considerations

EBMUD has close to 2,000 employees and DSRSD about 110. The partners have had to overcome differences in size and corporate culture to communicate efficiently with each other and their customers. For example, as operations began in 2006, small bits of plastic debris began clogging sprinklers and meters. DSRSD and EBMUD field crews responded to their customers and began looking for causes, but in the early stages they did not discuss the problem with each other. The problem was eventually traced to dime-sized plastic produce labels passing through the SFUV system. Both agencies realized they could have provided better customer service by comparing notes earlier during the troubleshooting process (Requa, 2008).

Similarly, DSRSD failed to notify EBMUD when the reclaimed water plant went offline after a series of process upsets in 2007. DSRSD staff assessed the quantity of water in storage and struggled for many hours to resume reclaimed water production before deciding to add potable water to the distribution system. However, a major EBMUD customer ran out of water, and EBMUD was unaware of the production problem until contacted by a customer (Requa, 2008).

The partners have since jointly developed and agreed to processes to improve communications and coordinate responses. In the second year of operation, they also began conducting an annual communications roundtable to walk through potential incidents such as cross-connections, pressure problems, and water quality concerns. These roundtables bring together a cross-section of staff from each agency. Simply getting to know each other has helped to foster a team culture.

Successes and Lessons Learned

The partners also have found ways to leverage their differences. For example, it was a challenge to standardize automated meter reading (AMR) devices. EBMUD had a pilot AMR study in progress and decided to also evaluate DSRSD's device. Since DSRSD had meters in stock, its employees installed them for EBMUD, avoiding lengthy procurement and training delays. DSRSD crews also installed isolation couplings on both DSRSD and EBMUD connections to the DERWA backbone. The couplings protect field staff from stray current from overhead electrical lines. Because DSRSD operates the DERWA system, its staff was already trained in how to avoid shocks while working on DERWA pipelines and could install the needed protection more quickly (Requa, 2008).

Using a joint powers authority to develop reclaimed water service has benefited both partners. They share construction and operations costs and are maximizing the beneficial reuse of the only source of effluent in the area. Because the distribution systems are completely integrated, the two agencies must communicate about water quality and customer service on almost a weekly basis. Unexpected operational issues always occur in a new enterprise. Partners must work as a team to successfully operate a joint system.

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City of San Diego – Water Purification Demonstration Project

Authors: Marsi A. Steirer; Amy Dorman, P.E.; Anthony Van; and Joseph Quicho (City of San Diego Public Utilities Department)

US-CA-San Diego

Project Background or Rationale

The City of San Diego is the eighth largest city in the United States and delivers an annual average of 210 mgd (9200 L/s) to 1.3 million people in a water service area of 404 square miles (1,046 km^2). With approximately 10 inches of rain a year, nearly 85 percent of San Diego's water supply is imported from the Colorado River and the California State Water Project. In the past, importing water from the Colorado River and Northern California has been a low-cost, dependable water supply option, but in recent years, these sources have become less reliable and more expensive. Additionally, the cost of imported water has increased by 85 percent in the last eight years and is expected to double by 2020. These conditions have intensified the need to identify new, locally controlled water sources.

San Diego has had an active water conservation program since the mid-1980s, and has been recycling water for irrigation and industrial use since the late 1990s. While this has helped reduce dependence on imported water, non-potable reclaimed water use is seasonal, does not provide relief the entire year, and requires a separate distribution infrastructure to be operated and maintained. In 2004, the city embarked on its Water Reuse Program with the goal of maximizing water recycling, either through a non-potable market expansion, potable reuse, or a combination of these practices. The Water Reuse Study was the first phase of the Water Reuse Program and was completed in 2006; indirect potable reuse through reservoir augmentation was identified as the preferred strategy. This case study focuses on the second phase of the Water Reuse Program, the Water Purification Demonstration Project (Demonstration Project), which will conclude in early 2013.

Type of Reuse Application and Capacity

The Demonstration Project will evaluate the feasibility of using advanced treatment technology to produce water that can be sent to the city's San Vicente Reservoir, to be later treated for distribution as potable water. This multiple barrier concept is depicted in Figure 1. If this concept for developing a new local supply proves viable, Phase 3 of the Water Reuse Program would implement a full-scale facility.

As part of the Demonstration Project, the city is testing and operating a 1 mgd (44 L/s) demonstration-scale Advanced Water Purification (AWP) Facility at the North City Water Reclamation Plant (North City). It is using the tertiary-treated water from North City as feed and is producing purified water of distilled water quality. Water quality is being monitored across the entire purification process to determine the effectiveness of the process and to ensure that all systems are functioning properly. Ultimately, the city will be able to determine if the purified water meets all drinking water standards and can be put in the San Vicente Reservoir; test water will not be placed in San Vicente Reservoir during the demonstration phase. Additionally, an independent advisory panel (IAP) of experts has been convened to provide the technical oversight and input throughout the demonstration process.

A limnology study of the San Vicente Reservoir is being conducted to establish minimum residence time, water quality, and other regulatory requirements. The dam is currently being raised to nearly triple the reservoir's storage capacity. The primary tool for this study is a three-dimensional computer model of the enlarged reservoir, which has been calibrated, reviewed by an IAP, and validated for use on this project.

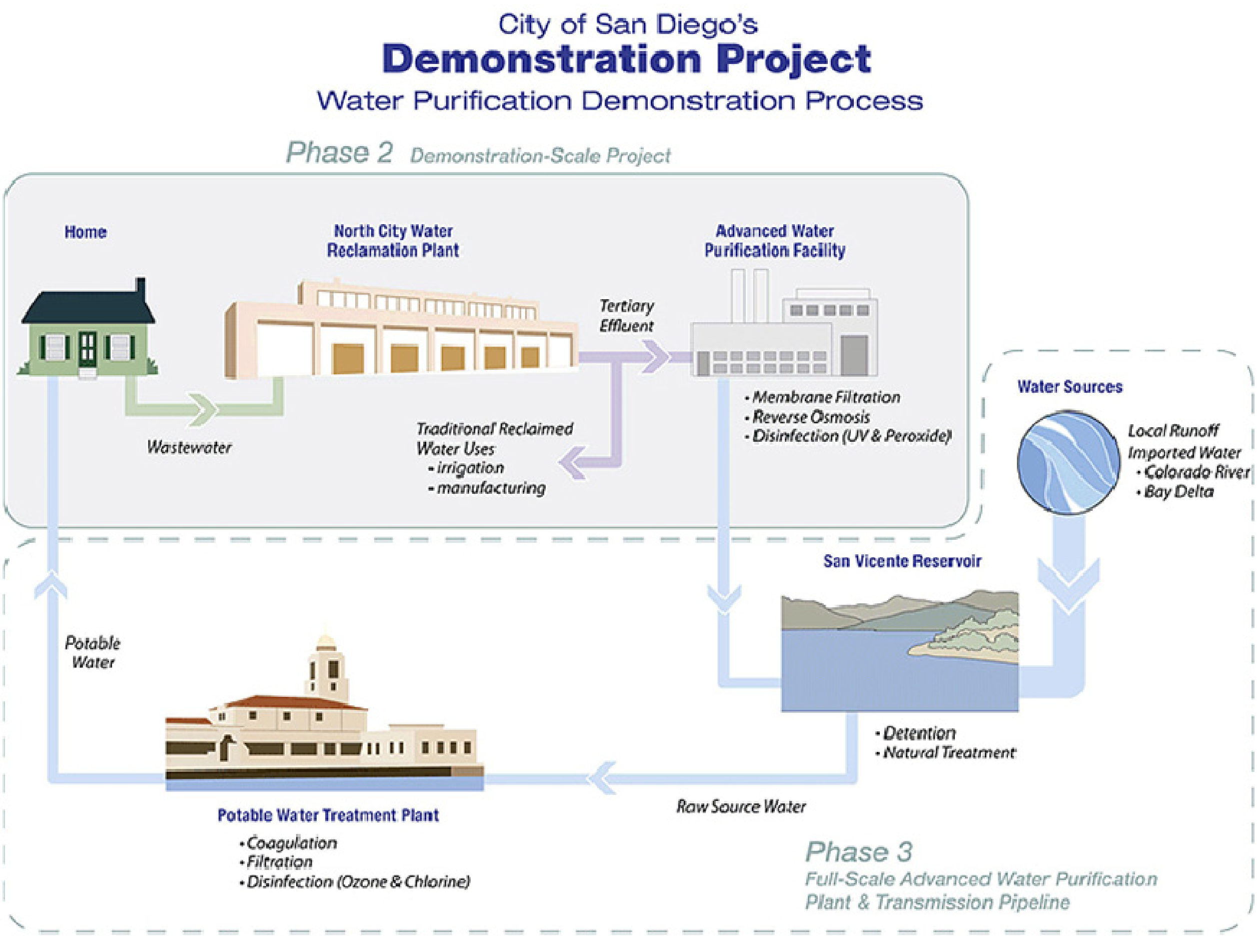

Figure 1
Water Purification Demonstration Process

As of 2012, regulatory requirements for Indirect Potable Reuse through reservoir augmentation have not been defined in California. Thus, defining such requirements is a key component of this demonstration project, and the city has engaged both the California Department of Public Health (CDPH) and Regional Water Quality Control Board (RWQCB). The State's draft guidelines for groundwater recharge systems are being referenced for the advanced water treatment performance criteria.

Treatment Technology and Water Quality Parameters

The AWP Facility is equipped with microfiltration (MF) and ultrafiltration membranes, reverse osmosis, and advanced oxidation (ultraviolet and hydrogen peroxide); the demonstration system incorporates membranes of the same size, specification, and configuration as those that would be utilized for a full-scale facility. Demonstration testing is being conducted over a 12-month period and in accordance with the Testing and Monitoring Plan that incorporated review comments from the IAP, CDPH, and RWQCB. Monitoring of several water quality parameters in the Testing and Monitoring Plan include, but not limited to the following:

- Contaminants regulated by the Safe Drinking Water Act or California State regulations
- Disinfection by-products and trace constituents
- Nutrients that may lead to eutrophication of San Vicente Reservoir
- Specific contaminants and surrogates that effectively monitor integrity of each unit process

- Local constituents of concern, endocrine disrupting compounds, pharmaceuticals, and personal care products

Project Funding and Management Practices

In 2008, the San Diego City Council approved a temporary water rate increase to fund the project. The Water Purification Demonstration Project has a budget of $11.8 million with federal and state grants providing up to $4 million in assistance. In addition to the AWP Facility and reservoir study, the project also includes public outreach, energy and economic analysis, and an alignment study for the 23-mile (37-km) purified water pipeline to San Vicente Reservoir.

Institutional/Cultural Considerations

The indirect potable reuse concept was first introduced to the community in the mid-1990s. There was negative public reaction at the time that continued well into the next decade. Some dubbed it, “toilet to tap.” However, comprehensive education efforts about the need for conservation, increasing calls for water supply diversification and increased awareness of the region’s existing raw water supply sources, have all helped turn the tide. In January 2011 and editorial in the local paper stated, “…this water would likely be the purest and safest water in the system.”

To build upon the growing awareness of the need for local supplies, a comprehensive public outreach program was launched as part of the Demonstration Project. Through the program substantial collateral material has been produced, a project website was created, e-updates and e-newsletters are sent out regularly to a growing interested parties list, and over 100 project presentations have been given to community and business groups, especially those of underserved communities, throughout the city. These efforts will continue through the duration of the project. With the completion of the AWP Facility, facility tours are being offered to the public.

Successes and Lessons Learned

While the project is ongoing there have been two interim successes that can be highlighted. One success is the regulatory agencies involvement and cooperation. Both CDPH and RWQCB have been willing to attend and engage in project workshops on approximately a quarterly basis and provided comments to Demonstration Project reports.

Another success is that public outreach and education program efforts appear to be effective. There has been a recent shift in perception regarding purified water within the media and the community. The Demonstration Project received positive coverage both locally and nationally in early July 2011. It is not just the media who are coming to accept water purification as a viable option for San Diego. Public opinion polls show that strong opposition to indirect potable reuse dropped from 45 percent in 2004, to 12 percent in 2009, and to 11 percent in 2011 (SDCWA, 2011). The same 2011 study by the San Diego County Water Authority found that 65 percent of respondents somewhat or strongly favor adding purified water to the drinking water supply and 77 percent of respondents informed about the Demonstration Project either strongly favor or somewhat favor the goals of the Demonstration Project.

With continued regulatory involvement and public outreach and education efforts the Demonstration Project is on the path for gaining regulatory approval and public acceptance. If the concept of using purified water to augment local reservoir supplies is deemed viable by the mayor, the city council, and the regulators, the city would implement it on a large scale. Full-scale facilities could produce up to 15 mgd (660 L/s) of purified water.

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Groundwater Replenishment System, Orange County, California

Authors: Mike Markus, P.E., D.WRE; Mehul Patel, P.E.; William Dunivin (Orange County Water District)

US-CA-Orange County

Project Background and Rationale

For decades, semi-arid Orange County, Calif., has depended on Northern California and the Colorado River for much of its drinking water. However, with multi-year droughts and environmental constraints, imported water is becoming more expensive and less available. Population studies indicate that California could increase by 15 million people by 2020; Southern California alone could grow by 7 million and Orange County by 300,000. As new water supplies are sought, water recycling plays an important and key role.

In the 1990s, the Orange County Water District (OCWD) and Orange County Sanitation District (OCSD) joined efforts to provide a reliable water supply by developing a water purification program called the Groundwater Replenishment System (GWRS), which came on-line in January 2008. Prior to the GWRS, OCWD operated Water Factory 21 (WF-21), a first-of-its-kind water treatment facility that produced 15 mgd (960 L/s) for a seawater intrusion barrier, from 1976 through 2004.

Using up to two-thirds less energy than it would take to import water from Northern California, and three times less energy than ocean desalination, the GWRS currently produces enough water for nearly 600,000 residents, while saving enough energy to power 21,000 homes each year. Additional benefits include eliminating the need for another ocean outfall and increasing “water diversity” in an arid region.

Capacity and Type of Reuse Application

The GWRS is the largest advanced water purification facility of its kind, capable of producing 70 mgd (3070 L/s) for indirect potable reuse (IPR). This revolutionary and innovative system removes pharmaceuticals, pesticides and other harmful contaminants before it is pumped to recharge basins, where it naturally filters into the groundwater basin, replenishing scarce drinking water supplies. The heart of the GWRS is the Advanced Water Treatment Facility (AWPF) facility, which includes microfiltration, reverse osmosis, and advanced oxidation processes, which consist of ultraviolet and hydrogen peroxide (**Figures 1, 2 and 3**). The plant may be upsized in the future to produce 130 mgd (5,700 L/s).

Figure 1
GWRS microfiltration system (Photo Credit: Gina DePinto)

Figure 2
GWRS reverse osmosis trains (Photo Credit: Gina DePinto)

Water Quality and Treatment Technology

During startup of the AWPF, monitoring water quality was an important component of the permit issued by the Regional Water Quality Control Board (RWQCB), in conjunction with the California Department of Public Health (CDPH). During acceptance testing of the AWPF, specific water quality tests were required.

Water quality monitoring is a fundamental component of ongoing GWRS operations. During the first two years of operation (2008-2009), concentrations of metals (e.g., aluminum and chromium), organic contaminants (e.g., trichloroethylene, NDMA, and 1,4-dioxane), nutrients (nitrogen and phosphorous), and microbial indicators were all either non-detectable or well below state and federal drinking water quality limits. Similarly, unregulated chemicals such as pharmaceuticals and personal care products (e.g., ibuprofen, bisphenol-A) and endocrine disrupters (e.g., hormones) were consistently non-detectable in 2008, at parts per trillion concentrations. Nearly identical results were found in 2009, with two isolated detections (e.g., caffeine) occurring at concentrations below available health screening guidelines.

Figure 3
GWRS ultraviolet reactor system (Photo Credit: Gina DePinto)

The GWRS water quality data is reported quarterly and formally documented in an annual report to state regulators. The GWRS is also reviewed annually by an Independent Scientific Advisory Panel of experts appointed by the National Water Research Institute (NWRI).

Project Funding and Management Practices

The GWRS capital cost was $480.9 million. OCWD received $92 million in grants from state and federal agencies and a $196 million contribution from OCSD. OCWD used a combination of long-term debt and state loans to fund the remaining capital cost, which has an annual debt service of $11.5 million. The debt service and cost to operate the GWRS is covered by OCWD's general fund. The annual operating budget (excluding debt service) is about $28.5 million, which includes electricity, chemicals, labor and maintenance. The project receives an annual operational subsidy of approximately $7.5 million for 12 years from the Metropolitan Water District of Southern California for reducing demand on the state's imported water supplies.

OCWD receives revenue primarily from three sources: the replenishment assessment paid by retail agencies for pumping groundwater, a percentage of local property taxes, and investment income. The assessment is currently $249/ac-ft ($0.20/m^3), which is well below the cost of imported water supplies that start at $750/ac-ft ($0.61/m^3). To replenish the groundwater basin, OCWD uses a combination of flows from the Santa Ana River, GWRS water and imported water. The cost of GWRS water is less than treated imported water and is the highest quality, drought-proof and reliable source of water available. Imported water supplies, especially untreated or raw water supplies, can be interruptible and available for purchase only when a surplus exists.

Institutional/Cultural Considerations

The GWRS program is a direct result of a mutually beneficial partnership between OCWD and OCSD, cultivated over nearly 40 years, beginning with WF-21 in the 1970s. In the mid-1990s, OCSD faced the possibility of building a second ocean outfall at a cost of $200 million. At the same time, OCWD was dealing with problems of seawater intrusion and the need to expand WF-21 from 15 to 35 mgd (920 to 1530 L/s). Joining efforts in 1997, OCSD agreed to supply OCWD with 96 mgd (4200 L/s) of secondary treated wastewater at no cost. OCSD committed to maintaining a stringent source control program to keep potentially harmful contaminants out of the treated wastewater before it was supplied to the GWRS. OCSD and OCWD also agreed to share the $481 million cost to construct the GWRS. Approving the GWRS was a significant and risky step for its Boards of Directors because, at the time, IPR had been politicized and suffered major defeat in San Diego.

Coordinating two Boards and gaining support was challenging. One month after signing a cooperative agreement to plan and construct the GWRS, OCWD and OCSD established the GWRS Steering Committee to oversee planning, design and construction in cooperation with each agency's governing board. The committee made decisions and approved expenditures, while OCWD led engineering, construction, operations and outreach with OCSD's engineers and Public Affairs. Today, communication between the staffs is excellent and the Steering Committee is still intact to work through ongoing operational issues.

One of the most important measures OCWD uses to evaluate success is public acceptance of IPR. An aggressive outreach program was established to educate and secure support from local, state and federal policymakers, business and civic leaders, health experts, environmental advocates and academia. Because of the negative and misinformed public perception of purifying wastewater to drinking water, the agencies decided that the "clean water" agency should be out front to manage day-to-day management of the outreach campaign.

To brand the safety, purity and high quality of water, OCWD staff led outreach and interfaced with consumer media, while OCSD staff served as advisors on outreach decisions and helped manage trade media relations. The team made more than 1,200 presentations from 1999 to 2007, secured thousands of media impressions, and garnered more than 600 letters of support including those from all 21 city councils, the district's senators and congressional representatives, local state assembly members, state senators, the governor, and the Orange County Board of Supervisors. Agencies that govern or influence water policy were also supportive including the Department of Water Resources, CDPH and the Santa Ana RWQCB.

Without such strong support from policymakers, the project may not have moved forward, nor would OCWD have been able to secure $92 million in state, federal and local grants to help fund the project. The Metropolitan Water District of Southern California also awarded GWRS an $85 million operational subsidy for reducing dependence on the state's imported water supplies.

As public support grew, a comprehensive supporter list was developed, and eventually the Boards formed a committee of respected community opinion leaders and experts that served as project spokespeople. In preparation of the initial expansion to 100 mgd (4381 L/s), the agencies are mindful that opposition is still a threat, and so the outreach effort continues. OCWD continues to make presentations to business and civic groups and at conferences, employs social media, and conducts tours of the GWRS. In 2010, about 4,000 visitors toured the facility. Many were elected officials and water experts from across the United States, Africa, Australia, China, Japan, Korea, Spain, Italy, Germany and Israel. To date, there has been no organized or significant public opposition to the GWRS and the outreach initiative is touted as one of the key reasons for the project's success.

Successes and Lessons Learned

OCWD and OCSD successfully partnered to build a potentially controversial water project that garnered overwhelming public support and overcame a "toilet-to-tap" misperception. The GWRS has revolutionized how consumers look at wastewater—as another resource they should take care of and reuse.

The partnership between OCWD and OCSD has become an international model for water recycling recognized globally with numerous awards, including the prestigious Stockholm 2008 Industry Water Award, Säid Khoury Award for Engineering Construction Excellence and the American Society of Civil Engineers Outstanding Civil Engineering Achievement. Municipalities across California, the United States, and Australia are planning similar projects, and the city-state of Singapore modeled a smaller scale IPR project after the GWRS. By developing a project that puts recycled water into the drinking water supply, OCWD is paving the way for others to gain public acceptance of this environmentally-friendly and safe practice.

EDR at North City Water Reclamation Plant

Authors: Eugene Reahl and Patrick Girvin (GE)

US-CA-North City

Project Background

The city of San Diego, Calif., shares a problem common with many other western cities—meeting the ever-increasing challenge of developing adequate drinking water supplies to satisfy regional development. Unfortunately, new sources of fresh water are not readily available without large capital expenditures. As a result, in the late 1990s, San Diego took a major step in helping to solve this problem by equipping the brand new North City Reclamation Plant with an electrodialysis reversal (EDR) system. The EDR system could desalinate tertiary treated wastewater to provide a new source of high quality irrigation water, thereby reducing demand on the fresh water supply.

Treated wastewater effluent that supplies the reclamation facility has salinity levels up to 1,300 mg/L TDS during the summer and early fall. In order to use this water for golf courses, plant nurseries, parks, highway green belts, and irrigation water for common areas in homeowner associations, the treated water needed to have a water quality of less than 1,000 mg/L TDS with low sodium levels. EDR was able to achieve the required removals and also allow for blending of a stream of raw water with the feed, increasing total volume of reuse water produced.

Treatment Process and Capacity

The EDR system operates at 85 percent recovery of the treated flow, compared to 80 percent offered by a more conventional microfiltration-reverse osmosis (MF-RO) system, which was originally evaluated as an alternative to the existing system. Another added benefit of the EDR system is a reduction in use of chemicals compared to other technologies for reducing TDS concentrations. The EDR runs with no chemicals added to the feed stream; although, chlorine is added to the concentrate recirculation loop of the EDR to help prevent biological growth. The EDR membranes are not sensitive to chlorine and can tolerate brine residuals, reducing frequency of cleaning.

When the reclamation plant was originally installed in 1998, the capacity of the EDR system was 2.2 mgd (96 L/s). Since this initial installation, the facility has undergone 4 expansions. In 2011, the EDR capacity at the plant could produce 6.6 mgd (290 L/s) as shown in **Figure 1**. This treated water is blended with treated wastewater effluent to provide up to 15 mgd (660 L/s) of total blended reclaimed water flow.

Figure 1
North City WRP with 6th EDR unit installed

San Diego used an existing 47-mile (75 km) pipeline to deliver high quality reclaimed water to local customers. This challenge of this strategy was to sell this water as an attractive alternative to using hard-to-replace fresh drinking water in non-potable applications such as irrigation. But, after successful implementation, the end result has been a reduction in use of potable water for these applications, conserving that precious supply for potable water uses.

Project Funding and Management Practices

Over the years, the facility has been expanded several times. For most of these projects, the city has provided their own funding for the expansion to their facility; however, addition of the 6th unit was partially funded through the Bureau of Reclamation.

Successes and Lessons Learned

The plant has successfully operated for over 10 years. Much of the plant's success may be attributed to the excellent operation and maintenance of the equipment. The EDR system utilizes liquid sodium hypochlorite addition to minimize biogrowth, and regular cleanings help maintain optimum membrane performance.

Due to the variable quality of the feed water to the facility, the EDR's ability to handle higher organic loading, up to 15 mg/L of total organic carbon was an important factor in keeping the facility running. The system could accept the higher levels without any negative impact on the product water conductivity. This produced a consistent product to the City's customers as shown in **Figure 2**.

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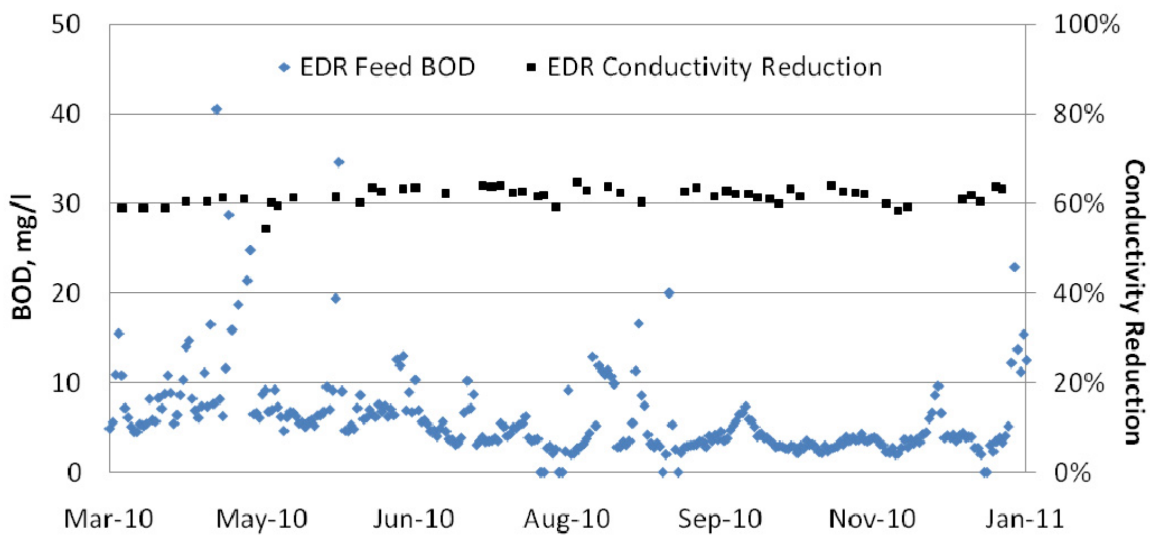

Figure 2
Performance of North City EDR system

Water Reuse Study at the University of California Santa Cruz Campus

Author: Tracy A. Clinton, P.E. (Carollo Engineers)

US-CA-Santa Cruz

Project Background

In response to the master plan for higher education, the president of University of California (UC) asked UC campuses to consider enrollment growth. For UC Santa Cruz (UCSC), this request corresponded to a 25 percent increase in student population. Already faced with severe water supply shortages and limited to no possibilities for increases, UCSC decided to increase self-reliance and sustainability of campus water resources, and define measures for utilization of recycled water. These goals were to be achieved while considering challenges such as seasonal population fluctuations of the UCSC campus, city water supply limitations, campus elevation gradients, and the future challenge of UCSC population growth. Although campus water demand was expected to grow from 200 million gallons per year (MGY) (760,000 MCM/yr) in 2009 to 400 MGY (1.5 MCM/yr) in 2020, the city of Santa Cruz had previously reported that there was little to no increase in water supply available to UCSC. In response, the campus began addressing challenges by developing a decision analysis framework to enable the selection and ranking of a range of potential reuse projects that could be implemented both immediately, and in response to future potable water and/or energy reduction requirements.

Capacity and Type of Reuse Application

Approximately one-half of the allocation of total campus water consumption included non-potable uses (**Table 1**) that could be offset by using alternate sources (Maddaus, 2007). In addition, roughly 97 MGY (0.37 MCM/yr) could be offset with recycled water, rainwater, graywater, and well water, which are available in sufficient volumes (**Table 2**). Both the demand and the alternate water supplies have seasonal dependencies that must be considered. For example, water use is highest when classes are in session and lowest during summer and between quarters. The reuse opportunities that UCSC considered were ones that minimize energy consumption, maximize sustainability, and where seasonal and spatial dependence considering varying campus elevations of sources and demands for non-potable water are aligned.

Table 1 Summary of non-potable water demands

Demand	Volume Required (MGY)	Seasonal Dependence
Toilet Flushing	6.3	Dependent on student populations
Irrigation	29[1]	Dependent on weather
Cooling Towers	8[2]	Dependent on student populations and weather

[1] Volume for irrigation by the top 10 users; submetered irrigation demand on campus is 40 MGY
[2] Includes volume required at new cooling tower location

Table 2 Summary of alternate water supplies available for non-potable use

Demand	Volume Required (MGY)	Seasonal Dependence
Rainwater	8.3	Dependent on weather
Graywater	13.8	Dependent on student populations
Recycled	157[1]	Dependent on student populations
Well	56.5	Not seasonally dependent

[1] Represents entire campus wastewater flow

The lower area of campus, which includes administration offices and faculty housing, has an elevation of 426 feet and receives about 30 inches (76 cm) of rain annually. The upper area of campus, with an elevation of 982 feet (300 m) and about 48 inches (122 cm) of annual rainfall, includes residences and academic buildings. The middle area of the campus is open space and agricultural land. Peak rainfall occurs in January with little to no rain in the summer months of June through September. Rainwater is currently collected and systematically conveyed from the campus to minimize erosion. **Figure 1** shows the existing non-potable supplies and demands by general campus location/elevation. Options for replacing potable water demands were identified and grouped with respect to implementability into immediate, near-term, or long-term projects.

Water Quality Standards and Treatment Technology

The regulatory requirements defined for reuse of non-potable sources are outlined in **Table 3**.

Project Management Practices

A “Model College” was developed as a planning tool. This model considers non-potable supplies and demands assuming 100 beds (i.e., residential component only). This model can be used by the campus to analyze future proposed reuse projects regarding demands relative to non-potable water supplies, sustainability, and energy use. UCSC now has tools to move aggressively to offset the increased water demand that will accompany its growth. The campus potentially has more supply of non-potable water than demand for it, so factors other than maximizing supply can be figured into project selection. For example, future project selection criteria include cost per gallon of non-potable water, construction cost of specific projects, volume of potable water offset, components of sustainability (mainly environmental impacts), educational value, and ease of operations of the project.

The cost of implementing a reuse project is largely driven by the storage volume required for it, thus matching the seasonality of supply and demand (such as using rainwater for toilet flushing instead of irrigation) helps in reducing the cost of reuse projects. Another driver of cost is the proximity of supplies and demands because of energy requirements for pumping, particularly on this campus, which has over 550 ft (168 m) elevation difference between the upper and lower campus areas.

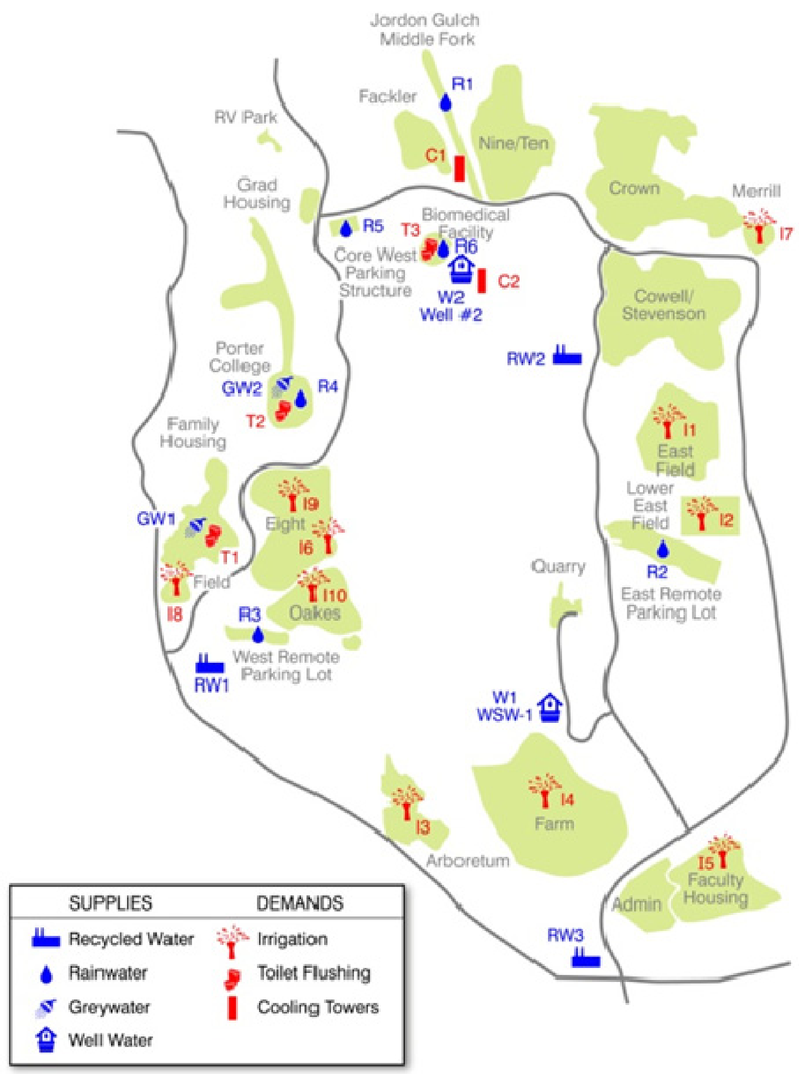

Figure 1
Existing non-potable supplies and demands on UC campus

Institutional/Cultural Considerations

The UC released a Policy on Sustainable Practices in May 2007 which provided guidelines to all the UC campuses to: *Incorporate the principles of energy efficiency and sustainability in all capital projects, renovation projects, operations and maintenance within budgetary constraints and programmatic requirements.* The current version of the Policy requires LEED^{TM} Silver certification for new UC construction and existing renovations.

Table 3 Requirements for reuse depending on source water

Source	Possible Reuse Applications	Appendix G Graywater Guidelines	Title 22 Reuse Guidelines	Campus Plumbing Codes and Ordinances
Rainwater	Irrigation, Toilet Flushing, HVAC processes			X
Graywater[1]	Subsurface Irrigation	X		X
Additionally Treated Graywater[2]	Irrigation, Toilet Flushing, HVAC processes		X	X
Tertiary Treated/Disinfected Wastewater[3]	Irrigation, Toilet Flushing, HVAC processes		X	X
Well Water	Irrigation, Toilet Flushing, HVAC processes			X

[1] Treated and applied as outlined in the California Greywater Reuse Guidelines - Appendix G, Title 24, Part 5, California Administrative Code.

[2] Treated to greater levels than outlined in the California Greywater Reuse Guidelines

[3] Treated to levels outlined in the Recycled Water Requirements – Title 22.

A campus workshop was held to determine screening criteria for construction and renovations; these criteria were then used to review the proposed projects. Key conclusions from the workshop included establishing a minimum microbial water quality requirement for all non-potable water, comparing the cost per gallon of non-potable to potable sources, developing a “model college” as a planning tool for future projects, and considering the educational value of a project in the project screening.

Successes and Lessons Learned

The campus study did not recommend which projects should be implemented; rather it provided a decision analysis framework to select and rank projects as triggers occur that require a reduction in use of potable water and/or energy. Project selection is a two-stage process. First, the projects are grouped into “implement,” “maybe implement,” and “currently infeasible.” “Implement” reuse projects are those that are the easiest to execute and that UCSC sees a clear value in implementing right away. The “maybe implement” are projects that merit further discussion. The projects should also be sorted into immediate, near and long-term periods. The second stage involves screening and ranking the projects, such as with a pairwise analysis, based on the screening criteria developed at the beginning of the process.

A small subset of possible projects were selected using the Campus Model based on input from USCS staff; six near-term projects were identified (**Table 4**). A trigger-based approach allows UCSC to implement projects activated by flow triggers based on a demand matrix. This approach considers meeting immediate needs such as droughts, short-term needs when a dormitory is being updated and refurbished, and long-term needs for future planned facilities. The outcome of this project is being monitored by all UC campuses for sustainably meeting growth demands. With the implementation of projects identified on the campus, UCSC has the opportunity to become a model campus for schools and areas in water stressed regions throughout the country.

Table 4 Summary of campus reuse projects selected for near-term implementation

Project	Supply	Demand
1. East Parking Lot East Field Irrigation	Rainwater	Irrigation
2. Porter College Toilet Flushing	Rainwater	Toilet Flushing
3. Biomedical Sciences Facility Toilet Flushing	Rainwater	Toilet Flushing
4. Jordan Gulch Middle Fork Cooling Towers	Rainwater	Cooling Towers
5. Irrigation	Recycled Water	Irrigation
6. Family Student Housing Landscape Irrigation	Graywater	Irrigation

References

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Long-term Effects of the Use of Recycled Water on Soil Salinity Levels in Monterey County

Author: B.E. Platts (Monterey Regional Water Pollution Control Agency)

US-CA-Monterey

Project Background or Rationale

Agriculture in Monterey County, Calif., is more than a $3 billion per year industry. Over-pumping of groundwater has caused sea water to intrude into wells located near the coast. In an effort to reduce groundwater extraction in the northern Salinas Valley, the Monterey Regional Water Pollution Control Agency (MRWPCA) in partnership with the Monterey County Water Resources Agency (MCWRA) began providing reclaimed water to 12,000 acres (4,860 hectares) of prime farmland used to grow cool season vegetables in April 1998. The dominant soil types in this region are clay loam and heavy clay soils, both of which are susceptible to sodium accumulation and water penetration problems. Because of grower concerns that salts, particularly Na and Cl, in the reclaimed water would reduce yield and quality of their crops a long-term study was developed to monitor salinity levels in commercial vegetable fields.

Capacity and Type of Reuse Application

The MRWPCA water recycling facility provides a relatively constant flow, around 20 mgd (876 L/s) of reclaimed water. This rate is inadequate to serve the Monterey County Water Recycling Projects (MCWRP) service area during peak demand periods. Therefore, supplemental wells, tapping groundwater from the 400-ft (122-m) aquifer, are used to augment the reclaimed water supply, as necessary. During periods when reclaimed water must be supplemented, incidental blending of reclaimed water with well water takes place within the pressurized distribution system. The prime irrigation water constituents of concern are sodium and chloride. Reclaimed water, blended with well water, is used to irrigate artichokes, broccoli, Brussels sprouts, celery, cauliflower, lettuce, spinach, and strawberries within the project area.

Water sampling was conducted throughout the recycling project system as standard procedure in the MCWRP Monitoring Program. First, MRWPCA's tertiary effluent was sampled on a weekly basis to determine the levels of salt present in the reclaimed water before blending with the supplemental well water. Second, monthly delivery system sampling confirmed the specific quality of the water received by the growers after supplemental well water was added to the reclaimed water. These data were used to generate the observed and calculated values of water delivered to each field sampling location. The water samples were analyzed for pH, conductivity, sodium, potassium, magnesium and chloride. The MRWPCA laboratory, an accredited laboratory, analyzed the water.

Soil salinity levels were monitored at eight sites receiving reclaimed water beginning in the spring of 2000. The different sites received a range of blends of the reclaimed and well water depending on location. The range of blends was from 1:1 reclaimed to well water to reclaimed water only. The soil was sampled three times per year at each site and composites of 4 cores were collected from the 1- to 36-in (2- to 90-cm) depth at 12-in (30-cm) intervals. Soil samples were analyzed for pH, electrical conductivity (EC_e), extractable cations (B, Ca, Mg, Na, and K) and extractable anions (Cl, NO_3, and SO_4). Valley Tech Agriculture Lab Services in Tulare, CA, an accredited laboratory, analyzed the soil samples.

Water Quality Standards and Treatment Technology

Reclaimed water in the state of California must meet Title 22 standards for microbiological quality. However, there are no legal requirements in the state of California for the quality of reclaimed water in reference to agronomic standards for agricultural use. MRWPCA's long-term study early on in the development of the water recycling project found no ill effects on vegetable production with the use of water of the estimated quality to be supplied (Engineering Science, 1987). By agronomic standards, the average sodium adsorption ratio (SAR) of the reclaimed water at 4.94, in combination with an ECw (electrical conductivity) of 1.6, are quite safe for long-term irrigation (Richards, 1969). The optimum level of sodium in agricultural irrigation water is less than 5.0 meq/L (115 mg/L) (Ayers, 1985). The average sodium in reclaimed water before addition of supplemental well water is 7.64 meq/L (175 ppm). The optimum level of chloride in agricultural irrigation water is less than 5.0 meq/L (177 mg/L) (Ayers, 1985). The average chloride of reclaimed water before addition of supplemental well water is 7.36 meq/L (257 ppm). Thus, sites receiving reclaimed water only were at risk for increasing levels of sodium and chloride.

After 10 years of monitoring, data showed that soil salinity levels exhibited a range of responses including increased salinity, decreased salinity and stable salinity at different sites. The increase at some sites was due to chloride accumulation and was large enough to potentially affect chloride sensitive crops such as strawberries. The decrease in soil salinity at some sites and improved the soil productivity and was due to sodium leaching. Sites with stable salinity were at values acceptable for growing cool season vegetable and berry crops. Average soil salinity values were highly correlated with average water quality over the length of the study.

Project Funding and Management Practices

Funding for the salinity monitoring project was incorporated into the annual operations and maintenance costs by MRWPCA. The water sampling plan was an expansion of the standard operating procedure. The incremental cost of the soil sampling program was approved by the Water Quality and Operations committee, which provides input to MRWPCA and MCWRA in regard to operational and budgetary decisions for the recycling water project. MRWPCA, MCWRA and grower representatives have reviewed water quality and operations decisions monthly since the project became operational in 1998.

Institutional/Cultural Considerations

The value of crops and farmland within the MCWRP area is significant. At the inception of the water recycling projects, MRWPCA and MWCWRA were very aware that grower acceptance would be key to the project's success. Therefore, the initial water quality study studying agricultural productivity was conducted to provide data to the growers. Throughout the development of the project, grower support and cooperation were good and the Agencies provided multiple avenues for grower input and participation in making critical decisions. The Water Quality and Operations Committee has been the long-term method of incorporating stakeholder involvement in the project.

Successes and Lessons Learned

The variation in annual water quality and annual variation in soil values for SAR, sodium and chloride at each site did not correlate. However, average water quality and average soil values for these parameters over the ten-year study correlated very well. This indicates that short-term studies may not accurately reflect changes in soil salinity. Correlation coefficients for averages over the study were robust. It is important to note that the range of SAR, sodium and chloride in the reclaimed water, applied to the different sites, were near or only slightly higher than optimum values. This demonstrates that slight increases in SAR, sodium and chloride in irrigation water are associated with increasing levels of SAR, sodium and chloride in the heavy clay irrigated soils within the water recycling project area. Therefore, initial concerns about changes in soil salinity were justified.

Variability of the trends between different sites is an important observation. For all three salinity parameters, SAR, sodium and chloride, there were multiple trends observed. The different test sites were selected to represent the range of water quality, farming and soil type conditions within the water recycling project area. The wide variety of sites resulted in a wide range of soil salinity trends, indicating that soil salinity studies should include broad range of conditions in order to accurately estimate the variability of soil salinity responses.

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Metropolitan Water District of Southern California's Local Resource Program

Author: Raymond Jay (Metropolitan Water District)

US-CA-Southern California MWD

Can regional incentive programs maximize development of local recycled water projects?

Background

The Metropolitan Water District of Southern California (Metropolitan) was established in 1928 by the state legislature to import water supplies to Southern California. Metropolitan is a regional water wholesaler to 26 member agencies serving approximately 19 million people across six counties and delivers approximately 1,700 mgd (74,500 L/s) of water from the Colorado River Aqueduct and State Water Project in its 5,200-square-mile (13,470-km^2) service area.

Metropolitan is in the Southwest part of California, the most urbanized and populous region of the state, with slightly more than half of the state's population. The region has a mild, dry subtropical climate with approximately 75 percent of the rainfall occurring between December and March. The region experienced significant drought and regulatory reductions in the past challenging Metropolitan's ability to meet growing demand with imported water. As a result, Metropolitan is both actively developing imported water and incentivizing the development of local water resources for the region.

Metropolitan's Integrated Resources Plan (IRP), provides a long-term strategy to protect the region from future supply shortages, with an emphasis on water-use efficiency through conservation and local supply development. The 2010 IRP calls for meeting increased future demand within Southern California through expanded local supplies and conservation programs. The IRP includes a target of 580,000 acre-feet (189 billion gallons) per year of combined water conservation and water recycling, which incorporates California's goal of 20 percent reduction in per capita potable water use by the year 2020.

In order to meet long-term water demands, Metropolitan provides financial incentives through the Local Resource Program (LRP) for recycled water and groundwater recovery projects that reduce demand on imported water supplies. Metropolitan also provides educational outreach to stakeholders to advance acceptance of recycled water and the LRP program.

LRP History

The LRP was initiated in 1982 to provide financial incentives to local and member agencies for water recycling projects that reduce demand on Metropolitan's imported water supplies and enhance local supply reliability. In consultation with its member agencies, Metropolitan has made periodic improvements to the LRP including refinements to eligibility, selection, performance, and incentive levels. The program has evolved from a fixed incentive to competitive selection and now to its current version providing a sliding scale incentive based on actual project costs up to Metropolitan's estimated avoidable cost of importing water, currently \$250/ac-ft (\$0.20/m^3). The LRP program is currently undergoing review by a Local Resources Development Strategy Task Force to assess alternate approaches to support and expand local resources development.

Metropolitan currently accepts LRP applications on a continual basis. Applications are reviewed for estimated yield and readiness to proceed. Incentives up to \$250/ac-ft (\$0.20/m^3) are provided monthly based on the difference between the actual cost and Metropolitan's prevailing water rates. Incentives are reconciled annually. LRP agreements can last up to 25 years or until the maximum yield is achieved, or until the average price of Metropolitan's water exceeds the cost of the project water.

LRP Analysis

To date, Metropolitan has provided incentives to 64 water recycling projects throughout Metropolitan's service area (**Figure 1**). The map in Figure 1 shows the wide distribution and success of the LRP. Participating projects are expected to produce an ultimate yield of about 323,000 ac-ft/yr (398 MCM/yr) when fully implemented.

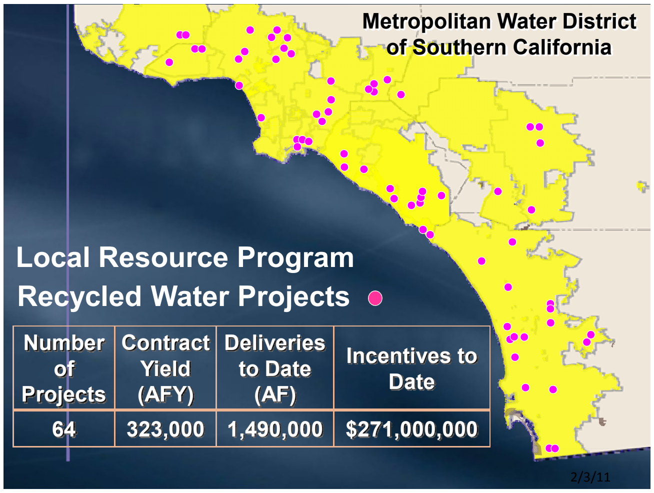

Figure 1
Local Resource Program Recycled Water Projects

Most recycled water developed through the program is used for irrigation, groundwater replenishment and seawater intrusion barriers for coastal groundwater basins. LRP funding can be used for treatment, storage, or distribution facilities. Water quality and treatment technology for each project is based on the proposed use and appropriate California standards. Treatment technologies differ among projects.

Since inception of the LRP in 1982, Metropolitan has provided approximately $271 million for production of about 1.5 million ac-ft (1,850 MCM) of recycled water. During fiscal year 2009/10, Metropolitan provided $29,000,000 for development of 177,000 ac-ft (218 MCM) of recycled water.

Successes and Lessons Learned

Several key factors that contribute to the success of the LRP include: cost effective financial incentives; collaboration among local and regional agencies; appropriate recycled water targets; an open application process; strong performance provisions including requiring construction within 2 years and operational within 5 years; allowing long-term agreements up to 25 years for the project to be completed; and regular refinement of the program have contributed to the success of the LRP.

Summary and Conclusions

There are several long-standing constraints to the development of recycled water including cost, public acceptance, institutional coordination, and regulatory approval. Metropolitan addresses three of these constraints with the LRP. Cost and institutional barriers are directly addressed through the LRP. Metropolitan's incentives reduce the cost of recycled water projects and Metropolitan's regional structure provides strong institutional coordination and collaboration opportunities. The LRP also facilitates public acceptance of recycled water by incentivizing local projects throughout the region. Although, the LRP does not directly address regulatory approval constraints, Metropolitan's participation in organizations like the WateReuse Association facilitates sound regulatory reform. The LRP has played a significant and important role in expanding the number of recycled water projects developed in Southern California.

Recycled water projects require large upfront capital and take a significant amount of time to build and become fully utilized. Without strong local support, development of additional recycled water projects is slow.

California is unlikely to meet recycled water goals adopted in the State Recycled Water Policy without regional support like Metropolitan's LRP. Recycled water projects can be increased through incentive programs like the LRP but also require strong local commitment and often additional State and federal funding. Funding sources for recycled water including SRF and Title XVI are necessary to maximizing development of local recycled water projects.

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Montebello Forebay Groundwater Recharge Project using Recycled Water, Los Angeles County, California

Authors: Monica Gasca, P.E. and Earle Hartling
(Los Angeles County Sanitation Districts)

US-CA-Los Angeles County

Project Background

The Montebello Forebay Groundwater Recharge Project (MFGRP) has successfully been recharging the groundwater with recycled water since August 20, 1962. This is the oldest planned groundwater recharge project using recycled water in California. To date, over 1.6 million ac-ft (1,970 MCM) of recycled water has been recharged at the MFGRP to replenish the Central Groundwater Basin, which provides 40 percent of the total water supply for Los Angeles County.

In the 1950's, following a rapid population growth in the region, excessive and unregulated pumping resulted in an overdraft that dropped the groundwater table and allowed seawater to intrude into the aquifer. In response, the Water Replenishment District of Southern California (WRD) was formed to manage this basin by regulating pumping and purchasing supplemental water supplies for replenishing the groundwater.

Sources of groundwater replenishment in the Central Basin include recycled water, imported river water (Colorado River and State Project water), and local storm runoff. Use of recycled water for replenishment began at the Montebello Forebay area of the Central Basin in 1962, following construction of the Whittier Narrows WRP. The effectiveness of reuse from the Whittier Narrows WRP led to the decision to construct additional WRPs in the Los Angeles area in the 1970's, two of which (San Jose Creek and Pomona) also contribute to the recharge of the Central Basin. In the late 1970's, the WRPs were upgraded with tertiary treatment resulting in production of an effluent that met federal and state drinking water standards for heavy metals, pesticides, trace organics, major minerals, nitrogen, and radionuclides, and had extremely low levels of microorganisms and turbidity.

In the early 2000's, the WRPs were upgraded again, to provide nitrification/denitrification, further improving the quality of the recycled water. In the late 2000's,

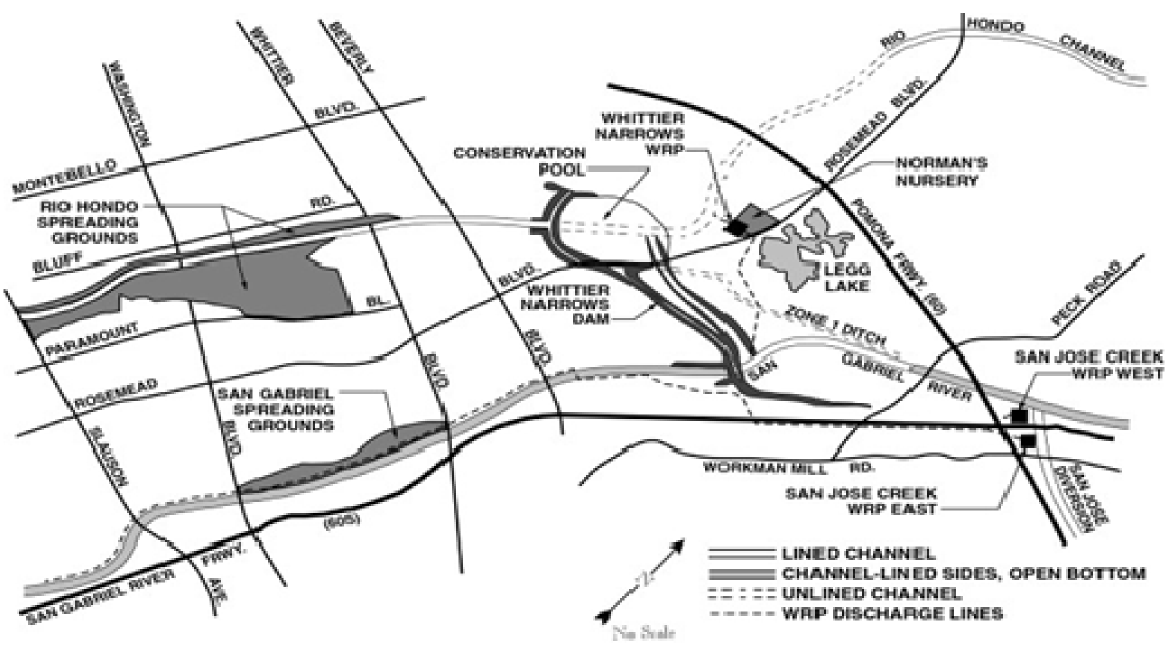

Figure 1
Montebello Forebay Groundwater Recharge Sites

sequential chlorination was implemented, minimizing production of trihalomethanes and N-nitrosodimethylamine. And in 2011, the Whittier Narrows WRP began using UV disinfection. All of these water quality improvements increased the suitability of recycled water for indirect augmentation of potable water supplies through groundwater recharge **(Table 1)**.

Project Operation

Water is percolated into the groundwater using two sets of spreading grounds (**Figure 1**): the Rio Hondo Coastal Spreading Grounds, which consist of 570 ac (235 ha) with 20 individual basins, and the San Gabriel Coastal Spreading Grounds which consists of 128 ac (52 ha) with 3 individual basins, and within portions of the San Gabriel River (308 ac [125 ha]). Recycled water is conveyed to spreading grounds by gravity through existing waterways and operated under a wetting/drying cycle designed to optimize inflow and discourage development of vectors. Extensive monitoring is conducted at the WRPs, at the headworks to the spreading grounds, and in the groundwater aquifers.

Project Effectiveness

In a typical year, more recycled water from the Sanitation Districts' WRPs is used for groundwater recharge than for all other (direct non-potable) applications combined due to its cost-effectiveness. The major advantage of the MFGRP is that it avoids significant construction costs and energy requirements of a dual distribution system for delivering recycled water to direct non-potable users by taking advantage of existing waterways to convey the water to spreading grounds. In addition, greater quantities of recycled water can be conserved by utilizing the substantial under-ground storage capacities of the local aquifers, and there is no strict daily, or even seasonal, timeframe in which recharge must take place; it can occur whenever recycled water supplies are available and infiltration capacity is not taken up by storm runoff.

Project Management and Funding

The MFGRP is jointly managed by three agencies: WRD manages the basin, Los Angeles County Department of Public Works (LACDPW) operates the system, and Los Angeles County Sanitation Districts (Sanitation Districts) provides the recycled water.

Funding is provided by the respective agencies. Treatment is funded by the Sanitation Districts through charges to users of its sewerage system. The recycled water must be treated to a tertiary level even if it's to be discharged to the river and wasted to the ocean; therefore, no additional treatment costs are incurred for this project. Delivery costs are minimal, as the WRPs were constructed alongside rivers for disposal and are upstream of the spreading grounds. Recycled water is delivered by gravity through existing infrastructure, obviating the need for additional capital or energy costs. Operation costs for the river channels, through which the recycled water is transported, and the spreading grounds are incurred by LACDPW as part of their ongoing maintenance and operation of their flood control system and their mission to conserve local water. Recycled water is purchased by WRD as part of their mission to increase storage of groundwater in the Central Groundwater Basin. The Sanitation Districts sells recycled water to WRD at a significant discount over imported water for the same purpose. Groundwater monitoring costs are also borne by WRD as part of their mission to ensure the groundwater quality in their service area. WRD's funds are derived from replenishment fees collected from pumpers of groundwater in their service area, which are collected as part of the basin adjudication.

Project Driven Research

The three agencies involved have successfully collaborated to perform in-depth research over the years to reassure regulators and the public that recycled water is safe for aquifer recharge. The effectiveness of Soil Aquifer Treatment (SAT) has been demonstrated for decades, and a number of health effects studies related to the use of groundwater for human consumption have been undertaken over that time. In addition, numerous studies have been performed on the presence and fate of pharmaceuticals and personal care products in the water, virus fate and transport, recycled water residence time in the aquifers using tracer tests, and total organic carbon reduction. None of these studies have found any adverse health effects associated with using the recycled water for groundwater recharge in the Montebello Forebay.

Table 1 Average recycled water quality and California drinking water limits October 2010-September 2011

Constituent	Units	SJC- East	SJC- West	Whit. Nar.	Pomona	Limit
Organics						
1,1-Dichloroethane	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	5 P
1,1-Dichloroethene	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	6 P
1,1,1-Trichloroethane	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	200 P
1,1,2-Trichloroethane	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	5 P
1,1,2,2-Tetrachloroethane	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	1 P
1,2-Dichloroethane	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	0.5 P
1,2-Dichloropropane	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	5 P
1,2,4-Trichlorobenzene	ug/L	< 5.0	< 5.0	< 5.0	< 5.0	5 P
2,4-D	ug/L	< 0.56	< 0.60	< 0.53	< 0.53	70 P
2,4,5-TP (silvex)	ug/L	< 0.56	< 0.60	< 0.53	< 0.53	50 P
Atrazine	ug/L	< 0.12	< 0.10	< 0.11	< 0.11	1 P
Benzene	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	1 P
bis(2-Ethylhexyl) phthalate	ug/L	< 2.0	< 2.0	< 2.0	< 2.0	4 P
Carbon tetrachloride	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	0.5 P
Chlorobenzene	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	70 P
cis-1,2-Dichloroethene	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	6 P
Endrin	ug/L	< 0.01	< 0.01	< 0.01	< 0.01	2 P
Ethylbenzene	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	300 P
Gamma-BHC (Lindane)	ug/L	< 0.01	< 0.01	< 0.01	< 0.01	0.2 P
Heptachlor	ug/L	< 0.01	< 0.01	< 0.01	< 0.01	0.01 P
Heptachlor epoxide	ug/L	< 0.01	< 0.01	< 0.01	< 0.01	0.01 P
Methoxychlor	ug/L	< 0.01	< 0.01	< 0.01	< 0.01	30 P
Methylene chloride	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	5 P
o-Dichlorobenzene	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	600 P
p-Dichlorobenzene	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	5 P
Pentachlorophenol	ug/L	< 1.0	< 1.0	< 1.0	< 1.0	1 P
Polychlorinated biphenyls (PCBs)	ug/L	ND	ND	ND	ND	0.5 P
Simazine	ug/L	< 0.12	< 0.10	< 0.11	< 0.11	4 P
Tetrachloroethene	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	5 P
Toluene	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	150 P
Toxaphene	ug/L	< 0.5	< 0.5	< 0.5	< 0.5	3 P
trans-1,2-Dichloroethene	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	10 P
Trichloroethene	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	5 P
Trichlorofluoromethane	ug/L	< 1.0	< 1.0	< 1.0	< 1.0	150 P
Vinyl chloride	ug/L	< 0.50	< 0.50	< 0.50	< 0.50	0.5 P
Xylenes	ug/L	ND	ND	ND	ND	1750 P
Inorganics						
Arsenic	ug/L	0.347	0. 592	0. 722	0. 295	10 P
Barium	ug/L	61.6	26.9	38.8	34.5	1000 P
Cadmium	ug/L	< 0.20	< 0.20	< 0.20	< 0.20	5 P
Total Chromium	ug/L	0.74	0.83	1.0	0.83	50 P
Copper	ug/L	3.00	5.69	5.00	5.47	1000 S
Fluoride	mg/L	0.446	0.708	0.685	0.342	2 P
Iron	ug/L	66	51	25	29	300 S
Manganese	ug/L	23.5	25.4	9.38	6.17	50 S
Mercury	ug/L	0.00123	0.00150	0.00245	0.00147	2 P
Nickel	ug/L	5.83	3.01	7.83	1.96	100 P
Nitrate + Nitrite nitrogen	mg/L	4.50	9.49	6.59	6.90	10 P
Selenium	ug/L	<1.00	<1.00	<1.00	<1.00	50 P
Silver	ug/L	< 0.20	< 0.20	< 0.20	< 0.20	100 S
Zinc	ug/L	52.4	47.0	56.3	62.3	
Other Constituents						
Color	CU	9	8	13	14	15 S
Surfactant (MBAS)	Mg/L	< 0.10	< 0.10	< 0.10	0.0083	0.5 S
Gross alpha radioactivity	pCi/L	0.898	1.40	1.02	0.670	15 P

P = Primary Maximum Contaminant Level (health)
S = Secondary Maximum Contaminant Level (aesthetic)
Values with "<" were below the Reporting Detection Limit reported

Regulatory Climate

Replenishment of the groundwater with recycled water in Montebello Forebay is regulated by the California Department of Public Health (CDPH) and Los Angeles Regional Water Quality Control Board (RWQCB) for protection of human health and of beneficial uses of groundwater. The recycled water used at the MFGRP receives rigorous tertiary treatment that ensures the high water quality standards are met.

Initially, the annual amount of recycled water recharged was limited to 32,700 ac-ft/yr (40 MCM/yr), which was determined to be the amount of effluent that had historically entered the groundwater from other sources. In 1987 (following the *Health Effects Study*), the maximum amount of recycled water used for recharge was increased to 50,000 ac-ft/yr (62 MCM/yr). In 1991, this was again increased to 60,000 ac-ft/yr (74 MCM/yr) in order to allow WRD to make up for those years in which excessive rainfall runoff prevented full utilization of the previous recycled water allotment.

In April 2009, the limit was revised again, as the RWQCB, with CDPH's concurrence, removed the quantity limits, replacing them with a dilution-based limitation of no more than 35 percent in any running five year period. WRD estimates that this could allow for the recharge of an additional 5,000 to 7,000 ac-ft/yr (6.2 to 8.6 MCM/yr) of recycled water, with a long-term goal of increasing replenishment with recycled water to 75,000 ac-ft/yr (93 MCM/yr). Currently, about 44,000 ac-ft/yr (54 MCM/yr) of disinfected tertiary municipal wastewater is being delivered to the MFGRP for groundwater recharge.

Successes

The MFGRP provides a new water supply, roughly equivalent to the demands of a quarter of a million people. After fifty years of operation, the WRPs continue to operate consistently, producing an extremely high quality effluent, and monitoring continues to indicate that groundwater quality has not been adversely impacted. In addition, the use of recycled water in lieu of imported water for replenishing the groundwater has saved tens of millions of dollars a year in water purchases.

Because recycled water is highly reliable, cost effective, locally controlled, and drought-resistant, there are ongoing plans to increase the amount of recycled water recharged in the Central Groundwater Basin and ultimately eliminate the basin's dependence on imported water.

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Recycled Water Supplements Lake Elsinore

Author: Ronald E. Young, P.E., DEE (Elsinore Valley Municipal Water District)

US-CA-Elsinore Valley

Project Background or Rationale

As imported water becomes more expensive, finding ways to make the most of existing water supplies becomes increasingly important. One of the best ways to stretch supplies is to recycle water. Elsinore Valley Municipal Water District (EVMWD) in southern California is finding more ways to use recycled water, including water for local playgrounds, commercial landscapes and most importantly, maintaining stable water levels in Lake Elsinore.

Lake Elsinore is southern California's largest natural lake and is situated at the bottom of the San Jacinto Watershed. Because Lake Elsinore is a natural lake, fed only by rain and natural runoff, with annual evaporation of 4.5 feet, it has been plagued, for decades, by low water levels and high concentrations of nutrients. Large amounts of nutrients are responsible for producing algae blooms which choke off oxygen in the lake and result in fish kills. The lake is a full body contact recreational lake with fishing, speed boats, beaches and swimming areas. The lake is not a drinking water source.

Water Quality Standards and Treatment Technology

In 1997, a local task force comprised of community leaders issued a white paper on the benefits and safety of using recycled water in the community and to fill Lake Elsinore. In 2003, through a 2-year pilot program, EVMWD implemented an extensive monitoring program to examine biological and nutrient impacts that recycled water might have on water quality in the outflow channel and throughout the entire lake.

The monitoring program was administered by Dr. Michael Anderson of University of California Riverside. The Anderson report was used by the Regional Water Quality Control Board to set total maximum daily load (TMDL) load allocations in 2004, which were then translated into the 2005 National Pollutant Discharge Elimination System (NPDES) Permit for EVMWD. This resulted in a lake target value of total phosphorus of 0.01 mg/l by 2015 and a reclaimed water limit of 0.5 mg/l based on phosphorus mass loading, instead of concentration.

Thus, phosphorus reduction was needed and ultimately grant funded to achieve the NPDES requirements. The Anderson report concluded "stabilizing the lake level may be of greater short-term concern than increasing nutrient concentrations. The poorest water quality observed in the lake was, in fact more closely associated with declining lake level than inputs of recycled water or high lake nutrient concentrations."

In 2005, the Regional Water Quality Control Board approved EVMWD's two-year pilot project to introduce recycled water into Lake Elsinore. Over this two year period EVMWD successfully completed the various State required permits to be able to permanently provide recycled water to Lake Elsinore as part of TMDL requirements for the watershed.

Project Summary

The two year EVMWD pilot study resulted in a construction project including almost 4,000 feet of pipeline, at a cost of $2.2 million. The project delivers approximately 5 mgd (219 L/s) of recycled water to Lake Elsinore. Also included in the project, was repair and retrofit of three local, shallow groundwater wells that deliver approximately 1 mgd (44 L/s) of non-potable water to Lake Elsinore. An additional $1.5 million project added chemical phosphorus removal to the Regional WRP.

The project was funded by EVMWD and the Lake Elsinore San Jacinto Watershed Authority (LESJWA). LESJWA was formed in 2000 to improve water quality and protect wildlife habitats in the 700 square mile watershed that runs from the San Jacinto Mountains to Lake Elsinore. The annual operations and maintenance costs are borne equally between EVMWD and the City of Lake Elsinore through a cooperative agreement that outlines funding guidelines and operating requirements.

Successes and Lessons Learned

EVMWD received several honors for its state of the art reclamation facility and the recycled water program for Lake Elsinore including being named 2006 Plant of the Year by the California Water Environment Association and the Theodore Roosevelt Environmental Award from the California Association of Water Agencies. **Figure 1** shows the Project Commemoration Ceremony.

Figure 1
October 2007 Commemoration Ceremony (Photo credit: Elsinore Valley Municipal Water District)

Replacing Potable Water with Recycled Water for Sustainable Agricultural Use

Author: Graham Juby, PhD, P.E. (Carollo Engineers)

US-CA-Temecula

Project Background

The city of Temecula, Calif., is located about 60 miles (97 km) north of San Diego. To the east and west lie agricultural areas that produce avocados, citrus and grapes. The agricultural area falls within the boundary of the Rancho California Water District (Rancho Water), which provides irrigation water to the local farmers. Rancho Water provides over 30,000 ac-ft/yr (37 MCM/yr) of fully-treated, drinking water for irrigation. Recognizing that delivering such large volumes of drinking water to agricultural users in water-short southern California is unsustainable, and the fact that discounted water rates for farmers was being phased out, Rancho Water conducted a study to determine the feasibility and cost of delivering recycled water.

In addition to purchasing irrigation water, farmers spend considerable funds on commercial fertilizers to provide nutrients to their crops, while treatment facilities spend considerable sums to remove some of the very same nutrients. The opportunity to provide nutrient-rich recycled water to farmers would benefit both sectors. Additionally, recycled irrigation water could improve plant nutrient uptake, and reduce nutrient runoff, providing another benefit to the region.

Capacity and Type of Reuse Application

Approximately 30,000 ac-ft/yr (37 MCM/yr) of drinking water is applied to the east and west farming areas. This project would be built in phases to ultimately replace the drinking water with 18,000 ac-ft/yr (22 MCM/yr) of recycled water and 12,000 AFY (315 MCM/yr) of untreated drinking water.

Recycled water would be obtained from two existing WWTPs centrally located between the eastern and western agricultural areas. One treatment plant is owned and operated by Rancho Water and has a capacity of 5 mgd (219 L/s). The second facility is owned and operated by the Eastern Municipal Water District and has a current capacity of 18 mgd, (790 L/s) expandable to 23 mgd (1000 L/s). Some of the treated tertiary effluent produced by these plants is already recycled for landscape irrigation, so the agricultural reuse project would make use of any remaining water. In order to implement such a project, significant new infrastructure would be needed to distribute the recycled water. Most of the agricultural demand, about 25,000 AFY (8.1 billion gallons), is in the western region (Santa Rosa Division) where avocado farms are located. This area also has steep terrain (**Figure 1**) and construction of new distribution pipes will be challenging.

Figure 1
Avocado farming area, west of Temecula, Calif. (Photo credit: Graham Juby)

Untreated surface water supply would be used to make up the required volume to match irrigation demands; water would be provided from the existing connections to Metropolitan Water District of Southern California's raw water system. Seasonal storage would be provided to match seasonal demand for agricultural irrigation water by constructing additional storage volume to augment Rancho Water's existing seasonal irrigation storage capacity.

Water Quality Standards and Treatment Technology

Water quality goals for the project were twofold. The first is the requirement of the San Diego Regional Water Quality Control Board that specifies irrigation water contains less than 500 mg/L of total dissolved solids (TDS), which applies to both the eastern and western areas that overlie groundwater basins. The second water quality requirement is limits for chloride, sulfate and boron, which are key considerations for irrigation of avocados, citrus and grapes.

The two WWTPs produce tertiary effluent containing between 690 and 720 mg/L TDS thus some salt removal would be required. However, once the TDS is reduced to below 500 mg/L to satisfy the groundwater basin objectives, the concentrations of other constituents that are of concern for agricultural use are also reduced to acceptable levels (Welch, 2006).

To achieve the desired recycled water quality for agricultural irrigation, conventional and advanced treatment would be required. Two treatment approaches were evaluated. The first treatment approach (**Figure 2**) would use microfiltration (MF) and reverse osmosis (RO) to treat about a third of the secondary effluent to result in a combined stream with the desired TDS limit of less than 500 mg/L. Considering that wastewater treatment includes nutrient removal, this approach would result in irrigation water that would apply nitrogen and phosphate at a rate of about 17 and 16 lb/ac, respectively, based on present agricultural-use water data.

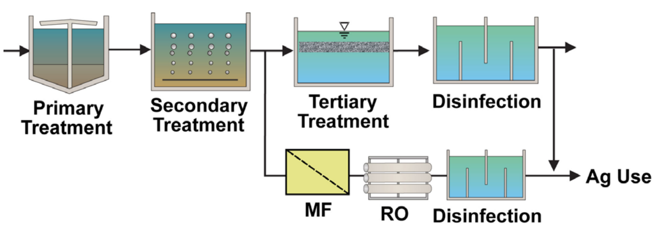

Figure 2
Conventional approach to producing partially desalted recycled water

Such nutrient application rates are much lower than typical rates used in California for oranges, avocados and grapes; which are 85, 116 and 33 lb/ac (95, 130 and 37 kg/ha) for nitrogen, and 34, 61 and 38 lb/ac (38, 68 and 43 kg/ha) for phosphate, respectively (Agricultural Statistics Board, 2004). Consequently, farmers would still need to apply significant quantities of commercial fertilizer.

A novel treatment approach that was also evaluated included the use of MF and RO treatment of primary effluent rather than secondary effluent. This approach would allow nutrients in the primary effluent be retained through the MF step, resulting in higher concentrations after blending with one third of the stream that passes through RO, as shown in **Figure 3**. The recycled water, in this case, would increase irrigation water nitrogen and phosphorus concentrations such that the application rates would become 124 and 25 lb/acre (139 and 28 kg/ha), for nitrogen and phosphate, respectively. These application rates would provide sufficient nitrogen for oranges, avocados and grapes; meaning that farmers would not need to supplement nutrients with commercial fertilizers.

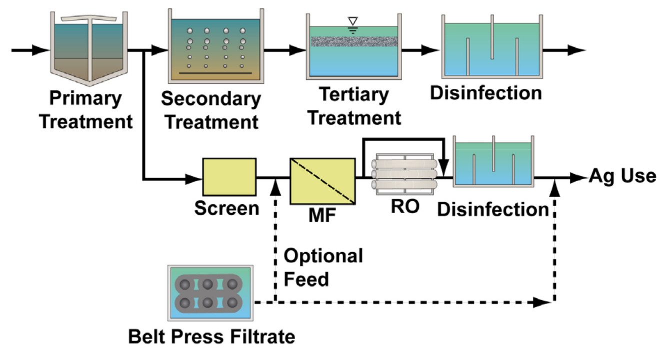

Figure 3
Use of primary effluent as source water results in higher nutrient concentrations in recycled water

As shown in **Figure 3**, other nutrient-rich side streams in the treatment plant (such as the belt press filtrate) could be utilized to further increase nutrient concentrations in the agricultural reuse water, avoiding the energy-intensive treatment of the high-nutrient return stream in the plant. By blending streams appropriately, nutrient levels could be controlled to supply a suitable range for agricultural reuse.

Providing water and nutrients are benefits of the treatment approach described in Figure 3; energy savings would be significant too. Avoiding the need for nitrogen removal in the secondary treatment process would save about 2060 BTU/lb (4.8 GJ/tonne) of nitrogen removed. But the biggest energy saving comes from manufacturing less commercial fertilizer – about ten times more energy than that needed to remove nitrogen via wastewater treatment, equating to 19,000 BTU/lb (44 GJ/tonne) of nitrogen (EFMA, 2007). For Phase I of the project, the 10,000 ac-ft/yr (12 MCM/yr) reuse is estimated to result in energy savings (associated with nitrogen) equivalent to 3,600 bbl/yr of oil, also reducing greenhouse gas emissions by 2800 tons/yr (2,500 tonnes/yr) of carbon dioxide equivalent (Juby et al., 2010).

Project Costs

Project cost estimates were updated in 2010 to include avoided costs and the latest projections for potable water costs in the region. Avoided costs included savings that would result from implementation of the project, such as the costs saved by importing less water to the region, and capital and operations and maintenance (O&M) costs that would be saved as a result of the modified treatment process.

The project was assumed to have a 30-year life, and interest on capital was calculated at an annual rate of 5 percent. Capital and O&M costs were annualized to develop an annual total, from which unit costs were calculated. The cost analysis showed that building the project to include 18,000 ac-ft/yr (22 MCM/yr) of partially-desalted, recycled water would result in the biggest long-term savings, $545 million over the life of the project. The project payback is projected to be between 8 and 10 years when compared with the "do-nothing" alternative that assumes continued use of potable water for crop irrigation.

Project Funding and Management Practices

Rancho Water applied for Title XVI funding through the U.S. Department of the Interior, Bureau of Reclamation. A total of $20 million was available for the project from this source. An additional $4 million was potentially available through the State of California via Proposition 84, and the Metropolitan Water District of Southern California offered a credit of $250/ac-ft ($0.20/m^3) of recycled water used to off-set potable water production through a local resources program.

A key to success of potential funding applications was the fact that this project had regional benefits in terms of its ability to reduce the demand for imported water and that it would free-up significant treated potable water; enough for a city of more than 120,000 people. The project's more sustainable approach in terms of water use and energy savings were also important success factors.

Institutional/Cultural Considerations

The key aspect for the overall success of this project is the availability of excess wastewater from the local treatment plants. Linked to that factor, is the institutional issue of sharing water between agencies. The economic downturn in Southern California since 2008, coupled with a drive to increase water conservation, has resulted in wastewater flows declining to most treatment plants. Concurrently, the rapid increase in potable water cost has resulted in two challenges for this project. First, the decline in wastewater flows has delayed the implementation plan for the project by several years. Second, other uses for recycled water have left less wastewater available for this project.

Consequently, Rancho Water has recently investigated smaller, alternative projects that would utilize around 5,000 to 10,000 ac-ft/yr (6 to 2 MCM/yr) of recycled water. These projects would not involve conversion of the entire agricultural region to recycled water; but one alternative would convert the entire eastern farming region (vineyards) to recycled water. The current lack of "excess" wastewater flow for reuse equates to higher risk of stranded assets, if costly infrastructure is installed without guarantee that water will be available in future. Another risk to the project is if farmers go out of business, due to the rising cost of potable water, before the recycled water project can be built.

Successes and Lessons Learned

This project is still in development however, a key lesson for success is securing wastewater resources for recycled water projects early in arid regions where these resources are in high demand.

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Water Reuse in the Santa Ana River Watershed

Author: Celeste Cantú (Santa Ana Watershed Project Authority)

US-CA-Santa Ana River

Project Background

Water reuse has long been seen as key to integrated regional water management planning in the Santa Ana River watershed and has been used as a strategy to stretch water supplies and improve supply reliability. The watershed includes most of Orange County, the western corner of Riverside County, the southwestern corner of San Bernardino County and a small portion of Los Angeles County in Southern California. When the watershed is viewed as a system, a comprehensive approach to managing water can be implemented, allowing available water to be matched to end uses by quality. For example, in the Santa Ana River watershed, there is significant demand for irrigation of landscaping, parks, golf courses and sports fields. Typical domestic wastewater can be recycled for these purposes without much more expense than would be required to discharge the wastewater legally to local receiving waters. In this case, reuse requires less energy than pumping imported water over the mountains into the watershed. Additionally, recycled water often contains nutrients, which can reduce the fertilizer needs for smart landscape managers.

Project Development

The Santa Ana Watershed Project Authority (SAWPA) has led the agencies and stakeholders in the watershed in a comprehensive, integrated planning process called "One Water One Watershed" (OWOW). The OWOW Steering Committee and the SAWPA Commission have developed goals for the watershed, several of which are related to water reuse, including increasing use of recycled water, matching water quality with intended uses, leveraging existing assets, reducing energy consumption, and identifying projects with multiple benefits.

SAWPA's member agencies have been leaders in reusing domestic wastewater. The Eastern Municipal Water District, Inland Empire Utilities Agency, Orange County Water District, and Western Municipal Water District have all developed recycled water supplies; other retail agencies in the watershed have also been very aggressive in making use of recycled water.

Capacity and Type of Reuse Application

The Santa Ana River watershed currently meets 10 percent of its total demand in average years with water reused within the watershed, and SAWPA expects this to increase to 15 percent by 2030. Recycled water uses include municipal use, agricultural irrigation, groundwater recharge, habitat and environmental protection, industrial use, and lake stabilization.

California currently recycles approximately 725,000 ac-ft (894 MCM) per year and has a goal of reusing 2.5 million ac-ft (3080 MCM) per year. This watershed represents a significant opportunity for the State to reach its recycling goal as the Santa Ana River watershed already reuses 217,000 ac-ft (268 MCM) per year or 29 percent of all of California's current reuse. The OWOW plan envisions increasing that to 437,000 ac-ft (539 MCM).

Water Quality Standards

Another of the OWOW goals includes salinity management, which has also been a key effort of SAWPA for forty years on a watershed scale. Salt is introduced into the watershed by way of domestic sewage, industrial discharges, and the importation of water. A side effect of increasingly efficient water use is that less water flows to the ocean, which normally also reduces the export of salt. As a result, water reused in the watershed can cause a salinity increase which has undesirable consequences.

Thus, SAWPA and its member agencies constructed the Inland Empire Brine Line, which is used to collect salty wastes from industry, allowing those economic activities to thrive while keeping the salt segregated from the river, the groundwater, and the reusable wastewater. The isolation and export of brine creates capacity for reuse of domestic wastewater.

Importation of water from the Colorado River accounts for about one-third of the salt inputs to the system. In addition to the Inland Empire Brine Line, SAWPA and its member agencies also invested in groundwater desalters, which also discharge brine to the Inland Empire Brine Line.

In the lower part of the watershed, another SAWPA member agency, the Orange County Water District (OCWD), operates extensive diversion and recharge facilities to capture as much surface flow as possible and move it to groundwater storage. For decades OCWD has used recycled water to protect the basin from salinity by injecting it to create a seawater intrusion barrier. More recently, OCWD has partnered with the Orange County Sanitation District to develop the Groundwater Replenishment System (GWRS), the premier indirect potable reuse project in the U.S., which treats and percolates 72,000 ac-ft (89 MCM) per year back into the basin for storage and reuse. The OCWD GWRS uses RO treatment to remove salt, ultimately keeping it out of the basin.

The upper watershed's desalters and the Inland Empire Brine Line reduce the salinity of the surface flows that OCWD captures and recharges, also protecting the quality of the groundwater resource. As a result, the Orange County groundwater basin supplies 65 to 75 percent of the water needs of the 2.5 million residents of north Orange County.

Successes and Lessons Learned

The Santa Ana River watershed experience illustrates the need for a comprehensive, watershed approach to resources management, as even laudable actions can have negative impacts that need to be balanced. The desire to increase water use efficiency and to reuse water to stretch supplies and improve reliability has focused attention on the need to manage salinity. The need to integrate strategies and invest in significant infrastructure to achieve these goals required collaboration and trust among stakeholders throughout the watershed.

The communities and stakeholders in the watershed are now implementing the OWOW plan and will continue to look for ways to optimize available water resources. Moving forward, the OWOW Steering Committee and the SAWPA Commission will look even harder at addressing the long-term impacts associated with climate change. In Southern California, this is likely to create greater impetus to increase efficiency and maximize the use of local supplies and groundwater storage. Water reuse, storm water management, and salinity management are key strategies in the plan, and the SAWPA and its member agencies will continue to aid watershed stakeholders in developing new cooperative agreements for implementing strategies in the context of a system-wide plan.

Leo J. Vander Lans Water Treatment Facility

**Authors: R. Bruce Chalmers, P.E. (CDM Smith) and Paul Fu, P.E.
(Water Replenishment District)**

US-CA-Vander Lans

Project Background or Rationale

The Water Replenishment District of Southern California (WRD) was established in 1959 to manage groundwater resources of the Central and West Coast Basins. WRD is responsible for maintaining adequate groundwater supplies, preventing seawater intrusion into underground aquifers, and protecting groundwater quality against contamination. WRD operates a program to artificially replenish the Central and West Coast Groundwater Basins by spreading and injecting replenishment water. Several sources are used for replenishment, including imported water and treated recycled water. WRD utilizes spreading facilities and three seawater intrusion barriers, including the Alamitos Seawater Intrusion Barrier.

Capacity and Type of Reuse Application

WRD constructed the Leo J. Vander Lans Water Treatment Facility (LVLWTF) in 2005 with a capacity of 3 mgd (130 L/s). The plant is being expanded to increase capacity to 8 mgd (350 L/s). WRD receives tertiary treated (Title 22) reclaimed water from the Los Angeles County Sanitation Districts (LACSD) Long Beach Water Reclamation Plant (LBWRP). WRD is also planning to acquire tertiary effluent from LACSD's Los Coyotes Water Reclamation Plant (LCWRP), approximately 6 miles (9.6 km) to the north of LVLWTF, to provide a sufficient supply of water to meet expansion requirements of the LVLWTF.

Treated water from the existing plant is mixed with imported potable water prior to injection into the Alamitos Barrier. The LVLWTF expansion will provide the entire supply to the barrier; therefore, eliminating the need for imported water.

Water Quality and Treatment Technology

Water quality from the LCWRP is essentially the same as the LBWRP. Comparison of average influent and effluent water quality parameters from 2010 is shown in **Table 1**.

Table 1 Influent and effluent water quality from 2010

Parameter	Influent		Product
	LBWRP	LCWRP	LVLWTF
TOC (mg/L)	6.7	7.5	0.44
Turbidity (NTU)	0.48	0.50	0.07
TDS (mg/L)	703	787	83
pH (SU)	7.9	7.9	8.12
TN (mg/L)	9	9.3	2.05
Nitrate (mg/L as N)	6	5.3	1.74
Ammonia (mg/L)	1.5	2.0	0.22
NDMA (ng/L)	291	296	4.9
1,4 Dioxane (ug/L)	RNR	2.55	ND

The treatment processes used at the LVLWTF follow the "California Model" for indirect potable reuse, using microfiltration (MF), reverse osmosis (RO), and ultraviolet (UV) (**Figure 1**). Facilities are located on a site adjacent to the LBWRP shown in **Figure 2.**

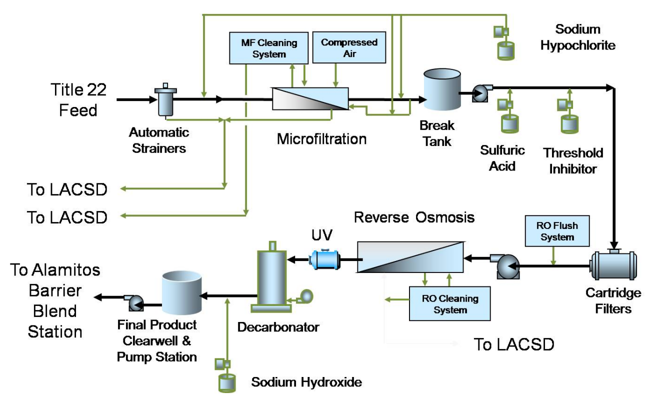

Figure 1
LVLWTF process flow diagram (Photo credit: CDM Smith 2011)

Microfiltration System. The existing MF system will be expanded to provide 8.35 mgd (370 L/s) of filtrate. The expanded system will have 6 MF racks with 100 modules per rack and is sized for a flux rate of 35 gallons per square foot per day (gfd) (58 L/m^2/hr) and a recovery rate of about 95 percent. Maintenance cleans can be performed daily while clean-in-place protocols are performed monthly. Half of the existing MF system will be modified to treat MF backwash from expanded MF equipment; while the remaining modules will be moved to the new MF racks.

Figure 2
LVLWTF site (Photo credit: CDM Smith 2011)

MF Backwash Treatment. MF backwash will be treated with a DAF and MF membranes as shown in **Figure 3**. Due to this level of treatment and the fact that no virus removal credit is being taken for the MF, 0.42 mgd (18 L/s) of water can be used as influent to the RO system.

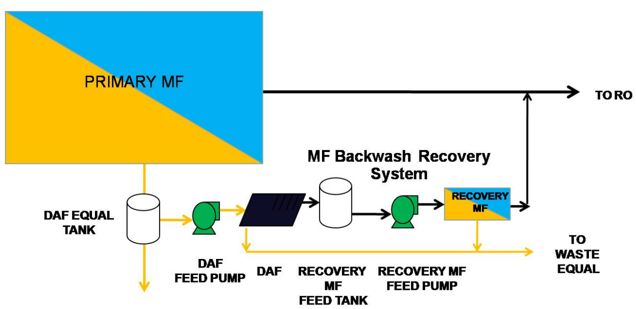

Figure 3
MF and MF backwash treatment systems (Photo credit: CDM Smith 2012)

Reverse Osmosis System. The current two stage RO system will be expanded to produce 8 mgd (350 L/s) of RO permeate at a flux rate of 12.2 gfd (20.3 L/m^2/hr). The two stage RO system will be supplemented with a third stage to increase the overall RO recovery to approximately 92 percent **(Figure 4).**

UV-A System. Additional equipment is being added to the UV system during the expansion to increase capacity to 8 mgd (350 L/s). Hydrogen peroxide will also be added to provide advanced oxidation. The system will provide 1.62-log to 2-log removal of NDMA and 0.5-log 1,4-dioxane removal.

Appurtenances. Finished water pumps deliver water to the barrier. Calcium chloride and sodium hydroxide will be added to provide minerals and pH control to stabilize the water. A chloramine residual will be required for the barrier injection. Plant wastes, including the RO concentrate, are conveyed to the local trunk sewer for further treatment downstream prior to discharge to the ocean outfall.

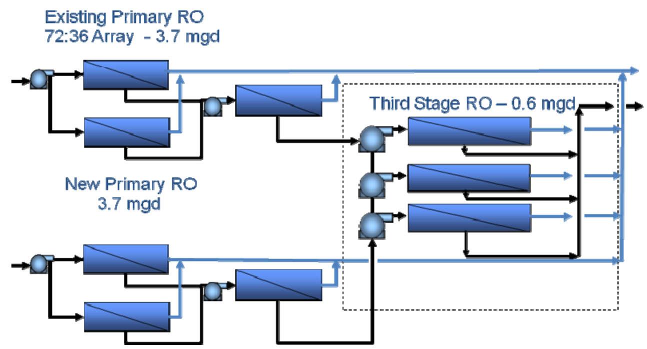

Figure 4
Three stage RO system (Photo credit: SPI 2011)

Project Funding and Management Practices

A Federal Title XVI grant and California Proposition 84 grant provided partial funding for the design and construction of the LVLWTF, with the remaining funded by WRD via debt financing. Operation of the LVLWTF is contracted to the Long Beach Water Department (LBWD). Influent water is obtained from the LBWD and the LACSD. The Alamitos Barrier is owned and operated by the LACDPW.

Institutional/Cultural Considerations

The expansion is similar to the existing facility except the waste flow is limited to 760,000 gpd (2,900 m^3/d). The LVLWTF expansion provides the additional 5 mgd (220 l/s) of treatment capacity without increasing waste flows to sewer. To accomplish this, backwash from the MF system will be treated and used while a third stage will be added to the RO to increase the recovery. The expanded plant will have an overall 92 percent water recovery rate.

Successes and Lessons Learned

The LVLWTF was the first indirect potable reuse plant in California to be designed to remove NDMA while the expansion construction may be the first permitted under the California Recycled Water Recharge regulations.

Use of Pasteurization for Pathogen Inactivation for Ventura Water, California

Author: Andrew Salveson, P.E. (Carollo Engineers)

US-CA-Pasteurization

Project Background or Rationale

Pasteurization, discovered by Louis Pasteur in 1864, is a process of applying heat to inactivate pathogenic or spoilage microorganisms. The process has since become standard practice in the food industry and has recently become an accepted practice in sewage sludge processing, to achieve Class A Biosolids standards. This technology has the ability to be used in sewage sludge processing as well as treated wastewater disinfection. The use of pasteurization as a disinfection technology was originally demonstrated to the California Department of Public Health (CDPH) at the City of Santa Rosa, California's, Laguna Wastewater Reclamation Plant. A demonstration scale system (**Figure 1**) was built by Pasteurization Technology Group for Ventura Water at the Ventura Water Reclamation Facility in Ventura, Calif.

Figure 1
400 gpm Wastewater Pasteurization Demonstration System in Ventura California (Photo credit: Greg Ryan, Pasteurization Technology Group)

Treatment Technology

Pasteurization is based on thermal inactivation of microorganisms. This process may depend on a number of factors: characteristics of the organism, stress conditions for the organism (e.g. nutrient limitation), growth stage, characteristics of the medium (e.g. heat penetration, pH, presence of protection substances like fats and solids, etc.), and temperature and exposure time combinations. In design of pasteurization systems, temperature and exposure time combinations are the dominant parameters. The most useful information within the literature is the demonstration of the relative sensitivities to heat for various pathogens and indicator organisms. The particular temperature and contact time required for bacterial and viral disinfection of treated wastewater is presented in **Figures 2** and **3**, respectively (adapted from Salveson [2007]).

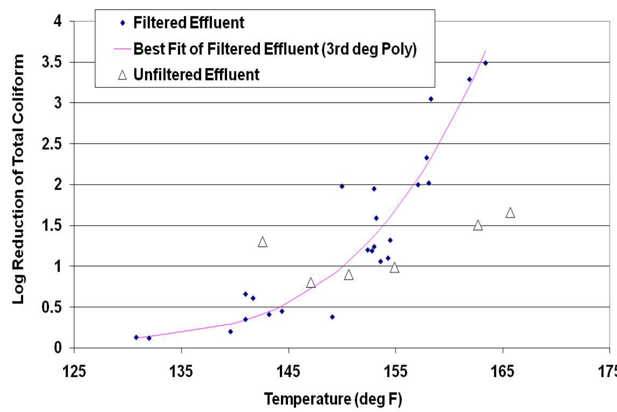

Figure 2
Disinfection of total coliform in treated effluent (Salveson et. al., 2007)

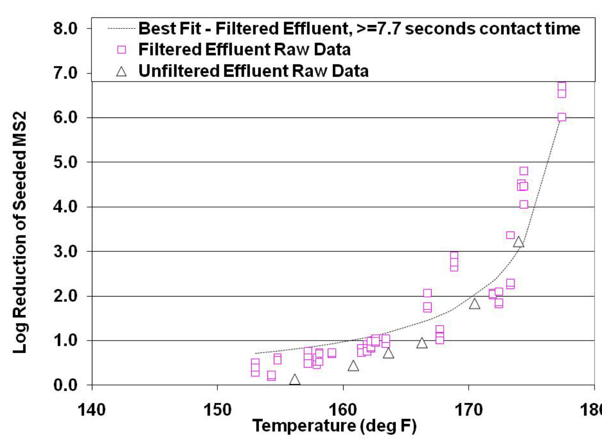

Figure 3
Disinfection of MS2 Coliphage in treated effluent (Salveson et. al., 2007)

Moce-Llivina et al. (2003) investigated pasteurization of seeded bacteriophages and enteroviruses in raw sewage and tested the effect of pasteurization at 140 degrees F (60 degrees C) for 30 minutes. They found that MS2 was the most heat sensitive coliphage and that somatic coliphages and phages infecting *B. fragilis* were the most resistant. Enteroviruses were significantly more heat sensitive than any of the phages, with poliovirus being the most heat sensitive.

Based upon this and other work, primarily the testing in Santa Rosa, Calif., the CDPH determined that a 4-log reduction in a seeded MS2 coliphage test conservatively provided equivalent disinfection to 5-log reduction of poliovirus. Pasteurization to this rigorous reclaimed water standard was demonstrated at the City of Santa Rosa's Laguna Wastewater Reclamation Plant where validation testing was conducted as part of the CDPH program to review new technologies and provide conditional approval (often referred to as "Title 22" approval). The detailed research is summarized in Salveson et al. (2011).

The CDPH approved pasteurization to meet the stringent "tertiary recycled water criteria" for coliform and virus reduction based upon a minimum contact time of 10 seconds at or above 179 degrees F (81.6 degrees C). **Figures 2** and 3 illustrate disinfection performance for bacteria and virus, respectively in filtered and unfiltered effluents. This data suggests that water quality does play a role in pasteurization disinfection kinetics, particularly with regard to coliform disinfection.

Economic and Management Practices

The economic value of pasteurization is favorable when waste heat can be captured and transferred for disinfection. The goal of pasteurization is to keep all heat in a loop, continuously transferring the heat in the disinfected water with the cool undisinfected water. To accomplish this, a series of carefully designed heat exchangers are used. The ongoing demonstration testing in Ventura, Calif., shows that all but two degrees of heat is continuously transferred, resulting in only a minimal need for continuous heat addition.

Example sources of waste heat include exhaust heat from a turbine fueled by natural gas, digester gas, hot water, or a combination of the waste heats. The economics of pasteurization appear extremely favorable where power costs are high. In Ventura, Calif., pasteurization costs project to be millions of dollars less than other alternative disinfection technologies. These economics (summarized in Salveson et. al, 2011) led to the demonstration testing in Ventura. Pasteurization Technology Groups has a worldwide patent for the process.

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California State Regulations

Author: James Crook, PhD, P.E., BCEE (Water Reuse Consultant)

US-CA-Regulations

Project Background or Rationale

The state of California has a long history of water reuse and regulatory activity and was the first agency to develop regulations specifically directed at the safe use of reclaimed water. The evolution of water reclamation and reuse criteria truly began in California, and the philosophy and rationale behind that state's regulations have pervaded many other regulations around the world.

Regulatory Authority

The principal state regulatory agencies involved in water recycling in California are the California Department of Public Health (CDPH), the California State Water Resources Control Board (SWRCB), and the nine Regional Water Quality Control Boards (RWQCBs) (Crook, 2010). In 1991, the SWRCB and RWQCBs were brought together with five other state environmental protection agencies under the newly crafted California Environmental Protection Agency (Cal/EPA).

The nine semi-autonomous RWQCBs are divided by regional boundaries based on major watersheds. Each RWQCB makes water quality planning and regulatory decisions for its region. The SWRCB is generally responsible for setting statewide water quality policy and considering petitions contesting RWQCB actions. CDPH has statutory authority in two areas with respect to direct potable reuse. It regulates public water systems (drinking water purveyors) and develops and adopts water recycling criteria.

History of Regulation Development

At the turn of the 20th century, California had at least 20 communities using either raw or settled sewage for agricultural irrigation. The earliest reference to a public health viewpoint on water quality requirements in California appeared in the California State Board of Health Monthly Bulletin dated February 1906, in which it was stated:

> *1906: "Oxnard is installing a septic tank system of sewage disposal, with an outlet in the ocean. Why not use it for irrigation and save the valuable fertilizing properties in solution, and at the same time completely purify the water? The combination of the septic tank and irrigation seems the most rational, cheap, and effective system for this State." (Ongerth and Jopling, 1977)*

Therefore, the first water quality requirement for reclaimed water use in California was septic tank treatment.

Official control on the sewage irrigation of crops began in 1907, with the publication of State Board of Health's April 1907 Bulletin specifying that local health authorities "watch irrigation practices" and not allow use of "sewage in concentrated form and sewage-polluted water...to fertilize and irrigate vegetables which are eaten raw, and strawberries." (Crook, 2002)

The first standards adopted by the State Board of Health in 1918, titled *Regulation Governing Use of Sewage for Irrigation Practices* (California State Board of Health, 1918), prohibited the use of raw sewage for crop irrigation and limited the use of treated effluents to irrigation of nonfood crops and food crops that were cooked before being eaten or food crops that did not come in direct contact with the wastewater. Garden crops of the type that are cooked before being eaten could be irrigated if the application of effluent was not made within 30 days of harvest. The regulations provided several exemptions, such as permitting irrigation of melons if the sewage did not come in contact with the vine or product and irrigation of tree-bearing fruit or nuts if windfalls or products lying on the ground were not harvested for human consumption.

The regulations were revised in 1933 and renamed *Regulations on the Use of Sewage for Irrigating Crops* (CDPH, 1933). These regulations prohibited the use of raw sewage for crop irrigation and prohibited the use of sludge as a fertilizer for growing vegetables, garden truck, or low growing fruits or berries unless the sludge was rendered innocuous. It prohibited the use of settled or undisinfected sewage effluent for the irrigation of the same type of crops and for the irrigation of orchards or vineyards during seasons in which windfalls or fruit lie on the ground. Irrigation of fodder, fiber, or seed crops with settled or undisinfected sewage was allowed, but milk cows could not be pastured on the land that was moist with sewage. The regulations exempted restriction of wastewater for the irrigation of garden truck crops eaten raw if the wastewater was well oxidized, nonputrescible, and reliably disinfected or filtered to meet a bacterial standard approximately the same as the then-current drinking water standard. Disinfection reliability was emphasized in that two or more chlorinators, weighing scales, reserve supply of chlorine, twice daily coliform analyses, and records were required. It was noted that the revisions were made because of an expressed interest by the Los Angeles Chamber of Commerce and others in the nearby communities to conserve water, to provide employment for fieldworkers in contemplated truck gardens, and to save beaches (Ongerth and Jopling, 1977). The 1933 standards marked the first appearance of cross connection control regulations. Cross connections between wastewater and domestic water supply pipelines were prohibited, and signs warning against drinking the water were specified on pipes and appurtenances that contain wastewater.

The 1933 regulations continued in effect until passage of the Water Pollution Act of 1949 eliminated the permit system that constituted the statutory basis for the regulation (Ongerth and Jopling, 1977). They were re-issued without change in 1953 as *Regulations Relating to Use of Sewage for Irrigating Crops* (CDPH, 1953).

The number of water reuse projects increased dramatically in the 1960s, and it became necessary to develop water reclamation standards for various types of use. In 1967, a state legislative committee reported that legislation relating to the use of reclaimed wastewater was needed to protect public health and that the CDPH should be required to establish statewide contamination standards. The committee recommended that the RWQCBs establish requirements for the use of reclaimed water that are in conformity with the statewide contamination standards. These recommendations resulted in revisions to the California Water Code in 1967, which gave the CDPH the authority and responsibility to establish reclamation criteria and gave the RWQCBs the responsibility to enforce the criteria (California State Water Resources Control Board, 1967).

As a result of the above-mentioned legislation, more comprehensive regulations were enacted in 1968 that were directed mainly at the control of disease agents. These *Statewide Standards for the Safe Direct Use of Reclaimed Water for Irrigation and Impoundments* (CDPH, 1968) included treatment and quality requirements intended to assure that the use of reclaimed water for the applications specified in the regulations would not impose undue risks to the public health.

Several studies conducted by the Department of Health in the late 1960s and early 1970s indicated a record of poor reliability at wastewater treatment plants (Crook, 1976; California Department of Health, 1973). At the request of the Department of Health, a modification in state law authorized the Department of Health to establish regulations on treatment reliability. The 1968 standards specified levels of constituents of reclaimed water and were revised in 1975 to include treatment reliability requirements, then renamed *Wastewater Reclamation Criteria* (California Department of Health Services, 1975). There have been two subsequent revisions to the criteria, one in 1978 that added general requirements for groundwater recharge and differentiated between different types of landscape irrigation (California Department of Health Services, 1978). Research and demonstration studies conducted in the late 1970s and 1980s, along with advances in treatment technology and a need to include requirements for additional types of reuse, resulted in a protracted effort to revise the 1978 criteria. This effort, begun in 1988, culminated in adoption of a new set of criteria in 2000. These *Water Recycling Criteria* include requirements for several new applications of reclaimed water, modify some of the treatment and quality requirements, prescribe requirements for dual water systems, include cross connection control requirements, and include use area requirements that formerly were issued as guidelines (California Department of Health Services, 2000). In conformance with terminology in the California Water Code, the word “reclaimed” was replaced with “recycled” and “reuse” was replaced with “recycling” in all regulations.

Additional information on the decision-making and rationale that went into the details of the 1968, 1975, 1978, and 2000 updated water reuse regulations in California is available in Crook (2002). California has used advisory committees, public meetings, and other means of communication with a broad spectrum of interested parties, including waste dischargers, regulatory agencies, and potential users over the years during development of its water reuse regulations in order to arrive at a proper balance of realistic and workable standards that ensure an acceptable level of public health protection.

Recycled Water Policy

In 2009 the SWRCB adopted a Recycled Water Policy (California State Water Resources Control Board, 2009). In response to an unprecedented water crisis brought about by the collapse of the Bay-Delta ecosystem, climate change, continuing population growth, and a severe drought on the Colorado River, the SWRCB was prompted to “exercise the authority granted to them by the Legislature to the fullest extent possible to encourage the use of recycled water, consistent with state and federal water quality laws.” The policy also declared, “Recycled water is a valuable resource and significant component of California’s water supply” (California State Water Resources Control Board, 2009). These recent declarations are part of broad state-wide objectives to achieve sustainable water resource management.

The SWRCB included a provision in the 2009 Recycled Water Policy to establish a Science Advisory Panel to provide guidance for future development of monitoring programs that assess potential threats from constituents of emerging concern (CECs) where recycled water is used for various water recycling applications. Recycling applications could include urban landscape irrigation and indirect potable reuse via surface water augmentation as well as drinking water aquifer recharge using surface spreading or subsurface injection. The Science Advisory Panel’s report, entitled “Monitoring Strategies for Chemicals of Emerging Concern in Recycled Water” was published in 2010 (California State Water Resources Control Board, 2010). The SWRCB subsequently released draft amendments to the Recycled Water Policy (California State Water Resources Control Board, 2012) in response to the Science Advisory Panel’s report that added many of the Panel’s recommendations related to monitoring strategies for CECs in recycled water.

Proposed Indirect Potable Reuse Regulations

CDPH first began crafting comprehensive regulations for indirect potable reuse (IPR) via groundwater recharge by surface spreading and direct injection into potable water supply aquifers more than two decades ago. The most recent version of the draft regulations (California Department of Public Health, 2011) was released in November 2011. The draft regulations include (among other criteria) requirements for treatment unit processes, water quality, dilution, source control programs, response time between treatment and extraction of the water for potable purposes, monitoring wells, and monitoring for indicators, surrogates, and selected CECs. They are scheduled to be finalized and adopted by the end of 2013. Upon adoption, the groundwater recharge regulations will be included in the CDPH *Water Recycling Criteria*.

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West Basin Municipal Water District: Five Designer Waters

Author: Shivaji Deshmukh, P.E. (West Basin Municipal Water District)

US-CA-West Basin

Project Background or Rationale

West Basin Municipal Water District (West Basin) is a special district of the State of California and an innovative public agency that provides drinking and recycled water to its 185-square-mile (480-km^2) service area located in coastal Los Angeles County. West Basin purchases imported water from the Metropolitan Water District of Southern California and wholesales the imported water to cities, water agencies, and private water companies in its service area. In order to reduce the dependence on imported water supplies, West Basin developed a world renowned recycled water program that currently produces more than 30 million gallons per day (1,300 L/s) of "designer" recycled water. West Basin recently began a new program, Water Reliability 2020, to expand its portfolio of locally produced water to ensure water supply reliability for future residents and businesses. This program is designed to reduce the dependence on imported water by increasing the amount of water conserved and produced locally. By 2020, West Basin will double water recycling and water conservation programs and include environmentally responsible ocean-water desalination as part of the water supply portfolio.

Capacity and Type of Reuse Application

West Basin's Water Recycling Facility is named the Edward C. Little Water Recycling Facility (ECLWRF) (**Figure 1**) to honor the 6-term commitment made to West Basin and our constituents by Director Edward C. Little. The ECLWRF is a world-class, state-of-the-art facility that is the largest of its type in the world. Working with customers such as Toyota, Honda, Chevron, Goodyear, California State University, Home Depot Center, Raytheon, Los Angeles Air Force Base, and Marriott, West Basin has built a unique water recycling program with the capacity to expand throughout our service area.

Figure 1
The Edward C. Little Water Recycling Facility is located in El Segundo, California

This facility produces more than 30 million gallons of recycled water every day for over 380 customer sites. Uses of recycled water include irrigation, boiler feeds, cooling towers, street sweepers, and injection into seawater barriers to provide protection for local groundwater supplies from saltwater intrusion by the ocean. This water purification facility produces five types of "designer" waters to serve specific customer needs for various uses, including golf courses, professional soccer fields, street sweeping, restrooms, boilers, cooling towers and other commercial, municipal and industrial uses. All five types of "designer" water meet the treatment and water quality requirements specified in the California Department of Public Health's Water Recycling Criteria and permitted by the Los Angeles Regional Water Quality Control Board. "Designer" Waters that are fit for various purposes include:

1. **Tertiary Water:** Secondary treated wastewater that has been filtered and disinfected for a wide variety of industrial and irrigation uses

2. **Nitrified Water:** Tertiary water that has been nitrified to remove ammonia for industrial cooling towers.

3. **Reverse Osmosis Water:** Secondary treated wastewater by microfiltration, followed by reverse osmosis (RO) and UV disinfection and advanced oxidation using hydrogen peroxide for groundwater injection, which is superior to state and federal drinking water standards.

4. **Pure Reverse Osmosis Water:** Secondary treated wastewater that has undergone micro-filtration and RO can be used for low-pressure boiler feed water.

5. **Ultra-Pure Reverse Osmosis Water:** Secondary treated water that has undergone micro-filtration and two passes through RO for high-pressure boiler feed water.

In addition to providing recycled water for commercial and industrial uses, high-quality recycled water produced by West Basin is injected into the groundwater basin to prevent seawater intrusion into the local aquifers. The West Coast Barrier is a series of injection wells positioned between the ocean and the groundwater aquifer. These wells inject water along the barrier to ensure that the water level near the ocean stays high enough to prevent the seawater from seeping into the aquifer. In April 2009, West Basin and the Water Replenishment District of Southern California (WRD) signed an agreement to increase the amount of water supplied to the barrier by 100 percent by 2012.

Figure 2
Reverse osmosis treatment at the ECLWRF

Water Quality Standards and Treatment Technology

With five distinct “designer” waters, many water quality requirements exist for West Basin’s recycled water program. While each has established water quality guidelines, the most regulated is recycled water for injection into the groundwater basin. This quality meets and exceeds all potable drinking water guidelines. In order to improve the flux through the microfiltration process of this treatment train, West Basin will soon implement the use of ozone as a pretreatment step prior to this filtration process. **Figure 2** shows the heart of the treatment process, reverse osmosis.

Project Funding and Management Practices

The recycled water program is funded though capital investment from major customers, state and federal grants, local supply subsidies, and recycled water rates. West Basin maintains a relatively small work force. Its operational model includes contract operations for the treatment plant and the distribution system. It also has employed various project deliver methods including design-build.

Institutional/Cultural Considerations

The focus of West Basin’s outreach is its award winning Water Reliability 2020 program. The district conveys news about water supply through multiple mediums including community events, media affairs, conservation classes and the district’s website. West Basin offers free conservation classes, classroom education and facility tours to more than 10,000 people each year.

Successes and Lessons Learned

West Basin has been a leader in application of technology to produce water for indirect potable reuse. Some of the technology successes have included application of microfiltration as a pretreatment step for reverse osmosis as well as implementation of low pressure, high intensity UV disinfection for disinfection and advanced oxidation of indirect potable water, leading the way for other agencies to follow suit with similar treatment processes. Once complete later this year, West Basin will be one of the first to use ozone as a pretreatment before microfiltration to improve water quality.

Denver Zoo

Authors: Abigail Holmquist, P.E. (Honeywell); Damian Higham (Denver Water); and Steve Salg (Denver Zoo)

US-CO-Denver Zoo

Project Background

Denver Zoo is one of the most popular cultural institutions in Colorado and is widely recognized as one of the nation's premier zoos. Denver Zoo's mission to "secure a better world for animals through human understanding" embraces not only worldwide wildlife habitat preservation, but local conservation as well. One practical way Denver Zoo is achieving its goals is through water conservation efforts and use of recycled water.

Capacity and Type of Reuse Application

Through a partnership with Denver Water, Denver Zoo has successfully reduced its water consumption by 42 percent over the past decade. Added to this accomplishment is implementation of a recycled water system. Denver Zoo is unique in that it uses recycled water not only for irrigation, but for enclosure wash-down and animal swimming pools (**Figure 1**). Denver Zoo currently uses approximately 2 million gallons (7600 m^3) of recycled water annually. At build-out of its master plan, Denver Zoo hopes to expand recycled water use to 75 percent of its total water consumption, representing over 134 million gallons (609,000 m^3) of recycled water per year.

Figure 1
Predator Ridge Exhibit in Denver Zoo (Photo credit: Denver Zoo)

Water Quality Standards and Treatment Technology

The Colorado Department of Public Health and Environment regulates recycled water through Regulation 84, which sets forth treatment standards, allowable uses and water quality standards for different water categories. Category 3 water is produced by the reclamation plant and has an *E. coli* maximum of 25 percent detectable in any given month and 126 cfu/100ml in any sample. Turbidity results must not exceed 5 NTU in more than 5 percent of samples in a month and 3 NTU as a monthly average. Additional treatment targets for ammonia and phosphorous at Denver Water's recycling plant were developed in cooperation with industrial customers to ensure that recycled water quality would be suitable for needs. Typical recycled water quality parameters are shown in **Table 1**.

Institutional/Cultural Considerations

As the animals are one of the primary assets of Denver Zoo, it was paramount that their safety be top priority when considering recycled water uses and implementation strategies. Veterinarians examined the chemical composition of Denver Water's recycled water and determined which animals should be allowed to come into contact with or consume recycled water.

Public and worker education programs are also important to impart the value of recycled water use, as well as the hazards associated with its use. These messages are communicated to the public with signage at the main entrance to Denver Zoo and in use areas with public access (**Figure 2**). Workers undergo annual training provided by Denver Water and by Denver Zoo ensuring they work with recycled water in a manner that will protect the animals, the public and coworkers.

Table 1 Typical water quality parameters

Parameter	Units	Typical Range
Alkalinity, as CaCO3	mg/L	50-150
Ammonia as N	mg/L	0-0.4
Boron	mg/L	0.2-0.4
Calcium	mg/L	40-70
Chloride	mg/L	65-170
Chlorine, Total	mg/L	1.5-4.0
Iron	mg/L	0.05-0.6
Magnesium	mg/L	5-20
Manganese	mg/L	0.003-0.08
Nitrate + Nitrite as N	mg/L	5-30
Nitrate as N	mg/L	5-20
Nitrite as N	mg/L	0.01-0.05
Ortho Phosphorous, Dissolved as P	mg/L	0.04-0.3
pH	SU	6-8
Phosphorous, as P	mg/L	0.04-0.4
Potassium	mg/L	10-20
Sodium	mg/L	90-200
Specific Conductance	mg/L	360-1250
Sulfate	mg/L	80-250
Temperature	^{0}C	10-30
Total Coliform	MPN/ 100mL	<1.0
Total Kjeldahl Nitrogen	mg/L	0.2-2
Total Organic Carbon	mg/L	4-8

Figure 2
Public education signage (Photo credit: Denver Zoo)

"The addition of recycled water has resulted in significant opportunities for Denver Zoo. The ability to reuse our natural resources fits perfectly with Denver Zoo's core values of conservation. With close to 2 million visitors annually, we can help spread the message of recycled water to the community. Plus, the money we save by switching to recycled water enables us to allocate some of those funds toward animal management programs and other important conservation efforts."

—Steve Salg (Denver Zoo Project Manager)

Successes and Lessons Learned

Denver Zoo has saved $14,700 on water during the infancy of their program, and with water use expected to nearly quadruple during the next two years, that trend should continue. Recycled water use has also contributed to Denver Zoo being named the greenest zoo in the nation by the Association of Zoos and Aquariums.

While the use of recycled water is beneficial to the zoo and Denver Water, the conversion of a complicated system to recycled water can be challenging. Even when only licensed plumbers are working on the system, there is still room for error. In 2006, while conducting a cross-connection control audit, Denver Water discovered an uncontrolled cross-connection on the potable system. Fortunately, this connection was not feeding water used for consumption, so the risk to the public was minimal.

Denver Water

Authors: Abigail Holmquist, P.E. (Honeywell); Mary Stahl, P.E. (AECOM); and Steve Price, P.E. (Denver Water)

US-CO-Denver

Project Background

The population along the Front Range of Colorado is expected to increase significantly in the next few decades; recent statewide reports project the Denver-metro population to double by 2050, fueling the need for additional renewable water supplies. Water use in this region includes significant irrigation; Denver is in an arid region (less than 20 in [50 cm] of annual rainfall) with warm summers. Amenities such as parks, sports fields, and golf courses require irrigation. Denver Water has operated a reclaimed water system since 2004 and will expand its system over the next decade to help meet demands.

Water rights are critical considerations for reuse projects in Colorado because local water law follows a first-in-time, first-in-right allocation; this is also known as the "prior appropriation principle." It typically prohibits rainwater harvesting and graywater use. Because the majority of the population in Colorado lives on the east side of the state, and the majority of the water originates on the West Slope, many water providers have a long history of diverting water out of its river basin to supply water where the demand is located. Once water is diverted out of its basin, it can typically be reused "to extinction." Recycling water helps Denver Water fulfill the 1955 Blue River Decree, which gave Denver Water the ability to reuse water that had been diverted out of this basin on the West Slope.

Capacity and Type of Reuse Application

Many of Denver Water's users do not require high quality such as provided for cooling systems and irrigation. Thus, reclaimed water for these uses should match the right water quality for the right use. In 2004, Denver Water commissioned a 30 mgd (1,310 L/s) reclaimed water plant to supply water for non-potable uses. Current demand for reclaimed water varies between 5,000 and 6,000 acre-feet (6 to 7.5 million m^3) annually, depending on precipitation and weather conditions. Current uses include cooling water for a large electric utility; irrigation of parks, golf courses, and schools; and operations at the Denver Zoo.

The water recycling plant is expandable to 45 mgd with an ultimate goal for Denver Water to shift 17,500 ac-ft (21.5 MCM) per year of demand to the reclaimed water system. During the 2010 irrigation season, Denver Water served a total of 29 customers. A recently completed master plan identified over 300 additional customers that will need to connect to the system to reach the reuse goal of 17,500 ac-ft (21.5 MCM) per year.

Water Quality and Treatment Technology

The reclaimed water treatment plant uses biological activated filtration, alum coagulation/flocculation/sedimentation, single media filtration, chlorine-based disinfection. Denver Water produces reclaimed water that meets Category 3 standards of Colorado Department of Public Health and Environment Regulation 84 that must meet the following requirements:

- No detects of *E. coli* in at least 75 percent of samples in a calendar month, and less than 126 cfu/100 mL in a single sample
- Turbidity, NTU: Not to exceed 3 NTU as a monthly average and not to exceed 5 NTU in more than 5 percent of the individual samples during any calendar month

Since Denver Water has implemented a reclaimed water program, interpretation of the state regulations has changed directly impacting the ability of certain customers to use reclaimed water, and how Denver Water operates its system. These issues are currently being addressed through a statewide update to the regulations and on an individual customer basis. Additionally, Denver Water has conducted studies related to commercial, industrial, and landscape operations to identify options for current and future customers to successfully use reclaimed water at their facilities.

Project Funding and Management Practices

Denver Water has funded the reclaimed water system via revenues from water rates, system development charges, and bonds. Water rates for all customers include funding the reclaimed water treatment plant because it is considered a source of new water supply. This methodology results in reclaimed water rates that are economically attractive for customers compared to potable water rates. Water rates for different water service are shown in **Figure 1**.

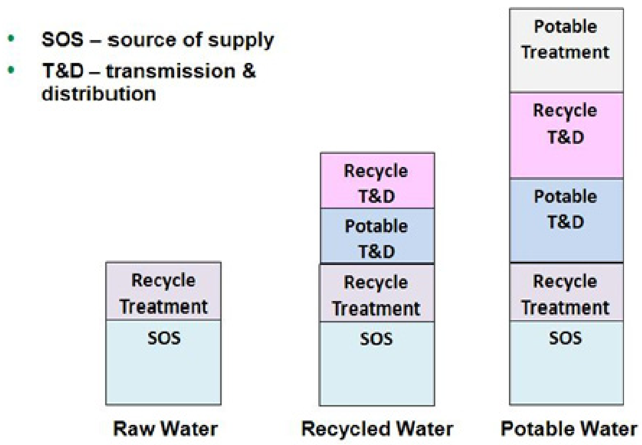

Figure 1
Water rates structure

Denver Water's rate structures include a monthly service charge and a volume rate structure that varies by customer class. The volumetric rate structures include uniform, seasonal, and inclining blocks. Rate structures (**Figure 2**) are applied to each class and are designed to encourage efficient water use.

Denver Water has developed policies to address different approaches to providing reclaimed water:

- Customer requests a conversion: Customer pays all conversion costs, including main extensions, service lines and point of service upgrades
- Denver Water requires a customer to convert: Denver Water pays all conversion costs, including main extensions and service lines, up to the first valve on the property
- New development in reclaimed water service area: Developer installs all infrastructures necessary for reclaimed water service

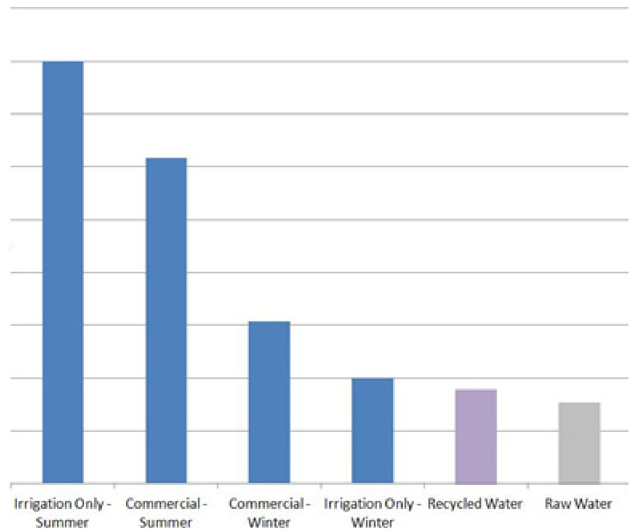

Figure 2
Relative water rates by class of service

Institutional and Cultural Considerations

Until the reclaimed water system began operating in 2004, Denver Water had only been responsible for operating raw and potable water systems. Thus, the water reclamation plant is staffed by drinking water operators and operations are strongly focused on maintaining internal water quality goals that are more stringent than those required by regulations and Denver Water has never violated reclaimed water quality criteria. CDPHE's Regulation 84 requires annual reports, training and inspections that require customers to employ best management practices and employee education. Denver Water personnel have an on-going relationship with reclaimed water customers that includes significantly more communication than is typical between a utility and its customers.

Successes and Lessons Learned

In general, the reclaimed water program received support when it was implemented. Denver Water has also implemented a youth education program that includes sixth grade curriculum covering the overall water cycle, including reuse. As part of this program, school children and teachers tour the reclaimed water facility each year. The program has achieved great success including the adoption of reuse at the Denver

Zoo and the electric company. Two Denver Water customers, the Denver Zoo and Common Ground Golf Course, have received awards from the WateReuse Association in recognition of their adoption of reclaimed water. In areas where reclaimed water service is available, some customers are now beginning to pay their own costs to connect to the reclaimed water due to long-term water savings and overall alignment with sustainability goals.

While the Denver Water reclaimed water program has been successful, there remain opportunities to address challenges that have the potential to impact the program. The reclaimed water system is a branched rather than a looped system, which creates challenges in providing water supply during planned/unplanned outages. Additionally, there is still limited infrastructure available for customers to connect to the system, prohibiting some customers from connecting as soon as desired. Customers are continuing to conserve water, which has resulted in reclaimed water being available to more customers than originally anticipated and these decreased customer consumption patterns are anticipated to result in a greater number of customer connections to the reclaimed water system being required to meet the overall recycling goal of 17,500 ac-ft (21.5 MCM) per year. Therefore, due to additional infrastructure needed to reach more customers, the overall system cost has increased compared to original estimates.

Xcel Energy's Cherokee Station

Authors: Abigail Holmquist, P.E. (Honeywell) and Damian Higham (Denver Water)

US-CO-Denver Energy

Project Background

Cherokee Station is one of Xcel Energy's largest Colorado power plants in terms of power production capability, **Figure 1**. Cherokee Station is located just north of downtown Denver, and can produce 717 MW of power. Cherokee is a coal-fired, steam-electric generating station with four operating units. The fuel source for the plant is low-sulfur coal supplied by several mines in western Colorado. The plant is also capable of burning natural gas as fuel. Cherokee uses 5,000 to 9,000 ac-ft/yr (393 MCM/yr) of water for cooling tower feed. Historically, all cooling tower water originated from nearby rivers that provided raw water to the plant.

Capacity and Type of Reuse Application

The Denver Water Recycling Plant is located about a half mile away from Cherokee and can produce 30 mgd (1310 L/s) of reclaimed water. As a conservation effort, Xcel Energy has taken steps to reduce fresh water consumption at the power plant. As part of this effort, Cherokee began using reclaimed water in 2004 and is now the largest customer of reclaimed water from the Denver Water Recycling Plan, using up to 5,200 ac-ft/yr (227 MCM/yr) of reclaimed water.

Today, Cherokee utilizes multiple sources of water to provide a diverse, reliable and affordable source water portfolio. Raw water is the least expensive option, and is used as the primary source. Cherokee combines raw water with reclaimed water in a large reservoir before feeding the cooling towers. This blend of raw and reclaimed water is also used on site for ash silo wash down and fire protection. The recirculating water system for the cooling towers typically runs four to five cycles and uses bleach as a biocide. When the conductivity of the cooling water necessitates blowdown, the cooling tower wastewater is treated with lime and ferric chloride to meet permit requirements for metals and other constituents before it is discharged into the South Platte River.

Figure 1
Cherokee Station (Photo credit: Xcel Energy)

Water Quality Standards and Treatment Technology

The Denver Water Recycling Plant purifies secondary effluent using a biological aerated filter to nitrify high source water ammonia which can cause brass fittings, common in industrial plants, to become brittle over time. This process is followed by conventional drinking water treatment to remove high phosphorus and turbidity. Unit processes in this treatment train include coagulation, flocculation, sedimentation, filtration and disinfection.

The Colorado Department of Public Health and Environment regulates reclaimed water through Regulation 84, which sets forth treatment standards and allowable uses for different reuse categories. Category 3 water is produced by the plant and has a limit for *E. coli* that includes less than 25 percent detects in any month, with a maximum of 126 cfu/100mL in a single sample.

Turbidity must not exceed 5 NTU in more than 5 percent of samples in a month and 3 NTU as a monthly average. Additional treatment targets for ammonia and phosphorous at the recycling plant were developed, in cooperation with Xcel Energy to ensure that reclaimed water quality would be suitable for cooling tower feed. Typical reclaimed water quality parameters are shown in **Table 1**.

Table 1 Water quality parameters

Parameter	Units	Typical Range
Alkalinity, Total as CaCO3	mg/L	50-150
Ammonia as N	mg/L	0-0.4
Boron	mg/L	0.2-0.4
Calcium	mg/L	40-70
Chloride	mg/L	65-170
Chlorine, Total	mg/L	1.5-4.0
Iron	mg/L	0.05-0.6
Magnesium	mg/L	5-20
Manganese	mg/L	0.003-0.08
Nitrate + Nitrite as N	mg/L	5-30
Nitrate as N	mg/L	5-20
Nitrite as N	mg/L	0.01-0.05
Ortho Phosphorous, Dissolved as P	mg/L	0.04-0.3
pH	SU	6-8
Phosphorous, Total as P	mg/L	0.04-0.4
Potassium	mg/L	10-20
Sodium	mg/L	90-200
Specific Conductance	mg/L	360-1250
Sulfate	mg/L	80-250
Temperature	^{0}C	10-30
Total coliform	MPN/ 100mL	<1.0
Total Kjeldahl Nitrogen	mg/L	0.2-2
Total Organic Carbon	mg/L	4-8

Project Funding

In order to receive reclaimed water service, Xcel Energy paid a system development charge (tap fee) to Denver Water and for construction of transmission facilities dedicated to their service. Costs were funded as capital improvements through Xcel Energy's annual capital budget. Cherokee pays $1.05/1,000 gallons ($0.28/m^3) of reclaimed water and a $5.58 monthly service charge. The rate increases to $1.11/1,000 gallons ($0.29/m^3) in 2012.

Successes and Lessons Learned

Cherokee has not encountered any problems using reclaimed water in the cooling water system or other plant processes, including fire protection and ash silo washdown. The major benefit of reclaimed water to Cherokee is the availability of a new water source and an overall increase of water supply. This is very important in dry or drought years when raw water sources may be less readily available or water rights priorities come into play.

There were factors that played larger roles than anticipated after initial program implementation. One was the effect that raw water pricing had on reclaimed water demand; a minimum use of reclaimed water was incorporated into the initial contract to provide the necessary demand to justify construction of the WRF. The expectation was that usage would grow with time; however, usage instead remained stagnant at the contract minimum due to the price of raw water making it the preferred water source. Another factor was accounting for possible changes in fuel sources when forecasting future reclaimed water demand. Natural gas power generation is less water-intensive than coal, reducing demand from on the plant; this was not anticipated in preliminary use projections.

Other emerging factors included possible effects of peripheral ground water regulations on the legality of impoundments, which were thought to be covered only by reclaimed water regulations. Recently, however groundwater discharge permitting has been discussed which would have significant repercussions, such as lining an impoundment or obtaining a ground water discharge permit. Another emerging factor is the impact of reclaimed water quality on Cherokee meeting effluent limits of its industrial discharge permit; changes to discharge parameter limits may necessitate modification of the current treatment process to meet potentially more stringent discharge limits due to reclaimed water use.

Effects of Recycled Water on Soil Chemistry

Authors: Abigail Holmquist, P.E. (Honeywell) and Damian Higham (Denver Water)

US-CO-Denver Soil

Project Background

In 2004, Denver Water began providing recycled water to customers in the greater Denver metro area. Nearly all of the original and current recycled water customers are landscape irrigators who had historically used potable water or raw water for irrigation. In an effort to provide information regarding effective recycled water use, Denver Water implemented a soil monitoring program designed to study soil characteristics of landscape irrigation sites before commencing irrigation with recycled water, and after 5 years of irrigation with recycled water. The results are provided as a resource for landscape managers irrigating with recycled water to help identify options for management strategies to ensure healthy landscapes.

Recycled Water Treatment and Quality

The Denver Water Recycling Plant utilizes a biological aerated filter to nitrify high source water ammonia. The biological process is followed by conventional drinking water treatment to remove high phosphorus and turbidity. Unit processes in the treatment train include coagulation, flocculation, sedimentation, filtration and disinfection. The plant is capable of producing up to 30 mgd (1300 L/s) and was constructed to allow build-out of 45 mgd (1970 L/s). The plant produces water, designated as "Category 3" as defined by the Colorado Department of Public Health and Environment (CDPHE), which must meet the following limits:

- *E. coli* - 126 cfu/100mL maximum and non-detect in at least 75 percent of samples
- Turbidity – 3 NTU or less as a monthly average and 5 NTU or less in 95 percent of samples.

While *E. coli* and turbidity are the only additional requirements CDPHE requires providers to meet through the recycled water regulations, nitrate is of concern whenever there is a potential discharge to surface or groundwater, making permitting necessary for most dewatering and unlined storage activities. Typical characteristics of recycled water are shown in **Table 1**.

Table 1 Typical reclaimed water quality

Water Quality Parameter	Value
Electrical Conductivity ECw (dS/m)	0.89
Total Dissolved Solids TDS (mg/L)	570
pH	6.92
Sodium Adsorption Ratio, adjusted (SAR_{adj})	3.7
Sodium - Na (mg/L)	130
Chloride - Cl (mg/L)	99.3
Boron - B (mg/L)	0.28
Bicarbonate - HCO3 (mg/L)	66
Nitrate - NO3-N (mg/L)	14.1

The nitrogen in Denver Water's recycled water allows irrigators, who make up 35 percent of the demand on the system, to cut back significantly on fertilization. This water also has higher concentrations of salts, primarily sodium and chloride, than potable water, and thus requires different management approaches to ensure soil and plant health.

Soil Sampling and Testing

In the fall of 2004, samples were taken from 10 sites including golf courses, parks and school grounds. At least three soil borings were collected from each site up to 40 in (100 cm) in depth. The cores were split into sub-samples representing 8-in (20-cm) strata and composited for each stratum at each sample site. The sampling protocol was repeated in the fall of 2009 at the same sites with samples being collected one foot from previous locations. Soil compaction and irrigation uniformity were also evaluated during both sampling events.

Testing was performed at the Colorado State University Soil, Water & Plant Testing Laboratory. Soil samples were evaluated for texture and dried, ground and screened prior to further testing. Boron, calcium, cation exchange capacity (CEC), chloride, copper, electrical conductivity, exchangeable sodium, iron, magnesium, manganese, nitrate, organic matter, pH, phosphorous, potassium, sodium and zinc were measured using standard methods. These results were used to calculate sodium absorption ratio (SAR), salinity and exchangeable sodium percentage (ESP).

Results

Results suggested that sodium and sodium-related parameters are of the greatest concern for soil health, with average ESP and SAR values approximately doubling over the five-year period.

Nitrate concentrations in soil irrigated with potable and recycled water was studied in 2009 as a function of soil depth (**Figure 1**). Nitrate content decreased significantly with soil depth, indicating that nitrate contamination of groundwater should not be of great concern when using recycled water for the irrigation of turf systems. This data demonstrates that dense, well-managed, and active-growing turf grasses serve as bio-filtration systems for removal of excess nitrate.

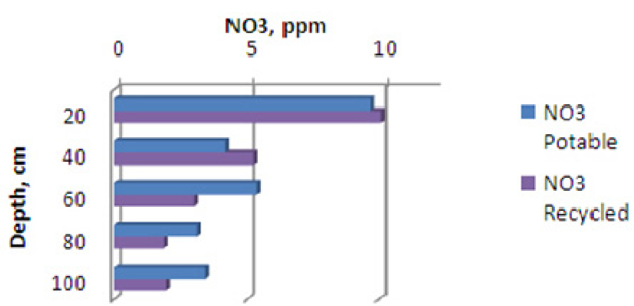

Figure 1
Soil nitrate profile

While reclaimed water quality affects landscapes, other factors, such as soil compaction, irrigation uniformity and precipitation can affect how water quality impacts landscape health and how that health is quantified. For example penetrometer readings of greater than 300 psi (2,070 kPa) indicate potential problems for plant growth due to soil compaction and this reading was exceeded in at least one subsample location, at four of ten study sites.

Irrigation uniformity (IU) is the measure of the consistency of water application. A poor IU can result in one area of landscape receiving too much water and another area receiving too little. All sites, except two, had a good to excellent irrigation uniformity. No clear relationship between irrigation distribution uniformity and measured soil parameters was observed.

Lessons Learned: Management Options for Recycled Water Providers

Recycled water can be a good source of irrigation water, depending on its quality, the type of soil, type of plants and the management practices employed. Denver Water's recycled water is well-suited for most landscapes in the surrounding area. Some tree species and soil types, however, can be sensitive to elevated sodium and other constituents and may require proper management to avoid damaging effects.

Because conditions vary by location, each recycled water provider must evaluate its system and the needs of potential customers to identify the most appropriate recycled water management strategy. Wherever recycled water is used for irrigation, regular monitoring of water and soil quality is recommended. Based on this research and the findings of others, the following best management practices can help to mitigate potential negative effects of irrigating with recycled water:

- Flushing: While consistent over-irrigation is not recommended, periodic over-watering or flushing may facilitate the movement of salts out of the root zone. This may also occur with heavy rainfall.

- Aeration: Aeration is the practice of removing small plugs of soil from the root zone and randomly discarding them on the turf surface. Aeration improves the movement of water through the soil, reduces soil compaction, and decreases thatch buildup thus minimizing potential for ponding and salt buildup in the root zone.

- Rotor head replacement: Using low-trajectory heads to avoid excessive spray on tree foliage can reduce harmful effects.

- Sodium replacement amendments: Gypsum ($CaSO_4$), calcium chloride ($CaCl_2$), or utilization of "sulfur burners" or sodium blockers have shown promise in limiting effects of sodium by displacing sodium bound to soil, thereby helping to leach sodium to deeper depths.

- Humates: Humates and humic acid are organic materials derived from decaying plant material. These substances are claimed to buffer salts, augment micronutrient availability to plants, promote soil aeration and water penetration, and encourage flocculation of soil particles.

- Vesicular-arbuscular mycorrhizal (VAM) inoculation: In some studies, recycled water irrigation has been found to deplete arbuscular mycorrhizae, which help plants to capture nutrients from the soil, though the mechanism for the depletion is unclear. This affect may be a significant constraint on landscape plant performance under saline conditions. Innoculation with VAM has been shown to be beneficial in some studies, especially when mycorrhizae are not well-establish in the soil.

- In cases where the potential for cross connections can be minimized or eliminated, blending recycled water with potable or raw water for irrigation or rotating between different water sources can help minimize sodicity issues.

- More intensive cultivation programs (deep aeration and water injection) to maintain oxygen diffusion and water movement, improved drainage systems and more vigorous traffic control programs, to avoid overuse of turf areas, can help alleviate compaction problems and promote drainage.

- Recycled water can provide nutrients, potentially fully or partially offsetting the need for chemical fertilizer. To avoid nutrient imbalances, analyses should be conducted to account for the nitrogen and phosphorous fertilizer value present in recycled water compared to soil nutrient content and crop requirements. Maintaining healthy plants that can withstand environmental stresses better and replacing susceptible plants with adapted, salt tolerant species and cultivars will alleviate most problems that cannot be solved with other corrective measures presented in this study.

As reuse becomes more prevalent, additional information will be collected to ensure proper use of this valuable resource. Denver Water will continue to monitor both new and existing sites to build an understanding of how sites evolve with recycled water use in the future.

Institutional and Cultural Considerations

Introducing recycled water as a source of irrigation water supply has necessitated significant outreach to the public, in general, and especially in areas supplied with recycled water. The source of recycled water and relative infancy of regulatory programs led to apprehension on the part of irrigators and the public as to health effects of recycled water use for the landscapes irrigated and the public enjoying them.

Panel discussions including industry experts, irrigators and the public were held at the start of this process to gauge concerns and how best to address them. Denver Water attended events parks and schools using recycled water to provide an opportunity to inform and address questions and concerns of local residents. Users were afforded the opportunity to attend forum discussions to voice concerns and find solutions to problems arising from recycled water use. Users were also required to attend an informational training session triennially to inform personnel about hazards associated with handling recycled water use and how to mitigate those hazards.

Some concerns surrounding recycled water use emerged within Denver Water as well. The cost of treating recycled water was higher than that of potable water and a holistic approach involving costs of new sources of supply and drought preparedness needed to be conveyed effectively in order to overcome those internal concerns. Additionally, supplanting potable use with recycled use shifted demands and led to some potable systems already in place becoming over-sized resulting in additional management and operational considerations.

References

Yaling Qian, 2009. *Soil Testing Five Years after Irrigation with Recycled Water*.

Sand Creek Reuse Facility Reuse Master Plan

Authors: Bobby Anastasov, MBA and Richard Leger, CWP (City of Aurora)

US-CO-Sand Creek

Project Background

The city of Aurora, Colo., developed a Reuse Water System Master Plan Update with short-range and long-range plans to improve and expand its reuse water system. A previous study (2003) explored options for maximizing reuse by building a large reclaimed water reservoir in the eastern plains or constructing new treatment facilities. The goal of this update was to explore other options for optimization of the reuse system, including expansion of the Sand Creek Water Reuse Facility (WRF), addition of operational storage system, and eventual inclusion of annual storage for reuse water. The study included the following:

1. Evaluation of sources and availability of reclaimed water
2. Evaluation of existing and future demands
3. Evaluation of potential reuse storage sites for local, operational and annual storage
4. Development of a hydraulic model of the existing reuse water system and scenarios for phased expansion of the system
5. Development of a capital improvements plan (CIP) for the Sand Creek WRF service area
6. Evaluation of Prairie Waters as a potential raw water irrigation source
7. Cost evaluation of reuse water produced at the Sand Creek WRF versus raw water from the Prairie Waters, a drinking water project utilizing Aurora's water rights to extract water through riverbank filtration along the South Platte River for drinking water supply

Two water sources were identified for non-potable irrigation sources: reuse water from the Sand Creek WRF and raw water from the Prairie Waters (PW) pipeline. The Sand Creek WRF is capable of providing 5.0 mgd (219 L/s) as currently operated, with potential to expand to 6.5 or 7.3 mgd (285 or 320 L/s). Raw water from PW will be available at an initial capacity of 12 mgd (526 L/s) in 2011, with an ultimate capacity of 50 mgd (2190 L/s).

A comprehensive list of demands was developed as part of the study including: parks, golf courses, schools, greenbelts, medians, cemeteries, residential developments, office parks and industrial users. More than 200 separate demand locations were identified throughout Aurora. Generally, demands within the existing system and surrounding the Tollgate Creek corridor were considered to be served from the Sand Creek WRF. Demands east of E-470 and north of I-70 were to be served from the PW pipeline. Demands located within the Cherry Creek Basin will not be served by either source due to nutrient loading (phosphorus) restrictions.

Capacity and Type of Reuse Application

Existing customers are provided reuse water from the Sand Creek WRF. The facility uses a biological nutrient removal (BNR) activated sludge process followed by tertiary filtration and UV disinfection to produce 5 mgd (219 L/s) of reclaimed water. In-plant waste flow generated at the facility is returned to the Metro Wastewater Reclamation District's (MWRD) interceptors for further treatment at the MWRD's Central Plant. Reuse water is pumped from the Sand Creek WRF into the reuse water system.

Currently, the Sand Creek WRF only utilizes approximately 26 percent of its available annual volume for distribution to reuse customers, largely due to a lack of storage within the system, requiring the Sand Creek WRF to provide each demand location with peak day flows. Addition of operational or annual storage within the system would allow for a greater percentage of total annual volume to be reused. More than 30 storage sites were evaluated ranging from 0.3 to 1,140 million gallons (1135 m^3 to 4.3 MCM) of reuse water storage. Storage sites are located throughout the city and many of the sites for operational storage are located within the limits of the existing reuse water system. Sites for annual storage are generally located at the eastern boundary of the city.

One of the primary goals of the study was to optimize the reuse water system by making use of the portion of reuse volume from the Sand Creek WRF that is currently being discharged to Sand Creek. A plan for optimizing the system was developed which uses a combination of pipeline, pump station and storage facility improvements to increase the irrigated acreage of the reuse water system. A schedule of major recommended improvements has been incorporated into a capital improvements plan (CIP) to provide a framework for design, construction, operation and financing of the improvements required to optimize the reuse water system (**Table 1**). Each phase is a step toward the ultimate goal of extending reuse water down the Tollgate Creek corridor to provide reuse water to the central and southern portions of Aurora.

Project Funding and Management Practices

The CIP outlining expansion of the reuse water system through 2025 phases improvements to limit rates to approximately 75 percent of anticipated commercial potable water rates and 66 percent of anticipated potable irrigation rates.

The costs of using treated water from the Sand Creek WRF versus using raw water from the PW system were compared for the existing and future irrigation water demands of the city's reuse system. The following costs were included in the comparison:

- Water loss in the South Platte River (7 percent)
- Capital improvements for the Sand Creek WRF and PW connection
- Sand Creek WRF operation and maintenance (O&M) costs
- MWRD O&M costs for additional wastewater treatment with the Sand Creek WRF offline
- Transmission and distribution (T&D) O&M costs and T&D capital improvements
- Debt service for the Sand Creek WRF
- Debt service for the existing T&D system and PW T&D

Successes and Lessons Learned

Without a master plan the city of Aurora would have no comprehensive document guiding its long term vision of the reuse water system. The plans should be revisited on a regularly to ensure they still reflect the vision of the city.

Table 1 Summary of recommended improvements

Phase and Year	Pipeline Improvements	Pumping Improvements	Storage Improvements	Additional Irrigated Acres	Total Construction Cost[1,2]
Phase 1 2010	▪ Coal Creek Area/Rio Grande Pit Connection Sand Creek Park Connection ▪ Signature Park Connection	SCWRF Pump Station Expansion (6.5 mgd)	▪ Aurora Hills GC Pond Expansion (1.2 MG) ▪ Rio Grande GC Pond Expansion (2.0 MG) ▪ Sand Creek Park Pond (0.4MG) ▪ Signature Park Pond (2.7MG) ▪ Spring Hill GC Pond Expansion (1.1MG)	197	$11.4 M
Phase 2 2015	n/a	n/a	▪ Fitzsimons GC Pond Expansion (1.6 MG) ▪ Murphy Creek GC Pond Expansion (1.4 MG) ▪ Sand Creek pond Expansion (2.0 MG) ▪ SCWRF Operational Storage (2.0 MG)	306	$16.1 M
Phase 3 2020	▪ Delaney Farm Pump Station ▪ Main Iliff Pump Station ▪ Main Iliff Service Main ▪ Wheel Park Connection	▪ Delaney Farm Pump Station (6.5 mgd) ▪ Iliff Pump Station (2.2 mgd)	▪ Delaney Farms Operational Storage (5.0 MG) ▪ Wheel Park Pond (2.5 MG)	364	$39.5 M
Phase 4A 2025	▪ Heather Gardens GC Connection ▪ Heather Ridge GC Connection	n/a	▪ Heather Gardens GC Pond (1.6 MG) ▪ Heather Ridge GC Pond (4.1MG)	486	$82.8 M
Phase 4B 2025	▪ Aurora Dog Park Connection ▪ Aurora Hills Interconnect ▪ Buckley Air Force Base Connection ▪ Expo Park Connection ▪ Quincy Reservoir Main Rocky Ridge Park Connection ▪ Summer Valley Park Connection	n/a	▪ Aurora Dog Park Pond (3.7 MG) ▪ Buckley Air Force Base Pond (4.3 MG) ▪ Expo Park Pond (6.4 MG) ▪ Heather Ridge GC Pond Expansion (0.7 MG) ▪ Quincy Reservoir (380 MG) ▪ Rocky Ridge Park Pond (2.3 MG) ▪ Summer Valley Park Pond (4.7 MG) ▪ Wheel Park Pond Expansion (2.1 MG)	1416	$97.6 M

[1] Construction costs are in 2008 dollars
[2] Construction costs for each phase include costs for previous phases

Water Reuse Barriers in Colorado

Author: Cody Charnas (CDM Smith)

US-CO-Water Rights

Background of Colorado Water Law

Due to water laws in Colorado, water reuse has many barriers that limit its implementation. Due to the limited amount of precipitation in Colorado, it is a precious resource that is essential for its residents. All the rain and moisture that falls within the state of Colorado is property of the state. The allocation of water is governed by "prior appropriation," which is also commonly referred to as "first in time, first in right."

Residents of Colorado can use the water for beneficial use if they own the water rights. This process of obtaining a water right is known as adjudication. With a water right, a resident owns the right to use the water, but they don't own the water. In addition, water that is not consumed for beneficial use must be returned to the river or stream by surface run-off or through subsurface infiltration. These returned flows are used by junior appropriators downstream.

As the population continues to increase in Colorado, the demand for water is also increasing. Other states with limited water supplies, such as Arizona and California, reuse water to supplement the limited resource. As a result of water laws in Colorado, water reuse and use of alternative water supplies is often not allowed. For example, rainwater harvesting and graywater use are prohibited.

Reuse in Colorado

In general, Colorado water law allows for one use of the water by the original appropriator. However, any water that is brought in to a watershed that is not connected to its original source is considered foreign water. Water that is considered foreign can be reused by its owner as it will never enter back into its source watershed. For example, water that is diverted from the West Slope to the east side of the Continental Divide is considered foreign as it will never flow back to the west side of the Continental Divide. Waters that are also considered foreign include nontributary groundwater introduced into a surface stream as well as water imported from an unconnected stream system ("transmountain water").

Once the importer brings foreign water from an unconnected source the owner can reuse the water to extinction as it is considered "fully consumable." However, the owner must maintain dominion and control over the water. "Dominion and control in this context refers to the intent to recapture or reuse such water, and is not lost when a municipal provider delivers water to a customer's tap or when consumers use such water to irrigate lawns" (CWCB, 2010).

In addition to being able to reuse water classified as foreign, agricultural water rights that are transferred to municipal use are considered fully consumable and can be used to extinction. The reason for this is "because the applicant in a change of use proceeding may take credit for, and reuse, the historical consumptive use (CU) associated with the prior decreed use" (CWCB, 2010). The water attributable to the historical CU of the senior water right may be reused to extinction.

Two larger utilities in Colorado that are currently reusing water include Denver Water and Colorado Springs Utilities. The reclaimed water is used for irrigating parks, golf courses and schools, cooling at power generating plants, and the Denver Zoo.

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Smart Water Management at Sidwell Friends School

Authors: Laura Hansplant, RLA, ASLA, LEED AP (Andropogon Associates [formerly] and Roofmeadow) and Danielle Pieranunzi, LEED AP BD+C (Sustainable Sites Initiative)

US-DC-Sidwell Friends

Project Background or Rationale

Sidwell Friends School (SFS) in Washington, DC, incorporated a constructed wetland into its Middle School building renovation. This water reuse system is part of an overall transformation of a 50-year-old facility into an exterior and interior teaching landscape that seeks to foster an ethic of social and environmental responsibility in each student. With a focus on smart water management, a central courtyard was developed with a rain garden, pond, and constructed wetland that utilizes storm and wastewater for both ecological and educational purposes. More than 50 plant species, all native to the Chesapeake Bay region, were included in the landscape and there was extensive use of reclaimed stone for steps and walls. Concrete containing recycled slag is used for walkways and reclaimed wood was used for the decking surfaces. Completed in 2007, the Middle School project was the first K-12 school to achieve a Leadership in Energy and Environmental Design (LEED) Platinum rating from the U.S. Green Building Council.

Capacity and Type of Reuse Application

The SFS facilities sit on a 15-acre campus in northwest Washington, D.C. The environmentally responsible stormwater and wastewater management systems are prominent in the landscape in order to promote education and to build awareness. The centerpiece of the new Middle School is a natural wastewater treatment and reuse system that produces high-quality water suitable for non-potable uses. A constructed wetland forms the heart of this system. It uses biological processes to clean water and serves as a living laboratory where students can learn about biology, ecology, and chemistry (**Figures 1 and 2)**.

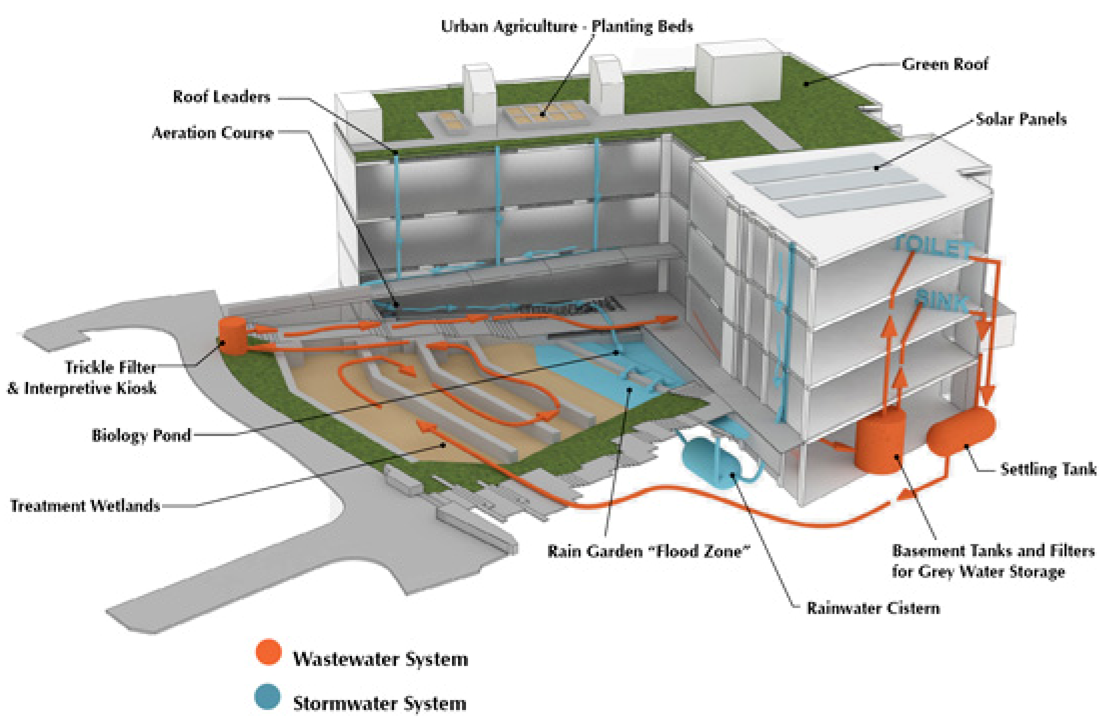

Figure 1
Natural wastewater treatment and reuse system (Image: Courtesy of Andropogon Associates)

Figure 2
View of new building extension (Photo: Courtesy of Andropogon Associates)

Wastewater is processed through the courtyard systems for approximately 3 to 5 days before entering a storage tank in the basement. From there it passes through 10 and 100 micron filters and is UV disinfected before being fed back into toilets and urinals in the building through a parallel set of pipes designated for recycled water. The project cost approximately $4 million (for site-related work) and was funded by the school.

Water Quality and Treatment Technology

Wastewater from the Middle School building is processed in a multi-step system that incorporates a variety of ecologies to provide robust, diverse treatment. System components include a passive primary treatment tank, followed by a series of terraced subsurface-flow constructed wetland cells, a recirculating sand filter, and trickling filter, which are all tightly integrated into the courtyard's landscape. The choice of subsurface-flow, as opposed to surface-flow, reduces or eliminates odor and prevents contact with the water. A variety of native and local wetlands plants provide an aesthetically pleasing landscape while their roots host a wide diversity of microorganisms that help break down contaminants from the water. The trickling filter and sand filter provide further polishing and reduction of nutrients such as nitrogen.

SFS engaged Lucid Design Group to monitor water quality within the constructed wetland system, and to display the data on a website for classroom use. The District of Columbia requires both regular water quality monitoring of the waste water system and periodic groundwater monitoring, to confirm that the system is functioning as planned.

The Middle School's stormwater system is a combination of vegetated roofs, swales, rain gardens, and a pond that double as outdoor classroom space. All the building roof runoff is conveyed to the pond via downspouts and an aqueduct along the access ramp that provides handicap access to the building. During large storm events, the pond overflows into the rain garden for biofiltration and infiltration, mimicking the functions of a natural floodplain. The rain garden is planted with native wet meadow species. The vegetated roof provides habitat for pollinators and also reduces runoff volumes. To address improving runoff water quality, the overland flow of runoff from paved areas is routed through a storm filter to remove suspended solids and excess nutrients. Excess water from the lawn also flows to the courtyard's pond. Some of the roof runoff is stored in an underground cistern, which provides additional water for the pond during dry weather. No permanent irrigation system was installed. None of the stormwater is combined with treated wastewater for non-potable use in buildings.

Institutional/Cultural Considerations

The water reuse installation is used in the school curriculum (**Figure 3**). SFS students monitor the building functions and constantly measure the "health" of the facility. Teachers of every grade level have access to the building's exposed systems for the study of flora and fauna, rainforests, human cellular structure, and environmental science, as well as many aspects of the mechanical, electrical, structural, and plumbing systems. For their Environmental Science class, 8th Grade students participate in labs in which they measure and compare nitrogen and phosphorus levels in various levels of the wetland and in the basement reuse holding tank, and learn the valuable role that wetlands play in purifying water. The Advanced Placement Environmental Science students conduct labs including comparing water quality in the on-campus biology pond to water in a nearby tributary, studying the invertebrate biodiversity in the soil on the green roof, and comparing stormwater runoff from the green roof with runoff from the conventional roof. Students and others at SFS are also encouraged to record wildlife sightings such as a Snowy Owl or Monarch Butterflies through the school's website. The biodiversity in the woods, wetlands, and native vegetation provide real-life lessons for the science classes. On the green roof, students also learn how to grow vegetables and herbs that are used in the school's cafeteria.

Figure 3
View of rain garden and pond (Photo: Courtesy of Andropogon Associates)

The Center for Sustainable Environmental Design, a collaborative effort between the Yale School of Forestry and Environmental Studies and the Yale School of Architecture, is conducting research to connect environmental science and management with architectural design and engineering. At SFS, a research team is studying the school to determine if the project's green strategies have a measurable effect on student and faculty performance and health. While the school was still using the older building, extensive questionnaires were administered to students, teachers, and staff. Numerous questions probed their awareness of the building, satisfaction, and environmental sensitivity. The response to these questionnaires will act as the baseline for the study. Additional surveys will continue to be conducted. This data will provide the first analytical examination of the effect of biophilic design on occupant satisfaction and performance.

Successes and Lessons Learned

When site systems become highly integrated, they achieve both efficiency and interdependence. For example, the green roof provides efficiency for both the stormwater system and the building HVAC systems; this efficiency also means that the stormwater system and the HVAC system also became dependent on the green roof for their efficient sizing. Consequently in integrated designs of this type, changes to project scope, whether for budgetary or philosophical reasons, need to be considered holistically. Projects of this complex nature are difficult to implement with a standard project delivery system. A very close partnership between the design team, the client, and the construction team is needed in order to help the contractors effectively organize and build these new, sustainable, site systems.

South District Water Reclamation Plant

Authors: R. Bruce Chalmers, P.E. (CDM Smith) and
James Ferguson (Miami Dade Water and Sewer Department)

US-FL-Miami So District Plant

Project Background or Rationale

The Miami Dade Water and Sewer Department (MDWASD) is the largest water and sewer utility in Florida, serving more than 2.2 million residents. It has three major water treatment plants, providing approximately 90 percent of the county's public water supply. Rapid population growth, drought, and environmental efforts to restore the Everglades created pressure for increased groundwater extraction to meet the additional demands. At the same time, the South Florida Water Management District (SFWMD) prohibited additional withdrawals from the Biscayne aquifer, which required MDWASD to develop new alternative water sources.

MDWASD agreed to implement a series of projects to meet the increasing demand, including aquifer storage and recovery (ASR), Floridan aquifer blending, Floridan aquifer brackish water treatment, and the South District Water Reclamation Plant (SDWRP) for indirect potable reuse. The SDWRP will help the county meet future water demands while protecting environmental resources.

Capacity and Type of Reuse Application

SDWRP will treat South District Wastewater Treatment Plant (SDWWTP) tertiary effluent to potable water quality. The capacity of the SDWRP will be 21 mgd (920 L/s) of advanced water treatment. Product water from the SDWRP will be recharged approximately 6 miles (9.6 km) away, at the Miami-Dade Metro Zoo. Recharged water will be injected into the Biscayne aquifer, the county's main drinking water source, upgradient of a county water supply wellfield. There will be seven groundwater injection wells with a total hydraulic mound of less than 1 foot. The recharged water will offset an average annual flow of 18.6 mgd (815 L/s) at the new South Miami Heights potable water treatment plant (SMHWTP). The SDWRP project facilities are shown in **Figure 1**. The SDWRP is required to be online by the end of 2014.

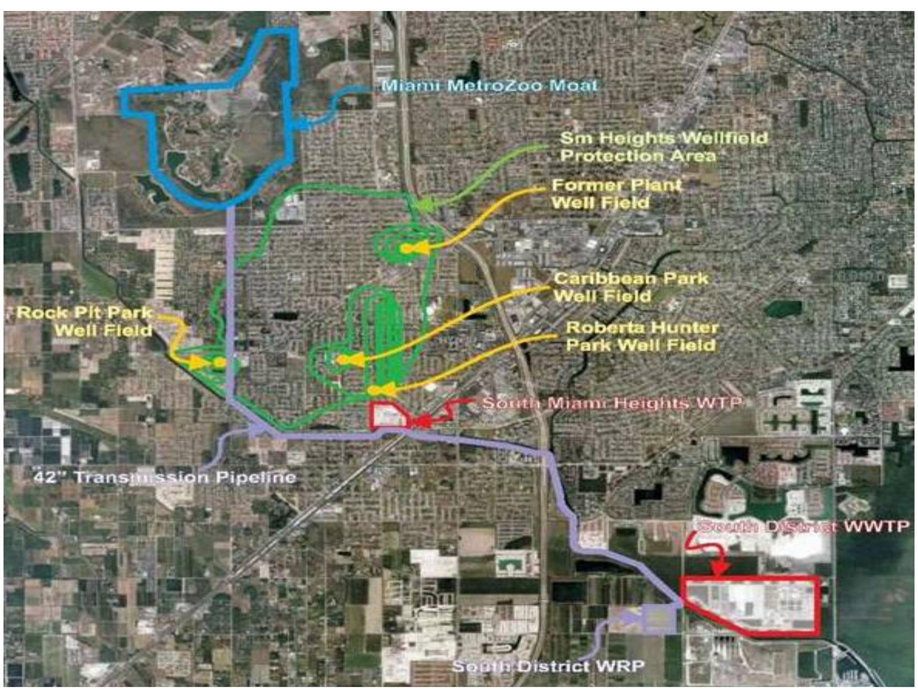

Figure 1
SDWRP facilities (Photo credit: CDM Smith 2008)

Water Quality Standards and Treatment Technology

The Florida Department of Environmental Protection is the state agency that has jurisdiction over implementation of reclamation treatment plants, specifically Part V of the Florida Administrative Code, Section 62-610 that regulates the detailed requirements applicable for the SDWRP. Part V also regulates applications for recharge facilities, including injection wells. Significant SDWRP water quality requirements are shown in **Table 1**.

Table 1 SDWRP water quality requirements

Parameter	FDEP Part V (mg/L)	DERM WQ Standards (mg/L)	DERM CTLs (mg/L)
TOC	3	N.R.	N.R.
TDS	500	500	
Total Nitrogen	10	N.R.	N.R.
Ammonia	N.R.	0.5	2.8
Phosphorus (μg/L)	N.R.	N.R. (< 10 proposed)	N.R.
NDMA (ng/L)	N.R.	N.R.	<2

A local county agency, the Department of Environment Resources Management (DERM) also has water quality standards (WQSs) that govern discharges and groundwater clean-up target levels, which are implemented for groundwater clean-up activities. Using the county's non-degradation policy, DERM also required very low effluent concentrations for phosphorus, NDMA, and other limits not specifically included in the WQSs. DERM requirements are also shown in **Table 1**.

Figure 2 shows the SDWRP process flow diagram. The SDWRP will have technologies successfully proven at Orange County Water District's (OCWD) Groundwater Replenishment System in Fountain Valley, California, including membrane filtration (MF), reverse osmosis (RO), and ultraviolet light with hydrogen peroxide (UV-AOP). Ion exchange will be added after the RO to meet the required ammonia limit. Major design criteria are shown in **Table 2**. MF backwash will be returned to the SDWWTP for treatment. RO brine will be discharged to a deep well for disposal.

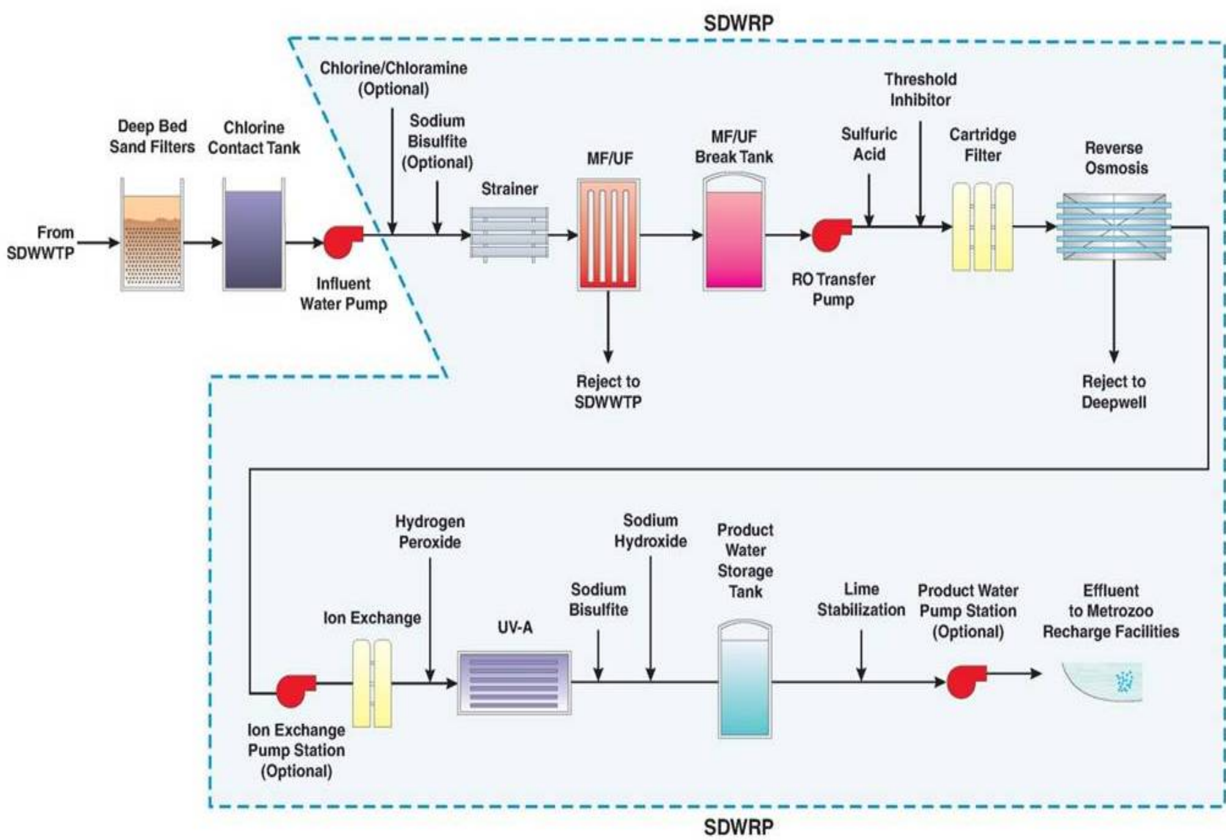

Figure 2
SDWRP process flow diagram (Photo credit: CDM Smith/Hazen and Sawyer 2008)

Table 2 Major system design information

System	Number of Trains	Train Capacity (mgd)	Comments
MF	13+1	1.9 (1.76)	94% Recovery
RO	4+1	5.25	3-stage, 12 gfd 85% Recovery
IX	12+2	1.75 (1.5)	Regeneration
UV-AOP	4+1	5.25 (4.2)	97% UVT

Project Funding and Management Practices

The SDWRP will have a total project cost of $357 million and will be funded by Miami Dade County bonds. The estimated cost for each of the construction contract is provided in **Table 3**.

Table 3 Estimate of probable construction costs

Phase	Contract	Cost
A	MF Offer	$13,400,000
B	UV Offer	$4,100,000
C	Site Preparation/ Earthwork	$18,800,000
D	Off-site Pipelines	$23,000,000
E	SDWRP	$195,100,000
F	SDWWTP Deep Injection Well	$1,700,000

Institutional and Cultural Considerations

The benefits of the SDWRP include implementation of a new, reliable, sustainable source of water; local control; support from the regulators, and reuses water previously discharged to deep injection wells and wasted.

The MDWASD's Public Affairs staff has developed an initial, conceptual, strategic communication plan for the SDWRP that identifies some broad goals for a public outreach program under the outreach efforts conducted as part of the 20-year Water Use Permit campaign.

Lessons Learned and Project Status

Because of the recession, substantial reductions in demand, financing/costs, and changes in the regulatory environment, MDWASD is rethinking its commitment to completing the SDWRP project at this time. An alternative project, extracting water from the brackish Floridan aquifer, thereby eliminating the need to construct the SDWRP, reduces project costs substantially, making it a more favorable option. Lower growth rates also reduced the increases in water demands, allowing a delay in implementation to further evaluate alternatives.

Therefore, MDWASD has suspended the design of the SDWRP at the 90 percent design completion point. If the regulatory commitments to Floridan injection and reuse are not obtained, the project may be restarted with a new completion date.

References

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City of Pompano Beach OASIS

Authors: A. Randolph Brown and Maria Loucraft (City of Pompano Beach)

US-FL-Pompano Beach

Project Background or Rationale

The city of Pompano Beach, Fla., began providing reuse for irrigation in 1989. Reuse began when the city's golf course over-pumped its groundwater wells and was unable to obtain further withdrawals upon renewal of the consumptive use permit. When the city Utilities Department attempted renewal of the consumptive use permit for the city's drinking water supply, the South Florida Water Management District (SFWMD) included reuse water as a permit requirement. The SFWMD also required an alternative water supply to address saltwater intrusion issues.

This was a challenge for the city, as it owned a sewer collection system, but no wastewater treatment facility (treatment is provided by the Broward North Regional Wastewater Facility), and could not reclaim its own wastewater. Fortunately, the Broward North Regional Wastewater Facility had an ocean outfall line running through Pompano Beach to the ocean. The city built the reuse plant adjacent to the 54-in (137-cm) line to divert secondary effluent for further treatment (filtration and disinfection) to improve its quality for use in irrigating the golf course, medians, and parks within the city. This reuse practice has reduced groundwater withdrawals and increased recharge, which has contributed to the reversal eastward of the saltwater intrusion line in this area. Over 20 years later, the city also provides reuse water to another city (Lighthouse Point) and to residential customers. The city's reuse pioneers gave the city a tremendous gift—the ability to sustain its water resources and better tolerate droughts.

Several drivers have made increasing reuse the most promising means of sustaining water resources and quality of life in the city. Recent legislation limits withdrawals from the region's groundwater aquifer (Biscayne Aquifer), requires closure of six ocean outfall lines in Eastern Florida by 2025 except during high volume stormwater periods, and requires a 60 percent of the previously discharged secondary effluent to be used for beneficial reuse. For the North Broward County ocean outfall, this amounts to 22 mgd (964 L/s) for inland reuse. Conservation requirements for consumptive use permits, high population growth, and severe droughts with minimal stormwater storage capacity have likewise put pressure on the city to increase reuse.

The city's OASIS (Our Alternative Supply Irrigation System) program takes a systematic approach to increase reuse and further increase capacity to achieve the region's reuse requirements. Current plant capacity is 7.5 mgd (329 L/s), of which only 1.8 mgd (79 L/s) are produced because of a lack of demand. With expansion possible up to 12.5 mgd (548 L/s), it is possible that OASIS could become a prime regional reuse provider.

The city's greatest reuse challenge has been in convincing single family residential customers to connect to the system. While connection is mandatory for commercial and multi-family customers, the city did not mandate connection for single family residences. Approximately 1,200 homes to date are connected to the reuse system with only 73 single family connections. Even though construction of reuse mains required work in neighborhoods that placed a reuse meter box at each home, single family residential customers chose not to connect to the system. Reasons ranged from the cost of connection to permitting issues. Residents also complained about the annual backflow preventer assembly certifications and the resulting payback time.

In 2010, the City Manager and the City Commission approved development of a connection program to target connection of single family residential customers. The new program allows the city, working through a contractor, to perform the necessary plumbing to connect the customer to the reuse system and eliminates the annual certification requirement for the customer. Installation cost is covered by the city's Utilities department, which also retains ownership of the dual check valve and meter. These costs are recovered through a slightly higher reuse usage rate ($0.85/1,000 gallons [$0.22/m^3] for the smallest meter size) than existing reuse usage rates ($0.61/1,000 gallons [$0.16/m^3]). The program includes a public outreach campaign, "I Can Water," which launched in July 2011 with meetings, media outreach, mailers, cable TV, webpage, and a hotline. To reward the existing 73 customers, the city will replace their backflow devices and keep them at the current lower rate. Customer response has been high.

Capacity and Type of Reuse Application

In 1989, the original plant was constructed with a 2 million gallon (7570 m^3) ground storage tank and a 2.5 mgd (110 L/s) design flow. The plant was expanded to 7.5 mgd (330 L/s) in 2002, with the ability to expand up to 12.5 mgd (550 L/s). The city produces reclaimed water for parks, golf courses, playing fields, medians, and residential irrigation. Current usage is about 1.8 mgd (80 L/s).

Water Quality Standards and Treatment Technology

Broward County effluent, which is the OASIS influent, is required to meet the state's CBOD standard as part of its NPDES permit. The reuse facility consists of: two filter structures; associated pumps; a chlorine contact basin; two reuse water ground storage tanks (6 million gallon [22,710 m^3] capacity); two dedicated distribution systems (a high pressure system for the golf course and a low pressure system for irrigation of parks, medians, and residential customers); and a control system (run on Supervisory Control and Data Acquisition Systems [SCADA]) with telemetry to the water treatment plant for monitoring and control functions. Water quality requirements include:

- Fecal coliforms - 75 percent of samples must be non-detect with no single sample exceeding 25 cfu/100mL
- Total suspended solids less than 5.0 mg/L
- Chlorine residual greater than 1.0 mg/L

Project Funding and Management Practices

The city finances the reuse program through user fees, an availability fee, and a use rate based on meter size. The potable water rate subsidizes 47 percent of the reuse program, spreading the costs to all customers. OASIS is required by the city's potable water consumptive use permit and helps to defer additional capital improvements for potable water as well as defer other alternative water supply investments. The city issued a bond for construction of the treatment facility and main trunk line. The city has continued to aggressively seek grants for distribution system expansion, as well as feasibility/research projects. Broward County is providing a cost share grant up to $220,000 for the new "I Can Water" campaign. Since 2004, the city has received $1.4 million in grants to further the reuse program.

Institutional and Cultural Considerations

Broward County has stricter water quality standards than the State of Florida, which limits reclaimed water use in ways that are acceptable in other parts of the state or country. Local rules do not allow reclaimed water to be stored in unlined ponds, requiring lining storage ponds or using closed distribution systems to reach all end users. Local water quality standards also impede permitting of reuse recharge systems, such as rapid infiltration basins or shallow wells without advanced treatment beyond tertiary treatment.

In this case, reuse was not implemented as an effluent disposal method (the city has no wastewater treatment plant), but rather as a water supply and saltwater intrusion abatement tool, making this program different from reuse projects that cover the cost of their program as part of effluent disposal. The use of reclaimed water as a resource means its benefit must be evident to the public as a protective and sustainability measure.

Successes and Lessons Learned

The most important lesson learned is that public outreach and marketing is critical to the success of the project. Utility staff are usually technically and scientifically oriented and many are not adept at communicating with the general public. Having a third party communicate utility issues often helps the public accept the validity of the information.

Another lesson learned is that reuse as a water resource is the key to a city's future growth and development. Some interests attempt to limit the expansion and use of reclaimed water in order to limit development. Objections raised during a project startup may have little to do with the issue described by the resident/business owner and more to do with restricting growth.

Eastern Regional
Reclaimed Water Distribution System

Authors: Victor J. Godlewski Jr. (City of Orlando); Greg D. Taylor, P.E., and Karen K. McCullen, P.E., BCEE (CDM Smith)

US-FL-Orlando E. Regional

Introduction

The city of Orlando, Fla., has completed the longest, single reclaimed water project in Florida, representing a regional effort to provide reclaimed water throughout central Florida. The Eastern Region Reclaimed Water Distribution System (ERRWDS) provides public access reclaimed water to residential, commercial, and industrial users in the city of Orlando, Seminole County, Orange County, the city of Oviedo, and the University of Central Florida (UCF). The ERRWDS distributes reclaimed water, supplied by six wastewater utilities, through 35 miles (56 km) of transmission pipe, ranging in size from 20- to 48-in (50- to 120-cm) diameter.

Due to the size of the region and the location of WRFs, the regionalized system was effectively separated into the eastern and western service areas. The eastern system, the focus of this case study, serves areas in two state Water Management Districts (WMDs), the St. Johns River and the South Florida WMDs. For the eastern system, the primary source of reclaimed water would be provided from the Iron Bridge Regional WRF. Through system interconnects, Orange County's Eastern WRF would also be a source of reclaimed water.

Project Background

The Central Florida region is one of the fastest growing areas in the state; central Florida region's population increased 24.3 percent, while the state of Florida's population increased 17.6 percent from 2000 to 2010. Almost all of the region's drinking water is obtained from the upper and lower Floridan aquifer system. Reclaimed water has been used extensively in Florida to reduce potable water demands and stress on the Floridan aquifer system. Prior to the existence of regional systems like the ERRWDS, many individual utilities in central Florida, including the city of Orlando, and Seminole and Orange Counties, used reclaimed water for domestic irrigation and commercial crops.

These organizations were often motivated by their ability to obtain Consumptive Use Permits (CUP) for water withdrawals from the Floridan aquifer; a typical requirement of the permit is to participate in implementation and advancement of reuse. Thus, to reduce potable water demands and provide beneficial reuse, the city pursued a strategy that included a regional public-access reclaimed water system. The city of Orlando took the lead in planning, design, construction and operation of the ERRWDS and other organizations contributed financially, to secure reclaimed water from the system.

Capacity and Type of Reuse Application

Reclaimed water from the Iron Bridge Regional WRF is managed through a permitted 28 mgd (1,230 L/s) surface water discharge to the Little Econlockhatchee River, a 35 mgd (1,530 L/s) man-made treatment/reuse wetland system [US-FL-Orlando Wetlands], and a 20 mgd (875 L/s) public access reuse system. The ERRWDS is ultimately designed to transport an annual daily average flow of 24 mgd (1,050 L/s) throughout approximately 35 miles (56 km) of pipe, accounting for a peak hour flow factor of 4.5. An additional component of the ERRWDS is an inline booster pump station to deliver water from the north portion of the system to the south portion of the system, with a firm pumping capacity of 21 mgd (920 L/s). There is also a plan to construct a 10 million gallon (38,000 m^3) storage and re-pump facility in the southeast portion of the city of Orlando in order to feed the growing population and help attenuate the peak demands.

Water Quality Standards and Treatment Technology

The permitted capacity of the Iron Bridge WRF is 40 mgd (1,750 L/s). Although the majority of the wastewater treated by the Iron Bridge WRF is from the city of Orlando, flows are contributed from other sources, including parts of the City of Winter Park, the city of Maitland, the city of Casselberry and unincorporated portions of Seminole County. The treatment process is a 5-stage biological nutrient removal (BNR) system, designed to produce an effluent, after clarification and filtration, with the following characteristics expressed as annual average concentrations (total suspended solids is a maximum):

- Carbonaceous Biochemical Oxygen Demand (CBOD5): 4.28 mg/L
- Total Suspended Solids: 5 mg/L
- Total Nitrogen: 3.08 mg/L
- Total Phosphorus: 0.75 mg/L

Project Funding and Management Practices

The city of Orlando obtained grants from the EPA and the St. Johns River WMD, and loans through the FDEP State Revolving Fund and bond issuance. This allowed for low interest rate loans to fund design and construction of the facilities. The total design cost was $6.5 million and the projected construction cost of the Iron Bridge Regional WRF improvements, the supplemental ERRWDS pipeline, inline booster pump station, ground storage tank and re-pumping facility, and other facilities was approximately $47.5 million.

To help with project management and oversight, the ERRWDS pipeline and treatment plant improvements were broken up into multiple construction contracts allowing staging the work, lessening the impact on local ratepayers. Staging construction also allowed more stakeholders to be engaged during the process and permitted neighborhoods along the path to be connected to during construction, minimizing disturbances.

Project Success

The core success of this project is the collaborative effort of multiple reclaimed water utilities and potable water utilities in a regional project for the economic, environmental, and social benefit for all. Potable water from the Floridan aquifer is becoming a scarce resource, fostering competition between potable water utilities for access (permits) to utilize this precious and least expensive option for potable water. The potable water utilities (most of which are also reclaimed water providers) have permit conditions requiring them to incorporate reclaimed water in their supply plans for domestic and commercial irrigation. Collaboration among potable water utilities, reclaimed water utilities and water management districts, focused by the city of Orlando, allowed reclaimed water to be transported across political boundaries (WMD boundaries and county boundaries), cost-sharing from multiple reclaimed water and potable water suppliers, and created a win-win solution to delivering reclaimed water for all stakeholders.

Lessons Learned

A regional approach to solve a regional water supply problem can be a cost-effective way for stakeholders to benefit from cooperation. The project sponsor or leader must be willing to thoughtfully consider each stakeholder's unique needs and concerns and to develop a plan that attempts to address stakeholder issues. Creating a successful regional project thorough a master plan that identifies potential customers, construction routes, funding sources, and an implementation schedule requires each of the stakeholders to understand their individual systems. This allows accurate demand projections and in turn, better estimates on the amount of reclaimed water they so that appropriate system sizing can be planned for long-term benefits without additional costs; it also allows fair cost-sharing on a capacity basis.

Prompt, regular communication and collaboration between utilities, regulators, the general public, consultants, and contractors allowed participants to weigh-in as on the scope and planning of the project. Therefore, collective agreement on the final design was easier to obtain and construction was easier to manage. Each stakeholder had input into the planning of the reclaimed water system, with the overall decision of the design and construction of the pipeline resting with the city of Orlando.

Finally, public awareness of construction and availability of reclaimed water proved to be an invaluable asset. By informing the general public of the construction activities, better and more productive lines of communication, it was easier to anticipate possible issues and resolve the many of them prior to construction.

Economic Feasibility of Reclaimed Water to Users

Authors: Grace M. Johns, PhD (Hazen and Sawyer) and C. Donald Rome, Jr. (Southwest Florida Water Management District)

US-FL-Economic Feasibility

Project Background and Goals

Reclaimed water can be an effective way to diversify Florida's water resources in order to use fresh water more efficiently. The Southwest Florida Water Management District (District) developed evaluation criteria and a decision support model called "The Reclaimed Water Benefit-Cost Calculator for Irrigation and Industrial Applications," which is being used by the District to assess economic feasibility of reclaimed water in various applications.

Reclaimed water is economically feasible if the present value of reclaimed water benefits is comparable to or greater than the present value of reclaimed water costs to the user. The model guides potential users in collecting and assembling the necessary information and provides estimates of benefits, costs, and net benefits. The model can be used to conduct sensitivity analyses to evaluate uncertainties in the input data and can evaluate partial offsets, where a portion of the next available water source is replaced with reclaimed water.

Evaluation criteria in the model were developed from a survey of 37 reclaimed water users in Florida including farmers using reclaimed water for crop irrigation; golf courses and a homeowner association using reclaimed water for turf, lawn, and landscape irrigation; and industries using reclaimed water primarily for cooling. Ninety-seven percent of the respondents were either very satisfied or satisfied with reliability of their reclaimed water supply and 86 percent and 84 percent, respectively, were either very satisfied or satisfied with water quality. The survey responses

Table 1 Benefits of reclaimed water for irrigation and industrial applications (Survey Results)

Reclaimed Water Benefits (a)	Respondents Who Said Yes to Benefit		
	Number Said Yes	% of Responses	Total No. of Respondents (b)
1. Have a guaranteed and reliable water source	25	68%	37
2. Able to conserve fresh water for their other uses	25	68%	37
3. Able to irrigate more frequently	17	63%	27
4. Able to apply more water to the crop/lawn/ landscape	15	56%	27
5. Better able to supply water to crops during drought	5	50%	10
6. Irrigation or water costs are lower	17	46%	37
7. Our permitting requirements have been reduced	3	30%	10
8. Net income is higher than with traditional water source	11	30%	37
9. Fertilization costs are lower	7	26%	27
10. Revenue is higher than with traditional water source	9	24%	37
11. Business increased during fresh water restrictions	4	24%	17
12. Better able to protect crops from freezing	2	20%	10
13. Crop yield or product quantity has been higher	2	10%	20
14. Pounds of juice per acre is higher	1	10%	10
15. Our production cost is lower	1	10%	10
16. Water storage costs are lower	3	8%	37
17. Quality of crop/lawn/landscape/product is higher	3	8%	37

(a) All changes are relative to the freshwater source.
(b) Total number of respondents is: 37 if the question was asked of all respondents; 27 if the question was asked of the Agricultural and Recreation / Aesthetic respondents; 20 or 10 if the question was asked of the Agricultural respondents and/or the Industrial respondents, respectively.

demonstrated that there are cost-savings and value-added benefits of reclaimed water use. Benefits are listed in **Table 1** in order of importance, with the top five benefits being that more water is available when needed relative to fresh water sources. Additional details of the survey results are provided in **Table 1**.

Benefits of Reclaimed Water Use

Survey results were used to validate the model, which provides guidance in estimating benefits of reclaimed water to the user relative to the next available water source (NAWS), which include:

1. Nitrogen fertilizer cost savings - annual.
2. Change in value of crop production - annual.
3. Value of change in quality of crop, lawn, and/or landscape - annual.
4. Value of additional water available from the reclaimed water source - annual.
5. Value of additional water "freed up" by the reclaimed water use - annual.
6. Value of water available during NAWS water shortage restrictions - annual.

Costs of Reclaimed Water Use

The model compares costs associated with accessing and using reclaimed water to those from using the NAWS. There are potentially three costs associated with using reclaimed water: (A) installation costs; (B) annual operations and maintenance (O&M) costs; and (C) recurring non-annual O&M costs (**Table 2**). A reclaimed water user will not necessarily need to spend money on all of these cost items. The model directs the user to enter costs relevant to their potential reclaimed water use, and relative to using the NAWS. It reminds the user to consider the need and cost for a backup water supply when reclaimed water is not available.

Table 2 Costs of reclaimed water for irrigation and industrial applications

Potential Initial Costs
1. Install pipes to connect system to reclaimed water pipeline
2. Install pressure regulating valves to control water pressure
3. Install water meter
4. Install storage pond or tank and pump station
5. Disconnect existing water source from system
6. Install or expand the water pretreatment system (industrial applications)
7. Install or upgrade filtration and/or chemical injector systems to reduce micro-jet and drip emitter clogging
8. Create disposal area when reclaimed water flows are higher than crop water needs
9. Change plant material to more salt tolerant species
10. Costs associated with the provision of water from the existing water source for other uses due to the reclaimed water connection
Potential Operations and Maintenance Costs, Annual and Recurring, Non-Annual
11. Reclaimed water payment to the utility
12. Maintain water meter, pipeline, pump and storage pond; repair pipeline due to fluctuating water pressure; repair or replace rusty controllers, power boxes and equipment
13. Fertilizer management including water quality and plant tissue testing and nutrient evaluations
14. Salinity and pH management including chemical applications, water blending, soil leaching and mechanical means
15. Pest or algae management including cleaning or repairing nozzles, water chlorination, pesticide applications, and filter replacement
16. Chemicals needed for reclaimed water treatment prior to industrial application
17. Recording water data and providing reports to regulatory agencies

Economic Feasibility of Reclaimed Water

Given the data provided by the user, the model provides the following results:

- Total benefit in dollars (other than cost savings) relative to next available water source: Annual and per 1,000 gallons
- Total cost in dollars, including cost savings, relative to NAWS: Annual and per 1,000 gallons
- Net benefit (benefit minus cost) of reclaimed water use relative to NAWS: Annual and per 1,000 gallons

A partial screen shot of the model is provided in **Figure 1**, showing the portion of the model that provides nitrogen fertilizer cost savings. The green-shaded cells indicate that information is provided by the user. The dark blue-shaded cell indicates that the data came from a public source, specified in the model. The light blue-shaded cells contain values calculated by the model.

Summary

The Economic Feasibility report and model are available on the District's website (SFWMD, n.d.). The model assists water users and the District in evaluating economic feasibility when a water use permittee or applicant is required to consider the use of reclaimed water. This would be the case where reclaimed water is available from a wastewater treatment plant located in a water resource caution area. The model results are viewed in the proper context of all other information submitted and relevant to the water use permit application or renewal.

References

Southwest Florida Water Management District (SFWMD). n.d. Retrieved on Sept. 4, 2012 from <http://www.swfwmd.state.fl.us/permits/wup/>.

Reclaimed Water Benefit Cost Calculator for Irrigation

Economic Comparison of Reclaimed Water Versus Next Available Water Source For Irrigation by Agricultural, Recreation and Aesthetic Water Users

Row No. (1)	Benefit or Cost Item (2)	Next Available Water Source (NAWS) (3)	Reclaimed Water Used Instead & Other Sources if Applicable (RW/Other) (4)	NAWS Minus RW/Other (Except A. which is RW/Other minus NAWS) (5)
70	**E. Nitrogen Fertilizer Cost Savings - Annual:**			
71	N Fertilizer Cost per Ton:	$552	$552	
72	Nitrogen concentration in ppm or mg/l of Irrigation Water (for reclaimed water, obtain from utility. For NAWS, use available info or assume 0):	0	6	
73	Percent of Nitrogen in water that is taken up by the plant:	50%	50%	
74	*Nitrogen Fertilizer Cost Savings Per 1,000 gallons of irrigation water:*	*$0.00*	*-$0.015*	*$0.015*
75	Nitrogen Fertilizer Cost Savings due to N in applied water - Annual	$0	-$1,258	$1,258

Figure 1
Partial screen shot of reclaimed water benefit cost calculator for irrigation, nitrogen fertilizer cost savings module

Reuse at Reedy Creek Improvement District

Author: Ted McKim, P.E., BCEE (Reedy Creek Improvement District)

US-FL-Reedy Creek

Project Background or Rationale

Reedy Creek Improvement District (RCID) is a special district in central Florida that serves the Walt Disney World resort with municipal services, including water supply, wastewater treatment, and reuse. Reuse has been practiced since the early 1970s, and began with irrigation of a tree farm and nursery operations, utilizing 2 to 3 percent of the effluent. From that modest beginning, reuse practices have grown and today RCID practices 100 percent reuse, and has done so for over 20 years. Reclaimed water meets the majority of irrigation demands of the Walt Disney World resort, and is used for cooling tower makeup, wash down of sidewalks and streets, fire protection and fire suppression, vehicle washing, dust control, clean up, and process uses at the treatment plant and solid waste transfer station. Reuse currently provides between 25 and 30 percent of the total water supply needs of the District, and meets a majority of the non-potable demand, typically between 5 and 6 mgd.

The primary reason for instituting reuse stemmed from a climate of conservation and sustainability and regulatory desires. In the 1980s, Florida Department of Environmental Protection (FDEP) encouraged utilities to reuse as a means of reducing surface water discharges. Additionally, planning projections indicated that traditional water supplies would be unable to meet future demands unless alternative sources were utilized. Finally, most utilities also discovered that reuse was a cost-effective means of meeting both of these needs.

Capacity and Type of Reuse Application

RCID employs a treatment plant with a 15 mgd (657 L/s) capacity. Reclaimed water is provided to two reuse systems, one with a 10 mgd (438 L/s) capacity and a rapid infiltration basin system (RIB) of 12.5 mgd (548 L/s). The reuse system capacities exceed plant capacity to meet variations in demand due to distinct wet and dry seasons. The reuse systems consist of a distribution system with about 80 miles (129 km) of pipeline, a pump station, and reservoirs with 15 million gallons (56,800 m^3) of storage capacity. Reclaimed water is used principally for landscape with over 80 percent of irrigated areas within RCID using reclaimed water (**Figure 1**). When the supply of reclaimed water exceeds demand, reclaimed water is used to recharge groundwater through the RIB system, which consists of 85 1-ac (0.4-ha) basins constructed in a sandy ridge area located 2 to 3 miles (3.2 to 4.8 km) from the plant site. The USGS conducted studies in the early 1990s concluding that approximately 70 percent of water applied to the RIBs reaches the Upper Floridan aquifer and the balance diffuses to the surficial aquifer. The Upper Floridan aquifer is the primary source of drinking water for much of central Florida.

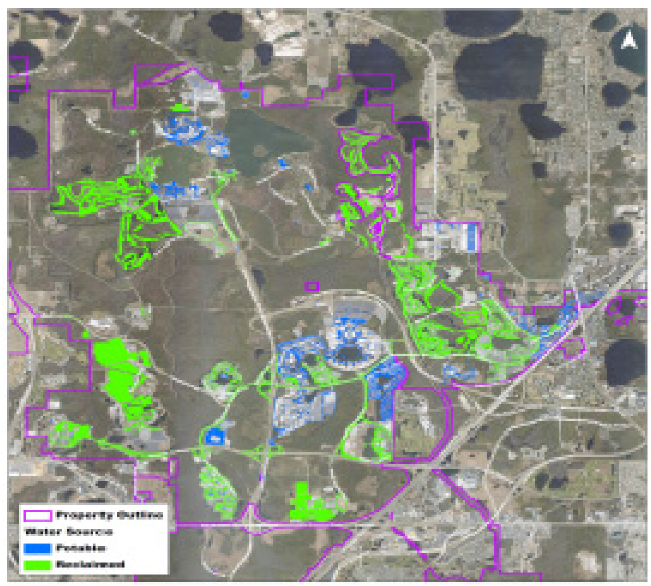

Figure 1
Areas irrigated with potable water and RCID reclaimed water (Photo credit: Reedy Creek Energy Services Surveying and Mapping Department)

In a typical year, flow is split about equally between the two systems but is weather dependent. In dry weather, demand on the distribution system increases (typically peaking in April and May); some augmentation with groundwater is typically required to supplement flows in the reclaimed water distribution system during dry weather to meet peak demands. In wet weather, demand on the distribution system drops and flow is diverted to the RIBs, which are used almost exclusively during storms and hurricane events. **Figure 2** shows the historical distribution of flow between the RIBs and reuse distribution system (values are shown as annual averages).

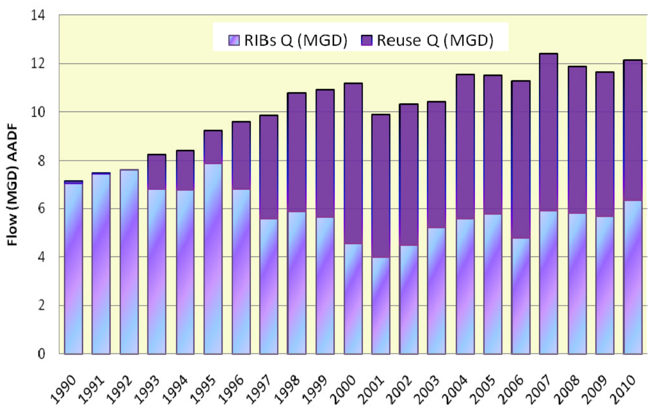

Figure 2
Allocation of reclaimed water to RIBs and reuse distribution system

Water Quality Standards and Treatment Technology

RCID employs a five stage Bardenpho™ process for carbon and nutrient removal, followed by filtration and chemical disinfection (hypochlorite solution) to achieve a water quality suitable for public access reuse purposes per Chapter 62-610 of the Florida Administrative Code.

Annual testing of the reclaimed water shows that it typically meets USEPA primary and secondary drinking water standards, with one exception for TTHMs (**Table 1**). The reclaimed water also meets the targeted thresholds for protozoan parasites (*giardia* and *cryptosporidium*) as recommended by FDEP (5 ocysts/100 mL). The facility operates under an FDEP permit because the facility is a zero-discharge operation, and does not have an NPDES permit.

Project Funding and Management Practices

The reuse distribution system is operated much like a typical water distribution system, and matches the pressures in the potable system, which facilitates conversions. Reclaimed water is metered, invoiced, and monitored similar to potable water, and the distribution system is constructed using similar standards for materials, installation, and testing. Chloride concentrations in the reclaimed water are typically an order of magnitude higher than the potable water (>120 mg/L versus 10 mg/L) and this marked difference is used in the field as an aid in identifying the source of the water during leak detection procedures. Indicator test strips are used for determination of chloride levels. All reclaimed water piping is color-coded using purple (Pantone #522C); plastic pipe is pigmented and other pipe materials are striped with paint, tape, or both. Buried pipe is installed with identification tape. Additionally, all above, or at-grade appurtenances, are identified with purple coloring and purple and yellow markers and tags, including fire hydrants. RCID employs a robust backflow prevention and cross connection program to ensure that reclaimed and potable water systems are not inadvertently cross connected. RCID also requires all new development to connect to the reclaimed water system for non-potable uses.

Institutional and Cultural Considerations

Sustainability has been a driving force for use of reclaimed water for non-potable uses and for aquifer recharge at RCID. The realization that the Upper Floridan aquifer is a finite and precious resource has led to its conservation, which in turn has fostered growth of reuse as an alternative water supply. As a result, reclaimed water is an accepted and desired utility, and has gained increasing acceptance as a valuable resource.

Successes and Lessons Learned

The reuse system employed by RCID has reaped many benefits and has undergone transformation in its 40-year history. Initially employed as a means of ceasing surface water discharge, it has evolved into an alternative water supply and a means of achieving a higher level of sustainability by returning a significant portion of the consumed water to its source, in effect practicing indirect potable reuse. The reuse distribution system and related consumption has allowed RCID to remain within its Water Use Permit, which limits the amount of groundwater that can be withdrawn). The recharge of the aquifers by the RIBs has also allowed the net withdrawal of groundwater at RCID to remain relatively constant over the past 20 years, despite a more than doubling of growth and development within the service area.

Table 1 Water quality characteristics of RCID effluent (2007 – 2011) compared to drinking water standards

Parameter	Units	2007	2008	2009	2010	2011	Drinking Water Standard
Inorganics							
Arsenic	mg/L	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	0.05
Barium	mg/L	<0.0025	0.0028	0.0035	0.0015	0.0015	1
Cadmium	mg/L	<0.00038	<0.00038	<0.00038	<0.00038	<0.00038	0.01
Chromium	mg/L	<0.006	<0.006	<0.006	<0.006	<0.006	0.05
Flouride	mg/L	0.31	0.08	0.19	0.03	0.02	4
Lead	mg/L	<0.00054	<0.00054	<0.00054	<0.00054	<0.00054	0.05
Mercury	mg/L	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.002
Nitrate as N	mg/L	0.391	0.57	0.664	0.688	0.402	10
Selenium	mg/L	<0.0015	<0.0015	0.0018	<0.0015	<0.0015	0.01
Silver	mg/L	<0.0005	<0.0001	<0.0001	<0.0001	<0.0001	0.05
Sodium	mg/L	160	73.8	71.9	82.3	77.9	160
Volatile Organics							
Ethylene dibromide (EDB)	µg/L	<0.01	<0.006	<0.009	<0.009	<0.0081	0.02
Para-dichlorobenzene	µg/L	<1.0	<1.0	<1	<0.1	<1	75
Vinyl chloride	µg/L	<0.5	<0.5	<0.5	<0.083	<0.71	1
1,1 -dichloroethane	µg/L	<0.5	<0.5	<0.5	<0.15	<0.5	7
1,2-dichloroethane	µg/L	<0.5	<0.5	<0.5	<0.082	<0.5	3
1,1,1-trichloroethane	µg/L	<0.5	<0.5	<0.5	<0.00015	<0.5	200
Carbon tetrachloride	µg/L	<0.5	<0.5	<0.5	<0.082	<0.5	3
Trichloroethane	µg/L	<0.5	<0.5	<0.5	<0.068	<0.55	3
Tetrachloroethane	µg/L	<1.0	<1.0	<1.0	<0.099	<1.0	3
Benzene	µg/L	<0.5	<0.5	<0.5	<0.05	<0.58	1
Trihalomethanes							
Total Trihalomethane (TTHM)	µg/L	66.7	59.4	179**	46.5	54.2	80
Organics							
Endrin	µg/L	0.021**	<0.02	<0.019	<0.003	<0.01	0.02
Lindane	µg/L	0.097	0.03	<0.025	<0.0031	<0.005	4
Methoxychlor	µg/L	<0.0021	<0.02	<0.024	<0.024	<0.019	100
Toxaphene	µg/L	<0.090	<0.09	<0.09	<0.00022	<0.96	5
2,4-D	µg/L	<0.12	0.32	<0.091	<0.099	<0.037	100
2,4,5-TP (Silvex)	µg/L	<0.11	<0.087	<0.056	<0.05	<0.06	10
Radiologicals							
Gross Alpha	pCi/L	<2.1	<1.6	<1.3	1.3	1.6	15
Radium 226 and 228	pCi/L	0.75	0.2	0.7	0.7	0.8	5
Secondary Chemistry							
Chloride	mg/L	104	142	166	110	114	250
Copper	mg/L	0.0021	<0.0015	0.0015	<0.0015	0.0015	1
Iron	mg/L	0.12	0.13	0.1	0.15	0.16	0.3
Manganese	mg/L	0.0038	<0.0015	0.0017	<0.0015	<0.0015	0.05
Sulfate	mg/L	50.9	60.3	53.9	55.3	47.1	250
Zinc	mg/L	<0.025	<0.025	0.025	<0.025	0.025	5
pH (units)	mg/L	7.4	6.2	7.5	7.6	8.15	6.5 - 8.5
Total Dissolved Solids	mg/L	391	410	419	402	414	500
Foaming Agents	mg/L	0.045	<0.006	0.021	0.059	0.12	0.5

mg/L are milligrams per liter or parts per million
µg/L are micrograms per liter or parts per billion
pCi/L are picoCuries per liter
BDL means below the detection limit of the analysis technique employed
** Indicates sample parameters that did not meet or exceeded the drinking water standard
N/A indicates that an average value was not possible to calculate due to a mix of results above and below detection

Marco Island, Florida, Wastewater Treatment Plant

Authors: Jennifer Watt, P.E. (General Electric); Solomon Abel, P.E. (CDM Smith); and Rony Joel, P.E., DEE (AEC Water)

US-FL-Marco Island

Project Background

The City of Marco Island, Fla., is located in southwest Florida among the 10,000 islands that are part of the Florida Everglades. This resort community population varies from 17,000 in summer to 40,000 in winter. The majority of Marco Island was man-made in the late 1960s to early 1970s, by filling mangrove and swamp areas, and creating a back yard canal system.

The Marco Island Wastewater Treatment Plant (WWTP) is about 40 years old and the original treatment technology has been expanded in phases to accommodate its growing community. Originally, wastewater treatment consisted of onsite residential septic tanks and a 3 mgd (130 L/s) central sewage treatment plant for condominium and commercial facilities. In 2005, the city initiated a 7-year residential septic tank replacement program. In an effort to protect the clean Gulf of Mexico waters that lap the local beaches and draw tourists and winter residents, city officials launched a 7-year plan to phase out all septic systems.

Capacity and Treatment Technology

In 2003, Marco Island Utilities selected a packaged membrane bioreactor (MBR) system to upgrade the existing contact stabilization process and increase treatment capacity. Because the existing plant is surrounded by water, commercial facilities, and other utilities, little room is available for expansion and an increase in capacity with conventional technology would not have been possible.

The MBR process offered a high level of treatment for producing reclaimed water in a small footprint by eliminating secondary clarifiers and tertiary filtration systems required in conventional treatment. The treatment capacity in 2012 is 3.5 mgd (150 L/s); projections of population growth and septic tank conversions are anticipated to result in a wastewater demand on the island of 5.0 mgd (220 L/s).

The existing contact stabilization process was upgraded in multiple phases to minimize interruptions of treatment operations, stage funding requirements, and ease of constructability. The first phase added the MBR treatment process in four trains and kept part of the contact stabilization process in operation. In the second phase of the project, the remaining contact stabilization plants were taken out of service. A second bioreactor tank with anoxic and aerobic volume to match the existing tank was installed, as well as a fifth membrane train to provide a total capacity of 5 mgd (220 L/s) with one standby membrane train (**Figure 1**).

Figure 1
Marco Island WWTP membrane trains (Photo credit: Jeff Poteet)

Final disinfected water flows to a pump-station wet well for transfer to two onsite 0.5-million-gallon (1,900 m^3) storage tanks. Reclaimed water is used to irrigate the Marco Island, Hideaway Beach, and Marco Shores golf courses or sent to an onsite deep-injection well when reclaimed water demands have been met.

The MBR system produces effluent exceeding Marco Island discharge requirements and provides high-quality reuse water, reducing the demand of potable supplies by creating a continuous drought-proof supply for golf course and residential property irrigation.

Project Funding and Management Practices

A challenge to the new system was financing the expansion project. The original system was financed by users; each condominium that connected was allocated a capital cost and provided a 10-year finance plan. Those that joined the system were guaranteed a \$0.52/1,000 gallon (\$0.14/m^3) cost for the 10-year period.

It was important not to burden consumers that were not going to receive direct benefits of using irrigation water. The indirect benefit is that the size of the water plant capacity expansion could be reduced by the volume of reuse water that is distributed, saving all water utility customers the cost of plant expansion.

The reuse system expansion cost was \$1.6 million; \$750,000 of funding was a grant award from Big Cypress Basin, a component of South Florida Water Management District. The balance of the project was paid for by condominiums connecting to the system. The city mandated that all condominiums adjacent to the reuse system must connect to the system within 365 days to provide cost recovery. Based on the cost to be recovered and the volume of water used for irrigation by each condominium, the cost per 1,000 gallons (3.8 m^3) of the reuse water was the same as the potable water for 24 months. At the end of this period, the cost of reclaimed water was reduced to the same rate as all other reuse water customers (40 percent of the potable water rate). The FY12 cost for reuse is \$1.56/1,000 gallons (\$0.41/m^3).

The FY2012 potable water cost is:

- Base rate - \$30.89
- Use rate - \$3.85/1,000 gallons (\$1.01/m^3)

The FY2012 wastewater cost is:

- Base rate - \$25.14
- Use rate - \$4.97/1,000 gallons (\$1.31/m^3)

Institutional/Cultural Considerations

The biggest cultural challenge was for operations staff at Marco Island Utilities to transition from operating a contact-stabilization facility to MBRs. Monitoring the biological process and amount of settling in the clarifier was the measure of performance for the original system. Operators had to learn how to monitor the membrane system and view the biological process in a different light—important for optimization but not in relation to settling and treatment quality. The transition required a comprehensive training program and extra attention to automation and controls, including the creation of a new position devoted to instrumentation and controls. All the team members were trained extensively in the new process and were closely involved with the construction before MBR start-up.

A public education program was developed to demonstrate the benefits of expanding the system and reducing use of potable water for irrigation. The per capita water consumption is approximately 450 gallons (1.7 m^3) per day on Marco Island. Considering interior consumption is approximately 110 gpcd (0.4 m^3 per capita per day), the majority of water is used for irrigation.

No single family homes have access to reuse water, which became an issue, as these customers wanted access to the low cost irrigation water. The challenge to meet this demand is twofold: first, the supply of reuse water is dependent on the volume of wastewater generated, and second, a distribution system does not exist. Based on interior residential water consumption, approximately four full-time occupied homes would generate the volume required to irrigate one home. In addition to not having available product, the cost to install new irrigation lines would be approximately \$6,000 per residential site resulting in a 10-year recovery for the capital investment.

Successes and Lessons Learned

The biggest success of the project was the expansion of the existing WWTP from 1 to 3 mgd (44 to 130 L/s) with only the addition of membrane trains. Use of membranes required only a small additional footprint so that the plant could be expanded on the existing site. Modular expansion with additional membrane trains to 5 mgd (220 L/s) allowed for phased construction to match increases in capacity demands, funding, and schedule requirements including construction activity scheduling between the rainy season (May to August) and the arrival of winter residents around the beginning of January.

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Everglade City, Florida

Author: Rony Joel, P.E., DEE (AEC Water)

US-FL-Everglade City

Project Background or Rationale

The city of Everglade City, Fla., is a small fishing community in the southernmost portion of Collier County on the western coast of Florida (**Figure 1**). The city is the interface to Big Cypress Swamp with coastal wetlands lining the north coast of Chokoloskee Bay. This highly sensitive estuarine, shallow water region is part of the “Ten Thousand Island” area that is known to be a vital part of the ecology of Southern Everglades National Park, and is home to many species of birds, fish, and other wildlife. The outer portions of the city are characterized by mangrove wetlands.

The city has a total of 250 single family residential homes and 130 mobile home units. At build-out (2030), an additional 482 home units will be added. The current population of the city is approximately 800.

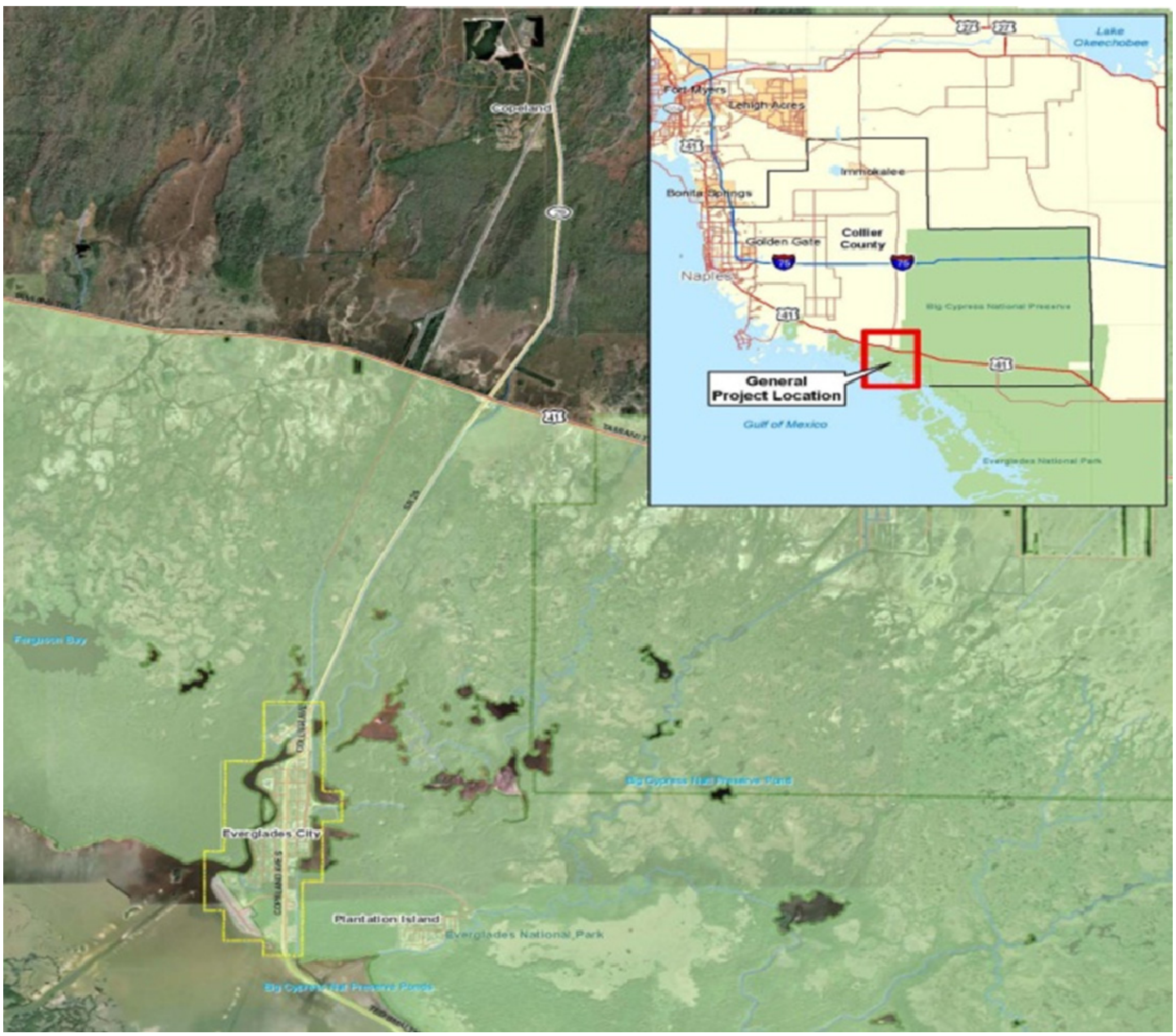

Figure 1
Location of Everglade City (Photo credit: Collier County, Fla. Appraiser)

The city has developed areas that are at an elevation of 2 to 5 feet (0.6 to 1.5 meters). Because of the low elevation, the city and surrounding areas experience tidal and storm surge flooding.

Capacity and Type of Reuse Application

The Everglades City wastewater treatment system provides service to the incorporated area of the city and to portions of Copeland and Chokoloskee. The existing plant has a capacity of 0.16 mgd (7 L/s) on an annual average daily flow basis.

The treatment process consists of flow equalization, aeration, secondary clarifications, membrane filtration, chlorination, dechlorination, aerobic sludge digestion, sludge drying beds, reject storage, reclaimed storage and distribution, and surface water discharge. Flow is delivered to the plant via 245 grinder pump stations in the city and two master pump stations (Copeland and Chokoloskee).

The city has two permitted options for land application of reclaimed water. The first option is for distribution or reclaimed water for public reuse for irrigation of residential lawns, city landscape areas, roadway medians, the airport, school, and park. If the demand for reclaimed water is less than the total production of reclaimed water, the remaining water is used to recharge the local shallow aquifer through a rapid infiltration basin.

Water Quality Standards and Treatment Technology

The Florida Department of Environmental Protection operating permit mandates the following annual average treatment standards:

- biochemical oxygen demand, Carbonaceous 5 day – 20 mg/L
- total suspended solids – 5 mg/L
- coliform – 25 #/100 mL
- pH – 6.0 min to 8.5 max
- chlorine residual – 1 mg/L
- total nitrogen – no limit
- total phosphorous – no limit

The monitoring is required at the following locations: after chlorination, but before dechlorination, at the discharge point to the percolation ponds, and at the discharge point to the public access reuse system.

Project Funding and Management Practices

The city distributes reuse water at no cost to their customers. The average monthly cost of potable water (base and use fee) for a user of 4,000 gallons (15 m^3) is \$17; this typically reflects a \$13 base fee that includes 3,000 gallons (11 m^3) of water and \$4/1,000 gallons (\$1.03/m^3) for use above the base volume. The monthly wastewater treatment cost for the same level of service is \$16.20 (\$13 base fee plus \$3.20/1,000 gallons (\$0.83/m^3) above 3,000 gallons (7.74 m^3) water use).

The current wastewater plant is at the end of its useful life. The city is evaluating the need to upgrade the plant for full build out and increasing their service area. The total flow at build out is estimated to be 0.50 mgd (22 L/s). At this flow, new use opportunities for the generated reuse water will need to be established.

The city's current customer base cannot sustain the projected needs without a rate increase. A consultant has determined to meet the current 5-year capital improvements plant, and would require a rate increase in excess of 100 percent over the next 3 years. To reduce the rate impact, the city has started the process of applying for grants to reduce the rate increase.

Institutional/Cultural Considerations

The city of Everglades City has demonstrated that small communities can effectively incorporate a reuse water system into their effluent disposal scheme and not charge a fee for its use.

Mayor Sammy Hamilton, Jr. stated that: "The only negative comments I receive about city operations is when our homeowners do not get the reuse water they have become accustomed to receiving." He also states, "Our water supply is treated as our community life blood and any alternative water source we can identify will sustain our community for the next 100 years."

The city has landscaped its medians with Florida native plantings and as a component of the city conservation program; it uses the reuse water to irrigate the plantings. Annually the city has a 2-day seafood festival attended by over 60,000 persons. They call commenting how green the city is.

City of Orlando Manmade Wetlands System

Author: Mark Sees (City of Orlando)

US-FL-Orlando Wetlands

Project Background or Rationale

The Orlando Easterly Wetlands is an effort by the city of Orlando to enhance the environment with highly treated reclaimed water from its 40-mgd (1,750 L/s) Iron Bridge Regional WRF. The project began in the mid-1980s when the city, faced with the need to expand its permitted treatment capacity, was unable to increase nutrient discharge into sensitive waterways. Nitrogen and phosphorus were of concern because Florida water bodies are particularly susceptible to algae blooms, as a result of nutrient loading; these blooms can deplete oxygen and result in fish kills and other undesirable conditions during periods of very low flows that occur in the summer.

At its inception, there were no existing large-scale wetland treatment systems to serve as an example for city environmental services staff, consultants, or state regulators. But with the cooperation of all parties, work began on a 1,200-ac (485-ha), created wetland to provide nutrient removal for 20 mgd (876 L/s) of reclaimed water from the Iron Bridge facility. The Orlando Easterly Wetlands (OEW) site is located in east Orange County, Fla., approximately 2 mi (3.2 km) west of the main channel of the St. Johns River. Surveys performed in 1848 indicate that the site had once been a wet prairie, with smaller areas consisting of hardwood swamps and hammocks.

During the early to mid-1900s, land was ditched and drained for agricultural development; the ditches and swales that drain this site discharged directly into the St. Johns River. The drainage system had also lowered the groundwater table and transported runoff to the St. Johns River so that wetland vegetation could no longer be sustained throughout the site.

Water Quality Standards and Treatment Technology

Recognizing that aquatic ecosystems could be used to naturally remove nitrogen and phosphorus, the city used this site to create the large-scale wetland treatment system. Earthen berms were constructed, and 2.1 million aquatic plants were planted in 17 cells to "polish" reclaimed water that filters through the wetlands. Water is collected and discharged into the St. Johns River with no adverse impact. Creation of the wetland treatment system allowed the city to meet treatment and disposal needs, reclaim a vital wetland, and create valuable habitat for wildlife. The OEW has been continuously monitored through a Domestic Wastewater Operating Permit, which includes regulated daily, weekly, monthly, and annual water quality standards as shown in **Table 1**.

Table 1 Permit limits and wetlands performance in 2011

Parameter	Monthly/Annual Limit	2011 Wetlands Discharge
pH	6.0 – 8.5 s.u.	7.24 s.u.
Total Suspended Solids	15.0 mg/L	1.07 mg/L
Total Nitrogen	2.31 mg/L	1.00 mg/L
Total Phosphorus	0.20 mg/L	0.026 mg/L
Carbonaceous Biochemical Oxygen Demand	10 mg/L	0.67 mg/L
Dissolved Oxygen	3.8 mg/L	4.9 mg/L

Institutional/Cultural Considerations

In addition to providing outstanding water quality, the Easterly Wetlands is open as a park for passive recreation. Each year more than 12,000 people visit the park enjoying hiking, jogging, bicycling, bird watching, nature photography, and horseback riding. The park has an educational center where volunteers promote the success of the wetland treatment system by offering guided tours. Each year, more than 1,600 people are given personal tours of the system and 5 to 10 tours are given to delegates and representatives of foreign countries who are interested in economical alternatives for reuse.

Successes and Lessons Learned

After more than 2 decades of demonstrated performance, the Orlando Easterly Wetlands reclamation project has proven that large-scale, created wetlands can be used on a long-term basis, with resounding success, for the advanced treatment of wastewater and beneficial reuse.

Regional Reclaimed Water Partnership Initiative of the Southwest Florida Water Management District

Author: Alison Ramoy (Southwest Florida Water Management District)

US-FL-SWFWMD Partnership

Project Background or Rationale

The Southwest Florida Water Management District (SWFWMD) is one of five regional water management districts directed by state law to protect and preserve water resources in its boundaries (**Figure 1**). The district encompasses roughly 10,000 mi^2 (26,000 km^2) in all or part of 16 west-central Florida counties, serving more than 5 million people. The Regional Reclaimed Water Partnership Initiative (RRWPI) was developed in 2008 to maximize beneficial use of reclaimed water, while offsetting groundwater use. As part of its Cooperative Funding Initiative, a cost-share program for water resources management projects, SWFWMD was requested to fund up to half the cost of a series of projects that would accomplish these goals.

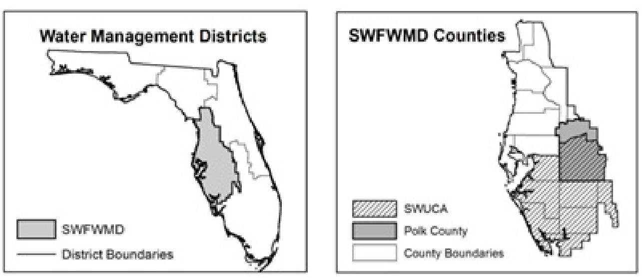

Figure 1
Water management districts and SWFWMD counties

Several potential concepts were initially proposed and after a series of meetings, the partners identified an industrial reuse project that would provide the Tampa Electric Company (TECO) with reclaimed water to offset groundwater use at its Polk Power Station in Mulberry, Florida. The location of this project (**Figure 2**) is significant because it is an area with depressed aquifer levels, which has caused saltwater intrusion, reduced river flows, and lowered lake levels. This area is the Southern Water Use Caution Area (SWUCA) and the district approved the SWUCA Recovery Strategy in 2006 (SWFWMD, 2006). Implementation of the strategy will ensure adequate water supplies to meet growing demands, while protecting and restoring water and related natural resources of the area. Among the SWUCA Recovery Strategy's components are alternative supply development and permitting.

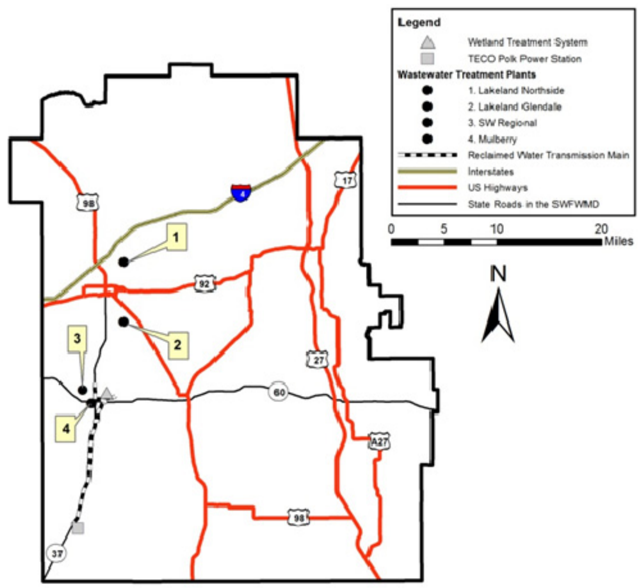

Figure 2
Project location

The primary source of water supply has been groundwater and developing alternative water supplies from surface water, reclaimed water and desalination will reduce groundwater use, while meeting growing water demands. SWFWMD's permit program requires water use permit holders to use alternative water sources where economically, technologically, and environmentally practical. This longstanding commitment to developing alternative water supplies along with the permit program has contributed to a trend of declining groundwater use in the SWUCA.

Capacity and Type of Reuse Application

This project is a unique public-private partnership that will provide TECO with approximately 7 mgd (300 L/s) of reclaimed water for industrial cooling and other uses for power generation expansion at its Polk Power Station. Three sources of reclaimed water have been identified.

The first source to come online will be the city of Lakeland's reclaimed water wetland treatment system. Lakeland has two wastewater treatment plants (WWTPs) with a combined capacity of 21.7 mgd (950 L/s) and an annual average flows of 11.5 mgd (500 L/s) (FDEP, 2010). In 2010, the city's McIntosh Power Plant used 4.79 mgd (210 L/s). The remainder was combined with 1.85 blowdown water from the McIntosh Power Plant and sent to the 1,400-ac (570 ha) wetland treatment system. TECO has agreed to use approximately 5 mgd (220 L/s) from the wetland treatment system, which is currently being discharged to the Alafia River and ultimately Tampa Bay. TECO's use of the reclaimed water will offset groundwater use and reduce nitrogen loading to Tampa Bay.

The second source of reclaimed water is the Polk County Southwest Regional WWTP. A separate transmission main will be constructed from the WWTP to connect to the transmission main being constructed from the Lakeland wetland treatment system to the Polk Power Station. It is anticipated that Polk County will initially provide 1 mgd (44 L/s) for use at the Polk Power Station, reclaimed water flows could increase to 2 mgd (90 L/s) by 2030 as wastewater flows continue to increase.

The third source is from the city of Mulberry, with approximately 0.5 mgd (22 L/s) of reclaimed water initially being provided from its WWTP for use at the Polk Power Station. Similar to the Polk County portion of the project, a separate transmission main will be constructed from the Mulberry WWTP and connected to the transmission main from the Lakeland wetland treatment system to the Polk Power Station.

Water Quality Standards and Treatment Technology

Water from Lakeland and Mulberry meets advanced waste treatment standards required for surface water discharge (Section 403.086, F.S.). In addition to high level disinfection, the following is required on an annual average basis:

- biochemical oxygen demand (BOD) less than 5 mg/L
- total suspended solids (TSS) less than 5 mg/L
- Total nitrogen less than 3 mg/L
- Total phosphorus less than 1 mg/L

Project Funding and Management Practices

The project is possible, in part, from funding allocated by SWFWMD through its Cooperative Funding Initiative program. The district and TECO entered into an agreement in 2009 for design and construction of approximately 15 miles (24 km) of reclaimed water transmission main, a pump station, and additional treatment. The anticipated cost is $72.7 million, and SWFWMD has been requested to reimburse TECO for up to half the cost. Because this project is a component of the West-Central Florida Water Restoration Action Plan, an implementation plan for components of the SWUCA Recovery Strategy, additional funding in the amount of $3.3 million has been allocated from the state. The project is under way and construction is expected to be complete in 2014.

TECO and the city of Lakeland have entered into a 30-year service agreement for delivery of reclaimed water, which was also a condition of the water use permit issued by SWFWMD to the city of Lakeland. As a result, the district was able to issue a 20-year water use permit to Lakeland. This is significant because SWFWMD has generally not issued 20-year water use permits for traditional sources in stressed water resource areas such as the SWUCA. This set the stage for a 20-year water use permit to also be issued to Polk County for its Southwest Regional Utility Service Area.

Successes and Lessons Learned

The RRWPI has resulted in a public-private partnership enabling TECO to continue plans for expansion at its Polk Power Station, while reducing its reliance on groundwater for cooling. Reclaimed water that will be used will no longer be discharged to surface waters, also benefiting Tampa Bay by reducing nitrogen loading. Maximizing the beneficial use of reclaimed water ensures that the water resources of the SWUCA can continue to recover. Most importantly, the RRWPI has provided opportunity for the partners, and other stakeholders, to identify uses for reclaimed water that can offset use of limited groundwater supplies, allowing the recovery of the resource, while meeting growing water needs.

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The City of Altamonte Springs: Quantifying the Benefits of Water Reuse

Author: David Ammerman, P.E. (AECOM)

US-FL-Altamonte Springs

Reclaimed Water and Potable Water

Potable water systems experience demands for drinking water, car washing, irrigation, and many other uses. Design of potable water delivery systems are also subject to fire flow requirements, which provide capacity in excess of routine water demands. This collection of uses and design requirements dilutes the impact of any one use on seasonal and diurnal patterns associated with that demand; the opposite is often true of reclaimed water systems. In many nonpotable reclamation systems, reclaimed water is used almost exclusively for irrigation and influences of irrigation on hourly, daily, and monthly demands dominate in these systems.

A second, important difference between potable and reclaimed water supplies is the nature of the source. In Florida, most utilities derive potable water from groundwater sources that are vast with respect to the short-term water supply demands. Reclaimed water supplies, on the other hand, are limited to wastewater flows on a given day. To complicate matters, wastewater flows vary considerably throughout a day and on an annual basis, and these variations are often opposite of variations in irrigation demands.

A 5-year historical water-use record for the City of Altamonte Springs in central Florida (**Figure 1**) shows seasonal peaks and valleys typical of municipal water demands in the area. However, unlike most cities, Altamonte Springs operates an extensive urban reuse system and can track water uses by source. The blue area at the base of the bar chart reflects average monthly potable water demands. Because a majority of the city has reclaimed water available for outside uses, it is reasonable to assume that potable water use that remains is primarily within homes and commercial units. The purple area indicates reclaimed water flows from the city's water reclamation facility into a dual distribution system for use as irrigation. In addition to these two local sources, the city has found it necessary to augment its reclaimed water system in

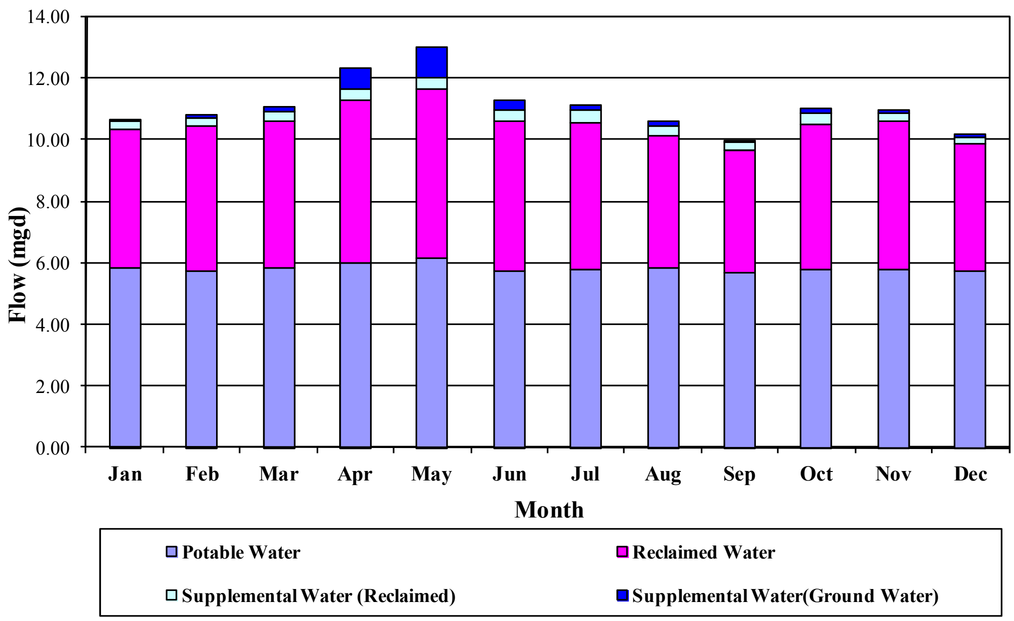

Figure 1
Average monthly water use by source

periods of peak irrigation demand to avoid shortages. The supplemental water sources include reclaimed water from a neighboring utility, raw groundwater supplies, and surface water.

It is worth considering the variability in potable and reclaimed water demands in the City of Altamonte Springs in more detail. Overlays the 5-year average monthly demands for both potable and reclaimed water are provided in **Figure 2**. It is apparent that seasonal variability in potable water demands is less than that in the reclaimed water system, suggesting that implementation of an urban reuse system has been successful in transferring seasonal variations in water demands associated with irrigation from the potable water system to the reclaimed water system. Undoubtedly, this has resulted in a reduction in the maximum-day and peak-hour demands for potable water, which in theory could be translated into reducing the design criteria used for max day water treatment capacity and peak-hour pumping facilities.

Conservation of Potable Supplies

Given the time, effort, and expense of implementing dual distribution projects, consideration for the expected gains is warranted. How well do these systems work in reducing the use of potable water?

Potable water use in Altamonte Springs, from 1975 to 2010, (**Figure 3**) shows a continuous increase until 1989; the decline in potable demands, despite continued population growth corresponds to implementation of the dual distribution system. The continued decline in demand correlates to expansion of the system. The city has also implemented a conservation program and by 2010, potable water demands were back to 1979 levels, such that the per capita use of potable water is currently 30 percent less than prior to construction of the reuse system. Concurrently, the city was able to reduce the volume of effluent discharged to surface waters to approximately 20 percent of their flows.

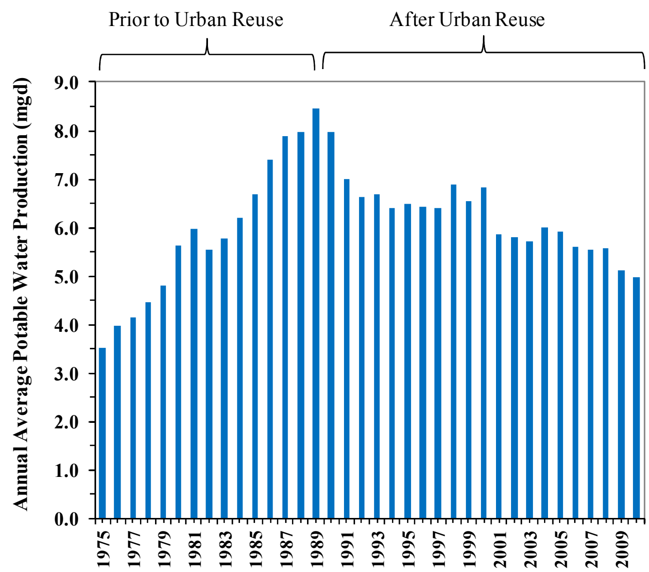

Figure 3
Potable water use

Lessons Learned

Implementation of a dual distribution system within the City of Atlamonte Springs has allowed the city's potable water demand to reach levels last seen in 1979, despite an increase in population. The use of a dual distribution system has resulted in the reclaimed water system bearing the majority of the seasonal variations in demand, which could theoretically result in reduced design criteria.

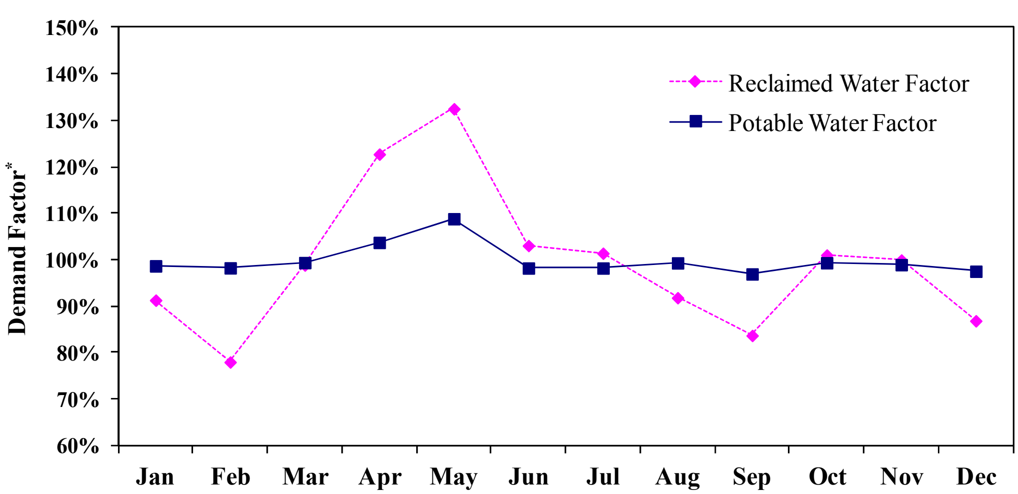

Figure 2
Comparison of seasonal variations in reclaimed and potable water demands

Evolution of the City of Clearwater's Integrated Water Management Strategy

Authors: Laura Davis Cameron, BSBM; Tracy Mercer, MBA; Nan Bennett, P.E.; and Rob Fahey, P.E. (City of Clearwater Public Utilities)

US-FL-Clearwater

Project Background

Clearwater, a coastal Florida city straddled by Tampa Bay and the Gulf of Mexico, distributes potable drinking water to more than 110,000 residents and nearly 800,000 visitors annually (Clearwater, 2007). As a coastal Florida city, only about 33 percent of the potable water demand, which was 11 mgd (480 L/s) in 2010, can be met with local sources; excess demand is met by importing water from surrounding counties, and purchases from some sources are at a high rate. The excess demand is purchased and imported at a higher rate from Pinellas County.

Clearwater realized the need to decrease water demand through conservation and use of reclaimed water, which also reduces treated wastewater effluent discharge to local surface waters. Education and incentive programs sparked the genesis of Clearwater's conservation plan, which included low-flow toilet rebates, high-efficiency shower heads, and faucets. Education moved to 5th grade classrooms, where students learned about conservation and brought home conservation devices for family use. This multi-level water use and conservation plan was the beginning of Clearwater's Integrated Water Management Strategy (IWMS), formally adopted in 2007 with specific goals:

- Conserve limited water supplies
- Preserve drinking water source
- Produce more drinking water locally
- Protect coastal environment
- Manage the rising cost of potable water

The prelude to the program, which began in 1990, provided reclaimed water to local golf courses for irrigation. Initially, these users were not charged but later, a bulk rate was established, and a metered bulk rate was created for larger, interruptible customers. In 1998, residential customers were added. Expansion strategies to retrofit areas of high potable water irrigation demand (500 gpd [1.9 m^3/d] or higher) were included in the Reclaimed Water Master Plan. Addition of residential projects and interconnection of the city's three wastewater treatment plants provides a city-wide system serving over 3,000 metered accounts.

Expansion of the Reclaimed Water System

As part of the IWMS, Clearwater is expanding use of reverse osmosis (RO) technology and considering groundwater recharge (GWR), a form of indirect potable reuse (IPR). The GWR project includes construction of a water purification plant on the WRF site to supply 3 mgd (131 L/s) of highly treated water to recharge the Floridian Aquifer. Clearwater's GWR project is now in pilot demonstration to optimize treatment and verify groundwater injection. Conditions are favorable to support GWR and additional withdrawal of groundwater for potable use in the future. GWR's further benefits to the IMWS are projected as increasing permitted raw water supply, reducing bulk potable water purchases, reducing surface water discharges, and complying with total maximum daily load (TMDL) requirements and improving sustainability of the water resources.

Clearwater prides itself in its holistic view of water resources and technologies, both traditional and advanced, from wells to purchased water, conventional treatments to reverse osmosis, and reclaimed to potable reuse utilizing groundwater replenishment. **Figure 1** illustrates the reduction in potable water demand over the past 2 decades due to conservation, education, and IWMS steps. Clearwater hopes to continue this trend in potable water use reduction.

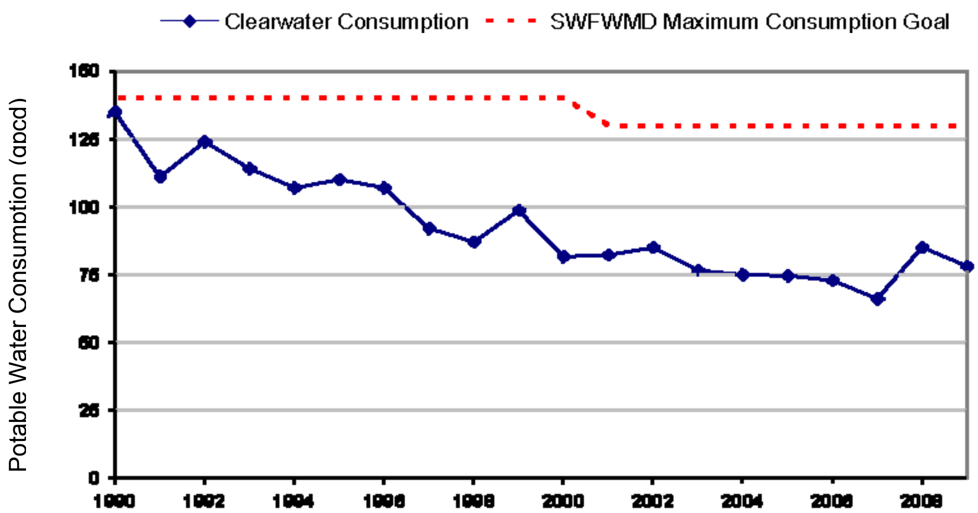

Figure 1
Potable water consumption compared to District goals

Public engagement is critical as Clearwater implements its IWMS plan. A Community Partnership Program, launched in 2008, includes communication with leaders in business, civic groups, and other community stakeholders. Clearwater Public Utilities also chairs meetings with local municipalities' utility leaders to discuss regulations, technologies, and other issues.

Capacity and Type of Reuse Application

Clearwater is built-out with minimal growth reflected by a flat water demand; **Figure 2** shows the proportion of total potable demand eliminated by the use of reclaimed water.

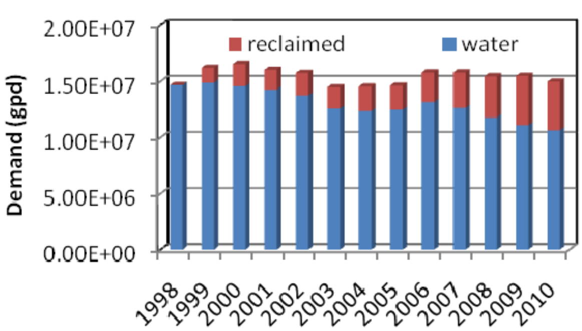

Figure 2
Total water demand

Project Funding

IWMS considers all water resources, and funding has been derived from rate payers and cooperative grants from the Southwest Florida Water Management District for infrastructure. From 1998 and projected through 2014, infrastructure costs are expected be $56.7 million. Wellfield expansion is $6 million, water treatment plant upgrades will be $46.7 million, and GWR will cost $29 million in capital improvement costs; all are slated for 50 percent grant funding.

Successes and Lessons Learned

Expansion of the reclaimed water system was based upon a cost-benefit ratio determined by weighing the cost to bring water to a certain geographic area compared to how much reclaimed water use could be expected. The more lushly landscaped neighborhoods ranked highly as well as coastal areas that had limited availability to fresh well water. As an incentive to connect and utilize the reclaimed water system, an availability charge was added to the utility bill of those properties that had opted to not connect to the reclaimed water system after completion of construction in their service area.

The city had to overcome a conflict in its ordinance, allowing private well owners and those irrigating from lakes and ponds to be exempt from the reclaimed water system. As the master plan moved inland from coastal neighborhood service areas, the number of well owners increased, and the payback period would have made some projects unsuccessful had the old ordinance remained. A modification was made in response to the definition and implementation of the IWMS. The strategy outlines the hydrologic cycle and illustrates that well owners draw from either the surficial or the Floridian aquifer, which is the same source that provides the city with its drinking water. Thus, if lower quality water is available for irrigation, it should be used first, allowing for best use of local drinking water resources.

References

City of Clearwater, 2007. Clearwater's Integrated Water Management Strategy. Clearwater Public Utilities, 1650 N. Arcturas Ave., Bldg C, Clearwater, FL 33765.

Assessing Contaminants of Emerging Concern (CECs) in Cooling Tower Drift

Authors: James P. Laurenson (HEAC) and Edward L. Carr (ICF International)

US-FL-Turkey Point

Background

One of the primary industrial uses of reclaimed water is for recirculating evaporative wet cooling at electric power generation plants. With power generation expected to increase by about 18 percent in the United States and close to 70 percent globally between 2012 to 2035 (EIA, 2011), the use of reclaimed water is expected to increase as fresh water supplies for cooling declines.

Wet cooling at power plants typically results in the majority of cooling water leaving the plant via evaporation and aerosolization, often collectively known as drift. Drift, and any associated microorganisms, particulate matter (PM), or chemicals, can be inhaled by plant workers and the public. Other exposures might occur, such as through dermal contact or ingestion, but inhalation is expected to be the dominant exposure pathway. If exposure is greater than health-based thresholds, such as minimum infective doses for pathogens, PM standards, or minimal risk levels (MRLs) for chemicals, then risks could be considered significant and require mitigation through additional treatment or greater setback distances from the towers. While considerable attention in recent years has been given to the risks and mitigations related to microorganisms and PM levels in cooling tower drift at power plants, less attention has been given to contaminants of emerging concern (CECs), which are present in reclaimed water.

Capacity and Type of Reuse Application

Florida Power & Light Company (FPL) and Miami-Dade County (MDC) have been collaborating on an agreement to use reclaimed water as the primary supply for cooling for two new nuclear power units (Units 6 and 7) that are proposed for completion in 2023 at the Turkey Point, Fla., facility (FPL, 2011). The reclaimed water also would be used for cooling an existing natural gas combined-cycle steam electric generating unit (Unit 5) that currently uses groundwater for cooling. Saltwater from Biscayne Bay would provide a backup cooling water supply for all three units. Waste heat would be dissipated by mechanical draft cooling towers. Draw-down (blowdown) wastewater from these towers would be discharged through the use of deep injection wells to the lower Floridan aquifer.

The use of reclaimed water at Units 5, 6, and 7 would be in addition to the current primary cooling system in place for existing units. The current system is a closed-loop set of approximately 5,900 ac (2,390 ha) of canals used for two natural gas/oil steam electric generating units (Units 1 and 2) and two existing nuclear units (Units 3 and 4). Because the canals are not lined, groundwater flow interacts with the hypersaline water in the canals, which has become a source of concern for this ecologically sensitive area within the Everglades watershed. Further, as part of a broader water resources management plan, MDC must increase its use of reclaimed water to more than 170 mgd (7450 L/s) by 2025. Thus, an MDC resolution was passed that prevents FPL from applying for any water withdrawals from the Biscayne aquifer and encourages the use of reclaimed water.

As part of the Environmental Impact Statement (EIS) being developed by the Nuclear Regulatory Commission (NRC) for the application process, the impact of the reclaimed water on the environment and human health is being assessed (NRC, n.d.). One area of concern highlighted by public comments is inhalation of cooling tower drift by workers and the public (NRC, 2010).

Water Quality Standards and Treatment Technology

Under the current plan, MDC would produce and deliver up to 90 mgd (3940 L/s), or 75 mgd (3290 L/s) on average, of reclaimed water to Turkey Point (FPS, 2011). The reclaimed water would be treated using high-level disinfection in accordance with Florida Department of Environmental Protection (FDEP) regulations (Florida Administrative Code 62-610.668). Reclaimed water would be conveyed 9 mi (14 km) via pipelines from to the Turkey Point plant property where an onsite FPL treatment facility would further treat reclaimed water to reduce iron, magnesium, oil and grease, total suspended solids, nutrients, and silica to suitable concentrations for the circulating water system.

For each of the two proposed nuclear power units, the cooling system would consist of three mechanical draft cooling towers and an open channel (flume) with a pump intake structure. Heated cooling water would flow through return piping to the mechanical draft cooling towers where heated cooling water would be circulated and heat would be transferred to the ambient air via evaporative cooling and conduction. After passing through the cooling tower, the cooled water would collect in the tower basin and be pumped back to the power unit, completing the closed cycle cooling water loop.

Makeup water from the FPL reclaimed water treatment facility would compensate for water losses during plant operation from drift and blowdown. Six circulating water cooling towers for Units 6 and 7, plus the existing Unit 5 towers, are estimated to result in evaporation and aerosol water losses of approximately 50 mgd (2190 L/s) during normal plant operation, or approximately 67 percent of the makeup water.

Exposure Modeling

An Environmental Report (ER), often used as a reference for developing an EIS, has been developed for Turkey Point (FPL, 2011). In the ER, the EPA CALPUFF and AERMOD dispersion models were used to evaluate cooling tower plume behavior. Five years (2001 through 2005) of hourly meteorological data from the Miami International Airport were used, along with physical and performance characteristics of the mechanical draft cooling towers. In the current version of the ER, CEC exposure has not been assessed, in large part because the additional treatment that FPL will apply to the reclaimed has yet to be fully designed. In the meantime, NRC is examining as a surrogate analysis the expected salt deposition described in the ER for the scenario whereby saltwater from Biscayne bay would be used as a backup cooling water source for Units 6 and 7. **Figure 1** illustrates the predicted salt deposition near the plant when these units would be using salt water only. Non-volatile CECs thus also are likely to be deposited in a similar fashion, i.e., with the majority of deposition occurring in the immediate vicinity of the cooling towers. Screening level modeling of CECs exposure is being conducted by NRC and will become publicly available when the draft EIS is published in the near future.

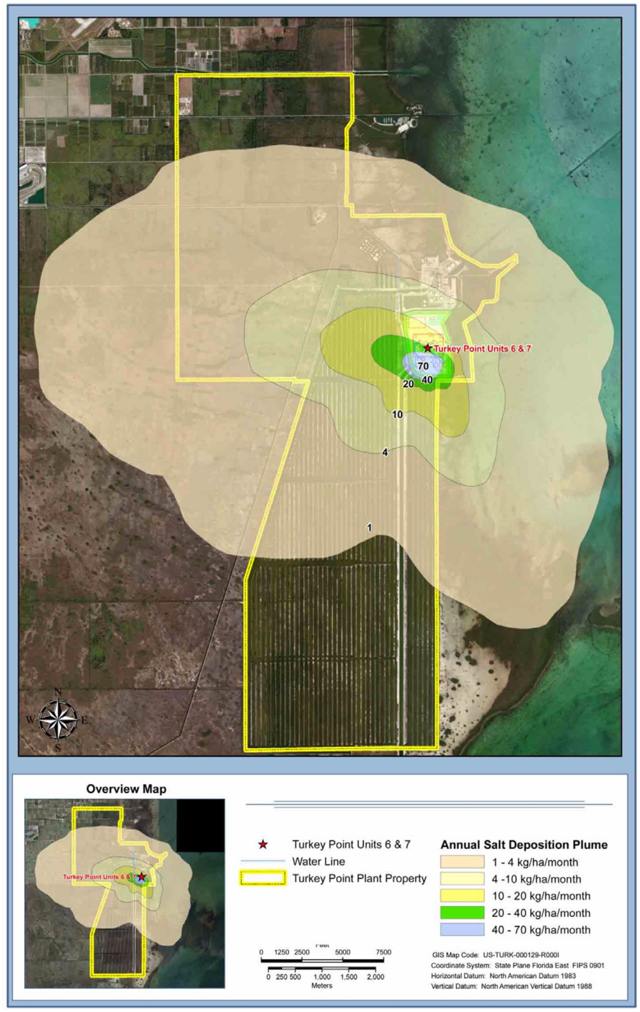

Figure 1
Surrogate for CECs deposition: predicted monthly salt deposition from use of only Biscayne Bay water for backup cooling (Photo credit: FPL, 2011)

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Sustainable Water Reclamation Using Constructed Wetlands: The Clayton County Water Authority Success Story

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US-GA-Clayton County

Project Background

The key water management challenges in Arizona are increasing demands for water, fully allocated existing water resources, and groundwater depletion. Groundwater depletion, or overdraft, is a result of excessive groundwater pumping and is problematic for numerous reasons, including its environmental impacts. Groundwater sustains rivers, streams, lakes, and wetlands providing the riparian habitat for wildlife. In the 19th century, wetlands, marshlands or cienegas, were common along rivers in Arizona; however, heavy pumping of groundwater beginning in the mid-20th century led to dewatered rivers and streams and loss of riparian ecosystems (Glennon, 2002).

Just south of Atlanta, Georgia, the Clayton County Water Authority (CCWA) provides water, sewer, and stormwater services to more than 280,000 county residents and portions of adjacent counties. Since its creation in 1955, CCWA's need for water supply and wastewater treatment has increased steadily with population growth, despite limitations on water supply and the assimilative capacity of the small local streams. CCWA began water reuse in the 1970s when a land application system (LAS) was selected as a way to increase water supplies for its growing population while minimizing the stream impact of wastewater discharges.

CCWA operated two LASs for almost 30 years as the County matured into a densely developed urbanized area. In response to the need for additional wastewater treatment capacity and as part of CCWA's master planning process, numerous wastewater treatment alternatives were evaluated. With their consultant, CCWA reviewed existing treatment wetlands in Georgia (Inman et al. 2001) and identified constructed wetlands as the most reliable and sustainable option for both treatment and water supply augmentation (Inman et al., 2000).

CCWA constructed its first wetland reuse system in the southern end of the county. The Shoal Creek LAS was converted into a series of treatment wetlands (Panhandle Road Constructed Wetlands, **Figure 1**) and the existing wastewater treatment plant was replaced with an advanced, biological treatment plant (Inman et al., 2003). Following this success, CCWA began developing a larger wetlands complex on the E.L. Huie Jr. Site (**Figure 2**). Wetland construction was phased with portions of the existing LAS taken out of service and replaced with wetlands.

Figure 1
The Panhandle Road Constructed Wetlands (Photo credit: Aerial Innovations of Georgia, Inc.)

Figure 2
The E.L. Huie Constructed Wetlands (Photo credit: Aerial Innovations of Georgia, Inc.)

Capacity and Type of Reuse Application

The wetlands consist of a series of interconnected, shallow ponds planted with native vegetation. The cells follow the site topography to allow water to flow passively through the wetlands by gravity. Even though a portion of the water in the wetlands is expected to infiltrate into the groundwater supply, the vast majority flows into two of CCWA's water supply reservoirs, Shoal Creek and Blalock Reservoirs. Water typically takes 2 years under normal conditions to filter through wetlands and reservoirs before being reused; the detention time is less than a year under drought conditions (Thomas, 2005).

The Panhandle Road Constructed Wetlands consists of three multi-cell treatment trains, in parallel with a treatment capacity of 4.4 mgd (190 L/s) (CCWA, 2011). The E.L. Huie Constructed Wetlands consist of nine multi-cell treatment trains built in four phases with a total treatment capacity of 17.4 mgd (760 L/s) (**Table 1**).

Table 1 Characteristics of constructed wetland systems

System	Date	Sites	Wet Area (ac)	Capacity (mgd)	Total Capacity (mgd)
Panhandle Road Constructed Wetlands	2002	North, Central, South	53	4.4	4.4
E.L. Huie Constructed Wetlands	2005	G	54	3.5	17.4
	2006	D, E, F	40	2.6	
	2007	B, C, H, I	47	3.2	
	2010	A	123	8.1	

Water Quality Standards

Both wetland systems polish highly treated effluent from primary and secondary wastewater treatment facilities that include nutrient removal followed by disinfection. These treatment processes provide a multiple-barrier approach to water reclamation and enhance the removal of nutrients, microbial contaminants, and other trace organic compounds, providing a safe and secure supply of water. In addition, the constructed wetlands buffer the reservoirs in the unlikely event of a treatment plant upset.

A National Pollutant Discharge Elimination System (NPDES) permit was received for the constructed wetlands following an extensive review and approval process through the Georgia Department of Natural Resources (GAEPD, 2002). The first step in the process was for the Georgia Environmental Protection Division to set discharge limits by determining the allowable pollutant application to the wetlands. Both systems are required to comply with the waste load allocations established in their NPDES permit. These systems have proven to exceed their treatment expectations and effluent quality (**Table 2**).

Table 2 NPDES discharge limits

Parameter	Panhandle Road Constructed Wetlands		E.L. Huie Constructed Wetlands	
	Limit (mg/L)	Actual[3] (mg/L)	Limit (mg/L)	Actual[3] (mg/L)
Flow (MGD)	monitor only	1.35	monitor only	14.45
BOD_5	10/15[1]	1	10/15[1]	3
TSS	30/45[1]	4	15/22.5[1]	5
NH_3-N	4/6[1] (May-Oct.) 8/12[1] (Nov.-Apr.)	0.03	1.4/2.1[1]	0.06
TP	2/3[1]	0.59	0.6[2]	0.24

[1] Monthly/weekly averages
[2] Annual average monitored only at the lake discharge
[3] Average effluent data for 2011

With the completion of the largest phase of constructed wetlands in the fall of 2010, CCWA is able to recycle as much as 65 percent of daily water use into their existing reservoirs. This system augments CCWA's water supply and reduces the need to withdraw water from the small streams that flow out of the county. During Georgia's second worst drought on record, this system sustained raw water reserves at 77 percent of capacity or greater. CCWA also has documented reductions in micro-constituents such as pharmaceuticals, hormones, and pesticides (CCWA, 2011).

Funding and Management Practices

CCWA's innovative water supply system and watershed protection program have required a significant commitment of resources. CCWA built the wetland system on land first purchased for the LAS in the late 1970s. Funding for the land purchase and construction of the LAS was primarily through the Federal Construction Grants program, under the Clean Water Act. Wetland cells were built using low-interest loans from State Revolving Funds, bonds, and rate payer revenue. Approximately four cents of every dollar collected for water and sewer service is set aside for watershed protection (American Rivers, 2009).

The transition from LAS to wetlands has saved energy costs through reduced pumping. The wetlands system is less expensive to maintain and operate and has allowed CCWA to reduce maintenance staff, equipment, and materials. Rather than maintaining miles of irrigation pipes and numerous valves and pumps, routine maintenance consists primarily of checking hydraulics and vegetation management.

Successes and Lessons Learned

CCWA has been recognized as one of the most innovative and well-managed utilities in the southeastern United States. Most recently, the American Academy of Environmental Engineers awarded CCWA's wetlands projects the "Excellence in Environmental Engineering" award for environmental stewardship. This approach to total water management has demonstrated that a sustainable water supply can be developed for a dense urban area where fluctuations in rainfall and water supply are common (Patwardhan, et. al, 2007). The wetlands treatment system and indirect reuse program have lowered CCWA's need for additional reservoir storage and water withdrawals.

The constructed wetlands have proven to require much less land, energy, and maintenance than the irrigation systems while sustainably using natural systems for water reclamation. Environmental benefits include CCWA's use of the constructed wetlands facilities as an educational tool for customers to explain the importance of protecting water resources. CCWA was recognized by American Rivers as one of America's "Water Smart" communities in 2009 and has received many awards for operations and innovation (CCWA and CH2M HILL, 2011).

This project is also an example of publicly accepted indirect potable reuse. CCWA has been polishing treated wastewater using natural treatment systems for more than 30 years and has actively communicated the wetlands reuse plan to the community. CCWA uses the constructed wetlands as an educational tool for customers to explain the importance of protecting water resources and hosts numerous community events. The wetlands also support the goals of land conservation. CCWA currently manages a wetlands education center that is open to the public to provide its customer base with information about how CCWA incorporates total water management in its day-to-day operations.

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On the Front Lines of a Water War, Reclaimed Water Plays a Big Role in Forsyth County, Georgia

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US-GA-Forsyth County

Project Background or Rationale

Forsyth County, Ga., lies on the west bank of one of the most controversial bodies of water in the country—Lake Lanier. Since 1989, Lake Lanier has ridden the front lines of the battle between Georgia, Alabama, and Florida dubbed the "Water Wars." Lake Lanier is the uppermost of four major water bodies along the Chattahoochee River system that runs from the North Georgia Mountains, through Atlanta and Columbus, Ga., the Florida panhandle, and eventually discharging to the Gulf of Mexico. Given that over three million people in Atlanta currently rely on Lake Lanier as a source for drinking water, and the fact that this number is expected to grow by 55 percent by 2035, downstream users are fighting to maintain flows in the rivers. The U.S. Army Corps of Engineers (USACE), who controls the lake system, has temporarily placed a cap on new water withdrawals from Lake Lanier until the legal fight has run its course.

The Forsyth County Department of Water and Sewer currently serves over 46,000 water customers and completely relies on raw or purchased water from neighboring utilities. The county has repeatedly requested a USACE surface water withdrawal from Lake Lanier and been denied each time. Throughout the 2000's Forsyth County has maintained its status as one of the top 5 fastest growing counties in the nation having grown from a population of 98,367 in 2000 to 175,511 in 2010. In order to meet the growing water demands for an ever increasing population, the county evaluated alternatives for water supply including increased water conservation and reuse.

In the late 1990's Forsyth County realized it needed a centralized wastewater treatment plant to support rapid development and the projected growth. During the planning phase, the county understood the value that reclaimed water could play with respect to minimizing its potable water demand. The county embarked on design and construction of one of the first membrane facilities in Georgia. In addition to the new facility, a reclaimed water pipeline leading to a land application system was constructed. In 2004, Forsyth County completed construction of the Fowler Water Reclamation Facility (WRF) and reclaimed water pipeline. Soon after startup, the county implemented a reuse program that included construction standards, public information, and applications and end user agreements for connecting to the system. Today, Forsyth County serves 16 major end users with reclaimed water including several parks, schools, shopping centers, golf courses, a bus wash facility, neighborhood green space, and a rock quarry.

In 2011, Forsyth County purchased the James Creek WRF whose reuse quality effluent is also discharged into the common 20-in (50-cm) distribution main. With connection of the James Creek WRF an additional 1 mgd (44 L/s) of capacity was added to the reclaimed water system.

Reclaimed Water Use and Climate

Reclaimed water has been widely accepted within the community with little to no opposition. Local residents are intimately familiar with the value of water, having suffered through two severe droughts during the 2000's when the state ordered a ban on all outdoor water use. Generally, the metro Atlanta area receives over 50 in (127 cm) of rainfall per year. With such a high average rainfall, most communities are adorned with lush hydrophilic landscapes. When the outdoor watering bans were implemented, the interest in reuse increased.

During the summer months, Forsyth County distributes approximately 700,000 gallons (2,650 m^3) of reclaimed water per day, but this is reduced to less than 20,000 gallons (76 m^3) per day during the winter months. Up to 100 percent of the reclaimed water is distributed to end users during summer month peak demands, thus Forsyth County is limited in the number of end users that it can serve until it receives additional wastewater from new development.

Capacity and Type of Reuse Application

The Fowler WRF current capacity to produce reclaimed water is 1.25 mgd (55 L/s) with a permit to upgrade the facility to 2.50 mgd (110 L/s) with the installation of additional membranes. The reclaimed distribution system pumps treated effluent from a 6 million gallon (22,700 m^3) ground storage tank through the 20-in (50-cm) pipeline to its end at a land application field where any unused reclaimed water is discharged. The 16 end user connections are scattered along the 11 mile pipeline route. The system is designed to maintain a minimum pressure of 20 psi (140 kPa) at the high point of the pipeline.

Reclaimed water in Forsyth County is generally supplied for irrigation however the school system utilizes reclaimed water for bus washing. Additionally, hydrants are provided in multiple locations for contractor use in dust control, paving, hydro seeding, etc.

Water Quality Standards and Treatment Technology

In Georgia, reclaimed water must undergo secondary treatment (30 mg/L BOD_5 and 30 mg/L TSS) followed by coagulation, filtration and disinfection, or equivalent treatment. The reclaimed water treatment criteria are summarized in **Table 1**.

Table 1 Georgia reclaimed water treatment criteria

Parameter	Criteria
BOD_5	≤ 5 mg/L
TSS	≤ 5 mg/L
Fecal Coliform	≤ 23 cfu/100mL monthly geometric mean, 100 cfu/100mL maximum per sample
pH	6-9 standard units
Turbidity	≤ 2 NTU

The Fowler WRF utilizes hollow fiber membrane filtration and UV disinfection to achieve reuse quality effluent. The James Creek WRF utilizes flat plate membrane filtration and UV disinfection.

Project Funding and Management Practices

Forsyth County constructed the Fowler WRF and 20-inch reuse pipeline with revenue bonds. The County sells reclaimed water for $1.75/1,000 gallons ($0.45/m^3), equivalent to half the potable rate, which it uses to repay its debt in conjunction with its water and sewer fees. Forsyth County has a designated representative from the water and sewer department in charge of managing end user accounts, providing public education to end users, overseeing system operations and performing cross-connection testing.

Institutional/Cultural Considerations

The public education program includes an in-person learning session after which the end user is required to satisfactorily pass a 20-question application test prior to connecting to the system. Open house style public information sessions have not been needed as the public is generally in favor of the reuse program.

Successes and Lessons Learned

The key factors for success for this project included the early considerations for sufficient reclaimed water storage to handle peak demands and the installation of infrastructure sized for the future growth of the system.

A few lessons have been learned from the management of a reclaimed water system. First, when connecting any new user to the system, a cross-connection test should always be performed by the utility. Cross-connection tests should also be performed by the end user on an annual basis. Second, consideration should be made to maintain a minimum pressure in the distribution main to meet pressure requirements of an irrigation system. Otherwise, end users will require a booster pump station to increase system pressures.

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Recovery and Reuse of Beverage Process Water

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US-GA-Coca Cola

Project Background or Rationale

In the face of increased water scarcity, water costs, growth projections, and other drivers, Coca-Cola bottling plants sought to further improve their water use efficiency. This led to the pursuit of a scientifically rigorous, widely applicable water recovery and reuse approach that could be used by virtually any of the nearly 900 bottling plants in the Coca-Cola system.

Capacity and Type of Reuse Application

Water is typically recycled for applications such as floor washing, landscape irrigation, etc. Though used for non-product activities and applications, the quality of this highly purified water enables its use for a higher degree of purpose, such as indirect potable reuse.

Water Quality Standards and Treatment Technology

The framework for this project was based on the water safety plan approach consisting of: source vulnerability assessment, source water protection plan, system design, operational monitoring, and management plans.

The system design takes beverage process wastewater and further purifies it to high standards for use in non-product applications. This process uses a combination of technologies: chemical treatment, biological treatment in a membrane bioreactor, ultrafiltration (UF), reverse osmosis (RO), ozonation, and ultraviolet (UV) disinfection. These technologies are described below.

- Secondary biological treatment.
- UF uses a pressure-driven barrier to remove suspended solids and pathogens.
- RO forces water through membranes under high pressure, removing some dissolved chemicals and other compounds to produce water with very high purity and low total dissolved solids.
- Ozonation destroys microorganisms and oxidizes organic materials.
- Medium pressure UV light disinfects water by rendering microorganisms inactive.
- Mixed oxidant disinfection.
- Chlorination at several points, as appropriate for disinfection and oxidation.

The choice of treatment technologies would be dependent upon the characteristics of the beverage waste stream and the planned point-of-use of the water. Some of these technologies effectively remove contaminants, such as heavy metals, while others disinfect. Further, the system employed significant continuous monitoring, automation, and controls.

Two water recovery options were assessed: in-process treatment and process waste water treatment. The in-process reuse option involves the manufacturing process wastewater stream being treated and reused in the same manufacturing function before it reaches the wastewater treatment system, reducing the fresh water requirements for the manufacturing function. The wastewater stream from a given manufacturing process is sent directly to advanced treatment, bypassing the plant-wide wastewater treatment process. After passing through appropriate treatment the process waste stream is recycled back into the process from which it originated. The quality of the water meets the water standards required for the process.

In the process wastewater treatment configuration, the wastewater streams from all manufacturing processes are sent to the existing wastewater treatment system. A portion of the treated effluent is then sent through required advanced treatment steps and recycled back to one or more manufacturing processes. This option provides the greatest quantity of reuse water because it aggregates manufacturing waste streams (but not sanitary or cafeteria waste streams) from the entire plant. **Figure 1** shows both options for in-process reuse and advanced process wastewater treatment.

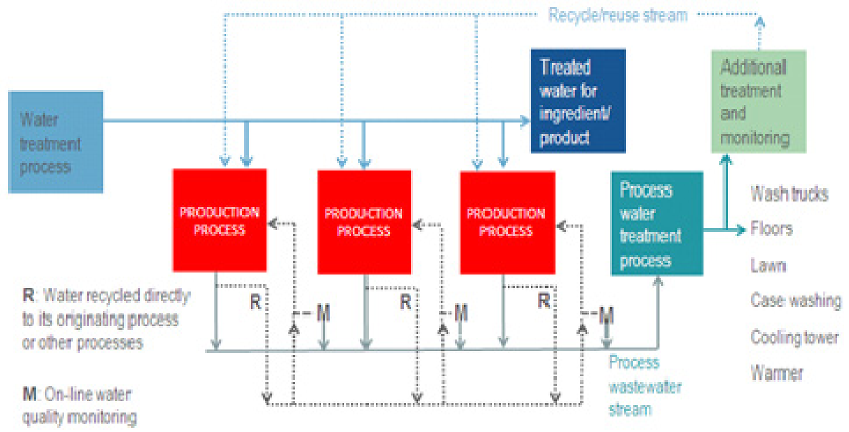

Figure 1
Water recovery schematic of The Coca-Cola Company

Project Funding and Management Practices

On-going sustainability activities are imperative to our business and community. The Coca-Cola Company is implementing a holistic approach to water stewardship, recognizing that water must be considered in the greater context of political, societal and ecological dynamics (TCCC, 2012). Industry-sponsored guidelines for the implementation of water reuse in the beverage industry are currently in development (ILSI, 2012). Future work will include measures to reduce the overall impact of energy usage. By implementing this recycle and reuse model, The Coca-Cola Company will continue to reduce its water usage.

Successes and Lessons Learned

The highly purified water from this commercial trial consistently met internal and external regulatory standards and specifications. Samples were analyzed throughout the process treatment train to assess the efficiency and capabilities of each step of the treatment process. The quality of the final effluent water was crucial to the success of the commercial trial.

Samples at each intermediate process as well as the final effluent were tested extensively by internal and external laboratories. Analyses by the third party labs were conducted for 126 parameters, including: inorganics, synthetic organics, “semivolatile organics,” volatile organics, disinfection related chemicals (including trihalomethanes), pesticides, and microbial analysis for *E. coli*.

The analytical results of final treated water were compared to internal standards, WHO guidelines for drinking water, EPA drinking water regulations, and applicable local regulations per plant locations. Meeting drinking water quality specifications was considered to be essential for much of the recovered water even though the water was only reused for non-product activities. The results (**Table 1**) comply with all parametric limits: 1) chemical, 2) microbial, and 3) operational. The analysis indicated all results were below specification limits or non-detected.

Table 1 Summary of six months of process performance indicators (sample frequency every 4 hours)

Parameter	Internal Specification	Average	Standard Deviation
Alkalinity	85 mg/mL as $CaCO_3$	27.72	3.02
pH	4.9 minimum	6.32	0.68
TDS	500 mg/l	34.91	4.63
Turbidity	0.3 NTU	0.11	0.02
TOC	0.5 mg/L	0.17	0.03
Color	Sensory	Acceptable	
Odor	Sensory	Acceptable	

In addition to microbial analysis of the renewed water, the plant was required to assess the microbial levels at the start and end of each process step. The plant analyzed for total plate count (TPC) and coliforms; an external laboratory performed the analysis for *E. coli*. Neither coliforms, nor *E. coli* were detected in any of the samples. The results (**Table 1**) of our 6 months of monitoring process performance indicators every four hours demonstrate the effective operation of each process step of the wastewater recovery and reuse system.

The commercial trial conducted in this study successfully demonstrated the capability to recover and treat process wastewater to the highest quality standard using a multi-barrier approach with advanced treatment technologies.

The treatment system was operationally stable and consistently produced highly purified water that met all physical, chemical, and microbial specifications. This highly purified water meets the stringent drinking water guidelines and requirements of World Health Organization, the European Union, EPA, the Coca-Cola Company, as well as local regulatory requirements for each plant location.

Reclaimed Water Use in Hawaii

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US-HI-Reuse

Project Background or Rationale

Hawaii has been established a reclaimed water program over the past two decades. The program varies by county, based on specific drivers for water reuse. Hawaii has six major islands (Hawaii, Maui, Oahu, Kauai, Molokai and Lanai) and two smaller islands (Niihau and Kahoolawe) totaling 6,463 mi2 (16,740 km2) that comprise an island chain stretching northwest to southeast over a zone 430 mi (706 km) long. Each island has wet areas and dry areas with great surpluses in some areas and great deficiencies in others. Historically, there has been an overall abundance of water but the challenge has been one of distribution rather than a general water shortage. The majority of Hawaii's potable water sources are groundwater. A growing population is increasing stress on the sustainability of these limited groundwater resources. Almost 70 percent of Hawaii's potable water is used to irrigate agricultural crops, golf courses, and residential and commercial landscaping.

The state of Hawaii, the city and county of Honolulu (Oahu), the county of Maui (Maui, Lanai and Molokai), the county of Kauai, and the county of Hawaii are increasing water conservation and water reuse efforts to manage and preserve potable water resources. The Hawaii State Department of Land and Natural Resources Commission on Water Resource Management, in partnership with the U.S. Army Corps of Engineers, has determined that a water conservation plan for Hawaii should be established. Reclaimed water is anticipated to be a significant contributing component of the plan's policy and program development.

Regulatory Requirements

Explosive growth in Japanese visitors to Hawaii in the 1970's and 1980's spurred a corresponding increase in resort and golf course developments. The search for nonpotable water resources for resort golf course and landscape irrigation led to many inquiries to the Hawaii State Department of Health about the availability of reclaimed water for reuse. Thus, in the early 1990's the Hawaii State Department of Health deemed the state's existing wastewater regulations deficient in providing proper guidance for the treatment and beneficial use of reclaimed water, which led to the development of Hawaii's first reuse guidelines. The Hawaii "Guidelines for the Treatment and Use of Reclaimed Water" were issued in November 1993 and were adopted into Hawaii Administrative Rules Title 11, Chapter 62, Wastewater Systems. The guidelines were updated in May 2002 and re-titled the "Guidelines for the Treatment and Use of Recycled Water." The guidelines define three classes of recycled water as R-1, R-2, and R-3 water.

R-1 Water is the highest quality recycled water. It is treated effluent that has undergone filtration and disinfection and can be utilized for spray irrigation without restrictions on use.

R-2 Water is disinfected secondary (biologically) treated effluent. Its uses are subjected to more restrictions and controls.

R-3 Water is the lowest quality recycled water. It is undisinfected secondary treated effluent whose uses are severely limited.

Water Reuse Program

Although all six major Hawaiian Islands have reclaimed water projects, the existence or non-existence of reclaimed water programs varies by county. The county of Maui and city and county of Honolulu have committed significant resources to promote and develop their respective reclaimed water programs. The county of Kauai does not have a stated reclaimed water program. The county of Hawaii does not have a reclaimed water program.

County of Maui (Islands of Maui, Molokai and Lanai)

The county of Maui consists of three islands; Maui, Molokai, and Lanai and are located to the northwest of the Big Island of Hawaii. The county's water reuse efforts are led by its municipal wastewater agency, the Wastewater Reclamation Division. The first feasibility studies were conducted in 1990 and led to a long-term program to reuse millions of gallons of reclaimed water, previously disposed into injection wells. The program began with passing of a mandatory reclaimed water ordinance. In 1996, the county then adopted its own County of Maui Rules for Reclaimed Water Service incorporating the State of Hawaii's Guidelines for the Treatment and Use of Recycled Water, the State of Hawaii's Water System Standards and Chapter 11-62 of the Hawaii Administrative Rules. To date, Maui County provides reclaimed water for irrigation, toilet flushing at the National Park Service, and dust control. Currently, landscape irrigation using reclaimed water occurs at five golf courses, five community parks, the elementary school, intermediate school, public library, fire station and fire system, community center, four multi-family housing units, highway shoulders and medians, a shopping center, landscape at commercial buildings, seed corn crop irrigation, green waste composting/vermiculture, and constructed wetlands.

County of Honolulu (Island of Oahu)

Honolulu is located on the Island of Oahu northwest of Maui County's Islands. The municipal drinking water agency on the Island of Oahu is the Honolulu Board of Water Supply (BWS). The Honolulu BWS expects to meet Oahu's water demands through 2030 through an integrated strategy of combining existing water system capacities, planned infrastructure improvements and watershed protection strategies. As part of Oahu's integrated water resources plan, the Honolulu BWS has taken the lead on water reuse efforts on the island. With a heavy military presence on Oahu, the various military branches, in collaboration with the state of Hawaii and the Honolulu BWS, are implementing energy and water conservation programs. In 2000, the Honolulu BWS purchased the newly completed Honouliuli Water Recycling Facility from U.S. Filter. The facility produced 12 mgd (526 L/s) of R-1 water, 10 mgd (438 L/s) designated for irrigation and 2 mgd (88 L/s) for reverse osmosis (RO) water.

Honolulu BWS incorporated into its rules and regulations that if a suitable nonpotable water supply is available, the department shall require the use of nonpotable (reclaimed) water for irrigation of large landscaped areas such as golf courses, parks, schools, cemeteries, and highways.

In 2004, the U.S. Army awarded a 50-year privatization contract for the upgrading the Schofield Wastewater Treatment Plant in order to produce R-1 water for irrigating the Schofield Army Barracks/Wheeler Army Air Field golf course, athletic fields, parade grounds and parks.

R-1 water produced at the Honouliuli Water Recycling Facility currently provides reclaimed water to numerous sites and is continually adding additional users. Existing users include nine golf courses, four community parks, municipal and state building facilities, public library, police station, highway shoulders and medians, four multi-family housing units, private college campus, shopping center, sports field, commercial landscaping, agriculture, feed for RO water for steam generation at refinery and energy facilities, and dust control at construction sites.

County of Hawaii (Island of Hawaii)

The county of Hawaii, which encompasses the Big Island (Island of Hawaii), does not currently have a water reuse program. All municipal wastewater facilities produce R-2 quality water, for permitted infiltration basin and permitted ocean outfall disposal. The use of reclaimed water on the island of Hawaii is primarily driven by private resort developments with their own wastewater treatment plants that produce R-2 water. Most reclaimed water is blended with brackish water sources and used for irrigation. The blended water is used for irrigation at six private golf courses, pasture, airport landscaping, plant nursery, sod farm, and composting.

County of Kauai (Island of Kauai)

The County of Kauai is located on the Island of Kauai, in the northwestern most island of the state. Kauai has four municipal wastewater treatment facilities (WWTFs). Although water reuse is a responsibility of the county of Kauai's Division of Wastewater Management under its Wastewater Treatment Facilities Program, the county does not have a stated reclaimed water program. Kauai's abundant surface water resources provide nonpotable irrigation water for many golf courses and agricultural operations. As such, historically, reclaimed water use on Kauai, whether derived from municipal or private WWTFs, was considered more of a convenient effluent disposal option rather than a water supply resource.

In 2011, the county's Lihue WWTF was upgraded to an R-1 facility through funding from an adjacent private resort development seeking higher quality R-1 irrigation water for golf course expansion and subdivision development. In addition, the county's Waimea WWTF located on the dryer, west side of the island is being upgraded to an R-1 facility to provide irrigation water for parks, school fields and a future golf course.

Project Funding and Management Practices

Funding for the county of Maui's R-1 water reuse program is through a combination of recycled water fees and sewer user fees. Sewer user fees pay for approximately 75 percent of program costs including debt service and operation and maintenance expenses. Fees for reclaimed water service are set in Maui County's annual budget. Reclaimed water fees are divided into three consumer classes: major agriculture, agriculture, and all others.

Most of the funding of the Kihei WWRF R-1 water production and distribution infrastructure was obtained through the State Revolving Fund program general obligation bonds.

Engineering design and physical improvements to upgrade the county of Kauai's Lihue Wastewater Treatment Facility from an R-2 to R-1 facility was borne by the owners of the existing adjacent Kauai Lagoons Golf Club resort development. The developers needed the higher quality R-1 water to spray irrigate the common landscaped areas of proposed private home developments within the resort property and the newly redesigned golf course.

Successes and Lessons Learned

Public acceptance of reclaimed water throughout Hawaii over 20 years has been very positive. This success can be largely attributed to the understanding primarily by state and municipal officials, private consultants and developers of lessons learned gleaned from the early challenges and hurdles faced by water reuse advocates in other parts of the country, especially California. Early involvement of reclaimed water stakeholders and ongoing public education has been key to Hawaii's successful reclaimed water program.

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Sustainability and LEED Certification as Drivers for Reuse: Toilet Flushing at the Fay School

Author: Mark Elbag (Town of Holden)

US-MA-Southborough

Project Background or Rationale

The Fay School is a private day and boarding school for elementary and middle school students in Southborough, Massachusetts (**Figure 1**). It consists of 22 buildings that facilitate 552 students and faculty, 30 percent of which reside on campus as part of the boarding school. In 2011, the school was producing 7,900 gpd (30 m^3/d) of wastewater and is projecting a 20 percent growth of students and faculty resulting in a future wastewater production of 10,500 gpd (40 m^3/d). The most significant opportunities for water reuse at the Fay School were identified. Project drivers for the implementation of a water reuse program included cost savings from reduced water use, environmental awareness and sustainability teaching opportunities, and the potential for LEED Gold Certification.

Figure 1
The Fay School, Southborough, Massachusetts

Capacity and Type of Reuse Application

This project was part of a campus expansion that included LEED certification of buildings and use of "green" technologies and construction practices. The consultant worked closely with the school and the Massachusetts Department of Environmental Protection (DEP) on the water reuse system permitting, effluent testing and quality requirements. Construction of a 26,500 gpd (100 m^3/d) membrane bioreactor wastewater treatment facility was completed in 2009. A portion of the reclaimed water is to be reused for toilet flushing in five new dormitory facilities and a new maintenance building. Based on fixture count, the water reuse demand was estimated at 40 gpm (262 m^3/d). As a school facility, the Fay School experiences significant fluctuations in wastewater flow rate over the course of a day and throughout the year. Careful planning was required so that adequate pre-treatment and post-treatment storage capacity was provided and the treatment capabilities of the equipment at the facility would be able to address these fluctuations.

Water Quality Standards and Treatment Technology

The system is designed to produce effluent total nitrogen concentrations below 10 mg/L. The membranes are designed to produce filtered effluent with less than 2 NTU, as required for reuse in the state of Massachusetts. Ultraviolet disinfection is designed to meet reuse limits of less than 14 cfu/100 mL as a monthly median fecal coliform concentration.

Project Funding and Management Practices

The project was privately funded through Fay School student tuition. The additional capital cost for wastewater treatment attributable to reuse was $75,000. The cost of potable water at the Fay School is approximately $6/1000 gallons ($1.59/m^3). A financial analysis was conducted that showed when water demand is greater than 5,000 gpd (19 m^3/d), the cost of reclaimed water is less than potable water based on a 20-year lifecycle analysis (**Figure 2**).

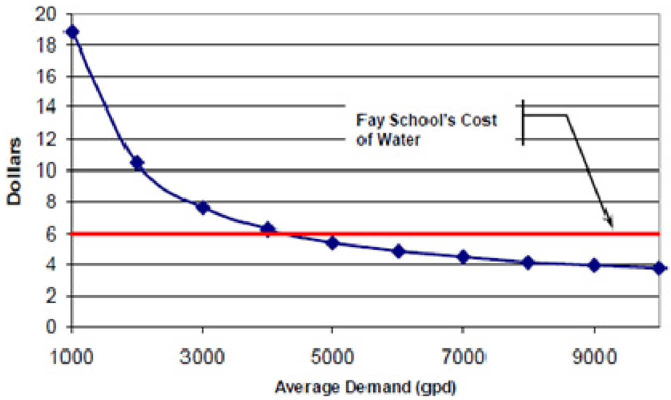

Figure 2
Cost of water per 1,000 gallons

Successes and Lessons Learned

Fay School Achieved LEED Gold Certification from the U.S. Green Building Commission for the Phase 1 Project. Fay School students now monitor building energy and building water consumption from a digital readout in each new dormitory building. The entire project was developed out of the Fay Schools interest in sustainable design principles which is a benefit to the education of students and the importance of water reuse. This concept is an excellent example of how to integrate and promote water reuse into an educational institution.

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Decentralized Wastewater Treatment and Reclamation for an Industrial Facility, EMC Corporation Inc., Hopkinton, Massachusetts

Author: Mike Wilson, P.E. (CH2M Hill)

US-MA-Hopkinton

Project Background or Rationale

EMC manufacturers electronic data storage systems and has a one million square foot campus located in Hopkinton, Mass. The corporation had an interest in LEED certification and green design principles for engineering and production facilities, which are located in watersheds of the Charles, Concord, and Blackstone Rivers.

EMC is the town's largest potable water user. Water supply is groundwater from wells in the town, and a neighboring town. During summer peak seasonal demand, Hopkinton can experience water shortages and in these periods has banned outdoor water use. EMC went beyond basic environmental compliance and built a decentralized wastewater treatment plant and wastewater reclamation facility which produces reclaimed water for toilet flushing and irrigation. Construction of the EMC Corporate Headquarters achieved a LEED EB certification for use of sustainable design best management practices and energy reductions. The project reduced potable water demand on a seasonally limited aquifer and provided needed groundwater recharge.

Capacity and Type of Reuse Application

The plant includes a sequencing batch reactor activated sludge process followed by cloth media filtration and UV disinfection before storage in a finished water tank. The facility went into service in 2000 and has a capacity of approximately 83,000 gpd (314 m^3/d) and has the ability to reclaim 100 percent of its wastewater. Approximately 25 percent is used for toilet flushing and the remaining 75 percent is used for groundwater recharge and irrigation. Approximately 4 million gallons (18,000 m^3) of water is reclaimed per year.

Water Quality Standards and Treatment Technology

The reclaimed water quality exceeds the requirements for reuse in Massachusetts. A summary of the typical influent wastewater characteristics and reclaimed water quality is provided in **Table 1**.

Table 1 Typical water quality

Parameter	Raw Wastewater	Effluent
BOD (mg/L)	221	< 2
TSS (mg/L)	286	< 2
TN (mg/L)	64	< 2
Turbidity (NTU)		< 1

Project Funding and Management Practices

The project was constructed with private funds from EMC Corporation; the water reclamation facility decreases the potable water demand by approximately 25 percent. Approximately $500,000 per year in cost savings is realized due to reduced water and sewer fees from the town. The plant's annual operating cost is approximately $400,000.

Successes and Lessons Learned

Monitoring of toilet flush valves, flows, and system demand is important because a sticking toilet flush valve can significantly impact the use of reclaimed water by rapidly depleting the finished water storage. Installation of flow limiters and low flush toilets has reduced the impacts of this issue.

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Sustainability and Potable Water Savings as Drivers for Reuse: Toilet Flushing at Gillette Stadium

Author: Mike Wilson, P.E. (CH2M HILL)

US-MA-Gillette Stadium

Project Background or Rationale

The New England Patriots management determined that the new Gillette Stadium (**Figure 1**) was projected to increase potable water demand by as much as 600,000 gpd (2,300 m^3/d) during home games, largely due to toilet flushing. Increased water demand would stress water supply wells and storage tank system, and the corresponding increase in wastewater produced at the stadium would be greater than the capacity of Foxborough's wastewater treatment plant. To reduce impacts of the projected increases in potable water use and wastewater demand, the Patriots worked with the town and Massachusetts Department of Environmental Protection (DEP) to construct a new water reclamation facility (WRF) that would reduce demand for potable water. The benefits of the new system were reduced potable water demands and recharge of the groundwater. The system was put into operation in 2002 when the new stadium opened.

Figure 1
Gillette Stadium, Foxborough, Mass. (Photo credit: Kathleen Esposito)

Capacity and Type of Reuse Application

A 0.25 mgd (11 L/s) wastewater reclamation plant that is expandable to 1.3 mgd (57 L/s) was constructed, along with a subsurface disposal system for a portion of the reclaimed water. The plant includes a membrane bioreactor (MBR), and ozone and UV disinfection (American Water, n.d.). Reclaimed water is pumped to a 500,000 gallon (1900 m^3) elevated storage tank or to the subsurface disposal system. A new purple pipe (to indicate reclaimed water) system was constructed because it was determined to be favorable to retrofitting existing piping. On average about 60 percent of the wastewater is reused for toilet flushing at the stadium. The remaining reclaimed water is pumped to the subsurface disposal system where it recharges the groundwater. Toilet flushing demands can vary dramatically and to accommodate these demands, the new reclaimed water supply system includes a one million gallon elevated storage tank at the stadium, and several thousand feet of new water distribution mains.

Water Quality Standards and Treatment Technology

The complete system required integration of a groundwater discharge permit with water reuse requirements because the system included infiltration basins under the parking area. The project included design of an on-site infiltration field and "daylighting" of the Neponset River from an underground culvert to a meandering open channel. When the system was designed, the Massachusetts DEP did not have formal water reuse regulations; there were however, guidelines and precedents had been established through implementation of several other previous water reuse projects. The plant is meeting all of its permit limits and water quality objectives which include biochemical oxygen demand, total suspended solids, total nitrogen, and fecal coliform. The facility reuses approximately 10 million gallons (38,000 m^3) of reclaimed wastewater per year.

Project Funding and Management Practices

The project was constructed with private and municipal funds and the reuse system was constructed on a design-build basis (AW, n.d.). The complete water and wastewater system project had an overall capital construction cost of $13 million.

Successes and Lessons Learned

The town owns the potable water system and the WRF is operated by a private contract operator (American Water, n.d.). The WRF was designed and built by the private contract operator and constructed adjacent to the stadium in order to minimize the cost of the reclaimed water distribution system.

The design-build delivery of the WRF allowed a public–private partnership to plan and implement a reuse system for a major stadium. The lesson learned is that major private projects can be successful using a design and construction method that reduces risks, by placing that risk on a single entity.

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Snowmaking with Reclaimed Water

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US-ME-Snow

Reclaimed Water Use for Snowmaking

While recreational use of reclaimed water is most often associated with irrigation of golf courses, winter sports venues can also benefit from reclaimed water use as an alternate or supporting water source in the seasonal production of engineered snow. The practice of snowmaking by large ski resorts is increasing, especially with recent changes in weather patterns and a need to provide an adequate snow base to attract skiers throughout the ski season.

Snowmaking in Maine

The use of reclaimed water for snowmaking is a relatively new practice, but the potential for its use to replace groundwater or stream-flow that could otherwise support domestic water supplies and aquatic habitat is increasingly attractive to many ski resorts. In the United States, the use of reclaimed water for snowmaking developed in New England as a means to allow for continued discharge of treated effluent from zero discharge lagoons and land application systems during the winter.

The Carrabassett Valley Sanitary District (CVSD) in Maine operated a state permitted lagoon and land application site serving the Sugarloaf Mountain Ski Resort area. By the early 1990's, the treatment system was receiving 50 million gallon (189,000 m^3) of wastewater per year, mostly during the winter months, filling the seven storage lagoons. Because cold climates and varied topography can limit land applications of treated effluent during the colder months, in the spring of 1994 CVSD investigated use of the Snowfluent™ developed by Delta Engineering of Ottawa, Canada. Snowfluent™ is essentially snowmaking during winter months with treated wastewater effluent as the water source for snow. Testing was conducted by the Maine Department of Environmental Protection (MDEP) during the 1994 ski season; with no adverse impacts observed during the testing period, the MDEP permitted a permanent system which was installed in 1995 (Nelson, 1992).

Following the first successful year of operations that included treatment and use of 28 million gallons (106,000 m^3), CVSD acquired three additional snowmaking towers (**Figure 1**) and a diesel generator, and later added SCADA controls to more effectively manage the system. Operationally, CVSD has found that by beginning snowmaking as freezing weather starts, the ground does not freeze, which aids the infiltration of melting snow in spring through early summer (Maine Lagoons online, 2012).

Figure 1
CVSD District employee Joseph Puleo checks the nozzles atop a snow gun tower. (Photo credit: David Keith)

Another Maine site, the Chick Hill Pollution Control Facility serving the town of Rangeley, was completed in fall 1996. Seven snow guns were added in 1998 for winter operation with construction of the winter effluent storage and disposal facility. The system treats over 14 million gallons (53,000 m^3) annually with one 28 million gallon (106,000 m^3) lagoon and 40 ac (16 ha) of application fields. The Mapleton Sewer District (**Figure 2**) formed in 1965 upgraded its treatment facility in 2004 by adding a 5 million gallon (19,000 m^3) facultative lagoon, 14.5 million gallon (55,000 m^3) storage lagoon, and snowmaking system on its land application site, converting to a zero-discharge system and eliminating recurring discharge permit violations to the North Branch of the Presque Isle Stream. The use of snowmaking with spray irrigation allowed year-round operations using a smaller storage lagoon facility.

Figure 2
Mapleton Sewer District Wastewater Treatment Facility sign (Photo credit: Gilles St. Pierre)

Snowmaking in Pennsylvania

Two ski resorts in Pennsylvania are starting to include reclaimed water as a portion of their snowmaking water supply. Seven Springs Mountain Resort uses diluted recycled wastewater to augment the collected surface water it uses to make snow. The executive director of operations says "It's been treated, it's filtered, it's probably better than the pond water" (Nasaw, 2011). Seven Springs has developed a virtually closed-circuit water system for snowmaking and developed a potable water system that recycles water by treating and returning it back to drainage areas to recharge its sources. The water used for snowmaking is captured in a series of collector ponds at the base of the mountain, which are filled by rain, run-off and melting snow. During the snowmaking process, the water is pumped to the top of the mountain and then with the help of gravity, which minimizes energy use, it is supplied to more than 900 snowmaking towers on the mountain. Water is stored on the slopes in the form of snow until the melting process returns it through channels to the collector ponds for the process to begin again (Seven Springs, 2009).

The Bear Creek Mountain Resort general manager hopes to begin using recycled wastewater to make ski snow in the 2012 season, at a 9 to 1 ratio with untreated fresh water (Nasaw, 2011). The on-site wastewater treatment system uses biological treatment processes to produce reclaimed water that is also used for irrigation and ground water recharge.

Western Snowmaking

In the western U.S. states, reclaimed water is viewed as a resource. In California, Donner Summit Public Utilities District in Soda Springs has a wastewater discharge permit that allows stream discharge, land application and snowmaking at Discharge Point "REC-1." Reclaimed water must meet California Title 22 standards that include a median concentration of total coliform bacteria in the disinfected effluent that shall not exceed 2.2MPN/100mL. This pPermit includes a provision (IV.C.12) that requires chlorine disinfection with a chlorine concentration/contact time of 450 mg-min and average NTU of 2 (CRWQCB-CVR, 2009). Title 22 requirements for disinfected tertiary recycled water allow use of demonstrated, alternative disinfection processes with filtration; however, only chlorination is allowed under this permit.

In Cloudcroft, N.M, severe drought has caused water shortages that required trucking of potable water to the community at up to 20,000 gpd (76 m^3/d). In response to this shortage, the community moved forward with development of an integrated water conservation plan that includes indirect potable reuse. Cloudcroft implemented membrane technology to produce highly treated reclaimed water that would be used to supplement the existing spring and well water sources. The reclaimed water, produced using an ultrafiltration (UF) membrane bioreactor and chloramine disinfection, is stored in a small reservoir. A portion of the water is diverted for non-potable purposes (golf course and athletic field irrigation) with 100,000 gpd (380 m^3/d) further treated with reverse osmosis (RO) through a three stage, single-pass system using high rejection, low pressure thin film composite membranes. The RO permeate is treated with hydrogen peroxide and UV, and stored in two covered, lined reservoirs, prior to blending with spring flow and groundwater. The final stage in the water treatment process is ultrafiltration of the blended water source, GAC filtration, and disinfection with sodium hypochlorite prior to distribution in the potable water system.

The two streams from the water treatment process, the RO concentrate and UF backwash are diverted to a 250,000 gallon (950 m^3) reservoir that stored water used for road dust control, construction, snowmaking for the ski area, gravel mining operations, forest fire fighting, and other beneficial purposes (Government Engineering, 2008).

Snowmaking in Australia

The Mt. Buller and Mt. Stirling Alpine Resort are located 3 hours northeast of Melbourne. An expanded wastewater treatment plant can provide an additional 503,000 gpd (2,000 m^3/d) of Class A recycled water for snowmaking per day. Class A is the highest achievable standard in recycled water in Australia and is allowed for use on food crops. The production of artificial snow requires large volumes of water and with global climate change induced forecasts for decreasing snowfalls in the future, ski resorts worldwide are increasing reliance on snowmaking. Mt. Buller has invested in this technology in order to provide a better, longer ski season.

Prior to 2008, when use of reclaimed water for snowmaking was implemented, water was drawn from Boggy Creek. Treatment of Mt. Buller's recycled water also provides benefits to the local environment by improving the quality of run-off that enters surrounding areas and waterways. Mt. Buller management advises skiers that if snow made from recycled water is ingested, it will not have any significant health implications; however, just like natural snow, once it hits the ground it is vulnerable to contamination by animals, vehicles and other skiers, so snow should not be eaten. In addition, Mt. Buller management plans to also use this reclaimed water for household use in new developments and for irrigating open spaces to deliver further benefits to the local alpine environment (Mt. Buller, 2012).

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Reclaimed Water for Peaking Power Plant: Mankato, Minnesota

Authors: Mary Fralish (City of Mankato) and Patti Craddock (Short Elliott Hendrickson Inc.)

US-MN-Mankato

Project Background or Rationale

The city of Mankato, Minn., supplies reclaimed water for cooling water at the Mankato Energy Center (MEC), a peaking power plant with an ultimate design capacity of 640 MW (2,300 GJ/hr). The first phase of the energy project was initiated in 2005 and included the installation of a 365 MW (1,300 GJ/hr) plant with two natural-gas fired combustion turbines, two heat recovery steam generators, and one steam turbine generator estimated to operate about 60 percent of the year. Calpine Corporation approached the city of Mankato about a water supply, and through a collaborative process the decision was made to use reclaimed water for cooling water.

Mankato uses groundwater and shallow wells under the influence of the Minnesota River for its potable supply. Aquifer limitations in the area posed concerns for use of the groundwater supply for the MEC. The local surface water supply, the Minnesota River, is heavily influenced by upstream agricultural land use and would require treatment prior to use as cooling water. As the power plant was being constructed, a fast-track project to provide new water reclamation facilities at the wastewater treatment facility (WWTF) was also initiated. Calpine's experience with use of reclaimed water at other facilities, city staff that embraced and understood the value of reclaimed water for their community, and early involvement with the state regulatory agency provided for a collaborative environment for the facility improvements.

Capacity and Type of Reuse Application

A new water reclamation building and treatment processes were added at the existing WWTF site (**Figure 1**). The system was sized to provide up to 6.2 mgd (272 L/s) of water to meet the maximum water supply needs of the MEC. The supply is provided on an intermittent basis, and through 2011 the peak daily flow has not exceeded 2.6 mgd (114 L/s). Additional capacity was added to provide a peak flow of 18 mgd (789 L/s) for phosphorus removal, for more efficient operations and capacity to meet more stringent effluent standards in the future.

Figure 1
Mankato WRF

The MEC uses the reclaimed water for cooling water on an intermittent basis to meet peaking power needs. The cooling water blowdown, which is approximately 25 percent of the reclaimed water used by the power plant, is returned to the Mankato WWTF for discharge under its NPDES discharge permit, as the power plant has a pretreatment permit but not a discharge permit.

The process train improvements added at the WWTF to provide reclaimed water include: high-rate clarification process with ferric chloride and polymer addition; cloth media disk filtration; chlorine contact basins; secondary pump station, and a standby generator. Existing sodium hypochlorite and bisulfate chemical systems are used for disinfection and dechlorination.

Water Quality Standards and Treatment Technology

The state of Minnesota permits water reuse projects on a case-by-case basis using the California Title 22 reuse criteria (State of California, 2000) as the basis for design and effluent requirements. Site-specific conditions and monitoring are applied to each unique permitted application.

Mankato was required to provide tertiary treated water that meets a total coliform limit of 2.2 cfu/100 mL as a 7-day median, with a maximum single sample not to exceed 23 cfu/100 mL and provide 90 minutes of chlorine contact time. The existing NPDES permit requirements for fecal coliform and other constituents characterizing the effluent discharge to the Minnesota River were not changed, but additional requirement for reuse including the total coliform limit and monitoring were added. Because a scalant with phosphorus in it is added to the MEC cooling water and the MEC blowdown water is sent to the city's WWTF prior to river discharge, additional phosphorus monitoring was required to ensure the city's phosphorus permit limits are not exceeded.

Project Funding and Management Practices

The new water reclamation center capital project was funded by Calpine Corporation. The city of Mankato selected an engineering firm to design the new processes and building, with construction provided by Calpine Corporation. The city owns, operates, and maintains the facility and there is no cost to Calpine for reclaimed water until cumulative operations and maintenance costs exceed the capital cost or 20 years is reached, at which time Calpine will be charged on a per gallon basis. A 20-year agreement was established with four 10-year renewal options including one item specifically requested by the city identifying that the city has priority to use reclaimed water for plant and other city uses. The city of Mankato is expanding its use of reclaimed water to include urban irrigation of a new city park and for street washing and vehicle cleaning.

This project provided a unique opportunity for the city of Mankato to incorporate more flexibility in their operations to meet their existing phosphorus effluent discharge limits, as well as the ability to meet more stringent future limits, by adding capacity for phosphorus removal. The city also made improvements to their internal water systems to replace use of secondary effluent water with reclaimed water, which has resulted in fewer issues with effluent pump screen clogging and maintenance.

Successes and Lessons Learned

While the facility has operated well since startup in 2007, there was a learning curve related to providing a chlorinated supply for intermittent use. Intermittent production also required establishing a good communication system with the energy facility and laboratory staff to ensure efficient operations for intermittent demand and proper laboratory sampling.

One impending issue for the city of Mankato and other Minnesota communities is the potential for new dissolved solids discharge limits. While many industrial NPDES permits have limits for chlorides, sulfates, and other ions, municipal WWTFs do not. For Mankato, this could be a concern given the MEC cooling water blowdown has elevated dissolved solids. It is possible that future partnerships like Mankato and the MEC may not be viable if there are new ion limits.

This project was a collaborative partnership of an industry, municipality, contractor, engineer, and regulatory agency to provide a system to meet both the needs of the energy facility and the short and long term needs of the municipal WWTF. The energy facility met its schedule and continues to receive high quality water for their operation. Use of reclaimed water has reduced use of the local aquifer by 130 million gallons per year which extrapolates to over 300 million gallons per year with the MEC operating at design capacity.

The municipality has also provided a significant environmental benefit to the Minnesota and downstream Mississippi River watersheds, and helped numerous communities and industries delay major capital improvements. Mankato has supported the phosphorus trading permit framework established for the Minnesota River by using its excess capacity to remove phosphorus for other permitted dischargers that do not have the infrastructure to meet new phosphorus limits. The trading program resulted in meeting phosphorus goals for the watershed ahead of schedule.

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Town of Cary, North Carolina, Reclaimed Water System

Authors: Leila R. Goodwin, P.E. (Town of Cary) and Kevin Irby, P.E. (CDM Smith)

US-NC-Cary

Project Background

The town of Cary, N.C., conducted a reclaimed water feasibility study in 1997 to evaluate how best to meet its goals of reducing per capita water consumption by 20 percent by 2015, to preserve the town's allocation of raw water from its drinking water source, Jordan Lake. In June 2001, Cary became the first municipality in North Carolina to pump reclaimed water to homes and businesses for irrigation and cooling.

Capacity and Type of Reuse Application

The town of Cary treats wastewater for Cary, Morrisville, the Raleigh-Durham International Airport, and the Wake County portion of the Research Triangle Park at its two water reclamation facilities (WRFs). Both the North Cary WRF and South Cary WRF have reclaimed water systems consisting of piping systems as well as bulk reclaimed water distribution stations.

The town of Cary's reclaimed water system began with several hundred customers in targeted service areas identified through an analysis of high irrigation demands and proximity to the WRFs. The system provides reclaimed water for irrigation and cooling for commercial facilities, lawn irrigation for single and multi-family homes, and irrigation for schools and a recreational complex. The system also includes bulk reclaimed water distribution stations at the town's two WRFs for filling tanks for uses such as irrigation, road construction, dust control, sewer flushing, and street cleaning (**Figure 1**).

Cary's reclaimed water system has a production capacity of approximately 5 mgd (219 L/s). The system produces approximately 1 mgd on a peak day and up to 20 million gallons per month (76,000 m^3) during the summer.

The North Cary WRF reclaimed water service area includes a 9 mgd (394 L/s) pump station and 1 million gallon (3,800 m^3) storage tank at the North Cary WRF required to meet peak day peak hour demands. It also includes approximately 9 miles (14.5 km) of 4- to 20-in (10- to 51-cm) transmission and distribution mains. The South Cary WRF reclaimed water service area includes a 1.2-mgd (52.5-L/s) pump station at the South Cary WRF and approximately 1.4 miles (2.3 km) of 8- to 12-in (20- to 30-cm) transmission and distribution mains. The reclaimed water pumps at the town's WRF are shown in **Figure 2**.

Figure 1
Bulk reclaimed water distribution station (Photo credit: David Heiser)

Figure 2
New reclaimed water pumps at the WRF (Photo credit: David Heiser)

Water Quality Standards and Treatment Technology

The town of Cary's reclaimed water system was designed to meet the state's mandatory treatment standards (**Table 1**). Both WRFs treat wastewater using biological nutrient removal and regularly meet the state reclaimed water quality standards.

Table 1 Minimum state reclaimed water quality standards

Parameter	Daily Maximum	Maximum Monthly Average
BOD5	15 mg/L	10 mg/L
TSS	10 mg/L	5 mg/L
NH_3	6 mg/L	4 mg/L
Fecal coliform	25 cfu/100mL	14 cfu/100mL
Turbidity	10 NTU	10 NTU

Project Funding

The total project cost for the reclaimed water system including both the North Cary and South Cary WRFs was $11 million. The project was funded through the town's capital improvement budget.

Reclaimed water in the town of Cary currently costs $3.60/1,000 gallons ($0.93/m^3), which is the same as the town's Tier 1 potable water use rates. Reclaimed water rates were set less than potable water while recovering a substantial part of the town's capital cost for implementing the system. Use of reclaimed water allows customers to avoid higher Tier 2, 3, and 4 water rates that apply to water use greater than 5,000 gallons (19 m^3) per month. Reclaimed water customers are also exempt from the town's alternate day watering restrictions. The town does not charge customers for reclaimed water obtained at its bulk reclaimed water distribution stations.

Reclaimed Water Program Management

The town of Cary's reclaimed water program is managed by a Reclaimed Water Coordinator, who is responsible for development of policy recommendations and selection of program alternatives; evaluating program effectiveness; collecting data; working with homeowners, businesses, and other potential reclaimed water customers; coordinating programs to encourage the use of reclaimed water; and inspecting the reclaimed water system for potential problems such as cross connections.

During implementation of its initial reclaimed water program, Cary sponsored numerous public education efforts, including public information sessions and hearings, fact sheets, news releases, meetings with homeowners groups and other potential customers, an education program for plumbers and contractors, and information on the town's website. The town requires bulk reclaimed water users to complete a 1-hour training session in order to obtain a permit to use the reclaimed water.

Expansion of the Reclaimed Water Program

The town of Cary is currently expanding its reclaimed water system into a third service area. The town of Cary, Wake County, and Durham County are jointly implementing the Jordan Lake Water Reclamation and Reuse project. This project will provide reclaimed water from Durham County's Triangle Wastewater Treatment Plant to customers in the Wake County portion of Research Triangle Park and to the town of Cary's Thomas Brooks Park, the site of the USA Baseball national training center. The service area also includes some currently undeveloped portions of northwestern Cary.

The project is being financed by a State and Tribal Assistance Grant (STAG) from the federal government (administered by the Environmental Protection Agency) as well as the town of Cary, Wake County, and Durham County. The portion of this project serving the Wake County portion of Research Triangle Park and some of western Cary began operating in early 2012 and the remainder will be completed in 2013.

The town has recently initiated a comprehensive master planning study to develop a roadmap for future expansion of the town's reclaimed water program.

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Identifying Water Streams for Reuse in Beverage Facilities: PepsiCo ReCon Tool

Author: Liese Dallbauman, PhD (PepsiCo Global Operations)

US-NY-PepsiCo

Project Background or Rationale

The beverage industry is dependent on sustainable supplies of water for the ongoing survival of its business. Water is included within most of the final products, and also used within the supply chain. The beverage sector has taken the concept of water stewardship very seriously for decades, partly because of the direct financial impact on the business that water efficiency can afford through productivity savings, and partly because of the broader importance of corporate social responsibility in preserving water supplies and using water resources wisely.

Capacity and Type of Reuse Application

The Beverage Industry Environmental Roundtable (BIER) is a technical coalition of leading global beverage companies working together to advance environmental sustainability within the beverage sector. Formed in 2006, BIER aims to accelerate sector change and create meaningful impact on environmental sustainability matters. Through development and sharing of industry-specific analytical methods, best practice sharing, and direct stakeholder engagement, BIER accelerates the process of analysis to sustainable solution development.

Each year, the industry water dataset continues to grow in size, with 2011 representing the most robust report to date, including over 1,600 facilities distributed across six continents. Analyses were conducted to determine industry water use, production, and water use ratio over the three year period from 2008 to 2010. Over this period, the industry aggregate water use ratio improved by 9 percent, avoiding the use of approximately 39 billion liters of water in 2010–enough water to supply the entire population of New York City for 8 days. So the beverage industry as a sector has been quantitatively using water more efficiently. An important part of water efficiency practices is identifying opportunities for water reuse.

Project Funding and Management Practices

At PepsiCo, ReCon is the name given to our corporate global set of best practice tools for resource conservation. The first tool was constructed several years ago for energy management within the beverage production plants, based heavily on tools and information from the U.S. Department of Energy. The ReCon suite has grown to include ReCon Water, ReCon GHG, and ReCon Waste. The power of these tools comes from leveraging a common approach. Each first quantifies a plant's resource usage streams and sub-streams and calculates the relative value of the streams. In the case of water, for example, the online ReCon Water Profiler allows the plant to dissect its water use and then provides a mapping of the relative volumes and values of each stream (**Figure 1**). The values are determined based on local cost of incoming water, treatment or conditioning chemicals, energy used to heat or cool prior to use, and finally costs associated with discharge.

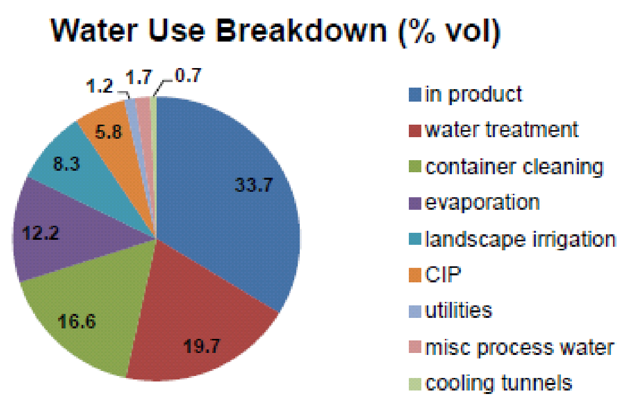

Figure 1
Example output from Recon Water Profiler that compares water use volume for different uses at a beverage plant

Comparing these data allows a quantitative assessment of which streams offer the greatest opportunities for saving water, whether by avoiding water use altogether, reducing the volume of water used, or reusing spent water. The Diagnostic, a series of customized audit-type questions, then assesses whether the plant is following best practices, and which opportunities exist for improvement. Involvement of the plant's quality organization ensures that any changes in water use practices meet strict quality standards.

The Water Purification Eco-Center

Authors: Jeff Moyer and Christine Ziegler (Rodale Institute)

US-PA-Kutztown

Project Background/Rationale

The Water Purification Eco-Center (WPEC) is a decentralized wastewater treatment and disposal system for Rodale Institute's new Visitor Center in Kutztown, Pennsylvania. Rodale Institute is a nonprofit research, education and training facility. The WPEC Project was developed to maintain and demonstrate an on-site wastewater treatment system that captures rainwater and uses it several times before returning it to the soil as clean water. The system, which incorporates a cistern, a septic/equalization tank, a constructed wetland cell, a trickling filter, and subsurface drip irrigation disposal unit, utilizes wastewater as a resource, demonstrating an alternative to standard septic and sand mound on-lot sewage systems. This system is scalable and can be used in sustainable landscapes for small commercial entities as well as residential units (**Figure 1**).

Capacity and Type of Reuse Application

The system demonstrates wastewater treatment utilizing natural systems, as well as resource conservation and recycling. The system was constructed to provide fresh, collected and/or recycled water source to toilet fixtures designed to conserve water. Effluent passes to a dual-compartment septic tank, and then on to a flow equalization tank to provide uniform flow rates and to allow compensation for intensified use. Wastewater is then directed through a wetland treatment cell, where soil biology and plant roots utilize excess nutrients from the water, where pathogens are also neutralized. Once wastewater has passed through the wetland treatment cell, it is sent to a trickling filter and then back through the wetlands cell. Finally, the treated water is directed to the subsurface irrigation system servicing the landscaped areas surrounding the Visitor Center.

The design capacity of the system is 400 gpd (1.5 m^3/d) and flow equalization allows the system to address a peak flow of 800 gpd (3 m^3/d). This is the typical size used for a single residence, minus the flow equalization tank, which was added to account for usage patterns specific to a visitor center.

Water Quality and Treatment Technology

Water quality tests at several points in the system allow researchers to capture information on how the various treatment stages are working. Annual sampling of the surrounding soils will indicate the impacts of the system on its immediate environment, demonstrating how the wetlands system design can achieve and surpass EPA discharge standards for secondary effluent.

Many watersheds in the state of Pennsylvania house residential communities with on-lot sewage systems located within their boundaries, and the numbers are growing daily. The materials leaving these systems, if treated properly are no longer to be viewed as waste products; rather, they need to be viewed as resources. The proper use of these resources can have a profound impact on land use and water quality in the areas where they are located. Viable and practical alternatives to both standard septic and sand mound systems are needed for residential communities using on-lot sewage systems.

The water quality objective of this project is to transform standard septic effluent into clean water that will meet EPA discharge standards for secondary effluent, while affecting no net change in the nutrient parameters of the soil or water surrounding the system. In order to achieve this objective, each component of the treatment system must be functioning properly. Thus, treatment component integrity is being assessed through analysis of monthly water samples drawn from lysimeters (porous access tubes) located in the surrounding soil, and component function will be assessed through analysis of monthly water samples collected at the outflow of each component, and at the end of the system. All water samples are being collected and processed in accordance with standard operating procedures and the analysis being conducted by MJ Reider and

Associates, Inc. laboratory is being assessed for statistical changes in nutrients and other contaminants.

Project Funding and Management Practices

The WPEC project is funded by the EPA (Congressionally Mandated Projects - Wetlands for the Prevention of On-Lot System Pollution, Agreement Number XP-83369301-0, CFDA Number 66.202), the Pennsylvania Department of Environmental Protection, Rodale Institute and other corporate and private funders. The Berks County Community Foundation has also provided funding for addition of solar panels to the facility.

This project is managed as a research and education facility, to highlight the viability and functionality of the system as an alternative to traditional sewage management. A broad cross-section of society is being education on concepts and principles of regeneration that are applied through the system. The intended audiences include two main groups. First, on the demand side, are those who want or need a decentralized system. Second, on the supply side, there are those who will provide and regulate the systems. These groups include elementary school children, municipal officials, land developers, watershed management groups, planning commissioners, policy makers, and sewage enforcement officers. Rodale Institute is also reaching out to those who cannot visit the center, in person, through a distance learning program and information on the project website.

Institutional/Cultural Considerations

Since the grand opening of the facility in 2011, outreach and education efforts have included development of an informational project brochure, newsletter features, site tours that include an electronic kiosk featuring informational text, animation of the whole system and interactive games that test visitors' knowledge of water-related issues. Other educational outreach has included on-site and off-site speaking engagements and workshops. The first on-site workshop, entitled "Constructed Wetlands in Wastewater Treatment," was conducted in June 2011 and a second workshop was held in June 2012. Rodale Institute is also arranging continued speaking engagements at targeted tradeshows that will help increase understanding and expand use of wetland technology.

The WPEC has been featured in local, regional and national print publications and in electronic media. A Rodale Institute website re-design in 2012 will enhance capacities to present the WPEC in a clear and accessible manner for a wider range of audiences. Other Water Purification projects across the nation that have similar goals, and fit with the mission of Rodale Institute will be featured on the website.

Successes and Lessons Learned

The facility was considered "on-line" as of the grand opening in June 2011 and the systems have been up and running, as designed, since October 2011 purifying wastewater without any issues. Continuous monitoring allows tracking system performance and will allow minor adjustments to optimize the operations of each individual component of the system.

Some minor issues with automated controllers were experienced in early stages of this system. Water float control adjustments and pump timing changes have been made. Once tested and confirmed effective, the adjustments will be shared in project trainings and documentation. Also, water sampling protocols have been finalized and sampling is in the early stages. Once several months of data have been collected, information will be shared and possible system adjustments will be made, if needed. This shared information will be helpful to other institutions and private individuals who may choose to install similar systems for their projects, properties and landscapes.

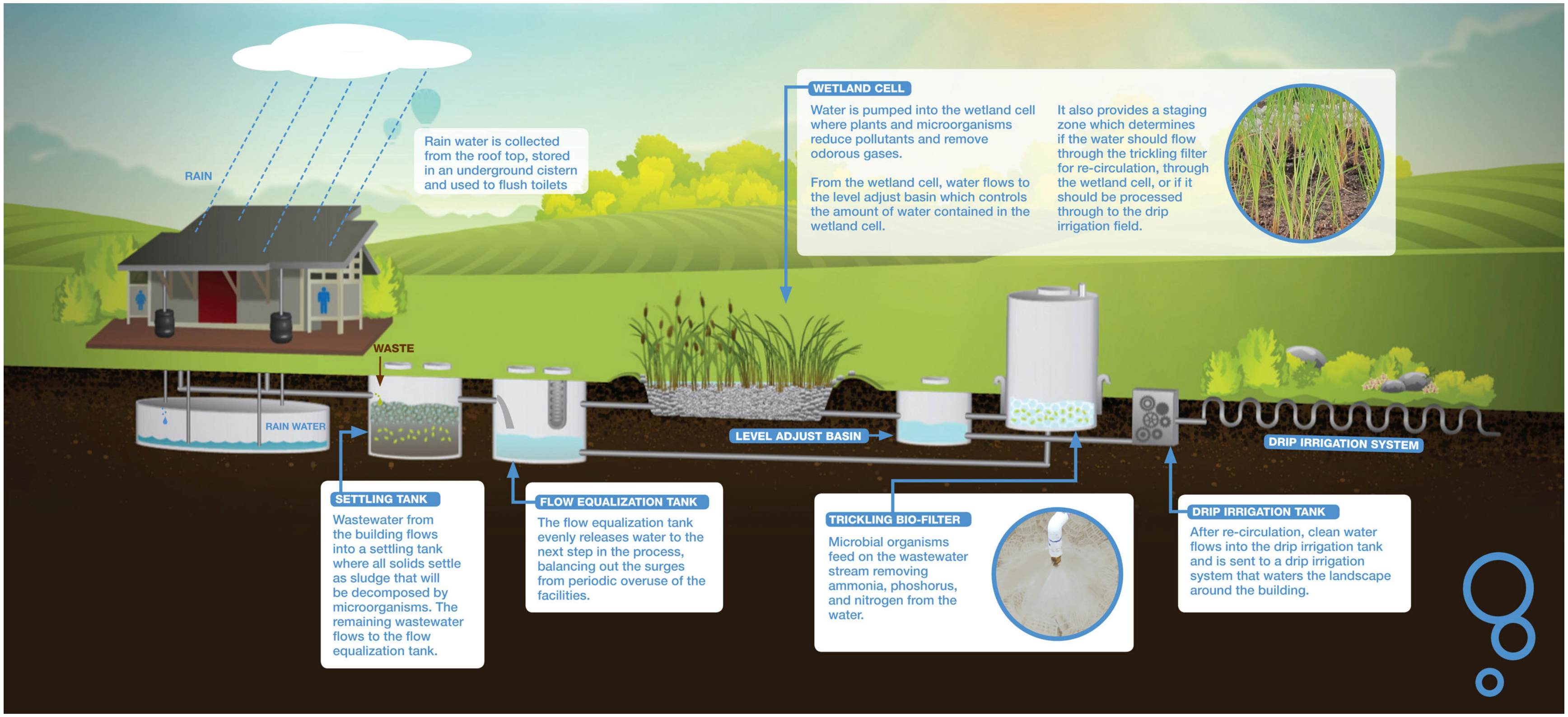

Figure 1
Schematic of the WPEC system components (Photo credit: Rodale Institute and NEWVISION Communications)

Zero-Discharge, Reuse, and Irrigation at Fallingwater, Western Pennsylvania Conservancy

Author: Mike Wilson, P.E. (CH2M Hill)

US-PA-Mill Run

Project Background or Rationale

In 1999, the Western Pennsylvania Conservancy (WPC) implemented a water reuse plan at Fallingwater to promote sustainable design principles and reduce potable water use through a zero-discharge wastewater reclamation system. Fallingwater, the world-famous "house on the waterfall," was designed and built by Frank Lloyd Wright—one of the most important architecture and design figures of the 20th century. The Main and Guest Houses were constructed in the 1930s and the Main House (shown in **Figure 1**) was cantilevered over a waterfall located on Bear Run, a stream of "exceptional value" as categorized by the state of Pennsylvania.

Figure 1
Main House (Photo credit: WEFTEC 2002)

Capacity and Type of Reuse Application

The visitors' center and onsite facilities produce approximately 8,000 gpd (30 m^3/d) of wastewater. The wastewater is pumped to the treatment facility, which is housed in a separate 1,800-square-foot (194 m^2) structure located away from the main house (**Figure 2**). The system recycles 100 percent of the wastewater that is produced by the facility's 140,000 annual visitors.

Figure 2
Treatment facility (Photo credit: WEFTEC 2002)

The treatment processes include an MBR followed by carbon adsorption and UV disinfection. The process produces an effluent suitable for public access reuse. Following treatment, the reclaimed water is recycled for use as toilet flush water at the visitor's pavilion, and at other site buildings. The system also includes irrigation of a forested site with a subsurface drip irrigation system to provide redundant reuse capacity during the winter months and wet periods.

Water Quality Standards and Treatment Technology

The membrane bioreactor treats wastewater to the reuse standards required by the Pennsylvania Department of Environmental Protection (DEP) as shown in **Table 1**.

Table 1 Typical water quality

Parameter	Raw Water	Effluent
BOD (mg/L)	350	< 5
TSS (mg/L)	350	< 5
TN (mg/L)	75	<10
Turbidity (NTU)	—	< 2

Project Funding and Management Practices

The project was paid for by the Conservancy Trust. The entire project cost $15 million and was completed as a design-build project. The system was put into operation in 2005. This approach provided a single point of accountability and allowed the conservancy to provide critical input to all project phases.

Successes and Lessons Learned

The project provided the conservancy with an opportunity to include sustainable design practices in their mission of environmental stewardship. The project had the added benefit of educating the public on an innovative sustainable water reclamation process and the benefits of reuse. The Fallingwater Wastewater Pumping, Treatment, and Reuse Systems won the National Design-Build Award for water projects under $15 million in 2005. The wastewater reclamation system can be a model for other sites facing similar constraints in the Northeast.

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Franklin, Tennessee
Integrated Water Resources Plan

Authors: Jamie R. Lefkowitz, P.E. and Kati Bell, PhD, P.E. (CDM Smith); and Mark Hilty, P.E. (City of Franklin)

US-TN-Franklin IWRP

Project Background or Rationale

Located 20 miles south of Nashville, the city of Franklin, Tenn., is a rapidly growing community of approximately 60,000 people. Franklin is one of the fastest growing cities in the nation—twice as many people live in the city today compared to a decade ago. And the trend is expected to continue: Franklin's population is projected to double again during the next 30 years. The rapid growth in Franklin is placing pressure on capacities for drinking water supply and wastewater treatment, along with increased maintenance of the collection, distribution, and stormwater infrastructure. As a result, the city faces a tremendous need for water resources planning in order to continue providing reliable water, wastewater, and stormwater services to its growing residential and commercial user base. These services must be provided to support growth, while protecting community's most valuable and resource—the Harpeth River.

Reuse is one key aspect of an integrated plan developed by Franklin to determine a course of action for water resources projects over the next 30 years. Currently, the city provides drinking water (approximately one-third from its own treatment plant and two-thirds from wholesale purchase), wastewater treatment, and reclaimed water for irrigation. Raw water is withdrawn from the Harpeth River for treatment at the Franklin drinking water plant, and treated wastewater effluent that is not further treated and reused for irrigation is discharged to the Harpeth River.

Capacity and Type of Reuse Application

Franklin's reuse system is fed directly from the wastewater reclamation facility (WWRF) that receives and treats almost all of the city's wastewater. The WWRF capacity is currently 12 mgd (526 L/s) and as of 2012 operates at approximately 80 percent of its permitted capacity. All wastewater treated at the plant receives tertiary treatment through a biological denitrification filter following secondary biological treatment, is of exceptionally high quality, and is available for reuse.

The reuse distribution system was installed in 1992 when the city entered into an agreement with a local golf course to supply reclaimed water for irrigation. The distribution system currently consists of a 7.5 mgd (329 L/s) pump station and more than 15 miles (24 km) of distribution pipelines. The distribution system delivers reclaimed water to customers that have connected to the reuse network and includes golf courses, residential communities, commercial developments, a recreational facility, and the high school. The highest demands occur in July and August averaging 2.6 mgd (114 L/s) in 2011; however, when considering daily peaking factors, there have been days when reclaimed water is not available to meet reuse demand.

Integrated Planning Process

In order to meet water resources demands of the growing population, Franklin must expand the capacity of its WWRF. The first step in this process is to obtain new discharge permits under the challenging regulatory situation involving water quality impairments in the Harpeth River. A total maximum daily load (TMDL) was completed for the Harpeth River in 2001 that defined stringent waste load allocations for the Franklin WWRF through its National Pollutant Discharge Elimination System permit. Faced by these challenges, the city opted to take a more holistic look at how it manages its water resources. The result was an integrated plan that would not only satisfy the wastewater and reclaimed water demands, but also provide long-term, sustainable solutions to Franklin's water challenges, and environmental enhancements to the Harpeth River.

In 2010, city officials, administration and staff embarked on a 2-year process to evaluate Franklin's water resources from a long-term, holistic perspective encompassing water supply and treatment, wastewater collection and treatment, biosolids treatment and disposal, reclaimed water distribution, stormwater management, ecological preservation, and restoration in the Harpeth River and its tributaries. Franklin decided that a facilitated, stakeholder process would be the best means to develop a broadly acceptable Integrated Water Resources Plan (IWRP). As a result, a broad range of representatives from city administration and staff, state regulatory agencies, the county, neighboring utilities, environmental advocates, and the community were involved in developing the project goals, objectives, performance measures and alternatives, and ultimately the recommended plan.

The Integrated Model

Franklin's water resources are a network of natural and man-made systems that satisfy demands on water (e.g., irrigation, industrial use, human consumption, habitat, and recreation). Water moves between these network segments through completely natural, altered natural, and manmade pathways. In order to conduct an alternatives evaluation of various sets of stakeholder-derived project options, a simulation model of the city's water resources system was developed to represent the system's segments and their interconnectivity.

An integrated network model was developed to represent the city of Franklin's water resources system, allowing the physical flow systems to be modeled with operational and planning level resolution. The integrated model was developed utilizing the STELLA software tool (Systems Thinking Experimental Learning Laboratory with Animation), which is a dynamic and graphical tool used to simulate interactions between, and within, subsystems that are part of a larger interconnected system. Because dozens of alternatives were identified by stakeholders (alternate water sources, use and reuse options, operational triggers, etc.), this tool was able to rapidly help screen information, identify key drivers, and understand the causal relationships throughout the complex water system.

The integrated model was divided into segments which represent the categories of the city's water resources: the Harpeth River, water supply, wastewater, reclaimed water, and stormwater. These sectors of the water resources system are interconnected so decisions or policies aimed at managing water within one sector often has direct effects and interacts with the other systems. For example, increasing the volume of reclaimed water use would effectively decrease demand on the potable water supply and treatment associated with irrigation demand; however, it would also decrease the volume of water returned to the river limiting supplemental flows during potential low-flow periods.

Evaluating the Benefit of Reuse

One of the most challenging and interesting components of the Franklin IWRP process was analysis and integration of the wastewater, reuse, and potable water systems. The initial driver of this project was addressing issues associated with the existing WWRF. Already in excess of its design capacity, the WWRF was evaluated to determine how much additional capacity could be achieved while meeting the anticipated permit limits for nutrients in the Harpeth River; nitrogen was the limiting factor for this project. Topography of the service area and previous development of the collection system in the city provides gravity flow of wastewater that could be split and routed to two separate locations. The first location is the existing facility and the second is a site where a facility in the southern portion of the city's service area could be constructed. The southern WWRF site is located approximately 3 river miles upstream of the existing drinking water treatment plant (WTP), and could provide additional benefits of augmented flows upstream of the WTP intake, particularly during seasonal low flows.

As part of the integrated plan, the probable increase in demand for reuse irrigation water was estimated based on potential new customers located near existing lines and could tie-in without a substantial capital expenditure by the customers or the city. The level of less-certain demand for the reuse water was also estimated. To serve these customers, new lines would need to be constructed and current development trends would need to continue. While less certain, the future reuse demands could increase the potential for reuse more than the base case, but only if the city completes infrastructure projects to treat and distribute the reuse water, and the anticipated development within Franklin results in a significant increase in wastewater volume for reuse supply.

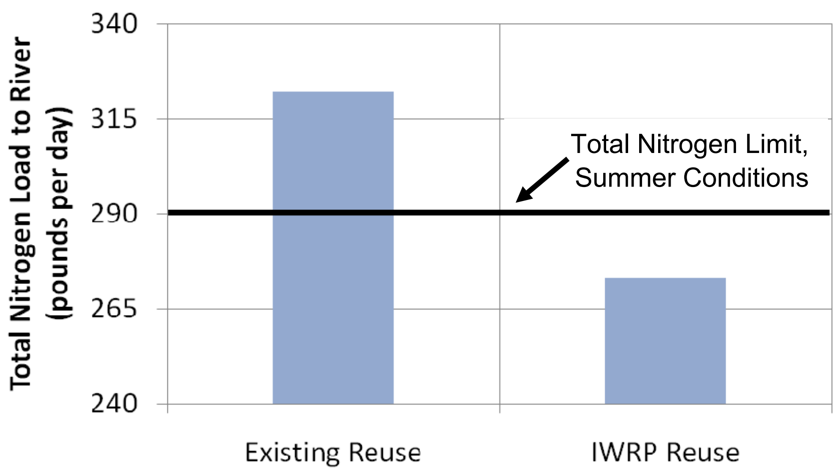

Figure 1
Estimated reduction in nutrient loading to Harpeth River resulting from increased effluent reuse

Increased reuse would help relieve non-potable irrigation demands, as well as alleviating nutrient discharges to the Harpeth River, allowing permitting and implementation of capacity expansion to meet the future wastewater demands. Results of the model demonstrated that increasing reuse was the key to implementing projects to address future wastewater demands, as shown in **Figure 1.** This graph compares the nutrient loading for the future wastewater capacity with no increases in the reclaimed water capacity to the IWRP alternative that results in reduction of nitrogen loading to the river by meeting the probable future reuse demands with reclaimed water (using projected 2040 wastewater flows).

Project Funding and Management Practices

Reclaimed water in Franklin has historically been used for non-potable uses such as irrigation. Although middle Tennessee is a water-rich region and potable water is sometimes used for irrigation, the cost of distributing potable water makes it increasingly attractive for customers to irrigate with reclaimed water instead. As with wastewater utilities across the country, Franklin's current water and sewer rates do not keep pace with infrastructure maintenance costs. However, providing low-cost reclaimed water allows the city to treat and purchase less potable water through its wholesaler by reducing overall demand for the relatively expensive commodity.

Institutional/Cultural Considerations

The inclusion of reuse in Franklin's integrated water resources plan allows the city to consider the complete water use cycle when planning for future growth. Utilizing reuse water gives the city flexibility in water supply and wastewater demand to better meet the needs of customers and environmental requirements. The final preferred option that was developed through a stakeholder process included future construction of a new WWRF upstream of the city where much of the new development is expected and where that wastewater would flow to the plant by gravity. To fully implement this plan, however, the public perception issues associated with discharging wastewater effluent upstream of the water treatment plant intake will require continued public outreach and communication.

Successes and Lessons Learned

The Harpeth River is a small river that is impaired with respect to dissolved oxygen and nutrients which creates challenges for permitting additional withdrawals and discharges. The use of reclaimed water is an essential part of planning for increased water service capacities in the city of Franklin; increased reuse can allow the city to meet stringent effluent permit limits by reducing nutrient loads to the receiving stream while also reducing demand for potable water. Franklin is only one of a handful of cities in the state of Tennessee with a centralized reuse treatment and distribution system that is serving as a model for other communities wishing to adopt the sustainable practice of integrating reuse into water resources management.

To address these needs, the IWRP was developed using a facilitated process involving stakeholders to assist with the definition of the goals, objectives, performance measures and alternatives, and ultimately the recommended plan as the final product. One of the most critical components in development of the plan was the transparency in the technical evaluations and stakeholder involvement in the planning process. Ultimately, adoption of the final IWRP, which identifies projects that would be adaptively implemented in phases over the next 30-year planning period, would not have been possible without this stakeholder participation.

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San Antonio Water System
Water Recycling Program

Author: Pablo R. Martinez (San Antonio Water System)

US-TX-San Antonio

Project Background or Rationale

The Edwards Aquifer is the primary water source for San Antonio, serving a population of 1.3 million. Reclaimed water is one resource in the San Antonio Water System (SAWS) water supply portfolio along with conservation and surface water. The SAWS continues to plan and develop additional water resources to meet current and projected demands and as a result, has a nationally recognized reclaimed water program designed to deliver 35,000 ac-ft/yr (43 MCM/yr) to customers using the product for stream augmentation, irrigation, cooling towers and industrial processes. The system includes 130 miles (210 km) of distribution pipeline, in-line storage tanks, and pumping facilities to deliver reclaimed water produced at three Water Recycling Centers (WRCs).

Capacity and Type of Reuse Application

Reclaimed water is produced at the Dos Rios, Leon Creek and Medio Creek WRCs, which have a combined capacity of 233 mgd (10,200 L/s). Above ground storage tanks provide in-line storage for reclaimed water which is distributed through 130 miles (210 km) of pipe ranging in sizes from 42-in to 24-in (107 cm to 61 cm) in diameter. The system is comprised of two major branches. Capacity in the east leg is 13,000 ac-ft/yr (16 MCM/yr) and capacity in the west leg is 22,000 ac-ft/yr (27 MCM/yr). At this point, both legs are near capacity with agreements for reclaimed water service. The reclaimed water is used for a range of uses, as shown in **Figure 1**.

Water Quality Standards and Treatment Technology

The state of Texas recognizes two types of reclaimed water quality (Type I and II). SAWS' WRCs produces type I reclaimed water, as shown in **Table 1**. The treatment technology used to meet these standards is advanced secondary treatment, filtration and chlorine disinfection at the WRCs and system high service pump and storage facilities. The reclaimed water quality falls under the responsibility of WRC operators who provide that reclaimed water is treated to regulatory and contractual standards.

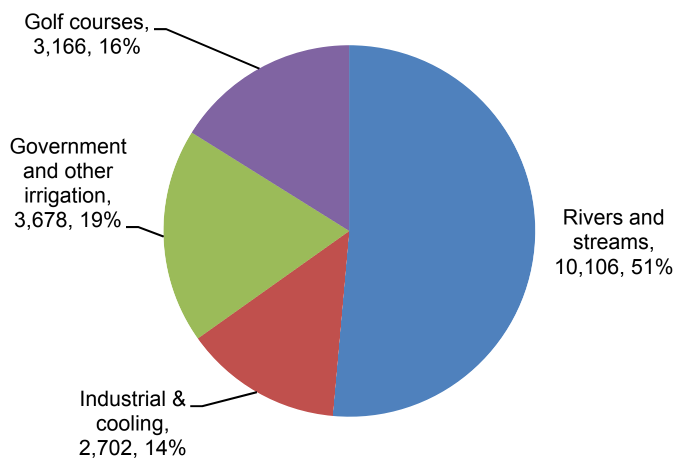

Figure 1
Reclaimed water use in ac-ft/yr and percent

The reclaimed water infrastructure maintenance is conducted by existing distribution and operations personnel and includes daily equipment checks, monitoring chlorine feed rates and addressing any system concerns or maintenance when needed.

Table 1 Standard and SAWS reclaimed water quality

Constituent	Type I Standard (Texas)	SAWS Reclaimed Water Quality
BOD_5	5 mg/L	2 mg/L
Turbidity	3 NTU	<1 NTU
Fecal Coliform	<20 cfu/100 mL	<2 cfu/100 mL

Project Funding and Management Practices

Funding for the reclaimed water system infrastructure (pipelines, storage tanks and pumps) was supported through the existing capital program with support from a state loan program. Initial capital cost for the system was $124 million. The cost for reclaimed water is about $1.00/1000 gallons ($0.26/m^3). Commercial, potable water can cost $2 to 3/1000 gallons ($0.52 to 0.77/ m^3) depending on the customer's rate structure, seasonal and out of city limit rates plus water supply and Edwards Aquifer Management Fee based on volume and stormwater fee based on size of property.

Institutional and Cultural Considerations

When the reclaimed water program was developed, management and operational aspects were not formulated into designated departments or organizations. All planning, design, operations and customer service responsibilities were incorporated into existing water utility functions.

San Antonio is most notably known for its Downtown Riverwalk, which is the cultural center of San Antonio and visited annually by millions of visitors, aside from those who live in San Antonio. Approximately 4.6 mgd (200 L/s) of reclaimed water can flow into the Riverwalk; thus, stakeholder input to address issues such as water quality, policy and rates was critical. Public involvement included informational packages and numerous public presentations to gain confidence from the ratepayers that the program was a viable alternative non-potable water project.

Successes and Lessons Learned

The key factors to ensure project success included three phases of implementation:

Planning phase. Public opinion can change from skepticism to acceptance, and building public trust takes work to gain and keep. Stakeholders (citizens, government leaders, business leaders and organizations, schools) were included in information fairs and presentations to educate the public on the pressing need to manage the local water resources better for all.

In San Antonio, the federal lawsuit over endangered species was front page news for several years. The lawsuit covered seven endangered species and ruled that pumping water from two springs for urban and agriculture use had to be curtailed to support minimum flows in two springs to protect the endangered species. Most of the individuals engaged in discussion of building a reclaimed water system knew San Antonio lost 20 percent of its water supply with the judge's ruling. SAWS presented a reasonable option to maintain quality of life for the community and minimize impact on water/wastewater rates.

Operations staff were included in initial planning and worked with water resources staff and customers to help provide a reclaimed water system to meet customer needs. Because staff were involved, they were accountable for the reclaimed water program's success.

Construction phase. It is common to coordinate with impacted neighborhoods by holding town hall meetings and information fairs in advance of construction. Because reclaimed water was a new utility bringing a new water supply, many residents had concerns about potential health impacts of reclaimed water. SAWS staff collected three samples of water in large glass containers (potable water, reclaimed water and San Antonio River water) for the information fairs and neighborhood meetings and most residents quickly excluded the river water but could not visually determine which jar contained potable or reclaimed water. This simple visual experience convinced many that reclaimed water was acceptable and clearly not sewage.

River discharge of reclaimed water is a benefit in urban environments; and once politicians were convinced reclaimed water was an acceptable alternative, the benefits of increased baseflow in the river and Riverwalk area downtown were evident to most businesses in the area, reinforcing the need for reclaimed water.

Operations phase. Get over the "us and them" attitude in organizations. The reclaimed water program at SAWS merged into previously distinct areas of the organization (water and sewer) and staff worked together to meet the program needs with their individual experience base. There were challenges such as chlorine dosing at low flows during system startup. When final phases of the project with rechlorination systems were complete, higher quality water was obtained in all parts of the distribution system, eliminating the few customer complaints that had been received.

Acknowledging that issues will happen (i.e. cross connections) in the best of reclaimed water systems and develop customer and staff training programs to educate all involved with immediate steps to resolve cross connections, pipe failures, or other anticipated actions.

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Raw Water Production Facility: Big Spring Plant

Author: David W. Sloan, P.E., BCEE (Freese and Nichols)

US-TX-Big Spring

Project Background or Rationale

Aiming to *"reclaim 100 percent of the water, 100 percent of the time,"* the Colorado River Municipal Water District (CRMWD, the District) in Texas anticipates launching operation of its first water reclamation plant in 2012 as step one in its ambitious program. In developing this plan, a 2005 feasibility study included the following:

- An inventory of effluent quantity and quality
- Determination of quality requirements for various blending scenarios
- Initial coordination with state regulators
- Concept-level cost estimates
- Development of a public information strategy

The Permian Basin of West Texas has always been challenged with water supply issues, and like much of the southwestern United States, has been subject to extended periods of low rainfall through the early 21st century. Since 1996, long-term drought has resulted in dangerously low reservoir levels prompting providers to consider new water supply sources. Water reuse has been practiced in the region for decades, and is increasing with application of new concepts in supply integration.

The CRMWD supplies water to its member cities: Big Spring, Snyder, and Odessa, Texas, as well as several customer cities such as Midland. The population of the CRMWD service area is about 350,000. Key components of CRMWD's water reclamation plan include:

- Facilities to capture treated wastewater effluent prior to discharge
- Local and regional reclamation facilities to purify captured water
- Blending facilities to combine the reclaimed water with other raw water supplies

Although treatment facilities and transmission costs will be significant, CRMWD anticipates savings over other raw water source development options and a reduction in long-distance pumping costs. Three projects are envisioned, with a potential net average yield of 13 mgd (570 L/s).

Capacity and Type of Reuse Application

The District has proceeded with implementation of its first project, near CRMWD headquarters in Big Spring. This project will intercept up to 2.5 mgd (110 L/s) of filtered secondary effluent from the City of Big Spring WWTP and transfer it to an adjacent site, where additional treatment will be provided. The additional processes consist of microfiltration (MF), reverse osmosis (RO) and advanced oxidation prior to blending with raw surface water in the District's raw water transmission pipeline as shown in **Figure 1**.

Project construction began in June 2011, with startup of treatment and transmission anticipated in fall 2012. Reclaimed water will represent up to 15 percent of the blended raw water in the existing pipeline network supplying member and customer cities, which operate conventional surface water plants which will continue to provide final treatment, including disinfection, prior to distribution.

Water Quality Standards

Due to the unique nature of this project—it is the first system in North America that directly blends reclaimed water with raw drinking water supply—there were no existing regulations or water quality standards that would drive specific treatment goals. The District worked closely with the Texas Commission on Environmental Quality to confirm that the proposed project approach and treatment level would be acceptable to protect public health and comply with source water approval regulations.

Treatment Technology

The established systems of the Orange County Water District in California and the Singapore NEWater

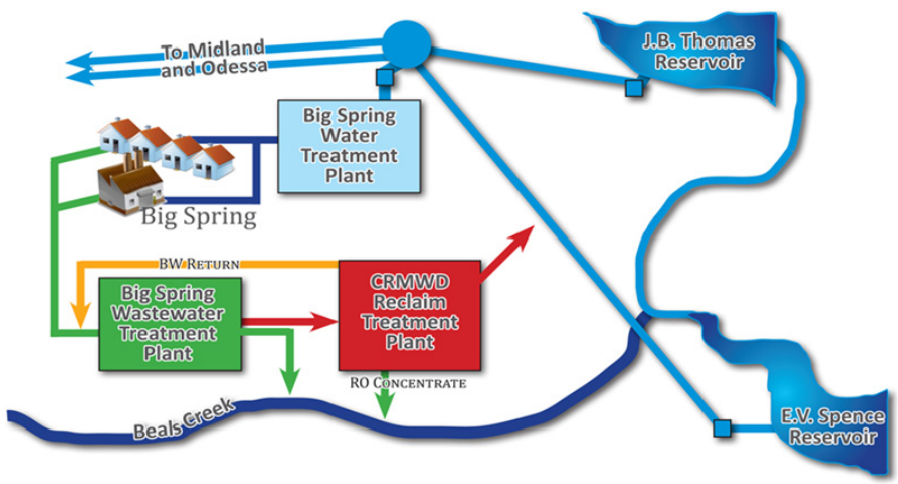

Figure 1
Project schematic, Raw Water Production Facility – Big Spring Plant

facilities provided an established treatment approach for high-exposure potable reuse. This treatment precedent was determined to be applicable for this project.

In selecting treatment processes, local conditions were considered. The use of natural systems such as wetlands or reservoirs was precluded due to high evaporation rates. In lieu of such an option, a rigorous, multi-barrier mechanical treatment scheme was deemed necessary. Water supplies in the District are high in dissolved solids, which are then further concentrated in the treated wastewater effluent. Desalination was therefore indicated as an essential element of the proposed treatment to meet total dissolved solids (TDS) standards for drinking water supply.

In the CRMWD plant system, MF provides removal of particulate material, including protozoan cysts resistant to chemical disinfection. RO provides removal of dissolved salts, viruses and bacteria, as well as many trace compounds such as pharmaceuticals and personal care products. Advanced oxidation with UV and hydrogen peroxide provides an additional barrier to potential pathogens and trace contaminants, not amenable to removal by RO.

Project Funding

The project has been funded primarily by District revenues from the sale of raw water. The initial feasibility study and preliminary design report were funded in part by a state water supply planning grant, which represented approximately 22 percent of the cost for those phases of the project. Construction is funded by a state loan program available for financing new water supplies. Study costs were approximately $440,000 and costs of design and construction of the reclamation plant and transmission facilities are approximately $13.6 million.

Institutional/Cultural Considerations

Local public awareness regarding scarcity of water and an independent, pioneering spirit have contributed to acceptance of the reuse concept by the Permian Basin communities. The area's historic struggle to develop a dependable supply of potable water has resulted in a profound local understanding of the area's needs.

The District has developed a transparent process to inform the public throughout the project. Public meetings were held near completion of the initial feasibility study and again during preparation of the preliminary design report. Numerous media releases, radio announcements, and website descriptions have been provided to raise awareness of the concept and the developing project. The District developed literature and illustrations to distribute at meetings and generally as the project progressed.

Successes and Lessons Learned

Open, proactive communications with state regulators and the public have been key to the success of this project, along with the open-minded evaluation by regulators and public. Lessons learned include recognition of the time required for working out agreements with other entities, such as the member cities of the District.

Site Suitability for Landscape Use of Reclaimed Water in the Southwest

Authors: Seiichi Miyamoto, PhD and Ignacio Martinez
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US-TX-Landscape Study

Project Background

As population and demand for potable water increase, reuse of reclaimed water for landscape irrigation is becoming a more attractive practice in many communities in the U.S. Southwest. It saves potable water, and provides a stable supply of irrigation water for maintaining urban greenery and recreational facilities. While the objective of conserving potable water is being achieved, there have been cases of landscape quality degradation at some reclaimed water use sites including foliar damage, stunted growth, early defoliation, and at times, tree mortality.

Reclaimed water in west Texas and southeastern New Mexico has elevated salinity, up to 1650 ppm (**Table 1**). The sodium adsorption ratio (SAR) is highly variable, but typically ranges from 7 to 12 in the Rio Grande watershed, and 2 to 3 in other areas. For comparison, salinity of reclaimed water used for landscape irrigation in California is generally less than 750 ppm, rarely exceeding 1000 ppm.

Type of Reuse Application

This study was conducted in five project areas where reclaimed water was used for urban landscape irrigation. The landscape areas involved were estimated at 150 to 300 ac (60 to 120 ha). Treated, secondary, municipal effluent is piped to storage facilities and then applied to various reuse sites including golf courses, municipal parks, school yards, and some apartments or commercial real estate irrigated with sprinklers, and occasionally, drip systems. Irrigation was usually managed by regional estimates of consumptive use, and for golf courses, following real-time monitoring.

Water Quality Standards

Municipal effluent in the study area is treated to meet "Public Access" reuse (Type I). The Texas regulation (TAC 210.33) for Type I use mandates biochemical oxygen demand, turbidity, fecal coliform (or *E. coli*), but not salinity. However, regulatory agencies or water providers can place additional stipulations for water quality goals. California guidelines, which are also the basis for the Food and Agriculture Organization (FAO) guidelines, outline hazard ranges, with no problems likely if salinity is less than 450 ppm, and increasing problems at 450 to 2000 ppm. The United States Golf Association (USGA) recommends a 1000 ppm limit for salinity, and a SAR limit of 6, except for special cases. **Table 1** includes typical water quality data of reclaimed water in west Texas and southern New Mexico, along with observed landscape degradation. The quality of the reclaimed water varies temporally, and data may not reflect current quality; some samples in the study area exceeded the USGA guidelines for salinity.

Table 1 Reclaimed Water Quality in West Texas, Southern New Mexico with Landscape Degradation Issues

Water Sources	Water Quality					Soil Suborder	Landscape Degradation
	TDS (ppm)	EC (dS m^{-1})	SAR	Na (ppm)	Cl (ppm)		
El Paso							
Rio Grande	660	0.9	3.2	110	92	Torrifluvents, Entisols	Soil salinization
Fred Hervey	680	0.9	3.7	150	180	Calciorthid, Aridisols	No problem (turf only)
Haskell	980	1.6	7.3	250	280	Torrifluvent, Entisols	Leaf damage, salinization
Northwest	1200	2.2	11.0	350	325	Paleorthid, Aridisols	Leaf damage, salinization
Alamogordo[1]	1800	2.7	2.0	310	480	Camborthid, Aridisols	Leaf damage, salinization
Odessa[2]	1650	2.4	1.9	330	520	Paleustal, Alfisols	Leaf damage

[1] These water sources contain substantial quantities of Ca and SO_4
[2] Reclaimed water quality of this source changes with season

Lessons Learned

In general, design of reclaimed water projects begin with the estimate of green areas with an assumption that all green areas can be irrigated with reclaimed water. This study has shown that this assumption may not be entirely valid for several reasons: 1) many landscape plants can be very sensitive to foliar salt adsorption caused by sprinkler application of water, 2) soil permeability can be too low to achieve necessary salt leaching to avoid buildup, and 3) difficulties of instituting policy changes necessary to reduce salinity and/or sodicity hazard.

Foliar-Induced Salt Damage. This problem is the most wide-spread. Plants adsorb salts through leaves when sprinkled, especially under high frequency irrigation. The extent of foliar damage is species-dependent, and ranged from minor leaf-tip burn to premature defoliation, and plant mortality. Sensitive species, such as broad leaf trees can suffer leaf burn at 150 ppm of sodium or chloride in irrigation water. At 250 ppm, nearly all species can be affected, except for pines and waxy leaf shrubs (Miyamoto and White, 2002). Because of the widespread occurrence of this problem, site suitability assessments should include identification of species sensitive to overhead irrigation with water of elevated salinity (Miyamoto, 2006). An alternative is to convert sprinklers to low trajectory or under-canopy types. (Ornelas and Miyamoto, 2003).

Degradation through Soil Salinization. Landscape degradation caused by soil salinization depends on plant species (Miyamoto, 2004; Miyamoto, 2008). Soil salinization is also soil-type dependent and the most extensive soil salinization, was found in public sports fields developed on clayey Torrifluvents and irrigated with water from the Rio Grande. These soils do not have sufficient permeability to maintain a salt balance, especially when compacted. Some sports fields which were constructed at upland sites with topsoiling were also found to be salinized. The cause and process is still being studied. At the same time, little salt accumulation was found in golf courses developed on upland soils with high permeability, even when irrigated with water of nearly 2000 ppm total dissolved solids. Likewise, apartment and commercial building landscape developed on upland soils have shown no significant level of soil salinization, especially when the site is located on sloped topography which allows lateral salt leaching.

Soil salinization can be minimized through subsoiling and soil profile modification (Miyamoto et al., 2008), and a change in construction protocols. However, there is a need to develop guidelines for soil improvements and design changes. Site suitability assessment must include identification of soil types prone to salinization.

Institutional Constraints. Methods of reducing salinity impact on landscape, such as proper plant selection, irrigation system alteration, and soil improvements are relatively easy to implement, except for upscale sports fields with many expensive features. However, voluntary implementation of these measures was not observed, especially at public facilities due significant changes in reuse expectations and policies. Site suitability assessments should include the evaluation of existing landscape codes and maintenance practices using potable water. Such information can provide indications of success potential when converting irrigation systems to reclaimed water.

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U.S. Water Recovery System on the International Space Station

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US-TX-NASA

Project Background or Rationale

International Space Station (ISS) crew members must conserve as much water as possible because each crew member is allocated only about two liters of water per day. Reclaimed spacecraft water (humidity condensate and urine distillate) was recognized as an efficient, innovative, and safe source for potable water for the ISS. The ability to recover water on ISS has allowed for habitation of six crew members and made the ISS less dependent on ground resupply.

In early phases of the ISS, astronauts relied on a Russian Mir system, in which atmospheric humidity condensate was collected and processed into potable water by a condensate water processor. NASA's water recovery system (WRS), launched to ISS in 2008, goes one step further: it recovers urine in addition to humidity. The system can recover about 85 percent of the water in urine. In order to accomplish this treatment goal, the process necessitated careful engineering and enhanced water quality monitoring and assessment.

The WRS uses physical and chemical processes to remove contaminants from wastewater (**Figure 1**). The produced water is tested by onboard sensors; unacceptable water is cycled back through the water processor assembly. The reliability and safety of the system was demonstrated using a 90-day "checkout" on-orbit, during which no crew consumption of the reclaimed water was allowed. Monitoring during that timeframe showed that inflight chemical and microbial characteristics were similar to those observed in pre-flight system design and testing (Straub and Schulz, 2010). U.S. crews have obtained approximately 75-100 percent of their potable water from this source, and have been able to store excess water for contingencies. Processing downtimes have been limited, and the WRS has proven reliable and efficient.

Microbial growth has been observed, but primarily only during periods of stagnancy. No pathogenic organisms have been detected and monitoring for non-pathogenic levels of microorganisms have been generally consistent with ground-based potable water systems in terms of concentrations and types of microorganisms. In addition to potable uses, other ISS systems (such as oxygen generation) successfully utilize reclaimed water.

Capacity and Treatment Technology

Under optimized conditions, the WRS will process approximately 7 liters of condensate daily, along with a similar volume of urine distillate. Approximately 12 liters of potable water per day are reclaimed for potable purposes. As shown in **Figure 1**, recovered crew urine is distilled in the urine processor assembly

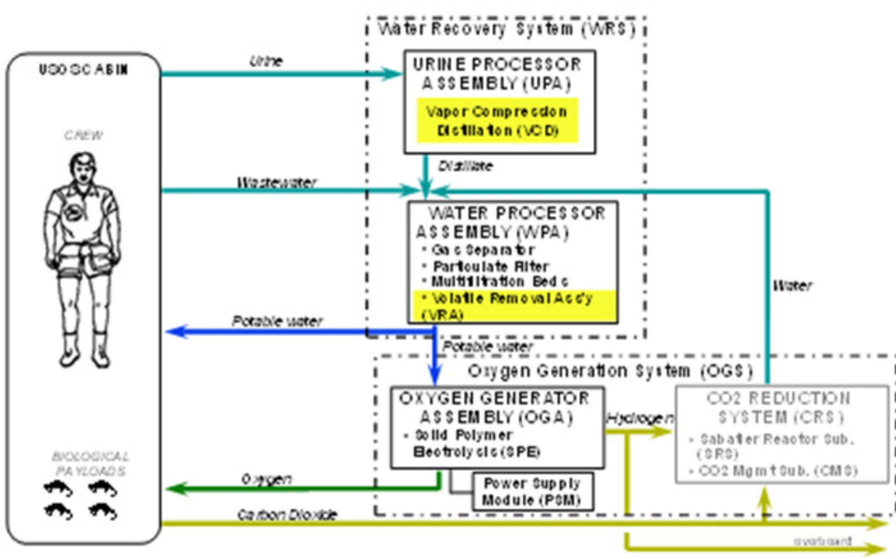

Figure 1
WRS and Oxygen Generator Assembly (OGS) process flow diagram

(UPA), and fed to the water processor assembly (WPA) along with humidity condensate/wastewater; these elements together constitute the U.S. water recovery system (WRS), as shown in **Figure 2**. Reclaimed water is used by the crew as a potable source, and is fed to the oxygen generation assembly (OGA) as a source of electrolytic oxygen that is returned to the spacecraft cabin.

Figure 2
Water recovery system on ISS

Project Funding and Management Practices

The ISS had substantial investments in the implementation of the WRS. Costs for launching water are approximately $10,000/lb ($50,000/liter) because of the relatively large weight of water necessary to support six crew members on ISS (~25 lbs/day or 11.3 kg/day), which makes a strong rationale for use of reclaimed water. Recycling water also serves to reduce crew dependency of resupply. Management was also interested in proving technologies such as WRS that represented skills/resources needed for more remote spaceflight missions.

Institutional and Cultural Considerations

Given the unique setting and end users, there were not significant objections to implementation of WRS on ISS. However, there were indeed stigmas regarding the reclaimed water use (especially in regard to urine recycling). Those stigmas were overcome through openness and effective communication with stakeholders. “Taste tests” and other forums were used to encourage acceptance among crew and decision-makers.

Successes and Lessons Learned

WRS has operated successfully since 2008, and serves as a model for implementation of complex and innovative hardware in a remote environment. Lessons learned have included the value of proper planning, the need for continued monitoring, and the challenges/strengths of multi-disciplinary collaboration.

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East Fork Raw Water Supply Project: A Natural Treatment System Success Story

Authors: Ellen T. McDonald, PhD, P.E. and Alan H. Plummer, Jr., P.E., BCEE (Alan Plummer Associates Inc.) and
James M. Parks, P.E. (North Texas Municipal Water District)

US-TX-Wetlands

Project Background or Rationale

North Texas Municipal Water District (NTMWD) currently provides potable water to a population of over 1.6 million in a region north and east of the City of Dallas. Water is diverted for treatment from the NTMWD's primary raw water supply reservoir, Lavon Lake, which is located in the Trinity River basin and has a firm yield of approximately 104,000 acre-feet per year (~93 mgd). This supply is supplemented with transfers to Lavon Lake from two other water supply reservoirs, one located in the Red River basin and one in the Sulphur River basin. In addition to its potable water supply facilities, NTMWD owns and operates 4 regional wastewater treatment plants and operates 12 smaller wastewater treatment plants within its service area.

NTMWD is located in one of the fastest growing regions in the United States. By 2020, the service area population is anticipated to grow by nearly 700,000 and more than double in the next 50 years. As a result of this unprecedented growth and a strong commitment to the efficient use of water resources, NTMWD developed the East Fork Raw Water Supply Project (EFRWSP) in order to further augment water supply in Lavon Lake.

The EFRWSP diverts return flows from the East Fork of the Trinity River, contributed by NTMWD-owned or customer-owned wastewater treatment facilities, and conveys the return flows through a constructed wetland prior to delivery to Lavon Lake. The project, when developed at full capacity, will add 91 mgd of raw water supply to Lake Lavon for subsequent treatment and use by NTMWD customers.

Capacity and Type of Reuse Application

The wetland covers 1,840 acres and is designed to remove sediments and nutrients from the water, where it is retained for 7-10 days prior to delivery to Lavon Lake. Work on the wetland began in 2004 with the design and construction of the first of two nursery wetlands. The initial nursery, 25 acres in size, was used to provide plant stock of selected emergent wetland species for a 180-acre second phase nursery. The 180-acre nursery was completed in 2006 and was used to provide over 1.6 million plants for the full-scale wetland (**Figure 1**).

Figure 1
ERWSP wetland, May 2009 (Photo credit: Alan Plummer Associates, Inc.)

The general layout of the wetland is shown in **Figure 2**. The diversion pump station includes a river diversion structure and 165 mgd pump station which is used to divert flow from the East Fork Trinity River to the upstream end of the wetland. Currently this pump station includes two 250 horsepower (hp), 16,810 gallon per minute (gpm) and two 500 hp, 33,620 gpm vertical turbine pumps. Space has been provided for one additional pump. The conveyance pump station also has a capacity of 165 mgd, and currently includes three 3,000 horsepower, 33,620 gpm vertical turbine pumps used to convey the wetland-polished water to Lavon Lake. Space for two additional pumps has been provided.

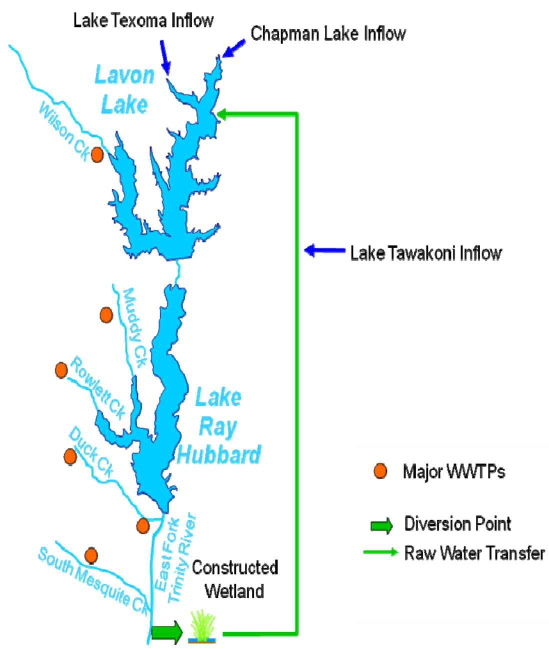

Figure 2
ERWSP Flow Directions

Water enters at the north end and travels through sedimentation basins prior to entering the main cells. The wetland includes parallel trains with multiple cells. There are three distinct geographic zones; the wetland trains in each zone discharge to a common channel or pool where outflows from each individual train commingle. The flow is subsequently redistributed to the uppermost cells of the trains in the next zone. In effect, this arrangement creates three distinct treatment wetlands which present some design challenges, but provide additional operational flexibility. Deep water zones were included at the inlet and outlet of each cell. Intermediate deep water zones were also included to help redistribute flow across the cells should preferential flows or short circuiting develop.

Water Quality Standards and Treatment Technology

Water quality within Lavon Lake was a key consideration during planning of the project. One of the imported supplies originates from a relatively high total dissolved solids (TDS) source. Furthermore, in addition to the imported supplies, the NTMWD's largest regional wastewater treatment plant (currently permitted at a capacity of 48 mgd) discharges into the western arm of Lavon Lake. Thus, the assimilative capacity of the lake as it relates to dissolved solids, nutrients and eutrophication, as well as potential impacts of microconstituents were addressed within the planning process.

Project Funding and Management Practices

The wetland was developed through a partnership with the Carolyn Hunt Trust Estate, which owns and operates a ranch and a smaller wetland on the property. This partnership has resulted in the construction of the largest water supply project of its kind in the United States.

Water rights permitting was also a key component of the EFRWSP planning process. Return flows from the Dallas-Fort Worth Metroplex travel down the Trinity River, ultimately reaching Lake Livingston, which is a major water supply reservoir serving the city of Houston. In addition, several of the NTMWD wastewater treatment plants supplying the EFRWSP discharge into an upstream reservoir owned by the City of Dallas. Furthermore, several environmental interest groups expressed concerns about potential decreases in freshwater inflows to Galveston Bay, located downstream of Lake Livingston. Securing the water right for the project required a lengthy negotiation process with all of these parties.

Institutional/Cultural Considerations

As indicated above, water rights in a water-short state raised significant discussions. By working together over several years, parties came to agreement, including several environmental interest groups initially concerned with Instream flows and cumulative flows to the Texas bays and estuaries. Through education and negotiations to limit internal Lavon Lake blending to 30 percent, these interest groups recognized the inherent environmental benefits of potential deferral of the need to construct new water supply reservoirs and the development of additional aquatic life habitat created by the wetland.

The wetland and nature center was developed through a partnership with the Carolyn Hunt Trust Estate, which owns and operates a ranch and a smaller wetland on the property. The project has experienced very little public opposition, and overall is seen as an asset to area by environmental interest groups, the water supply community and the general public. This positive image is largely attributed to the constructed wetland, which provides multiple benefits associated with water supply, aquatic life habitat enhancement, and extensive educational and research opportunities.

Successes and Lessons Learned

The EFRWSP is operational and providing immediate benefit to area water supply customers and the public. Time educating and negotiating differing opinions has resulted in a project with benefits for all interested parties.

Potable Water Reuse in the Occoquan Watershed

**Authors: Robert W. Angelotti (Upper Occoquan Service Authority)
and Thomas J. Grizzard, PhD, P.E. (Virginia Tech)**

US-VA-Occoquan

Project Background or Rationale

The Occoquan Reservoir is a critical component of the water supply for approximately 1.5 million residents of Northern Virginia, a highly urbanized region located west of Washington, D.C. (**Figure 1**). Reclaimed water represents a significant supplement to potable water supply yield from the reservoir and has been successfully augmenting the drinking water supply for over three decades.

Figure 1
Aerial view of the Occoquan Reservoir (Photo credit: Roger Snyder, Manassas, Virginia)

Rapid transformation from a largely rural to a predominantly urban/suburban region began in the 1960s as a result of unprecedented growth from the westward expansion of the urban core of Washington, D.C. By the mid-1960s, this urbanization was adversely affecting water quality of the Occoquan Reservoir, resulting in an unplanned and unintended indirect potable reuse scenario, where 11 small wastewater treatment plants were discharging effluent upstream of the reservoir. Poorly treated wastewater, with urban and agricultural runoff, threatened continued use of the Occoquan Reservoir for public water supply.

In 1971, the Virginia State Water Control Board (VDEQ) and the Virginia Department of Health (VDH) adopted a plan to protect the Occoquan Reservoir as a drinking water supply. The Occoquan Policy mandated a newly conceived framework for water reuse and set in motion the first planned and intentional use of reclaimed water for supplementing a potable surface water supply in the United States (VDEQ and VDH, 2012).

The Occoquan Policy mandated creation of a regional State authority, the Upper Occoquan Service Authority (UOSA), to provide collection and reclamation of wastewater, and the Occoquan Watershed Monitoring Program (OWMP), to continuously monitor the watershed and reservoir to provide independent water quality assessments and advice on protective measures for the reservoir. By the 1970s, Fairfax Water was responsible for potable water production and distribution for much of Northern Virginia. The VDEQ and VDH were also highly involved in developing the ultimate solution.

While water quality improvement was the primary driver for implementing planned and intentional potable water reuse in the Occoquan system, supplementing the raw water supply was always an underlying objective. Although the mid-Atlantic region of the U.S. is not considered dry or arid, the population density results in stressed water supply, and limited per capita water availability. This situation becomes more pronounced during periodic extended drought conditions.

Capacity and Type of Reuse Application

A diagram illustrating how the UOSA reclamation system interacts with the drinking water supply is provided in **Figure 2**. The UOSA reclamation plant produces about 32 mgd (1,400 L/s) of water on an annual average basis and the plant has the capacity to reclaim as much as 54 mgd (2,370 L/s) of water. A future annual average plant flow of around 65 mgd is

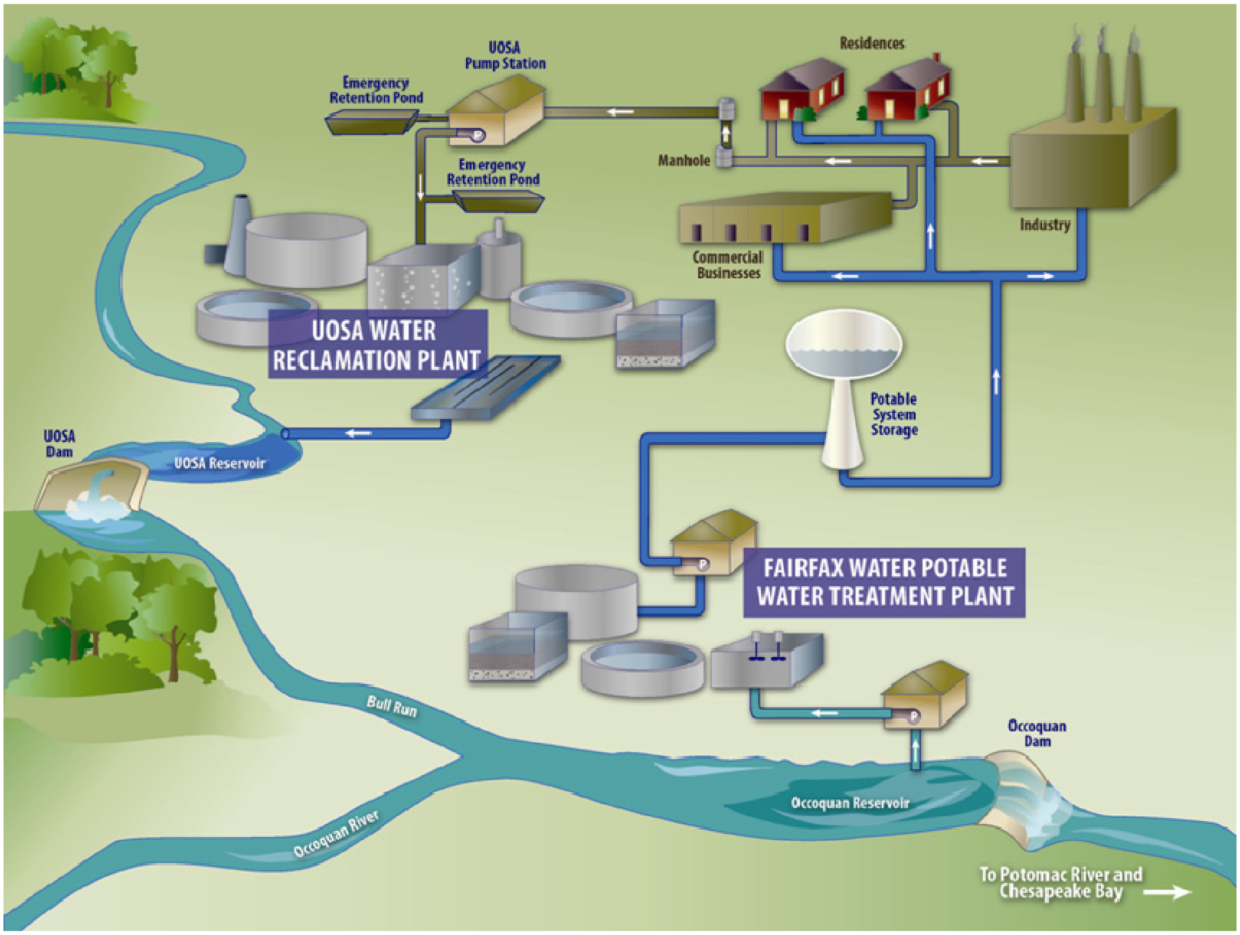

Figure 2
The UOSA Reclamation Plant provides an important source of water for the service area (Photo credit: CDM Smith for UOSA)

associated with the build out condition within the UOSA service area. Future reclaimed water production is anticipated to effectively double the safe yield of the Occoquan Reservoir. Although the majority of water produced supplements the drinking water supply, 1 to 3 mgd (44 to 130 L/s) is also delivered for nonpotable uses on the UOSA campus.

Water Quality Standards and Treatment Technology

The water reclamation process includes preliminary and primary treatment followed by complete mixed activated sludge with biological nitrogen removal. Advanced water treatment processes include lime precipitation and two stage recarbonation with intermediate settling; these processes remove phosphorus and are barriers to pathogens and heavy metals. Final polishing is accomplished with multimedia filtration, granular activated carbon adsorption, chlorination and dechlorination.

Reclaimed water is produced at concentrations that meet all Federal Primary and Secondary Drinking Water Standards except occasionally for nitrate and total dissolved solids. Seasonally, the nitrate drinking water standard is exceeded purposefully to accomplish specific reservoir water quality goals. Reclaimed water quality permit standards are provided in the UOSA discharge permit (UOSA and VDEQ, 2012), and typical characteristics of the reclaimed water are available from UOSA (UOSA, 2012).

Management Practices and Institutional Considerations

Today, the concept of indirect potable reuse is well communicated to regulators and public official stakeholders within the region. Interested parties within local municipalities are well aware that a significant portion of the water supply is comprised of reclaimed water. Both Fairfax Water and UOSA are run by a board of directors. Board members are representatives for their community and make decisions in the best interest of the communities they serve. It is not uncommon for UOSA to collaborate closely with representatives of local governments about issues relating to water quality.

The community and the independent water quality monitoring entity, OWMP, both openly acknowledge that the reclaimed water produced by UOSA is the most reliable and highest quality water entering the Occoquan Reservoir. The OWMP has a technical advisory panel that is comprised of members from EPA, VDEQ, VDH, and an expert from an accredited and well-renowned academic institution within the state (Virginia Polytechnic Institute and State University, otherwise known as Virginia Tech). This provides even greater confidence and credence for potable reuse in the region.

Periodically, water related issues within the region result in the formation of technical advisory groups, citizen action committees and task forces. These may be composed of agency stakeholders, city or county government officials, community representatives, water experts and interested citizens. Examples of issues tackled by such groups include: land zoning around the reservoir to protect water quality, siting of a major semiconductor industry within the UOSA service area, and consumptive use of reclaimed water by a proposed power plant. These collaborative efforts with interested and affected parties are used to gather input before important decisions are made that might impact water quality or its availability to users.

Cultural and Social Considerations

When water reclamation was first proposed, a number of hearings were conducted to explain what was to be implemented and to provide the public a venue to express their views. UOSA has always engaged in an active program to provide tours to local students, from grade school through college, during which potable reuse is thoroughly explained. These tours have been conducted for more than 30 years, providing public outreach to the local population on the importance of UOSA's mission. In addition, UOSA maintains a public website where it's role in potable water reuse is clearly expressed. UOSA's success has not required dedicated public relations staff or a formal public outreach and communication program.

Successes and Lessons Learned

Perhaps the greatest key to success of this project is that it was implemented specifically to improve water quality problems in the existing surface water reservoir being used as the drinking water supply. The project was initiated by the Commonwealth of Virginia, via state regulation (the Occoquan Policy) which was developed by the VDEQ and VDH. Early water quality problems in the Occoquan Reservoir were clearly articulated and the best solution for the region was presented to stakeholders and interested citizens. Although water quality was the major driver, it was clearly recognized that treated wastewater flows returned to the reservoir would be a significant and valuable resource in the future.

This project is unique in that there is a separate watershed management program (OWMP), along with its associated water quality monitoring laboratory (OWML) that provides oversight, independent accountability and recommendations to the water reclamation agent (UOSA), the potable water treatment and distribution entity (Fairfax Water) and state regulatory agencies. This was critical in establishing a credible voice of endorsement and recommendation for the plan. Collaboration among major institutional entities that work toward common goals of protecting and improving the water quality of the reservoir demonstrates the leadership for water-related issues for the community. More than 34 years of successful implementation has demonstrated confidence that the original plan is still working well today.

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Water Reuse Policy and Regulation in Virginia

Author: Valerie Rourke, CPSS, LPSS, CNMP (Virginia Department of Environmental Quality)

US-VA-Regulation

Project Background

The Commonwealth of Virginia has had a long history of water reuse, which formally began with the operation of an indirect potable reuse project by the Upper Occoquan Sewage Authority (now the Upper Occoquan Service Authority) (UOSA) in 1978 [US-VA-Occoquan]. Consistent with national trends, water reuse has continued to gain greater acceptance and application in Virginia due primarily to efforts to reduce or avoid wastewater treatment facility discharges to surface waters, and increasing urban population growth.

EPA has developed a total maximum daily load (TMDL) for nutrients that are discharged to the Chesapeake Bay. The TMDL affects all point source discharges of states, including Virginia, within the watershed of the Chesapeake Bay. As a result, Virginia's discharging wastewater treatment facilities are required to meet lower nutrient limits through nutrient trading[1], the installation of nutrient removal technology or the implementation of non-discharging alternatives, such as water reuse.

From 1950 to 2010, Virginia's population more than doubled from 3.2 million to 8.0 million inhabitants with an increase of 13 percent during the period of 2000 to 2010. Projected population growth will be in mostly urban centers of the state. Although Virginia has an average annual rainfall of 40 inches, it experiences water shortages during periods of prolonged drought. Such water shortages are compounded by population growth, which places an increasing demand on water supply. As a result, Virginia's Local and Regional Water Supply Planning Regulations (9VAC25-780) now require localities to develop water plans to ensure the availability of adequate and safe drinking water for citizens of the Commonwealth, and to protect all other beneficial uses of the Commonwealth's water resources. As part of their water plan, localities must provide a statement of water need and alternatives to meet this need; alternatives may include nontraditional options, such as inter-connection, desalination, recycling and reuse.

Current Regulations and Guidelines

Virginia does not have a singular, comprehensive policy or program for reuse of all types of water that have historically been wasted or disposed. Rather, multiple state agencies have regulations or guidelines that affect water reuse, determined in most cases by the type of wastewater to be reclaimed, with some degree of redundancy. For example, the following agencies have regulations or guidelines governing aspects of water reuse:

- The Virginia Department of Environmental Quality (DEQ) has regulations for the reclamation and reuse of domestic, municipal or industrial wastewater collected and treated through centralized systems.
- The Virginia Department of Health has regulations that allow the onsite treatment and reuse of sewage for toilet flushing in conjunction with a permitted onsite sewage system, and has guidelines for the non-potable use and reuse of harvested rainwater and graywater, respectively.
- The Virginia Department of Housing and Community Development has regulations for the indoor treatment and plumbing of recycled gray water and harvested rainwater, and for the indoor plumbing of reclaimed water meeting appropriate regulatory standards administered by the DEQ for indoor reuses.

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[1] Nutrient trading is a market-based program that provides incentives for entities to create nutrient reduction credits by going beyond statutory, regulatory or voluntary obligations and goals to remove nutrients from a watershed. To achieve a desired load reduction, trades of nutrient credits can take place between point sources (usually wastewater treatment plants), between point and nonpoint sources (a wastewater treatment plant and a farming operation) or between nonpoint sources (such as agriculture and urban stormwater sites or systems).

- The Virginia Department of Conservation and Recreation has limited regulations for the reclamation and reuse of storm water and evaluates such proposals on a case-by-case basis.

History and Regulation Development

Virginia's process to adopt regulations for the reclamation and reuse of domestic, municipal and industrial wastewater first began in 1999. The Virginia General Assembly directed DEQ to convene a committee to assist the agency with the development of a report (House Document No. 92), examining the advantages and disadvantages of water reuse as the basis for future legislation on this subject. In 2000, the General Assembly incorporated some of the recommendations of the report into the Code of Virginia, providing the statutory basis for the State Water Control Board to develop regulations for water reuse. Following two separate consecutive actions to develop such regulations, the Virginia Water Reclamation and Reuse Regulation (9VAC25-740) was adopted and became effective on October 1, 2008.

The Water Reclamation and Reuse Regulation is unique among other water regulations adopted by the State Water Control Board (SWCB). Most water regulations of the SWCB fall distinctly within policy, permitting, standards or technical categories. The Water Reclamation and Reuse Regulation (9VAC25-740) however, contains standards for reclaimed water and provides technical design and operational requirements for facilities that produce, store and distribute reclaimed water for reuse. It is not a permit regulation but, describes existing water permit types that may be used to authorize water reclamation and reuse projects. It is also a "bridging" regulation for projects that have both wastewater treatment and water resources or supply components, such as for indirect potable reuse.

The development or amendment of any regulation adopted by the SWCB must follow the procedures described in the Administrative Process (Act §2.2-4000 et seq. of the Code of Virginia). The SWCB typically delegates its authority to develop and implement regulations to the DEQ. In accordance with agency's Public Participation Guidelines (9VAC15-11), the DEQ may assemble a regulatory advisory panel or a technical advisory committee to assist the agency with the development of a regulation. DEQ assembled a technical advisory committee for the Water Reclamation and Reuse Regulation, which provided significant input and support during this process.

Resources Used to Develop the Regulations

To develop the Water Reclamation and Reuse Regulations, DEQ relied upon and benefitted from a variety of existing resources. These included the EPA *Guidelines for Water Reuse* (2004); rules, regulations, guidelines and regulatory contacts of water reuse programs in other states; the WateReuse Association; and WateReuse Symposiums. The EPA *Guidelines for Water Reuse* provided a preliminary framework and basic items that should be considered as part of any regulatory program for water reuse. Other states' water reuse rules, regulations and guidelines provided information about more detailed items to consider as part of a regulatory program. Discussions with other water reuse regulators, particularly through the WateReuse Association or at the annual WateReuse Symposium, were invaluable regarding unique problems and solutions, and the implementation of a water reuse program.

Media Involvement

The media was involved to occasionally cover the status of the regulation during development and eventual adoption.

Institutional/Cultural Considerations

There were no institutional or cultural issues that drove decisions during the development of the regulation.

Details Particular to Virginia

Water reclamation and reuse is strictly voluntary in Virginia. However, when a facility chooses to reclaim domestic, municipal or industrial wastewater for reuse, the facilities must comply with the requirements of the Water Reclamation and Reuse Regulation with some exceptions as described in 9VAC25-740-50. Treatment requirements and reclaimed water standards in the regulation were developed to be protective of public health and the environment, while providing options that, to the greatest extent possible, would allow most existing wastewater treatment facilities to produce reclaimed water with little or no change in their treatment processes. Less treatment, however, will limit reuse options in most cases. Indirect potable reuse projects may be permitted on a case-by-case basis but, direct potable reuse is prohibited. The Water Reclamation and Reuse Regulation specifically excludes graywater reuse and does not address the reclamation and reuse of storm water or harvested rainwater, which are addressed by the guidelines or regulations of other state agencies.

Unlike the water reuse rules, regulations and guidelines of other states, the Virginia Water Reclamation and Reuse Regulation requires that all irrigation with reclaimed water be supplemental. Supplemental irrigation is defined as irrigation, which in combination with rainfall, meets but does not exceed the water necessary to maximize production or optimize growth of the irrigated vegetation. This definition is intended to distinguish land treatment of wastewater, a method of disposal, from irrigation reuse that involves irrigation of crops for a beneficial use rather than disposal. Due to this difference, land treatment will generally require ground water monitoring, while irrigation reuse will not. Also, irrigation reuse may be either bulk or non-bulk determined by the size of the irrigation site. For bulk irrigation reuse of reclaimed water (irrigation of areas greater than five acres on one contiguous property), a nutrient management plan will be required where non-biological nutrient removal (non-BNR) reclaimed water (reclaimed water with annual average concentrations of total nitrogen and total phosphorus greater than 8 and 1.0 mg/l, respectively) will be applied to the irrigation reuse sites. Irrigation of non-bulk irrigation sites with non-BNR reclaimed water will not require a nutrient management plan but will be required to implement other measures to manage nutrients at the irrigation reuse site.

Successes and Lessons Learned

While water reclamation and reuse poses some unique issues in Virginia, it is still viewed as a useful tool among others to optimize water resources long term. It is shifting the paradigm from one that has viewed water resources and wastewater treatment separately, to one that views water resources and wastewater treatment as related and affecting each other.

References

§ 2.2-4000 et seq., Administrative Process Act.

9 VAC 15-11-10 et seq., Virginia Administrative Code, Public Participation Guidelines.

9 VAC 25-740-10 et seq., Virginia Administrative Code, Water Reclamation and Reuse Regulation.

9 VAC 25-780-10 et seq., Virginia Administrative Code, Local and Regional Water Supply Planning Regulations.

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City of Sequim's Expanded Water Reclamation Facility and Upland Reuse System

Author: Chad Newton, P.E. (Gray & Osborne, Inc.)

US-WA-Sequim

Project Background or Rationale

The city of Sequim is a community on the Olympic Peninsula in Washington State, along the Strait of Juan de Fuca and adjacent to the Dungeness River. Sequim is a rapidly growing community in part because, unlike the rest of the peninsula, Sequim has a dry climate and averages 15 inches of rainfall per year due to the storm-blocking effect of the Olympic Mountains. Adjacent to Sequim are marine waters with major shellfish harvesting areas for Dungeness crab, oysters, geoducks, and clams.

The city constructed the first wastewater treatment facilities at the current site in 1966 with a marine outfall into the Strait of Juan de Fuca. In 1994, following several years of contention over deteriorating surface water quality, shellfish restrictions and insufficient water supply, the city of Sequim signed an agreement with two state agencies to develop a plan for upland reuse of their wastewater. The 1998 Class "A" Reclaimed Water 100 Percent Upland Reuse Plan included three primary water reuse sites.

Development of Water Reclamation Facility

In 1998, parallel to the water reuse plan, the city upgraded its wastewater treatment facility into a 0.79 mgd (35 L/s) Class A Water Reclamation Facility (WRF). Class A is the highest quality class of reclaimed water in Washington State's reuse guidelines and must be continuously oxidized, coagulated, filtered and disinfected. The project upgraded the existing processes, including influent screening, grit removal, activated sludge treatment in an oxidation ditch, secondary clarification and aerobic sludge digestion. The project also added chemical coagulation, anthracite media filtration and low-pressure/low-intensity UV disinfection to produce reclaimed water. The effluent quality requirements at the Sequim WRF are summarized in **Table 1**. The facility is equipped with a bypass holding pond for diversion of inadequately treated wastewater if online monitoring indicates that reclaimed water does not meet permit requirements.

Table 1 Reclaimed Water Quality Requirements

Parameter	Effluent Limit	
	Monthly Average	Weekly Average
BOD_5 (mg/L)	30	45
TSS (mg/L)	30	45
D.O. (mg/L)	Must be present	
Filtration	**Monthly Average**	**Sample Maximum**
Turbidity (NTU)	2	5
Disinfection	**7-Day Median**	**Sample Maximum**
Total Coliform (MPN/ 100 mL)	<2.2	23
Nitrogen Removal	**Monthly Average**	**Daily Maximum**
Ammonia (mg/L)	3.3	5.7
Total Nitrogen (mg/L)	10	N/A

Following construction of the WRF and the water reuse sites, the Washington State Department of Health opened 2,800 acres of previously closed shellfish beds for harvesting, retaining only a 300-foot radius closure around the outfall.

Water Reuse System

The city has developed a reclaimed water distribution system that seasonally diverts a large portion of the reclaimed water away from the marine outfall. Reclaimed water is conveyed from the WRF to the reuse sites for the following uses:

- Reuse Demonstration Site at Carrie Blake Park, where reclaimed water is used for park irrigation, toilet-flushing and, following re-aeration, stream flow augmentation to Bell Creek (**Figure 1**) to improve stream flows for fisheries and habitat restoration.

- Highway 101 Bypass future rest stop, planned landscape irrigation system (rest stop and irrigation system have not yet been constructed).
- The City Shop, where reclaimed water is used for vehicle washing, street cleaning and fire truck water, and made available to the public for construction purposes such as dust control.
- Landscape irrigation of street medians.

Figure 1
Introduction of reclaimed water to Bell Creek (Photo credit: Gray & Osborne, Inc.)

WRF Expansion Project

In 2007, due to rapid population growth in the region, the city expanded the WRF, doubling capacity and converting the WRF from an oxidation ditch to a conventional activated sludge plant employing the Modified Ludzack-Ettinger (MLE) process for enhanced nitrogen removal. Construction of the expansion project began in August 2008 and was completed September 2010 at a project cost of $11 million.

The reclaimed water permit for the expanded WRF is not yet finalized, but is anticipated to retain the effluent quality limitations in **Table 1**. The 2008-10 WRF expansion project included:

- Conversion of the existing equalization basin (EQB) into a plug-flow activated sludge basin (MLE process with nitrogen removal)
- Conversion of the existing oxidation ditch into an EQB
- Addition of a third secondary clarifier
- Addition of a fabric filter to increase the filtration capacity of the existing anthracite media filter

The WRF expansion (**Figure 2**) project also included redundant aeration blowers with a dissolved oxygen control system, additional coagulation equipment, and a remote alarm system. Electric power for the entire treatment process is backed up by generators. For the protection of public health and the environment (including shellfish beds), expansion of the disinfection system was designed to meet the pathogen removal criteria developed by the National Water Research Institute (NWRI) to produce essentially pathogen free reclaimed water.

Figure 2
Sequim Water Reclamation Facility expansion (Photo credit: Gray & Osborne, Inc.)

Water Reuse System Expansion Project

In 2008, the city began an effort to identify additional uses of reclaimed water in order to reduce the volume discharged to the Strait of Juan de Fuca, and reduce demands on the Dungeness River aquifer for irrigation and potable water. The city received a grant from the Washington State Department of Ecology for planning and design of a water reuse system expansion.

A study identified potential new uses including groundwater recharge and additional irrigation areas. Five sites were studied for groundwater infiltration basins, which would allow year-round augmentation of the shallow aquifer with reclaimed water and significantly reduce marine outfall discharge outside the irrigation season. The 2008-10 WRF Expansion project provided reclaimed water with nitrogen levels suitable for groundwater recharge. Hydrogeological studies were performed at two of the sites in 2010, including monitoring well studies with pilot infiltration pits.

In 2011, an engineering plan was completed for the water reuse system expansion, which recommends the following improvements:

- Construction of 1.3 ac (0.53 ha) of rapid infiltration basins at the Reuse Demonstration Site, with an estimated capacity of 1.3 mgd (57 L/s).
- Construction of a booster pump station and reservoir to provide reclaimed water to the city's high pressure zone, for irrigation uses.
- Expansion of the distribution system to provide access to reclaimed water to additional irrigation users.
- Construction of additional reclaimed water storage at the WRF and the Reuse Demonstration Site.
- Conduct a pilot project of groundwater recharge at the City Shop property. If successful, reclaimed water could be applied to shallow groundwater throughout the reclaimed water pipeline system.

The city plans to implement the design and construct the water reuse system expansion projects as funds become available.

Results and Conclusion

In the mid-1990s, following several years of contention over deteriorating surface water quality, shellfish restrictions and insufficient water supply, the city of Sequim embarked on a water reuse program by upgrading their existing wastewater treatment plant into a "Class A" water reclamation facility and developing a reclaimed water distribution system and reuse sites. However, irrigation was the primary use for reclaimed water and the marine outfall was still needed, especially during the non-irrigation season. Ten years later, as the population continued to grow and the reclaimed water system matured, the city has expanded the WRF treatment capacity and is planning for a significant expansion of water reuse capacity.

The water reuse program at the city of Sequim has been successful since 2000 when 2,800 ac (1,130 ha) of previously closed shellfish beds were reopened for harvesting. Due to the upgrades in reliability and pathogen removal provided by the 2008-10 WRF expansion, the Washington State Department of Health concluded that the existing shellfish closure zone, a 300-yard (274-m) radius around the marine outfall, would not require enlargement, despite a doubling of flow capacity.

Due to the parallel efforts of the city to expand the WRF and develop additional reuse facilities, the city will experience improvements in fish and wildlife habitat and a reduction in the amount of reclaimed water sent through the marine outfall, and, eventually, achieve the goal of the 1998 "Class A" Reclaimed Water 100 Percent Upland Reuse Plan.

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Washington State Regulations

Authors: Chad Newton, P.E. (Gray and Osborne, Inc.)
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US-WA-Regulations

Project Background

Washington State has a reclaimed water program governed by comprehensive guidelines that define water quality standards and a variety of allowed beneficial uses. At the time of this publication, there are at least 25 water reclamation systems in operation or are in the process of being permitted in the state.

In 1992, Washington State initiated the Reclaimed Water Law, Revised Code of Washington (RCW) 90.46 after a prolonged drought. In 1995, the legislature declared that reclaimed water was no longer wastewater. In 1997 the Washington State guidelines, *Water Reclamation and Reuse Standards* were adopted, directing the State Departments of Ecology and Health to jointly administer the reclaimed water program (Washington State Department of Ecology and Washington State Department of Health, 1997). This created a framework to tap an unused water resource while assuring public health protection and environmental stewardship.

In 2006, the Department of Ecology began developing a Reclaimed Water Rule, a state regulation that would supersede the existing guidelines. The current draft of the regulation (Washington State Department of Ecology, 2010) was made available to the public in May 2010, and refers to a *Reclaimed Water Facilities Manual* for supplemental guidance on implementing the rule. The guidance manual is currently under development. Legislative amendments have been proposed to consolidate all regulatory duties at Department of Ecology, and to authorize fees to support the state's water reclamation program through rule for reclaimed water permits or for reviewing proposals. The draft rules are on hold due to 2011 governor and legislative mandates to halt non-critical rule-making because of state budget constraints. Adoption of the draft regulation and the guidance manual is tentatively anticipated in 2013.

Current Guidelines

The 1997 standards drew heavily from California's Title 22 recycled water program. The Washington State guidelines define four classes of reclaimed water, Class A, B, C and D, based on applied treatment processes and water quality (**Table 1**). Class A reclaimed water, the highest quality class, is oxidized, coagulated, filtered and disinfected. Reclamation plants must also meet reliability standards and have storage or alternate discharge locations for non-compliance. As the standards are based on 1997 common treatment technologies, other technologies are accepted if they can be demonstrated to provide the same level of treatment efficiency, reliability and public health protection.

Table 1
Requirements for reclaimed water in Washington State

	OXIDIZED		COAGULATED	FILTERED	DISINFECTED	
	Secondary Treatment (mg/L)	Dissolved Oxygen	Y/N	Turbidity (NTU)	Total coliform (MPN/100 mL)	
Class					7-Day Median	Single Sample
A	30	Must be present	Yes	2 NTU avg. 5 NTU max.	≤ 2.2	23
B	30	Must be present	No	No	≤ 2.2	23
C	30	Must be present	No	No	≤ 23	240
D	30	Must be present	No	No	240	N/A[1]

[1] Not applicable

The guidelines provide use area and water quality standards for the following beneficial uses of reclaimed water:

- Irrigation of food and non-food crops
- Landscape irrigation
- Landscape and recreational impoundments
- Commercial, municipal and industrial uses
- Groundwater recharge (by surface percolation or direct injection)
- Streamflow augmentation
- Wetlands

Proposed Regulations

In the 2006 draft regulation, the current four classes of reclaimed water would be streamlined to two: Class A and Class B. The regulation includes new provisions for production of Class A reclaimed water with membrane filtration and membrane bioreactor processes, for which stricter turbidity standards are provided. New virus removal standards for Class A reclaimed water are included: disinfection facilities must be designed to provide 5-log virus removal or inactivation (unless a 1-log filtration credit is applicable). Disinfection facilities must also be verified through a field-commissioning test prior to producing reclaimed water.

While Washington State law grants exclusive rights to distribute and use reclaimed water, the law also prohibits the facility from impairing existing downstream water rights without agreed compensation or mitigation. The draft regulation includes procedures for completing a satisfactory assessment of the potential to impair water rights that may be impacted by a water reclamation project.

Rule-making Process

An advisory committee was created that included stakeholders representing affected regulatory agencies, public and private reclaimed water utilities, environmental organizations, water rights attorneys, Native American tribes, engineers, and potable water utility and local governmental organizations. Several subgroups studied specific areas and developed direction and language for the committee and agencies.

- Removing Barriers Subtask Force: Identified major road blocks to developing and implementing reclaimed water, such as restrictive regulations, funding limitations, and public perception of the product and where it could be used.

- Long Term Funding Subtask Force: Assessed the effect of financial limitations on development of water reclamation projects.

- Water Rights Impairment Task Force: Defined the impacts and remedies for the effect on existing water rights when wastewater return flows are reduced or removed. The group could not find consensus on solutions during their two year effort.

- Technical Advisory Panel: Provided technical expertise to address issues with applying and implementing new technologies, including how to assure public health protection through treatment. The final draft rule includes the panel's recommendations.

- Trace Organics Committee: Considered concerns from the environmental community, such as potential public health and environmental impacts from trace organic chemicals in reclaimed water. The committee recommended no additional monitoring in the rule. They also requested that agencies remain cautious and be ready to respond as more information becomes available.

The advisory committee was still reviewing and commenting on a well-developed draft rule when it was put on hold in 2011. Concerns included:

- Waters rights impairment: State law requires that a facility producing reclaimed water must not impair "existing downstream water rights" without agreed upon compensation or mitigation. The advisability of reducing or removing wastewater discharges to water bodies within watersheds closed to further water rights appropriations, and to streams with minimum in-stream flows set to protect aquatic habitats, is not yet resolved.

- Rule implementation: What might happen during implementation of the rule as drafted? A guidance manual was initiated which would include details surrounding implementation. The manual was in its second draft when rule development was suspended.

Media Involvement

The Washington rule-making process requires that all meetings be open to the public and public hearings be conducted. Meeting minutes and outcomes are available to the public electronically through the Department of Ecology website. Newspaper articles were written after the three public hearings. There was little public feedback (Washington State Department of Ecology, n.d).

Details Particular to Washington

The Washington State program is similar to, and builds on the California recycled water program for technical detail. The Washington State program has to refine certain administrative and policy details related to state organization and existing requirements.

- Lead agency: Responsibility is shared by two separate state agencies with similar but different requirements. To help avoid confusion, a "lead agency" and "non-lead agency" is designated for each project. Since Department of Health hasn't developed a permit program for water reclamation yet, Department of Ecology will issue permits until then.

- Enforcement: The two state agencies have significantly different regulatory requirements and processes for enforcement. This has to be clearly addressed in the rule.

- Aquifer recharge responsibilities: RCW 90.46 requires Department of Ecology to be responsible for land application projects. Aquifer recharge projects are, in concept, land application projects. Reclaimed water can recharge an aquifer and be recovered as a potable water supply, which is regulated by the Department of Health. Significant coordination is needed to assure public health and environmental protection without redundancy.

- Access to reclaimed water: RCW 90.46 grants the exclusive right to distribute and use reclaimed water to the owner of the facility producing the water. Current state laws are silent regarding control or access to "sewage" and "sewage effluent". Areas served by regional collection and treatment entities and multiple public water systems have ownership and water rights disputes. This is a barrier to development of satellite reclaimed water facilities.

- Fees: RCW 90.46 doesn't give either agency authority to collect fees necessary to support the state's water reclamation program through rule for reclaimed water permits or for reviewing proposals. Another legislative amendment will be needed to ensure the agencies receive fee support.

[Note that due to budget issues and staffing cuts the state's regulatory program will experience significant but as yet undefined changes after July 1, 2012.]

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Demonstrating the Safety of Reclaimed Water for Garden Vegetables

Author: Sally Brown, PhD (University of Washington)

US-WA-King County

Project Background or Rationale

Currently, less than 1 percent of the 200 mgd (8760 L/s) of wastewater that is treated in King County, Washington is treated to produce Class A reclaimed water, with the remainder discharged to Puget Sound. Concern over Puget Sound's health and future nutrient discharge limitations prompted King County to explore reducing reliance on marine discharges. Increasing the use of reclaimed water could address this issue and assist with meeting existing and expected water demands. King County is constructing a new wastewater treatment facility designed to produce Class A reclaimed water using a membrane bioreactor (King County Reclaimed Water Division). In addition to this system, one of King County Reclaimed Water Division's existing treatment plants produces small quantities of Class A water using sand filtration.

As part of the process to expand the reclaimed water program, a study was conducted to identify potential users for reclaimed water. End uses including industry, landscape irrigation, ecological enhancement, plant nursery, and truck farm irrigation were identified. Prior research and regulations in Washington State have established the safety and efficacy of reclaimed water for these end uses. In Washington, reclaimed water is regulated according to the Reclaimed Water Reuse Act of 1992, and is monitored by the Washington State Departments of Ecology and Health. Treatment requirements are dictated by the required effluent quality which is designated by the Class of reclaimed water, ranging from A–D, with A requiring the most stringent level of treatment and D requiring the least (Stensel, 2006). Class A reclaimed water is safe to use for watering food crops.

In King County, all reclaimed water meets Class A standards. However, to both gain customer confidence and illustrate that local soil and reclaimed water characteristics are suitable for the end uses identified, King County partnered with the University of Washington to conduct research on the safety and efficacy of Class A reclaimed water. One series of studies focused on the use of reclaimed water for truck farms—small-scale farms that grow fruits, vegetables, and flowers for local farmers markets and community-supported agriculture (CSA) organizations. Here, the public concerns have bene centered on pathogens, potential for heavy metal accumulation, and changes in flavor as a result of using reclaimed water.

Reclaimed Water for Edible Crops

The University of Washington conducted both a greenhouse study (**Figure 1**) and a field trial to demonstrate the low potential for pathogen transfer (as indicated by presence of bacteria indicator species) and metal uptake from reclaimed water to garden vegetables. Lettuce, carrots and strawberries were included in the study, as each of these are commonly grown by local farmers and each presents potential risk pathways to test the contaminants of concern.

Figure 1
Greenhouse trial of Class A reclaimed water (Photo credit: Dana Devin Clarke)

Lettuce is known for high uptake of heavy metals and has been used as an indicator crop for metal availability (Brown et al., 1998). The edible portion of carrots is grown directly in soil and so may be more susceptible to pathogen contamination. Strawberries are often consumed without washing, also making them likely candidates for pathogen transfer.

During the greenhouse and field studies, reclaimed water source samples were collected weekly; crop and soil samples were collected at the end of the study when plants were ready for harvest. Soils, water samples and washed and unwashed edible portions of plant tissue were analyzed for bacterial indicators (total coliforms, fecal coliforms, and *E. coli*) and metals (arsenic, cadmium, lead, and nickel). Metal concentrations in the reclaimed water were at least 2 orders of magnitude below EPA regulations(Metcalf & Eddy). Bacteria tests were either negative or below the regulatory limit of 2 cfu/100 mL.

In general, metal uptake for plants grown using reclaimed water was similar to that for those grown with tap water. Results for lettuce from the field study are shown in **Figure 2**.

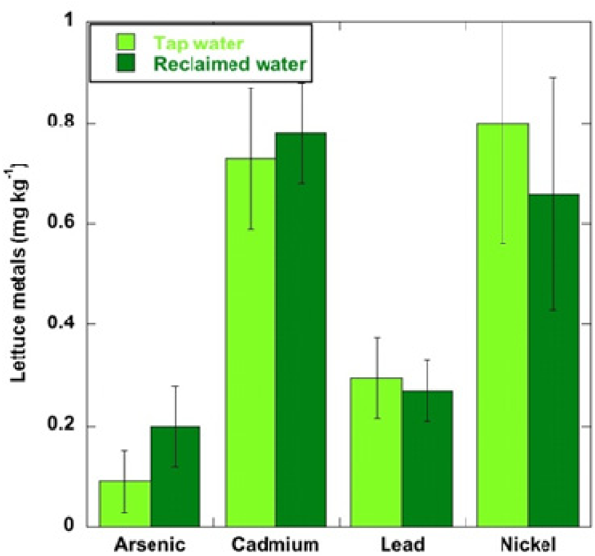

Figure 2
Metal concentrations in lettuce from field trial

In the greenhouse study, there were also no differences in bacterial indicators between the tap water irrigated crops or the reclaimed water irrigated crops for both washed and unwashed samples. Total coliforms were the only bacteria detected and they were only detected in the tap water control. In the field trial, total coliform counts were higher for all vegetables grown using reclaimed water in comparison to the tap water. This was likely due to increased contact with soil and coliform bacteria in the soil. Fecal coliform and *E. coli* were not detected in any of the vegetable samples grown in the field trial.

Public Outreach

Results of both studies reflect the quality of the source water, with respect to bacterial indicators and metal concentrations. It could be argued that these studies were superfluous based on the analysis of the reclaimed water. However, public perception and understanding of reclaimed water is an essential component in the development of a beneficial use program. To that end, luncheons and tastings were held at the end of each year's research. The first luncheon was limited to staff within the King County Wastewater Treatment division and featured presentations on the edible crops and ornamental plant research. Guests were served a main course and desert that included crops from the greenhouse study (**Figure 3**).

Figure 3
Dr. Brown presenting study data at luncheon (Photo credit: Jo Sullivan)

In the second year of the program, the luncheon was held at the wastewater treatment plant near the field site plots. Stakeholders, potential customers, and members of the community were invited. The menu was designed to feature crops grown in the garden and tables were decorated with flowers from the garden with bouquet giveaways at the end of the event. Presentations during the luncheon centered on results from these studies. Following the lunch, guests toured the gardens and were given bags to fill with potatoes (**Figure 4**). This type of outreach, in combination with research on locally produced reclaimed water has been an effective means for increasing acceptance and understanding of the safety and benefits of reclaimed water for irrigating food crops.

Figure 4
Harvesting potatoes after luncheon (Photo credit: Jo Sullivan)

Lessons Learned

The research described here, demonstrates the absence of plant metal uptake and bacteria transfer, and largely confirmed what was anticipated based on characteristics of the Class A reclaimed water. The research was important however, as it provided local data to help the municipality build trust with potential customers for their product. The public outreach efforts were also a critical component for public acceptance. The King County Wastewater Treatment division now has a number of farmers interested in using the Class A reclaimed water.

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City of Yelm, Washington

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US-WA-Yelm

Project Background or Rationale

The city of Yelm began its wastewater facility planning efforts to safeguard public health from septic system contamination of the area's shallow drinking water wells. In 1990, the city chose an affordable option that included a centralized collection system and a secondary wastewater treatment lagoon discharging to the Nisqually River. This quickly became a short-term solution. The Nisqually River supports five species of Pacific salmon and sea-run cutthroat trout and ends in a national wildlife refuge. Yelm was under considerable legal pressure from a variety of parties to find a better environmental option. The community wanted to embrace reclaimed water as the best solution to safeguard public health, protect the Nisqually River, and to provide an alternate water supply for city use. However, Yelm faced a number of new challenges in implementing this strategy:

- Finding additional funding to upgrade the treatment plant – again.
- Building local support to make the project work.
- Locating customers who could use the water immediately.

Institutional and Cultural Considerations

Yelm conducted intensive community outreach on these topics and as a result, in 1999 the city expanded its system into one of the first Class "A" Reclaimed Water Facilities in the State of Washington. Yelm constructed a wetlands park to have a highly visible and attractive focal point promoting reclaimed water use. A local reclaimed water ordinance was adopted establishing the conditions of reclaimed water use. The ordinance includes a "mandatory use" clause allowing Yelm to require construction of reclaimed water distribution facilities as a condition of development approval. Yelm continues to plan expansion of storage, distribution, and reuse facilities. In 2002, the city received Ecology's Environmental Excellence Award for successfully implementing Class "A" reclaimed water into its community.

Capacity and Type of Reuse Application

The Class A reclaimed water facility currently produces approximately 0.30 mgd (13 L/s) of reclaimed water and has capacity to produce up to 1.0 mgd (44 L/s) to accommodate growth.

Water Quality Standards and Treatment Technology

The Yelm reclamation plant had to modify the wastewater treatment plant significantly for reclaimed water production. The city chose to use sequencing batch reactor (SBR) technology for secondary treatment (biological oxidation) and nitrogen removal. Advanced treatment is followed by chemical coagulation, upflow sand filters, and chlorine disinfection. On-line monitoring of system and equipment performance provides that reclaimed water distributed to customers always meets the reclaimed water quality standards.

Project Funding and Management Practices

The total project cost including engineering and construction was $9.6 million. Funding was provided from state and federal grants and loans, along with a local utility improvement district. Yelm's annual operation and maintenance costs are approximately $1.4 million. This includes operator salaries and benefits, sewage collection, treatment and water reclamation, monitoring, solids removal, power, distribution, and public uses. The annual debt service for the project is $350,000.

Residential monthly sewer rates are $45.91 per month. The charge for a new residential connection is $6,219. Contractual agreements allow Yelm to recover some of the costs through charges for reclaimed water supplies. Yelm reclaimed water rates are approximately 80 percent of their drinking water rate.

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Washington State Department of Ecology. 2005 Case Studies in Reclaimed Water Use – Creating New Water Supplies Across Washington State. Retrieved on Sept, 5, 2012 from <http://www.ecy.wa.gov/pubs/0510013.pdf>.

APPENDIX E
International Case Studies and International Regulations

List of Case Studies by Title and Authors[1]

[1] To search for case studies by region or by category of reuse, please refer to Figure 9-1

List of Case Studies by Title and Authors[1]

Page No.	Text code	Case Study Title	Authors
E-43	India-Delhi	Reuse Applications for Treated Wastewater and Fecal Sludge in the Capital City of Delhi, India	Priyanie Amerasinghe, PhD and Pay Drechsel, PhD (International Water Management Institute); Rajendra Bhardwaj (Central Pollution Control Board)
E-47	India-Bangalore	V Valley Integrated Water Resource Management: the Bangalore Experience of Indirect Potable Reuse	Uday G. Kelkar, PhD, P.E., BCEE and Milind Wable, PhD, P.E. (NJS Consultants Co. Ltd.); and Arun Shukla (NJS Engineers India Pvt. Ltd.)
E-51	India-Nagpur	City of Nagpur and MSPGCL Reuse Project	Uday G. Kelkar, PhD, P.E., BCEE (NJS Consultants Co. Ltd) and Kalyanaraman Balakrishnan (United Tech Corporation)
E-54	Israel/Jordan-Brackish Irrigation	Managing Brackish Irrigation Water with High Concentrations of Salts in Arid Regions	Alon Ben-Gal, PhD and Uri Yermiyahu, PhD (Agricultural Research Organization, Gilat Research Center, Israel); Sirenn Naoum, PhD; Mohammad Jitan, PhD; Naeem Mazahreh, PhD; and Muien Qaryouti, PhD (National Center for Agricultural Research and Extension, Jordan)
E-58	Israel/Palestinian Territories/Jordan-Olive Irrigation	Irrigation of Olives with Recycled Water	Arnon Dag, PhD; Uri Yermiyahu, PhD; Alon Ben-Gal, PhD; and Eran Segal, PhD (Agricultural Research Organization, Gilat Research Center, Israel) and Zohar Kerem, PhD (The Hebrew University of Jerusalem, Israel) along with colleagues from the Association for Integrated Rural Development, West Bank and the National Center for Agricultural Research and Extension, Jordan
E-60	Israel/Jordan-AWT Crop Irrigation	Advanced Wastewater Treatment Technology and Reuse for Crop Irrigation	Josef Hagin, PhD and Raphael Semiat, PhD (Grand Water Research Institute Technion – Israel Institute of Technology, Haifa, Israel)
E-63	Israel/Peru-Vertical Wetlands	Treatment of Domestic Wastewater in a Compact Vertical Flow Constructed Wetland and its Reuse in Irrigation	Ines Soares, PhD; Amit Gross, PhD; Menachem Yair Sklarz, PhD; Alexander Yakirevich, PhD; and Meiyang Zou, MSc (Ben Gurion University of the Negev, Israel); and Ignacio Benavente, Eng, PhD; Ana Maria Chavez, Eng, MSc; Maribel Zapater, MSc; and Diana Lila Ferrando, Eng, MSc (Universidad de Piura, Peru)
E-66	Japan-Building MBR	A Membrane Bioreactor (MBR) Used for Onsite Wastewater Reclamation and Reuse in a Private Building in Japan	Katsuki Kimura, Dr.Eng. and Naoyuki Funamizu, Dr.Eng. (Hokkaido University, Sapporo, Japan)
E-69	Jordan-Irrigation	Water Reuse and Wastewater Management in Jordan	Bader Kassab, MSc (USAID Jordan) and Ryujiro Tsuchihashi, PhD (AECOM)
E-71	Jordan-Cultural Factors	Cultural and Religious Factors Influence Water Reuse	Tom A. Pedersen (CDM Smith)
E-74	Mexico-Tijuana	Water, Wastewater, and Recycled Water Integrated Plan for Tijuana, Mexico	Enrique López Calva (CDM Smith)

List of Case Studies by Title and Authors[1]

Page No.	Text code	Case Study Title	Authors
E-76	Mexico-Mexico City	The Planned and Unplanned Reuse of Mexico City's Wastewater	Blanca Jiménez-Cisneros, PhD (Universidad Nacional Autónoma de México)
E-79	Mexico-Ensenada	Maneadero Aquifer, Ensenada, Baja California, Mexico	Leopoldo Mendoza-Espinosa, PhD and Walter Daesslé-Heuser, PhD (Autonomous University of Baja California)
E-82	Mexico-San Luis Potosi	Tenorio Project: A Successful Story of Sustainable Development	Alberto Rojas (Comision Estatal del Agua), Lucina Equihua (Degremont S.A. de C.V.), Fernando Gonzalez (Degremont, S.A. de C.V.)
E-85	Pakistan-Faisalabad	Faisalabad, Pakistan: Balancing Risks and Benefits	Jeroen H. J. Ensink, PhD (London School of Hygiene and Tropical Medicine)
E-88	Palestinian Territories-Auja	Friends of the Earth Middle East's Community-led Water Reuse Projects in Auja	Elizabeth Ya'ari (Friends of the Earth Middle East)
E-90	Peru-Huasta	Assessing Water Reuse for Irrigation in Huasta, Peru	Daphne Rajenthiram (CDM Smith); Elliott Gall and Fernando Salas (University of Texas) and Laura Read (Tufts University)
E-93	Philippines-Market	Wastewater Treatment and Reuse for Public Markets: A Case Study in Sustainable, Appropriate Technology in the Philippines	Mary Joy Jochico (USAID) and Ariel Lapus (USAID-PWRF Project)
E-96	Senegal-Dakar	Use of Wastewater in Urban Agriculture in Greater Dakar, Senegal: "Adapting the 2006 WHO Guidelines"	Seydou Niang, PhD (Cheikh Anta Diop University of Dakar)
E-99	Singapore-NEWater	The Multi-barrier Safety Approach for Indirect Potable Use and Direct Nonpotable Use of NEWATER	Harry Seah, MSc and Chee Hoe Woo, MSc (PUB Singapore)
E-102	South Africa-eMalahleni Mine	Turning Acid Mine Drainage Water into Drinking Water: The eMalahleni Water Recycling Project	Jay Bhagwan (Water Research Commission)
E-104	South Africa-Durban	Durban Water Recycling Project	Jay Bhagwan (Water Research Commission)
E-107	Spain-Costa Brava	Risk Assessment for *Legionella* sp. in Reclaimed Water at Tossa de Mar, Costa Brava, Spain	Rafael Mujeriego, PhD (Universidad Politécnica de Cataluña) and Lluis Sala, (Consorci Costa Brava)
E-110	Thailand-Pig Farm	Sam Pran Pig Farm Company: Using Multiple Treatment Technologies to Treat Pig Waste in an Urban Setting	Pruk Aggarangsi, PhD (Energy Research and Development Institute-Nakornping, Chiang Mai University, Thailand)
E-112	Trinidad and Tobago-Beetham	Evaluating Reuse Options for a Reclaimed Water Program in Trinidad, West Indies	Matt McTaggart, P.Eng, R.Eng; Jim Marx, MSc, P.E.; and Kathy Bahadoorsingh, PhD, R.Eng (AECOM)
E-114	United Kingdom-Langford	Langford Recycling Scheme	Afsaneh Janbakhsh, MSc, Cchem, MRSC, Csci (Northumbrian Water Ltd, UK)

List of Case Studies by Title and Authors[1]

Page No.	Text code	Case Study Title	Authors
E-116	United Arab Emirates-Abu Dhabi	Water Reuse as Part of Holistic Water Management in the United Arab Emirates	Rachael McDonnell, PhD (International Center for Biosaline Agriculture) and Allegra K. da Silva, PhD (CDM Smith)
E-120	Vietnam-Hanoi	Wastewater Reuse in Thanh Tri District, Hanoi Suburb, Vietnam	Lan Huong Nguyen, MSc; Viet-Anh Nguyen, PhD ; and Eiji Yamaji, PhD; (Hanoi University of Civil Engineering, Vietnam)

Websites of International Regulations and Guidance on Water Reuse

Country	Title of Regulations or Guidelines	Link to Country Regulations or Guidance
Australia	Guidelines for Environmental Management: Use of Reclaimed Water	http://epa.vic.gov.au/our-work/publications/publication/2003/november/464-2
Australia	Australian Guidelines for Water Recycling	http://www.ephc.gov.au/taxonomy/term/39/
Brazil	RESOLUÇÃO No 54, DE 28 DE NOVEMBRO DE 2005	http://www.aesa.pb.gov.br/legislacao/resolucoes/cnrh/54_2005_criterios_gerais_uso_agua.pdf
Cyprus	Τομέας Ελέγχου της Ρύπανσης	http://www.moa.gov.cy/moa/environment/environment.nsf/All/26C40CAAAAEF746CC22578D1003B1FEA?OpenDocument
India	General Standards for Discharge of Environmental Pollutants Part-A: Effluents	http://cpcb.nic.in/GeneralStandards.pdf
Israel	Effluents and Waste	http://www.water.gov.il/Hebrew/ProfessionalInfoAndData/Water-Quality/Pages/treated_waste_water.aspx?P=print
Israel	קובץ התקנות	http://www.justice.gov.il/NR/rdonlyres/DF355FDA-0616-4D36-B8D3-64F706C494C9/19866/6886.pdf
Mexico	Normas Oficiales Mexicanas ordenadas por Materia	http://www.semarnat.gob.mx/LEYESYNORMAS/Pages/nomsxmateria.aspx
Mexico	Norma Oficial Mexicana Nom-001-Semarnat-1996, Que Establece Los Límites Máximos Permisibles De Contaminates En Las Descargas De Aguas Residuales En Aguas Y Bienes Nacionales	http://www.bvsde.paho.org/bvsacd/cd38/Mexico/NOM001ECOL.pdf
Mexico	Law: NOM-003-Semarnat-1997	www.conagua.gob.mx
Spain	Spanish Regulations for Water Reuse	http://www.asersagua.es/publicaciones/SpanishRegulationsforWaterReuseEN.pdf
Thailand	Pig Farm's Standard Waste Water Level	http://ptech.pcd.go.th/website/index.php?option=com_content&view=article&id=22:wwstd&catid=8:envlaw&Itemid=31
Vietnam	National Technical Regulation on Water Quality for Irrigated Agriculture	http://www.epe.edu.vn/file/C__Documents%20and%20Settings_CQ%2040_Local%20Settings_Application%20Data_Mozilla_Firefox_Profiles_6zquphxp.pdf

Special Restricted Crop Area in Mendoza, Argentina

Author: Carl R. Bartone (Environmental Engineering Consultant)

Argentina-Mendoza

Project Background or Rationale

Mendoza is located in an arid region in the foothills of the Andes in western Argentina. The city's wastewater has traditionally been used indirectly for irrigation. During the dry season, untreated wastewater represented 40 percent of resources available for irrigation in the Mendoza River Basin, raising serious health concerns (Zuleta, 2011).

At the time of this project, the greater Mendoza metropolitan area had 700,000 inhabitants, with 75 percent of the population connected to sewers. The projected population for 2010 was one million with a projected 95 percent sewer connection coverage (Idelovitch and Ringskog, 1997).

As part of the modernization of the water sector in the Province of Mendoza in the early 1990s, a number of reforms were put in place that helped introduce planned reuse of treated wastewater. One such case was the upgrading of the Campo Espejo waste stabilization ponds in 1993 and the introduction of microbiological standards for reuse.

Capacity and Type of Reuse Application

The Campo Espejo waste stabilization ponds were built in 1976 and upgraded in 1996. The new plant consists of 12 modules of three waste stabilization ponds in series (facultative, aerobic, and polishing), occupying some 790.7 ac (320 ha) in total (Idelovitch and Ringskog, 1997). Today they provide 39 mgd (147,000 m^3 /d) of effluent for direct irrigation (Zuleta, 2011).

The effluent from the Campo Espejo treatment plant is discharged to the Moyano Canal and conveyed to a special 6,672 ac (2,700 ha) restricted irrigation area, *Area de Cultivos Restringidos Especiales* (ACRE), for reuse (Zuleta, 2011). Farmers with properties within the special area receive treated effluent free of charge and are obliged to follow the irrigation regulations established for the ACRE. About one quarter of the irrigated area is devoted to the production of grapes, another quarter to the cultivation of tomatoes and squash, and the remaining area to the cultivation of alfalfa, artichokes, garlic, peaches, pears, and poplar biomass (Barbeito, 2001). The soil is slightly saline and therefore treated water is also used to wash salts from it (Jimenez, 2008).

Excess irrigation and drainage water from the Campo Espejo ACRE is discharged downstream into the Jocoli Canal, where it mixes with river water, and is used for the subsequent irrigation of an additional 17,297 ac (7,000 ha) (Zuleta, 2011).

Water Quality Standards and Treatment Technology

The provincial water and sanitation agency, *Ente Provincial del Agua y Saneamiento* (EPAS), was created in 1993 to regulate, control, and guarantee the provision of water and sewerage services in the Province of Mendoza. By means of EPAS' Resolution 35/96 (EPAS, 1996) standards were established for treated wastewater discharges and, in particular, for irrigation reuse in ACRE, including microbiological standards for fecal coliforms and nematodes. The latter standards were based on the World Health Organization Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture. (WHO, 1989). The upgrade of the Campo Espejo treatment plant in 1996 was in part to meet these new standards. Because of the generally low cost of land in Mendoza, waste stabilization ponds are a suitable treatment option for complying with the WHO guidelines.

Project Funding and Management Practices

The upgrade was carried out under a 20-year build-own-operate-transfer (BOOT) concession from the metropolitan water and sewerage company, *Obras Sanitarias de Mendoza* (OSM), to the private operator *Union Transitoria de Empresas* (UTE). UTE operates and maintains the existing installations, as well as designs, constructs, andoperates the 12 new modules (Idelovitch and Ringskog, 1997). The bidding documents specified criteria for the quality of effluent, such as a maximum of 1,000 fecal coliforms per 100 mL, a maximum of one helminth egg per liter, removal of at least 70 percent of biochemical oxygen demand, and removal of at least 30 percent of suspended solids.

Under the 1993 concession agreement, UTE committed to an initial investment of U.S. $15 million. The new plant was inaugurated in 1996. Under the BOOT agreement, UTE charges OSM U.S. $0.05 per m^3 of wastewater treated. OSM guaranteed a minimum of 3 million m^3 (793 million gallons) per month. Based on the average treated effluent flow, UTE's initial investment had an expected payback period of 7 years.

Institutional/Cultural Considerations

The chief provincial institutions responsible for wastewater treatment and use for irrigation in Mendoza are: OSM, which is responsible for water and sewerage services in Greater Mendoza; EPAS, which regulates and controls the provision of water and sewerage services; and the *Departamento General de Irrigación* (DGI), which is responsible for the management of water resources (Kotlis, 1998).

A special Sanitation Planning process was developed for the Campo Espejo ACRE (Barbeito, 2001). Furthermore, regulations were promulgated governing the conformation and operation of the ACRE (DGI, 2003). The DGI, OSM, and the ACRE Inspectorate were jointly responsible for developing and carrying out the Sanitation Plan and for supervising and controlling the direct use of treated wastewater in ACRE. The Inspectorate is comprised of members of the ACRE water users' association, and oversees the distribution of treated wastewater, control of authorized crops, irrigation methods allowed, and overall operational management within the ACRE.

The quality of the agricultural produce and the health of the agricultural workers are monitored by a special office of the DGI.

An agreement of cooperation was recently signed between OSM and ACRE farmers to study concerns of mutual interest, including the possibility of building effluent storage reservoirs that would optimize wastewater use during the dry season without requiring changes in the treatment plant operations, as well as the possibility of charging farmers part of the cost of treatment (Egocheaga and Moscoso, 2004).

Successes and Lessons Learned

The Mendoza ACRE model provides a practical and productive way of ensuring that there is sufficient land for the controlled use of available effluent from centralized treatment (Scheierling et al., 2010).

Zuleta (2011) summarized the benefits of the ACRE model as providing for:

- Reliable and steady supply of water
- Reduced cost of treatment
- Management of microbial health risks
- Reduced soil and aquifer pollution
- Natural fertilization of soils
- Attenuated aquifer exploitation

Other ACREs have since been established in Mendoza, including for the Paramillos treatment plant and the Pescara Canal industrial zone.

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Sewer Mining to Supplement Blackwater Flow in a Commercial High-rise

Author: Colin Fisher (Aquacell)

Australia-Sydney

Project Background or Rationale

Australia's warm climate and habitual droughts have resulted in innovative water conservation practices in commercial developments, such as 1 Bligh Street in Sydney. Commissioned in May 2011, the highly acclaimed 29 story office tower overlooking the Sydney Harbor captures nearly 100 percent of its wastewater and reuses it in the building. By recycling the vast majority of the waste stream, the developers have avoided sewer capacity issues and reduced the building's freshwater demand by approximately 90 percent. Not all of the wastewater reused at Bligh Street comes from the building itself.

Calculations revealed the building's total waste stream would not meet the non-potable demand for cooling tower makeup and toilet flushing (the desired reuse applications). Rather than supplementing non-potable demand with city water, the development has engaged in 'sewer mining', which involves tapping into the city's sewer main as a source of water (see **Figure 1**).

Capacity and Type of Reuse Application

The blackwater plant, located just off the parking garage in a maintenance room, treats approximately 26,000 gallons (100 m^3) of blackwater onsite daily.

A modular membrane bioreactor (MBR) was chosen, which would meet Water Industry Competition Act (WICA) and project objectives. Advances in modular mechanical design, membrane and instrument development, and remote monitoring via the Internet have helped improve the cost and reliability of MBR systems significantly in recent years. The MBR treatment consists of mechanical screening, biological treatment, and ultrafiltration (UV) (0.04 micron membranes). This approach provides the building a small footprint system with high yields (more than 99 percent) and high quality effluent. Disinfection via UV and a chlorine residual follows the MBR to provide multiple barriers of treatment. The recycled water reused for cooling tower makeup is also treated with reverse osmosis to remove salts.

Water Quality Standards and Treatment Technology

The reuse scheme required a New South Wales (NSW) WICA operator's and retail license. The NSW government introduced WICA in 2006 as part of its strategy for a sustainable water future. WICA is intended to harness the innovation and investment potential of the private sector in the water and wastewater industries. At the same time, the Act establishes a licensing regime for private sector entrants to ensure the continued protection of public

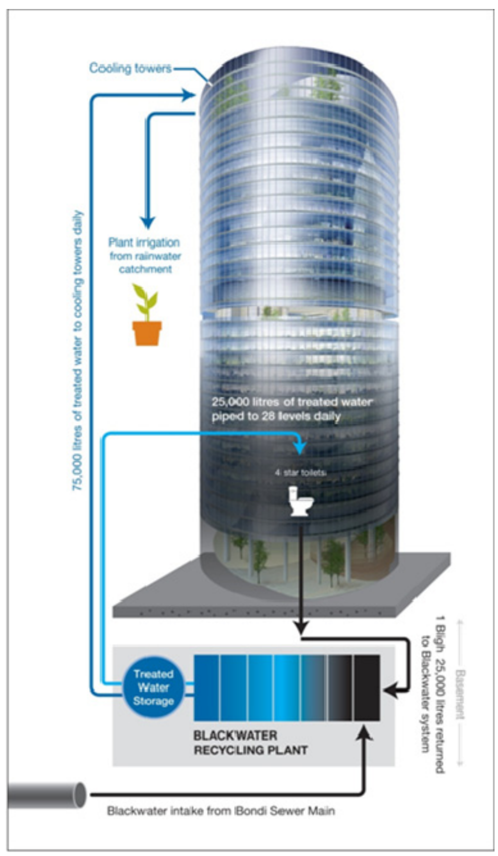

Figure 1
Bligh St Sewer mining and reuse schematic

health, consumers, and the environment (Independent Pricing and Regulatory Tribunal, 2011).

A corporation (other than a public utility) must obtain a license under the Act to construct, maintain or operate any water industry infrastructure, supply water (potable or non-potable), or provide sewerage services by means of any water infrastructure.

The approach in the WICA legislation is based on the Australian Guidelines for Water Recycling (AGWR); a risk based methodology that provides a framework for assessing the risks associated with reuse projects (Natural Resource Management Ministerial Council, Environment Protection and Heritage Council and Australian Health Ministers' Conference, 2006). The Bligh Street treatment program was deemed appropriate for the particular reuse scheme and adequate to manage the associated risks.

The application process for Bligh Street was done at the state level, submitted to the Independent Pricing and Regulatory Tribunal (IPART), which is responsible for ensuring a level playing field for private and public suppliers. IPART then sent the application to Public Health Offices for their input and it was also posted on IPART's website for public comment. Environmental concerns, plumbing and drainage codes, sewer access, waste disposal licenses, and potable water backup were all taken into consideration at this time. Successfully passing an independent audit of the treatment plant infrastructure and associated system management plans is additionally required for the plant to begin treating wastewater. Next, a verification period was initiated, where the treated water is sampled and tested according to a sampling protocol from the management plan. The plant must demonstrate the water is "fit for purpose" before treated water can be distributed throughout the building.

Institutional/Cultural Considerations

The *Australian Guidelines for Water Recycling* employs a "fit for purpose water" methodology (Natural Resource Management Ministerial Council, Environment Protection and Heritage Council and Australian Health Ministers' Conference, 2006). This approach involves an exposure risk calculation adopted from the World Health Organization's (WHO) Guidelines for Drinking-water Quality (WHO, 2004). The methodology designates tolerable risk to be 10^{-6} Disability Adjusted Life Years (DALYs), or 1 infection per 1,000,000 people per year. DALYs have been used extensively to account for illness severity by organizations such as WHO. For this particular site, in order to reach 10^{-6} DALYs for Protozoa, Viruses, and Camplyobacter, calculations determined Log Reduction Values (LRVs) needed to be 4.6, 6.0, and 4.8, respectively. Information on how these calculations are performed can be found in tables, 3.3, 3.7, and A2.1 of the AGWR (2006). Once LRVs have been established, plant performance objectives and components can be determined. In this case, a UV unit provides 1 LRV for Viruses and 4 LRV for Protozoa. A reverse osmosis (RO) unit provides >1 for each and chlorine disinfection provides 4 LRV for viruses. Thus, the performance requirements for the system are met. Note that in the LRV calculations there are no LRV credits sought for the submerged membranes. This may change in the future as California Title 22 gains wider acceptance.

Project Funding and Management Practices

The Bligh Street scheme was funded entirely by the building's developer thus it was critical the blackwater scheme be commercially viable from the outset. An innovative risk management methodology was adopted at first principles to properly address the economic challenges small schemes face with ongoing operations.

For many years the food industry has used Hazard Analysis and Critical Control Points (HACCP) risk management methodology. More recently HACCP has been adopted in the water industry. In a HACCP assessment the process is broken down into steps and at each step the question "what might happen and how might it occur" is asked. At Bligh Street, 6 CCPs were identified. These are influent pH, Turbidity, Electrical Conductivity across the RO, UV dosing, Chlorine residual and effluent pH. For each CCP, upper and lower limits were identified. If, during the course of production any one of the six CCPs is outside the limits, production is halted and an alarm is sent via SMS to a technician. Thus, HACCP ensures water quality fit for purpose will be delivered. As a result, end of pipe monitoring frequency can be reduced accordingly which reduces lab costs and directly effects the viability of the treatment plant without sacrificing public safety. Whereas *E. coli* sampling might have typically been required daily on a project like Bligh Street, with HACCP real-time verification monitoring in place, regulators agreed to monthly sampling of *E. coli*. The monthly sampling for *E. coli* simply serves as confirmation that the HACCP methodology is functioning properly.

Lessons Learned

The Bligh Street project was one of the first NSW WICA licensing schemes in Sydney Central Business District to include sewer mining for cooling tower reuse. Working in an uncharted regulatory environment is always challenging and requires a vendor that fully understands risk assessment, and treatment technology, and has operational experience. Permitting is one of the more significant hurdles often overlooked by private scheme proponents. The permitting process can be time consuming. As new regulations are phased in, there is a period of overlap where the existing and new regulations both apply. The potential for miscommunication and confusion between regulatory bodies and the applicants is real. In order to meet all requirements, applications under the existing and the new regulations have been filed in parallel, which doubles the effort involved. Officials are extremely cautious at every step of the process and this has the effect of slowing down the process to a point where a 12-month lead time for approvals is normal. Accordingly, customers who would like to engage water recycling should be aware that the approval process adds a dimension of complexity and cost to the project. This will change as officials become more familiar with the practice and regulations and requirements for small systems become more transparent.

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Retirement Community Graywater Reuse

Author: Colin Fisher (Aquacell)

Australia-Graywater

Project Background or Rationale

RSL Care's Sunset Ridge Retirement Community resides near the Pacific coast in Zilzie, Queensland, Australia. The retirement community includes 100 independent living villas, a 120-bed aged care residential complex, and resort style facilities. Although Zilzie averages 31 in (79 cm) of annual rainfall, RSL Care sought to install a graywater recycling system because of the environmental benefits and to secure and maintain an adequate water supply for the community's residents.

Capacity and Type of Reuse Application

The graywater treatment plant installed at the Sunset Ridge Retirement Community treats approximately 6,600 gallons (25 m^3) of graywater per day. The plant captures graywater discharged from the community's showers, bathtubs, and hand basins. The treated water is then reused in all of the toilets on site and for landscape irrigation.

Water Quality Standards and Treatment Technology

In Queensland, all graywater treatment plants must be granted Chief Executive Approval by the Queensland Department of Infrastructure and Planning before they are allowed to operate (Queensland Australia Government, 2011). Formal approval is based on 26 weeks of independent monitoring to demonstrate that the plant is able to treat graywater to the regulated quality standards. Once a system has been approved, it can be employed in other projects of similar nature.

Where treated graywater is used in high level reuse applications (e.g. toilets, urinals, laundry reuse, vehicle washdown) the Queensland regulations require the treated effluent to achieve the following minimum quality:

- BOD5 <10 mg/L
- TSS <10 mg/L
- *E. coli* (max) <10 cfu/100 mL
- *E. coli* (95th percentile) <1 cfu/100 mL
- turbidity (max) <5 NTU
- turbidity (95th percentile) <2 NTU

The challenge of meeting these effluent standards in decentralized scenarios is that wastewater quality and flows are often highly variable. As such, the design of the treatment plant needs to be robust enough to manage a range of situations.

The core technology at Sunset Ridge is a modular membrane bioreactor (MBR), which encompasses a bioreactor with ultrafiltration membranes of 0.04 micron. MBRs are an advanced low footprint treatment technology typically used for blackwater treatment. However, this technology has been adopted to treat graywater primarily because of the soluble and insoluble organics that are commonly seen in commercial graywater influents. Graywater is by no means clean water with a few dirt particulates. Filtration based processes are sometimes used to treat graywater, but they do not provide the resilience needed for commercial systems, which MBRs afford. Once the effluent has been through the ultrafiltration membrane in the MBR, it is disinfected with ultraviolet (UV) and chlorine to achieve a chlorine residual. This multi-barrier treatment approach is what ensures the treatment plant is able to confidently handle variable wastewater qualities that are typical of decentralized graywater schemes.

Project Funding and Management Practices

One of the key considerations that clients and regulators want addressed when establishing reuse treatment plants of any size is who will operate the plant in the long-term This is especially important if the scheme is to be implemented by the private sector for a specific private project. In this case, RSL Care privately funded the graywater scheme at Sunset Ridge.

Reuse schemes require a long-term strategy and cannot be treated as a fixed piece of plumbing equipment. The challenge for many private sector decentralized reuse schemes is that they typically do not have wastewater specialists located on site. Therefore, longer-term arrangements need to be considered early on and should inform decision making throughout the project. For example, a cheap solution with poor equipment may win on capital price, but may also lead to the highest overall life cycle costs because of poor performance and operational difficulties. Life cycle analysis (LCA) must be considered.

The Sunset Ridge graywater plant operation is managed as a shared responsibility between the onsite maintenance staff at Sunset Ridge and the graywater system contractor. Day to day servicing and management is provided by Sunset Ridge locally, with twice yearly full technical servicing, remote monitoring, and regulatory reporting being provided by the contractor. Different projects will have different maintenance arrangement outcomes.

Institutional/Cultural Considerations

The graywater contractor is able to provide local staff with a high level of support particularly due to the capabilities of its risk management methodology in combination with the system's built-in remote monitoring system. Utilizing Hazard Analysis and Critical Control Points (HACCP), a risk management methodology most commonly used in the food and beverage industry, the graywater contractor can ensure the delivery of high quality treated water. Different Critical Control Points (CCPs) of the treatment process are monitored in real-time providing data to the contractor. Corrective actions are programmed into the system if any of the CCPs are out of range, thus providing Sunset Ridge an additional layer of confidence with the quality of the treated graywater. In addition to the safety provided by the HACCP risk management approach, remote monitoring and controls allow technical staff to take the reins of the graywater plant if necessary. Operational data from the CCPs is continuously relayed back to the contractor's headquarters where technical staff can increase/decrease aeration levels, change chlorination dosing, turn pumps on/off and so on. Remote monitoring and controls means the client has the security of knowing operational experts always have an eye on the plants operation.

Results and Lessons Learned

The Sunset Ridge graywater plant has consistently met effluent quality expectations since commissioning in early 2010 and the success of the scheme can be summarized down to contractor experience. It is important that managing regulatory approvals, delivering a robust technology suitable for commercial applications (commercial and domestic approaches are very different), and ensuring the appropriate operational partnerships are established and considered at the onset of the project.

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End User Access to Recycled Water via Third Party-Owned Infrastructure

Author: Geoff Jones (Barwon Water)

Australia-Victoria

Background

Barwon Water supplies recycled water from five of its nine water reclamation plants (WRP). During times where there is no customer demand, the recycled water is discharged to the ocean, lakes or onsite tree lots. The water is used for a number of commercial and municipal uses, including:

- Irrigating golf courses, sporting grounds, and public open spaces
- Irrigating vineyards, hydroponic tomatoes, potatoes, and other crops
- Irrigating turf and flower farms
- Dust suppression for road works and major construction works

Barwon Water is a government owned water authority operating in Victoria, Australia. In Victoria recycled water schemes must be approved by the Environment Protection Authority (EPA Victoria) and recycled water pricing must be approved by the Victorian Essential Services Commission (ESC).

Recycled Water Schemes

Barwon Water does not construct the recycled water distribution infrastructure. Transport of recycled water from the WRP to a customer's reuse site is the responsibility of the recycled water customer. Generally a single large customer within a distribution network funds construction, operation and maintenance of the distribution pipelines. These infrastructure owners transport the recycled water from Barwon Water WRPs to other customers. Infrastructure owners are able to recover their capital and operational costs by charging an infrastructure service fee in addition to the cost of the water from Barwon Water. In this arrangement, even though Barwon Water does not own the distribution assets, Barwon Water has been able to supply additional customers via the privately owned infrastructure.

All private scheme owners pay Barwon Water to maintain and service their network.

Three main recycled water networks (schemes) have been constructed in the region:

- Torquay Scheme (Black Rock WRP) - 1997
- Portarlington Scheme - 1999
- Barwon Heads Scheme (Black Rock) - 2000

In all three of these schemes, the majority of the distribution infrastructure is owned by one of the recycled water customers.

This arrangement is uncommon in Australia as most recycled water schemes are usually wholly owned and operated either by the water authority or a private owner.

Recycled Water Quality

The recycled water supplied is guaranteed as Class C quality as defined by EPA Victoria (**Table 1**) which implies suitability for a range of agricultural and horticultural purposes.

Table 1 EPA Victoria Class C recycled water license limits (EPA, 2003)

Parameter	Range
E. coli	< 1000 org/100 mL
pH	6 to 9
BOD	< 20 mg/L
SS	< 30 mg/L

These are the only guaranteed parameters—other parameters are monitored but not guaranteed.

Legal Agreements

Barwon Water uses two legal agreements for supplying recycled water. EPA Victoria provides guidance on the content of legal supply agreements;

however this advice is brief and limited to suggested contents.

Recycled Water Supply Agreement: This agreement is between Barwon Water and the recycled water customer. Barwon Water treats all customers the same, the approach does not alter if they receive their water directly or via a privately-owned pipeline. The Supply Agreement states that the customer must negotiate directly with the infrastructure owner for access to their pipeline. An Infrastructure Access Agreement is negotiated between these parties.

Other conditions of the Supply Agreement include:

- An annual allocation (maximum volume) is defined, however this is not guaranteed due to unforseen events.
- The quality is only guaranteed to a specific class, not individual parameters. The end user accepts responsibility for suitability of the recycled water to their purpose.
- The pressure is not guaranteed, nor is the recycled water supplied at a pressure suitable to power irrigation equipment. All end users must store the water and apply it at their own cost.
- A "take-or-pay" clause ensures that an allocation is not "locked up" unused. This clause is only enforced when other customers are able to use the water not currently being used.

Infrastructure Access Agreement: This agreement is between the infrastructure owner and the recycled water customer.

Infrastructure Access Agreements have been written to various levels of detail, from a one page letter to a several page legal agreement. Barwon Water has developed a pro-forma agreement to assist new customers reach agreement with the infrastructure owners. The pro-forma agreement is provided to customers to use or modify as they see fit.

Fees and Tariffs

In accordance with ESC pricing principles, Barwon Water's recycled water tariff is calculated to only recover the cost of production. No additional profit margin is included.

In addition to Barwon Water's recycled water tariff, customers are also charged for transfer of the recycled water by the private scheme owners. These owners may seek one or more of the following fees from the customer:

- Once-off connection fee
- Annual fee (based on either the end user annual volume (allocation) or a portion of the overall scheme capital)
- Volumetric (transfer) fee

While not a party to the negotiation, Barwon Water must be satisfied the agreement is fair and reasonable. Despite no legal regulation for this requirement, Barwon Water has been able to facilitate these negotiations. In newer agreements, a clause is specifically included to ensure that private scheme owners are obliged to accept reasonable requests by new customers to access their infrastructure.

Successes and Lessons Learned

Barwon Water has intervened twice to mediate better terms (i.e., cheaper price) for new customers. Both times the scheme owners were intending to charge customer an exorbitant volumetric transfer fee.

Over time the various agreements have been improved by way of new and revised clauses. The current arrangements include a more robust arbitration process.

To date, this form of supply arrangement has worked well and in the last 14 years facilitated the reuse of more than 12,200 acre-feet or 4,000 billion gallons (15,000 mL) of water.

References

EPA. 2003. *Guidelines for Environmental Management: Use of Reclaimed Water* [publication 464.2]. EPA Victoria, Southbank, Victoria.

St Mary's Advanced Water Recycling Plant, Sydney

Authors: Stuart Khan, PhD (University of South Wales) and Peter Chapman (Sydney Water)

Australia-Replacement Flows

Project Background or Rationale

Drinking water supplies in the main storage reservoir for Sydney (Warragamba Dam) were rapidly diminishing between 2000 and 2006. The declining storage volume was primarily due to severe drought in the greater Sydney region. During this time, Warragamba Dam was also required to continue to provide satisfactory environmental flows in the downstream Hawkesbury Nepean River system.

The St Marys Advanced Water Recycling Plant is based in western Sydney and was developed by Sydney Water as a component of the New South Wales (NSW) State Government's Metropolitan Water Plan. The objective of the project was to produce an alternative high quality water source to replace more than 4.8 billion gallons (18 billion liters) of drinking water annually released from Warragamba Dam for the environmental flows of the downstream river, and improve river health through reducing the nutrient load.

Three existing wastewater treatment plants (St Marys, Penrith, and Quakers Hill) were identified, that could together supply the required volumes of source water to a new water recycling plant at St Marys. Advanced water treatment processes were required to ensure that the recycled water would be of a water quality standard suitable for environmental release into the Hawkesbury Nepean River system.

Capacity and Type of Reuse Application

A new advanced water recycling plant was designed to produce up to 4.8 billion gallons (18 billion liters) of highly treated recycled water annually.

The water recycling plant receives tertiary treated wastewater from the three wastewater treatment plants in variable ratios, depending on demand. Advanced treatment is then applied by ultrafiltration (UF) and reverse osmosis (RO), followed by decarbonation and chlorine disinfection.

Water Quality Standards and Treatment Technology

Water quality and treatment performance were subject to rigorous scrutiny by the relevant public health regulator, the NSW Department of Health (NSW Health). The Australian Guidelines for Water Recycling (AGWR) require the adoption of a risk management framework for managing water quality (NRMMC, EPHC, and NHMRC, 2006). An important aspect of the framework is a risk assessment to identify key potential hazards and hazardous events that may lead to elevated risks to the community. Although these guidelines were in draft form at the time, NSW Health imposed general compliance with the guidelines and the presentation of a satisfactory risk assessment as key criteria to be met in order for the project to receive the necessary endorsement for planning approval.

Risk Assessment and Performance Validation

A screening level human health risk assessment was undertaken at the concept stage for the St Marys project by the University of New South Wales (UNSW) (Khan *et al.*, 2007). Partially on the basis of that assessment, the NSW Government (including NSW Health) approved construction of the advanced water recycling plant with a number of conditions. One of those conditions was the construction and performance assessment of a pilot-scale plant. The pilot was constructed and a comprehensive chemical risk assessment and treatment performance assessment was then undertaken by UNSW (Khan *et al.*, 2009).

As an essential component of the chemical risk assessment, a chemical monitoring program was developed with the primary aim of validating many of the assumptions made in the screening-level risk assessment (Drewes *et al.*, 2010). This chemical monitoring program demonstrated that key prioritized chemicals of potential toxicological concern (including pharmaceuticals, endocrine disrupting chemicals, and emerging disinfection by-products) in the product water were either absent or present at trace concentrations that were not a risk to human health for downstream users of the river.

Lognormal probability plots were prepared for statistical analysis of the variability in concentrations of chemical contaminants in UF influents and filtrates; and RO influents permeates and three-stage concentrates (“conc 1”, “conc 2” and “conc 3”). An example is provided for the chemical dibromochloromethane in **Figure 1**.

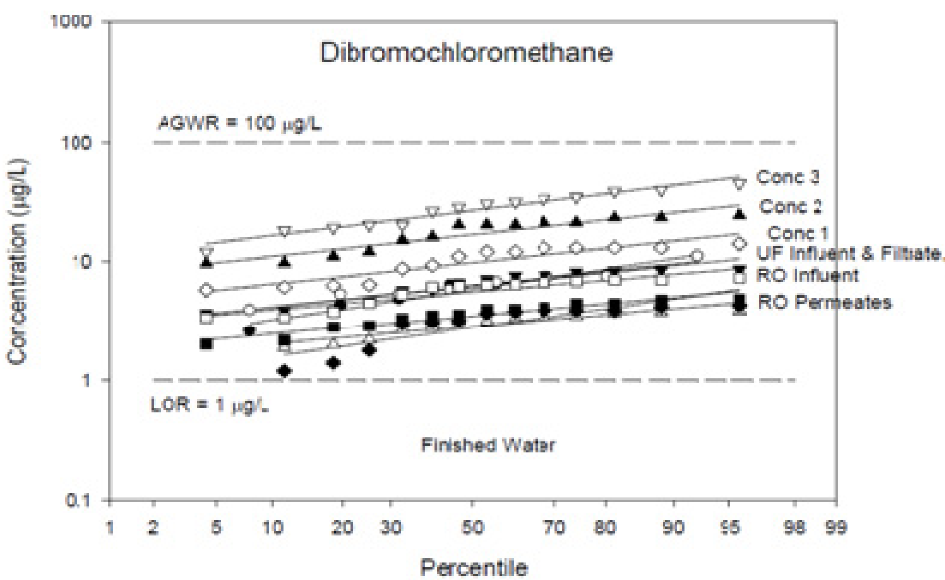
The full-scale water recycling plant was then constructed adjacent to the site of the existing St Marys wastewater treatment plant and commissioned in June 2010. This was immediately followed by a 42-day process proving period, which included validation monitoring.

An objective of the chemical validation monitoring was to confirm that the performance of the new full-scale plant was comparable to the pilot-scale plant, which had been subject to a more intensive performance assessment. The focus of the validation was on the reverse osmosis process since the pilot-scale assessment confirmed that this was the most important and effective barrier to trace chemical contaminants present in feed water. The validation testing successfully confirmed that the full-scale water recycling plant was operating with equivalent performance to the pilot plant (Khan and McDonald, 2010). Monitoring of chemical indicators in the recycled water provided evidence of high level of treatment performance and ultimately led to the final approval by NSW Health.

Project Funding and Management Practices

The project was funded through Sydney Water’s customer charges as approved by Sydney Water’s economic regulator, the NSW Independent Pricing and Regulatory Tribunal (IPART). Following a competitive tender process, Deerubbin Water Futures was engaged to design and construct the scheme, and operate and maintain the new advanced water recycling plant for a 10 year period.

Operations of the new advanced plant and transfer system have been completely integrated with the existing three wastewater plants, which are still required to meet pre-existing recycled water supply requirements for municipal irrigation and downstream irrigators.



LOR = limit of reporting

Figure 1
Example of comprehensive monitoring of chemical contaminants in the St Marys Water Recycling Plant

Institutional/Cultural Considerations

Planning approval for the overall project included conditions of public consultation, and the proposed project was reviewed at public forums as part of the Metropolitan Water Plan. The project team also worked closely with the community while 32 miles (52 kilometers) of pipelines were laid through residential suburbs of western Sydney.

Several heritage areas were identified and protected by boring the necessary pipework beneath them. The team consulted indigenous Aboriginal groups on managing significant artifacts, and monitored and recorded artifacts during the excavation works.

Successes and Lessons Learned

The project was completed on time, below budget, and met all objectives. The plant was officially launched in October 2010.

Water quality from the new plant has exceeded expectations on all quality parameters. To date, actual concentrations of nutrients are about half the predicted amounts, further reducing the nutrient load in the Hawkesbury-Nepean River. A Recycled Water Education Centre has also been included in the plant.

A key lesson learned from a project delivery and operations perspective, was that integration was critical. Successful operation of the plant relies on the ongoing contribution of approximately 20 different teams within Sydney Water, with one manager providing leadership and strategy. The approach taken through design and construction and into the operations and maintenance phase was to engage stakeholders early, and integrate the project into standard systems, processes, procedures and responsibilities, in order to realize the benefits of the project and achieve performance targets.

The initial construction of an *in situ* pilot plant for the risk assessment phase was also shown to be a highly worthwhile investment. With scalable technologies such as membranes, the pilot plant enabled realistic testing of the plant performance using water obtained from the actual catchment and this provided a high level of confidence to inform the design and construction of the full-scale plant.

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Economic Analysis of Water Reuse Options in Sustainable Water Resource Planning

Authors: William Y. Davis and Jason Johnson, P.E. (CDM Smith)

Barbados-Economic Analysis

Project Background or Rationale

The West Coast Sewerage Project is a plan by the Barbados Water Authority to provide sewer service to residents and businesses on the west coast of the island nation of Barbados. The designated "West Coast" area is a strip of land between the Caribbean coast and the base of the lower terrace. The area is approximately one-half mile wide from east to west and about 12 miles (20 km) from north to south. The white sand beaches and accessible coral reefs draw tourists from around the world. The West Coast is densely developed and accounts for about 80 percent of Barbados' billion dollar (U.S.) annual tourism industry.

The Government of Barbados signed onto international agreements related to the discharge of water through ocean outfalls to marine environments. In addition, the Government of Barbados mandated the appropriate implementation of water reuse into the water management strategy for the country.

The proposed West Coast Sewerage project has multiple components that address collection, treatment, and disposal. Option A called for a collection system with a secondary treatment facility at the south end of the region where an ocean outfall could be constructed without impacting coral reefs. In addition, five alternative discharge/disposal options (Options B, C, D, E and F) were considered with different configurations of reuse distribution systems and aquifer recharge.

The level of treatment is consistent for each option since the international agreements mandate advanced treatment requirements similar to those required for water reuse and recharge to potable aquifers.

A prior study determined the reuse potential of golf courses and other industries in proximity to the West Coast. Most of the potential for golf course irrigation with reclaimed water is midway up the West Coast and would occur only during the dry season. Aquifer recharge areas in proximity to the West Coast are in potable aquifer zones while non-potable aquifer zones are further distances from the planned treatment facilities.

Economic Analysis

The quantifiable present worth costs and benefits were estimated for each option. The economic benefits included residents' willingness to pay for sewage service, reduction of sanitation costs at commercial establishments, tourists' willingness to pay for sewage service, value of water reuse, reduced beach erosion, avoidance of beach closures, enhanced tourism activities, and public health. The value of water reuse was determined as the cost of the water to be used if reclaimed water were not available. Thus, costs were determined for potable water, desalinated water for irrigation, groundwater for irrigation, and brackish water for cooling.

The costs and benefits of each option were discounted from their future values to an equivalent present value for comparison. A range of discount rates was used to test the sensitivity of the results to changes in the discount rate. The different discount rates affected the net project costs but did not change the ranking of the options in the quantifiable economic analysis. Results using a discount rate of 6 percent are show in **Table 1**.

Table 1 Economic indicators

Options	A	B	C	D	E	F
Costs	$270	$371	$398	$322	$350	$381
Benefits	$427	$500	$500	$490	$490	$500
NPV	$156	$129	$102	$168	$141	$119
BC Ratio	1.58	1.35	1.26	1.52	1.40	1.31
ERR	11.8%	9.7%	8.8%	11.6%	10.5%	9.6%

Dollars are U.S. million
Discount rate is 6%

Based solely on the quantitative criteria, Option A was the most cost-effective option as it had the lowest costs, the highest ratio of benefits to costs (BC Ratio) (1.58) and the highest economic internal rate of return (EIRR) (11.8 percent). Option C, on the other hand, had the highest costs, the lowest benefit to cost ratio (1.26) and the lowest economic internal rate of return (8.8 percent) of the six options. Even though Option C ranked lowest among the options, it is still economically viable in that the benefits exceed the costs and the rate of return is acceptable.

Triple Bottom Line

The multi-criteria analysis evaluated the options based on environmental, social, and operational factors. The ***environmental*** factors included marine impacts, groundwater impacts, provision of a saltwater barrier for aquifers, overall sustainability, and odor control. ***Social*** factors included disruption during construction, overall public acceptance, meeting the government's objectives of compliance with marine discharges and reuse, land use conflicts, and promoting public education and awareness of stewardship of water resources. The ***operational*** factors included system reliability, flexibility complexity and emergency responsiveness, with a preference for less complexity and more reliability, flexibility and responsiveness in operations.

Weights ranging from 1 (low importance) to 5 (high importance) were assigned to each of these factors. Ratings on a scale of 0 (not applicable) to 10 (highest) were assigned to each option for each of these factors. These weightings and ratings were assigned, reviewed and refined in a stakeholder workshop.

Option C had the best (highest) score followed by Option A. On the environmental criteria, Option B had the highest score and Option A the lowest. On the social criteria, Option A is the least disruptive and thus scored best socially. Operationally, Option A is the most reliable and the least complex. However, Option C has the highest overall score.

Rankings of the options based upon results of the cost-benefit analysis and the multi-criteria analysis are shown in **Table 2**. Table 2 shows the rankings for both weighted and unweighted scores. The unweighted score gives equal weight to the five indicators (multi-criteria score and four economic indicators). In the unweighted score, the environmental and social impacts represent only 20 percent of the overall score. Alternatively, weights were assigned to the five indicators to provide a weighted score of indicators. A variety of weighting scenarios was used to test the sensitivity of the rankings to changes in the weighting of indicators. For example, the weighted score shown in Table 2 is based upon a weight of 70 percent for the multi-criteria score with the remaining 30 percent divided equally among the four economic indicators.

Table 2 Overall rankings

Options	A	B	C	D	E	F
Life-cycle Costs (US$ million)	$270	$371	$398	$322	$350	$381
Rank (1=lowest)	1	4	6	2	3	5
NPV* (US$ million)	$156	$129	$102	$168	$141	$119
Rank (1=lowest)	2	4	6	1	3	5
BC Ratio*	1.58	1.35	1.26	1.52	1.40	1.31
Rank (1=lowest)	1	4	6	2	3	5
EIRR*	11.8%	9.7%	8.8%	11.6%	10.5%	9.6%
Rank (1=lowest)	1	4	6	2	3	5
Total MCA Score	700	653	723	605	679	676
Rank (1=lowest)	2	5	1	6	3	4
Unweighted Score	7	21	25	13	15	24
Unweighted Rank	1	4	6	2	3	5
Weighted Score	1.78	4.70	2.50	4.73	3.00	4.30
Weighted Rank	1	5	2	6	3	4

* At 6% discount rate

In the weighted analysis, Option A received the best ranking regardless of the weighting of indicators. However, Option A does not meet the government mandate to develop a water management strategy that includes the reuse of valuable wastewater effluent. The analysis illustrates that meeting this reuse mandate imposes the acceptance of certain economic, environmental and social costs.

Summary

The importance of operational criteria became evident through the stakeholder workshop process. Barbados Water Authority staff determined that management of "worst-case" conditions of a highly complex wastewater and reclaimed water system was a critical factor. Thus, options were limited to those that included the ocean outfall infrastructure for emergency backup disposal in the rare instance of a plant failure. Again, the analysis illustrated the additional economic, environmental and social costs, or trade-offs, imposed operational preferences and the reuse mandate.

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Water Reclamation for Aquifer Recharge in the Flemish Dunes

Author: Emmanuel Van Houtte, Intercommunale Waterleidingsmaatschapij van Veurne-Ambacht (Intermunicipal Water Company of the Veurne Region, IWVA)

Belgium-Recharge

Project Background or Rationale

In the western part of Belgium's Flemish coast, water demand increased from 426 ac-ft (526,000 m³) in 1950 to 4,500 ac-ft (5,500,000 m³) in 1990. The dune water catchments, where fresh groundwater is pumped from the unconfined aquifer by the Intermunicipal Water Company of the Furnes Region (IWVA), could no longer produce more water as continued pumping could cause saline intrusion. Ecological interest in the dunes was also growing (Van Houtte and Vanlerberghe, 1998), so alternative exploitation methods were studied to remediate decreasing water levels and to guarantee current and future water extraction possibilities. This resulted in the development of a project for artificial recharge of the unconfined dune aquifer of St-André. Because no other water sources were available for year-round aquifer recharge, the IWVA decided to use reclaimed water from the Torreele facility for the production of infiltration water (Van Houtte and Vanlerberghe, 2001).

Capacity and Type of Reuse Application

The Torreele facility in Wulpen indirectly reuses reclaimed water to augment the potable water supply. The largest portion of the reclaimed wastewater is from households. The treatment process consists of primary sedimentation, predenitrification, and aerobic treatment, followed by secondary clarification and RO. Because the rainwater is collected in the same sewer system, the effluent water quality can vary greatly. In the first 9 years of operation, 4.6 billion gallons (17.5 million cubic meters) of infiltration water was produced at Torreele. Before being recharged in a 196,000 ft^2 pond (18,200 m²) in the dunes of St-André, the water undergoes a small pH correction dosing with NaOH. The extraction rate was 6.2 billion gallons (23.6 million m³) during that period, and the average residence time in the dunes was 55 days (Vandenbohede et al., 2009).

The recovered water is conveyed to the potable water production facility at St-André which consists of aeration, rapid sand filtration, storage, and ultraviolet (UV) disinfection prior to distribution. Dosing of chlorine is possible as a preventive action to prevent regrowth and recontamination in the distribution network.

Since the project started, 35 to 40 percent of IWVA's annual drinking water demand is fulfilled by the combination of reuse/recharge.

Water Quality Standards and Treatment Technology

The recharge water is subject to stringent water quality standards due to the sensitive environmental nature of the dune area to be recharged (**Table 1**). Because reclaimed water is high in both salt and nutrient content, RO was chosen as the final treatment step at the Torreele facility. RO requires a high-quality influent, so UF membranes precede the RO process (**Figure 1**).

Table 1 Quality standards set for the infiltration water

Parameter	Infiltration water
Conductivity (µS/cm)	1,000
Chloride (mg Cl/l)	250
Sulphate (mg SO4/l)	250
Total hardness (°F)	40
Nitrate (mg NO3/l)	15
Nitrite (mg NO2/l)	0.1
Ammonia (mg NH4/l)	1.5
Total phosphorous (mg P/l)	0.4

The RO system is a two-stage configuration with 21:6 pressure vessels in the first pass and 10:6 pressure vessels in the second pass. Scaling is prevented by pH adjustment and antiscalant dosing. Biofouling is prevented by dosing monochloramines. The average annual recovery is 77 percent.

Water reuse intended for drinking water production, both direct and indirect, is not possible without intensive water quality monitoring. Both UF and RO processes performed as expected – UF produced water free of bacteria and suspended solids. UF proved to be a good pretreatment for RO, and the infiltration water meets the quality standards that were set for the infiltration water (**Table 2**).

Table 2 Overview of quality in 2010

Parameter	Infiltration Water
Conductivity (µS/cm)	45 (<10 – 89)
pH	6.29 (5.28 – 6.86)
Total Organic Carbon (mg/l)	0.4 (0.1 – 1.1)
Total hardness (mg/l as CaCO3)	<0.5
Chlorides (mg /l)	3.2 (1.0 – 4.7)
Fluorides (mg/l)	<0.2
Sulfates (mg/l)	<1
Nitrate (mg NO3/l)	2.5 (<1 – 6.3)
Ammonia (mg NH4/l)	0.13 (0.03 – 0.38)
Phosphate (mg PO4/l)	<0.1
Silicium (mg SiO2/l)	0.3 (0.1 – 0.4)
Total trihalomethanes (µg/l)	3.8 (1.2 – 6.7)
Aluminum (µg/l)	12 (2 – 59)
Chromium (µg/l)	<2.5
Copper (µg/l)	<5
Lead (µg/l)	<5
Mercury (µg/l)	<0.2
Nickel (µg/l)	<3
Sodium (mg/l)	10.5 (4.5 – 17.7)
Zinc (µg/l)	<20
Totale Coliform bacteria (counts/100 ml)	0
E. coli (counts/100 ml)	0
HPC 22°C (counts/ml)	<1 (0 – 10)

Project Funding and Management Practices

The project was funded with IWVAs resources; no external funding was used. The total investment was 7 million Euros ($9 million) and the contractors remained responsible during a 10-year period. The daily operation is conducted by IWVA.

All membranes have been replaced only once since startup: the RO membranes in 2009, and the UF membranes between 2009 and 2011.

Successes and Lessons Learned

Meteorological and seasonal variations are a big challenge at the Torreele facility and influence operating conditions. Ongoing monitoring at the plant includes online and daily measurements taken by the operator.

Submerged UF (ZeeWeed), using outside-in filtration and air not only proved to be a good pretreatment prior to RO, but was also capable of handling the expected variations in influent water quality. Suspended solids and bacteria were removed from the water and turbidity is monitored as the first quality control step.

Biofouling and scaling prevention is a constant concern with water reuse when using membranes. Reduction in consumption of chemicals and energy has been achieved since start-up by reducing aeration in the UF system, optimizing RO recovery rates to minimize scaling, and intermittent chloramination for control of biofouling (Van Houtte and Verbauwhede, 2008).

The membrane waste concentrate streams are now combined with the portion of the treated wastewater that is not reclaimed and discharged in the nearby brackish canal. However, IWVA investigated natural systems for concentrate treatment (Van Houtte and Verbauwhede, 2011).

Temperature influences the volume of infiltration; more water is infiltrated in summer when temperatures are higher, which matches IWVA's demand for drinking water in a tourist area. The project was developed for an extraction rate of 1.4 times the infiltration rate. During the first years of operation, there was a surplus of recharged water. Since the beginning of 2009, however, the accumulated surplus appears to be corrected and currently averages 264 million gallons (1 million m³). In winter the surplus decreases as colder temperatures have a negative impact on the infiltration rate. Though Vandenbohede et al. (2008) predicted a dynamic equilibrium would not occur, even after 10 years of recharge, it appears that equilibrium may have already occurred. The latest ratio over the last 12 months for recharge/infiltration rate was 1:39, indicating that the dynamic equilibrium has been reached.

In recent years the drinking water demand in the area decreased from 1.5 billion gallons (5.5 million m³) in 2002 to just below 1.3 billion gallons (4.9 million m³) in

2010. Public education on the proper use of drinking water, increased prices due to higher taxes for discharge of the used water, and decreased leakage of the distribution network all contributed to this decrease. It is difficult to make a prognosis on how the evolution will be in the next years but the decreased use of drinking water meant that less infiltration has been required in recent years.

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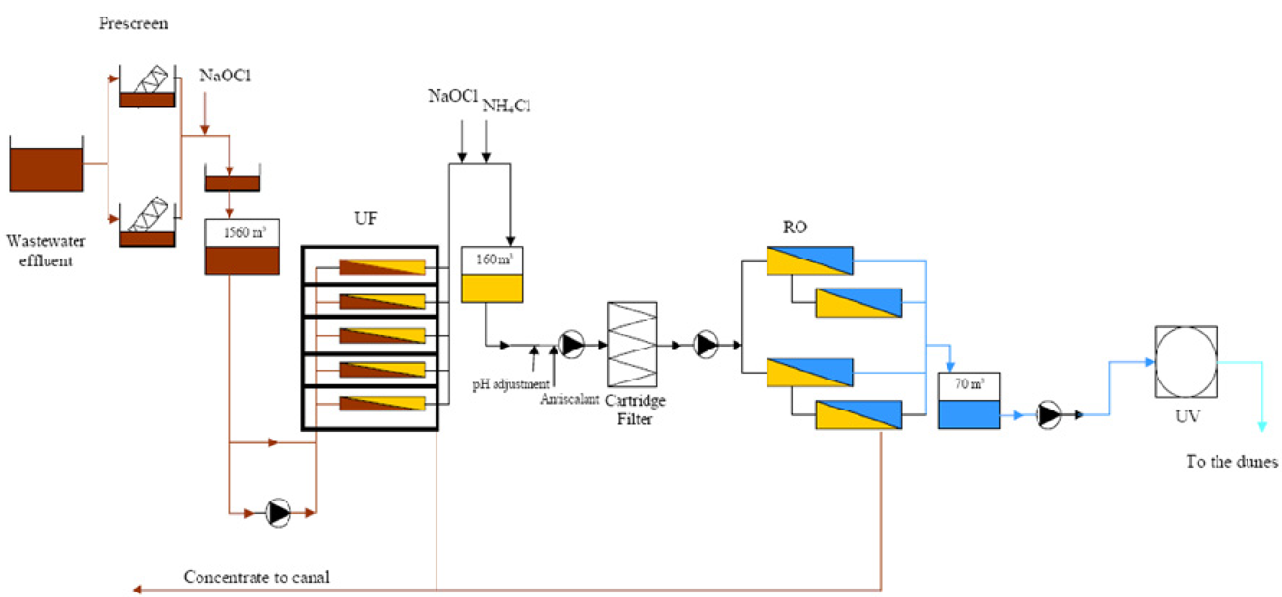

Figure 1 Process scheme of Torreele

Car Wash Water Reuse – A Brazilian Experience

Authors: Rafael N. Zaneti, MSc; Ramiro G. Etchepare, MSc; and Jorge Rubio, PhD, DIC
(Universidade Federal do Rio Grande do Sul)

Brazil-Car Wash

Project Background or Rationale

A full-scale car wash (hand washing) facility in Porto Alegre, South Brazil demonstrates the ability to utilize wastewater reuse (reclamation) for commercial car washing. This project validates an innovative process—Flocculation-Column Flotation (FCF), filtration, and chlorination—proposed by Rubio and Zaneti (2009), and Zaneti et al. (2011). Full evaluation was performed over a period of 20 weeks. The main parameters monitored were water consumption, quality of the reclaimed treated wastewater, water risks to health (customers and operators), vehicles, and washing machine damages.

Capacity and Type of Reuse Application

The installed car wash wastewater reclamation system (**Figure 1**) had capacity for reclaiming 264 gallons/hr (1 m^3/hr) to meet the requirements for a demand of around 60 car washes per day.

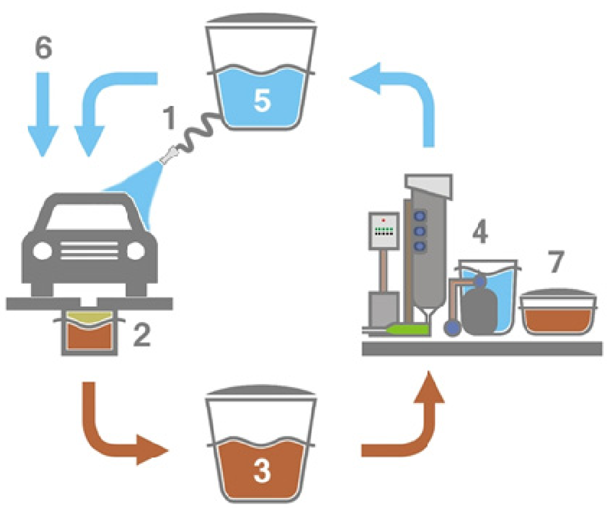

Figure 1
Car wash water reclamation system - Total storage capacity: 2,640 gallons (10 m^3). Stages include: 1.) Hand-operated car wash; 2.) Oil/water separator; 3.) Wastewater reservoir (sample point 1); 4.) FCF equipment; 5.) Reclaimed water reservoir (sample point 2); 6.) Fresh water supply; 7.) Sludge dewatering.

Neutral and alkali detergents, as well as waxes are employed in the wash procedure. Reclaimed water was utilized in the pre-soak, wash and first rinse (wash process). Makeup (fresh) water was used in the final rinse before the cars were dried. Water usage was monitored daily by single-jet water meters. A single three stage oil/water separator was employed after the wash rack to remove excess oil content (free oil) and grit particles.

Water Quality Standards and Treatment Technology

The water quality for vehicle washing has to be sufficiently high to avoid damage to vehicles and washing equipment (Brown, 2002). In addition, the water quality must minimize risk to operators and users and be aesthetically acceptable, lacking odor and having a turbidity of less than 15 NTU (Jefferson et al., 2004).

The FCF principle is to encourage rapid formation of flocs, followed by flotation using fine (micro) bubbles to remove particles. Chlorine is then used to disinfect the FCF treated wastewater. The floc generator reactor (FGR) (Carissimi et al., 2007) and the flotation column (Zaneti et al., 2011) are patented processes and are low energy, easy to control, and compact. The FCF system was run semi-automatically. The water level in the reclaimed water tank was monitored with an electric level sensor, triggering the treatment process to turn on automatically when sufficient volume was reached in the tank. A tannin-based polymer (concentration of 80–350 mg L^{-1}) was used in the coagulation-flocculation step and sodium hypochlorite (0.5 mg Cl2 L^{-1}) to disinfect the effluent.

Study Methods and Results

To ensure acceptable human health risk, risk analysis was performed employing dose-response models (Haas et al., 1999) using *E. coli* as an indicator of microbiological quality. Aerosol and ingestion exposure routes were considered for car wash customers (1 exposure per week) and operators (15 exposures per day).

Corrosion and/or scaling are the main concerns in wastewater reclamation systems for vehicle washing (Metcalf & Eddy, 2006). Total dissolved solids (TDS) and chloride were monitored and predicted using a mass balance model, assuming constant inputs of contaminants per wash cycle and no water loss.

The chemical, physicochemical and micro-biological water analysis results are shown in **Table 1**. Samples were collected at points 1 and 2 (Figure 1) and analyzed using standard methods (APHA 2005).

Table 1
FCF-SC process: Characteristics of wastewater and reclaimed water (20 samplings; mean values ± 1/2 standard deviation)

Parameters	Wastewater	Reclaimed Water	Examination Methods*
pH	7.4 ± 0.8	7.3 ± 0.5	-
TSS, mgL^{-1}	89 ± 54	8 ± 6	2540 D
TDS, mgL^{-1}	344 ± 25.5	388 ± 42	-
Turbidity, NTU	103 ± 57	9 ± 4	2130 B
Total coliforms, CFU/10	3.1E ± 5	3.3E ± 4	9223 B
E. coli, CFU/ 100 mL^{-1}	2.1E ± 4	7.4E ± 2	9221 E

* APHA, 2005.

Results showed that reclamation of 70 percent of the feed water was possible [only 11 gallons (42 L) of fresh water per car] in order to maintain odorless and clear water over 27 water cycles. A risk analysis indicated that car wash users were not at risk, and that a limit of 200 CFU $100mL^{-1}$ of *E. coli* would be recommended for an acceptable risk for car wash operators (risk analysis data not shown). This would be achieved, by increasing the chlorine concentration to 15 mg CL2 L^{-1} (data not shown). Moreover, the mass balance analysis indicated that the reclaimed water will have dissolved inorganic constituents below guideline parameters (TDS < 1000 mgL^{-1} and chloride < 400 $mg.L^{-1}$) (Nace 1975).

Project Funding and Management Practices

The work was supported by several research and educational institutions in Brazil, mainly the Ministry of Science and Technology and the Ministry of Education.

Successes and Lessons Learned

Based on comparison to other studies, reducing fresh water consumption in car washes is more effective through wastewater reclamation rather than rainwater harvesting systems (Zaneti et al., 2011). Rainwater harvesting for water savings in petrol stations with car washes in Brasilia, Brazil was studied by Ghisi et al. (2009). The author reported that large roof areas (550 m²) and a large tank (100 m²) are required to capture intermittent rainfall to reach the same 70 percent of water savings attained in the present study (at a demand of 15 car washes per day). Furthermore, according to the results of these authors, rainwater harvesting systems require longer pay-back periods for installed equipment.

In this study, more than 2000 cars were washed (16 daily washes) during the study period (20 weeks), with no reported problems regarding the wash service quality. The results have encouraged the application of FCF-SC process in many Brazilian bus companies and in more environmentally friendly car washes. However, public policies need to be developed that help to encourage effective implementation of water reuse, including by addressing water pricing.

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Water Reuse Concept Analysis for the Diversion of Phosphorus from Lake Simcoe, Ontario, Canada

Author: David C. Arseneau, P.Eng, MEPP (AECOM); David K. Ammerman, P.E. (AECOM); Michael Walters (Lake Simcoe Region Conservation Authority)

Canada-Nutrient Transfer

Project Background or Rationale

Lake Simcoe is one of the largest inland lakes in Ontario, Canada and supports a cold-water recreational fishing community that is vital to the local tourism economy. Human activity over the last two centuries has degraded water quality in the Lake, creating significant eutrophication from excessive phosphorus loading. The Lake Simcoe area is serviced by 14 water pollution control plants (WPCP), which discharge 5.3 tonnes of phosphorus per year (MOE, 2010). Such impacts are anticipated to increase due to the rapidly growing population. The Lake Simcoe Protection Act mandates the reduction of phosphorus discharges into the Lake, including effluent from all WPCPs servicing the urban areas of the watershed.

Costly upgrades to WPCP treatment technologies have been proposed to meet these reductions. In the interest of pursuing alternative means of reducing phosphorus loadings, this study was commissioned by the Lake Simcoe Region Conservation Authority (LSRCA) and Ministry of Environment (MOE) to evaluate the feasibility of implementing water reuse applications to divert effluent from the Lake. Implementing reclaimed water programs can divert wastewater effluent, and the associated nutrients, away from receiving watercourses while providing non-potable water for uses such as irrigation of farms and golf courses. Water reuse is an emerging practice in Ontario, with few implemented projects and an absence of dedicated legislation or policies to establish acceptable end uses or water quality requirements.

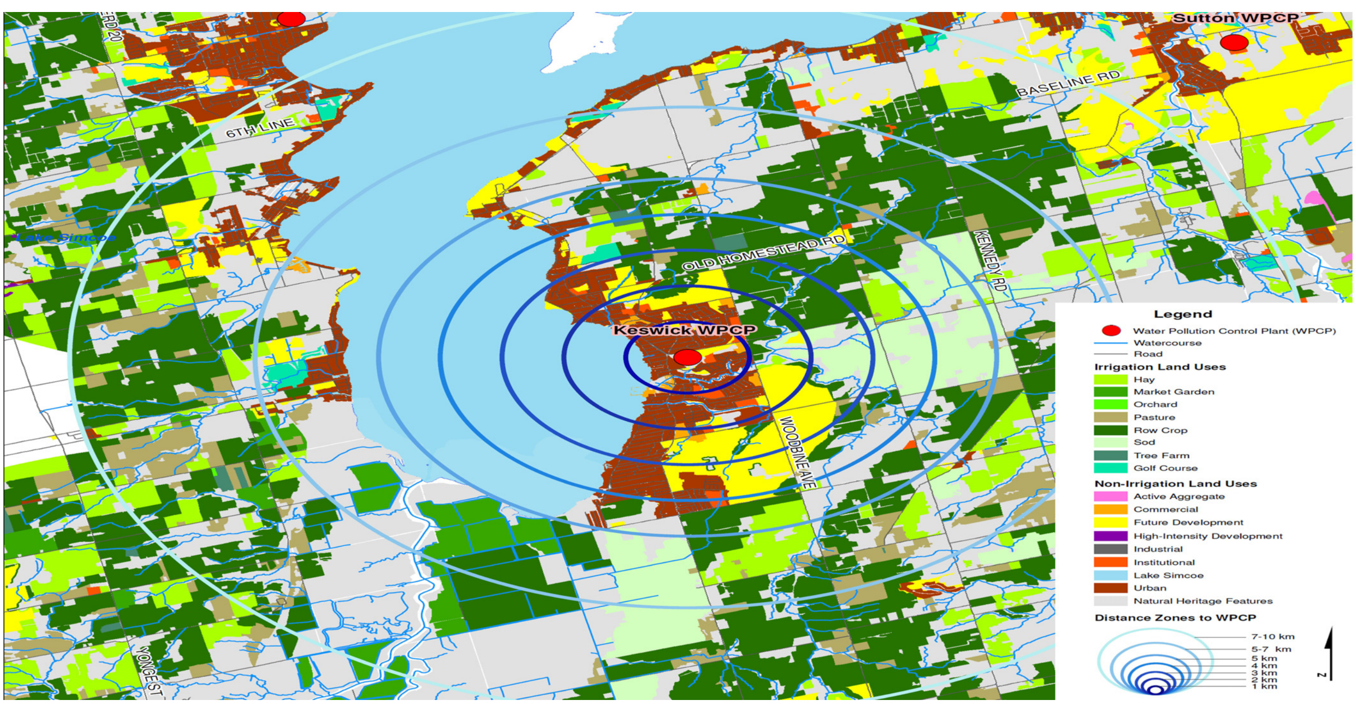

Figure 1
Illustration of the demand screening analysis for the Keswick Water Pollution Control Plant

Table 1 Summary of reuse scenario costs and phosphorus removal rates

Reuse Scenario	25-year Life Cycle Cost ($CAD 2010)	Annual Phosphorus Removed (kg/yr)	Percent Phosphorus Reduction (%/year)[1]	25-year Phosphorus Removal (kg)	Phosphorus Removal Cost Effectiveness ($/kg P)
Keswick WPCP Sod Farm Irrigation	$5.4-$10.4MM	116-184	22%-35%	2,900-4,600	$1,850-$2,250
Barrie Reuse for New Urban Development	$4.7-$9.5MM	12.6	0.50%	315	$14,950-$30,200
Uxbridge Brook WPCP Land Application	$3.2-$6.4MM	25-49	25%-49%	625-1,225	$5,080-$5,200

[1] Compared to current phosphorus loading levels

Conclusions

This study demonstrates the evaluation of the potential cost-effectiveness of water reuse for a variety of applications. The methodology used is scalable to large or small areas, and the parameters of the analysis can be readily modified to suit the management objectives of the operating authority, agency or municipality.

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Water Reuse in China

Authors: Allegra K. da Silva, PhD (CDM Smith) and Liping Lin (GE Water and Process Technologies)

China-MBR

Project Background or Rationale

Urbanization and accelerated economic growth have strained water resources in China and are the key drivers for water reuse. Though China has the fourth largest fresh water resources in the world by volume, the distribution of this resource is dramatically uneven, with Northern regions of the country experiencing severe shortages. Because of China's large population, current water resource volume per capita is 1.8 ac-ft (2,200 m^3), which places China 88th in the world in per capita water availability. As China's population grows to a forecasted 1.6 billion in the mid-21st century, per capita water resource will decrease to 1.4 ac-ft (1,760 m^3), which would result in serious water shortages. More than 400 cities throughout China face water shortages, with more than 100 cities facing serious water shortages, especially large cities such as Beijing and Tianjin. In addition to absolute volume shortages, environmental pollution of surface and groundwater sources has rendered many sources unfit for drinking water or industrial use.

China has taken on the challenge of dramatically improving its water and wastewater infrastructure, making significant improvements over the past decade. As of 2002, the official municipal wastewater treatment rate was 40 percent by total volume produced. According to Xinhua news, as of 2010, China increased its municipal wastewater treatment rate to 75 percent (Xinhua, 2011).

Water reuse is still a minor player in the water supply market in China. Installations that provide reclaimed water mostly for industrial installations including cooling water, but two example installations show how advanced treatment will likely play a growing role in water reuse to help meet China's future urban water needs:

1. Hohhot (capital city of Inner Mongolia province) – 8 mgd (31,000 m^3/d) water reclamation facility to supply cooling water for the Jinqiao Power Plant
2. Beijing – 21 mgd (80,000 m^3/d) water reclamation facility to supply landscape irrigation water for Olympic Park, as well as water for road washing, toilet flushing, vehicle washing and other nonpotable uses

Both systems were commissioned in 2006.

Capacity and Type of Reuse Application

Hohhot, located in Northern China, is dealing with serious water shortages. Municipal wastewater reuse in Hohhot is becoming more necessary and viable through the use of advanced treatment. In order to provide reclaimed water for a major water user, the Jinqiao Power Plant, an advanced multi-barrier approach was required, which uses a tertiary membrane bioreactor (T-MBR) system with ZeeWeed® MBR technology (**Figure 1**) and ion exchange.

Figure 1
Hothot MBR facility (Photo credit: Courtesy of GE Water and Process Technologies)

The Jinqiao Reuse Water Plant (JRWP) treats 8 mgd (31,000 m^3/d) of secondary effluent from a local municipal wastewater treatment plant. The high concentration of ammonium (20-30 mg/L) present in the secondary effluent is targeted for removal to meet requirements for the industrial cooling water application. The JRWP uses a The Zee-Weed®-membrane fiber has a nominal pore size of 0.04μm, which provides an absolute barrier to biomass, bacteria and most viruses, retaining them in the process tank.

The permeate from the membrane tank is then pumped to a weak acid resin system for hardness removal and then disinfected by a chlorination system. The reclaimed water from the JRWP system is used as influent for cooling tower water supply of Jinqiao power plant.

As mentioned, Beijing was also facing water shortages. In advance of the 2008 Beijing Olympics, the Beijing Wastewater Group installed the Qinghe Reclaimed Water Plant (QRWP), a 21 mgd (80,000 m^3/d) MBR water reclamation facility to provide water for municipal uses (**Figure 2**). Approximately 75 percent of the reclaimed water from WRWP is used as landscape supply water for Olympic Park, with the remaining water supplied to municipality of Haidian and Chaoyang District for road washing, toilet flushing, vehicle washing, and other nonpotable purpose. The system may also provide water periodically to Wanquan River, Xiaoyue River, North Tucheng Channel and the old summer palace.

Figure 2
Beijing MBR facility (Photo credit: Courtesy of GE Water and Process Technologies)

The QRWP system includes ZeeWeed® ultrafiltration (UF) technology followed by an activated carbon filter. The operation of QRWP will play an important role in relieving the growing water shortage in the northern area of Beijing.

Water Quality Standards and Treatment Technology

The Chinese central and regional governments have set up specific urban wastewater reuse targets, for example the overall reuse rate is expected to reach 20 percent for the whole country and 75 percent for Beijing by 2015. Technology wise, the Chinese government also published a series technical guidance (GB50335-2002, GB50336-2002, Jianke [2006] #100 etc.) and reuse quality guidance (GB/T18919-2002, GB/T18920-2002, GB/T18921-2002, GB/T19772-2005, GB/T19923-2005, GB20922-2007).

Project Funding and Management Practices

Urban reuse projects could be funded by local government budgets (such as Qinghe through government owned Beijing Drainage Group), by BOT investors and by reclaimed water users (such as Huaneng Power for the Hohhot case).

Institutional/Cultural Considerations

China's main legislation governing water resources, the Water Resource Law, was revised in 2002, introducing water tariffs, usage quotas, and wastewater treatment fees. The revised law also opened the possibility of foreign and non-state-owned capital financing for public water infrastructure. Prior to enacting these legislative changes, the water and wastewater treatment industry was a commonwealth enterprise in China, with only limited fees levied for the consumption of resources and provision of services. The market mechanisms introduced in the revised law have helped to incentivize conservation and reuse, by creating a value for water as a resource (International Trade Administration, 2005). The country has witnessed an increase in investment in water reuse over the past decade as a result (Frost & Sullivan, 2012).

Successes and Lessons Learned

The applications described in this case study demonstrate how advanced technology can be applied to upgrade existing secondary wastewater treatment plants to facilitate water reuse. The use of the activated carbon filter was found to not be a good option for tertiary treatment because of rapid exhaustion and regeneration issues. As a result, the QRWP was recently upgraded to an ozone AOP system.

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The Reuse Scenario in Bogotá

Authors: Juan M. Gutierrez, MS (Javeriana University) and Lucas Botero, P.E., BCEE (CDM Smith)

Colombia-Bogotá

Project Background or Rationale

Bogotá is the capital of Colombia and the home of almost 10 million people. The city is upgrading and expanding its existing wastewater treatment to improve the water quality of the Bogotá River. This will have many benefits, including making the water quality suitable for reuse for agricultural irrigation. In addition, as the Bogotá River is used to produce 7 percent of the country's energy needs through hydropower energy generation; improved water quality will make the operation significantly more efficient and safer for operators.

This case study illustrates how holistic water management planning benefits by considering reuse at the planning phases for wastewater treatment. Additionally, this is a case where water scarcity is not the key driver of reuse. Water reuse may be critical for a country with abundant freshwater resources, as providing water supply for dense urban populations drives the need to look at alternative sources for the various needs and uses.

Treatment Capacity and Technology

The city's sewer system is largely separated between sanitary and storm sewers, except for the old area of the city, which has combined sewers. The local utility company has been investing heavily to separate combined sewers. The city's sewer system is mainly divided into three sewersheds: Salitre at the north, Fucha in the middle, and Tunjuelo at the south. Effluent from the entire sewer system is discharged into the Bogotá River.

Early sewer master plan studies identified the need for two wastewater treatment plants. The first phase of the Salitre Wastewater Treatment Plant (WWTP) was constructed in the late 1990s as a chemically enhanced primary treatment (CEPT) process. Currently, the Salitre WWTP treats 91 mgd (4 m^3/s) with CEPT. The Salitre WWTP is in the process of upgrading to secondary treatment and increasing capacity to a projected total capacity of 167 mgd (7.3 m^3/s) in order to treat all wastewater from the north of the city.

The second municipal wastewater treatment plant is the Canoas WWTP, which will be constructed by 2016. The Canoas WWTP is planned to treat flows from the remaining sewersheds, Fucha and Tunjuelo, located in the Southern portion of the City, serving approximately 7.2 million inhabitants. Presently, these two sewersheds discharge their untreated flows directly into the Bogotá River. The Canoas WWTP will have a build out capacity of 320 mgd (14 m^3/s).

Type of Reuse Application

There are relatively large agricultural areas located near the Salitre WWTP called La Ramada irrigation district. This district currently uses 39 mgd (1.7 m^3/s) for irrigation purposes, but there have been plans for expanding the district, resulting in the need for roughly 114 mgd (5 m^3/s) in capacity. The water used for irrigation comes directly from the Bogotá River, which has already received a large amount of partially or untreated wastewater discharged by smaller towns located north of Bogotá. The existing irrigation infrastructure is operated by the environmental regional authority, Corporación Autónoma Regional (CAR).

Several years ago, some power agencies developed a hydroelectric generation scheme to use water from the Bogotá River, taking advantage of the river's 3,280 ft (1,000 m) drop in the area South of Bogotá, before discharging into Colombia's largest river, the Magdalena River. In fact, to enhance the water energy generation potential further, most of the river flow is currently being pumped to the Muña reservoir to allow the diversion of the river water through a newer hydropower complex. This reuse scheme provides for roughly 20 percent of the energy the city needs or 7 percent of the total energy required by the whole country. Due to this, water reuse from the Bogotá River is considered a national priority by the Colombia Government and it is critical to the economic stability of the country.

Figure 1 shows the main components of the Bogotá River wastewater treatment scheme including the agricultural and power generation schemes associated with the Bogotá River.

In the past 5 years, the local utility company has been evaluating several alternatives to use wastewater treatment plant effluent in a different way other than the current energy generation. Studies by the Javeriana University evaluated the quality of the effluent water and have concluded that the effluent from the Salitre WWTP should be used in the near future as a supplementary source for the Ramada District, based on its proximity to the district. The anticipated water quality would allow restricted agricultural reuse after the secondary treatment is implemented, in accordance with Colombian water quality use requirements for the Bogotá River for Class 4 usage (CAR, 2006). Though there is not current agricultural pressure for increased water reuse in the Canoas area, the plans for expanding the Ramada District southwardly, would present a driver to reuse the Canoas WWTP effluent in the expanded area. This option has the potential benefit of relieving the existing Ramada District agricultural area from drawing excessive water out of the Bogotá River.

Water Quality Standards and Treatment Technology

As the regulating agency for the Bogotá River, CAR established different water quality standards for river water reuse. There are five different Classes that range from reuse water from human use, agricultural use with or without restrictions, to energy generation and industrial use. Criteria for Class 4 (restricted agricultural irrigation) are provided in **Table 1**.

Table 1 Water quality requirements for the use of Bogotá River water for Class 4 use (restricted agricultural irrigation)

Table 1 Water quality requirements for the use of Bogotá River water for Class 4 use (restricted agricultural irrigation)

Parameter	Unit	Allowable Level
pH	pH units	4.5-9.0
BOD	mg/L	< 50
Total coliforms	MPN/100 mL	< 20000
Nitrites	mg/L	< 10
Suspended solids	mg/L	< 40
Aluminum	mg/L	< 5
Arsenic*	mg/L	< 0.1
Beryllium*	mg/L	< 0.1
Boron	mg/L	< 0.3-0.4
Cadmium*	mg/L	< 0.01
Cobalt	mg/L	< 0.05
Copper*	mg/L	< 0.2
Chromium (Cr+6)	mg/L	< 0.1
Fluoride	mg/L	< 1
Iron	mg/L	< 5
Lithium	mg/L	< 2.5
Manganese	mg/L	< 0.2
Mercury	mg/L	< 0.01
Molybdenum	mg/L	< 0.01
Nickel	mg/L	< 0.02
Lead	mg/L	< 0.1
TDS	mg/L	< 3000
Selenium	mg/L	< 0.02
Vanadium	mg/L	< 0.1
Zinc*	mg/L	< 2

* Based on CL 96/50, the concentration of an element or compound that produces a mortality rate of 50% in bioassays lasting 96 hours.

Project Funding and Management Practices

Since the water from the Bogotá River plays such a big role in Colombia's energy generation, and the wastewater from Bogotá contributes up to 50 percent of the Bogotá River average flow, then the sanitation of the Bogotá Rivers has become a national priority project. Since there are so many different agencies and institutions that benefit from the river (the Bogotá Water and Sewer Authority–EAAB, the Colombian National government, CAR, the energy generation company, and the State of Cundinamarca), they all came to an agreement to fund the projects collectively. However, most of the projects' funding will come from the national government, the CAR, and the EAAB.

Institutional/Cultural Considerations

The sanitation of the Bogotá River involves several interested parties as noted above. Since they all have different objectives, negotiating the project implementation scheme and the project funding was a very complex process that required over 15 years. Political pressures from the interested parties slowed down the project implementation significantly.

Successes and Lessons Learned

Water reuse may be critical even for countries with abundant freshwater resources. Therefore, water scarcity does not necessarily drive water reuse. Despite political difficulties, this case shows how different entities with different objectives can join forces to implement water reuse projects successfully.

Some issues that have arisen from the current irrigation with wastewater-impacted Bogotá river water include increased salinity of the soils, making them less fertile than they were originally.

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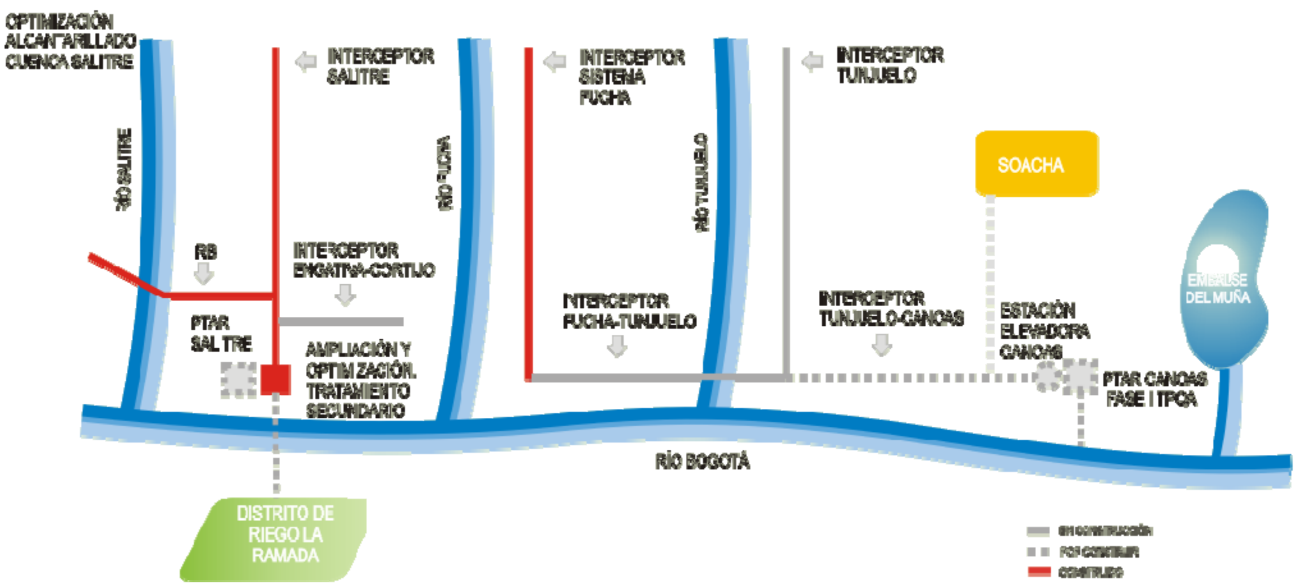

Figure 1
Components of the Bogotá River wastewater treatment scheme, showing components already constructed (red), under construction (grey), and planned (hatched grey). The two WWTPs, or PTARs in Spanish, are shown as squares (Salitre and Canoas). The Ramada irrigation district is shown in the green parallelogram in the bottom left-hand corner. The Muña reservoir (on the right) is the source for the hydropower complex.

Water Reuse in Cyprus

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Cyprus-Irrigation

Project Background or Rationale

Cyprus is the third largest island in the Mediterranean, measuring 150 miles (240 km) long and 62 miles (100 km) wide at its widest point. It is located in the eastern part of the Mediterranean, next to the Middle East countries. Cyprus is the most water-stressed member state of the European Union with a water exploitation index exceeding 45 percent (AQUAREC, 2006; EEA, 2009). At present, almost all of the renewable water resources in Cyprus are utilized and the amount of water extracted vastly exceeds natural recharge. As a result, in a number of areas, groundwater is being rapidly depleted, and sea water intrusion is occurring in the main coastal aquifers. Providing water for the expanding domestic and tourism sectors, while maintaining the agricultural sector, is becoming a critical issue.

For decades, water management in Cyprus has been characterized by impressive infrastructure projects to capture rainwater. The theme “Not a Drop of Water to the Sea,” Cyprus’s policy since the 1960s, was directed towards maximum capturing of run-off. Dam storage capacity increased by a factor of 50, from 4,700 to 240,000 ac-ft (6 Mm^3 to 300 Mm^3).

In 2008, after a series of dry years, the reservoirs dropped to unprecedented low levels and necessitated water supply cuts and water imports from Greece. The need to better adapt to aggravated water scarcity and drought further drives the development of water recycling. On the other hand, drinking water production is increasingly based on desalination which satisfies around 65 percent of the demand (WDD, 2010).

Capacity and Type of Reuse Application

In general, about 90 percent of treated wastewater is reused, primarily for the irrigation of agricultural land,

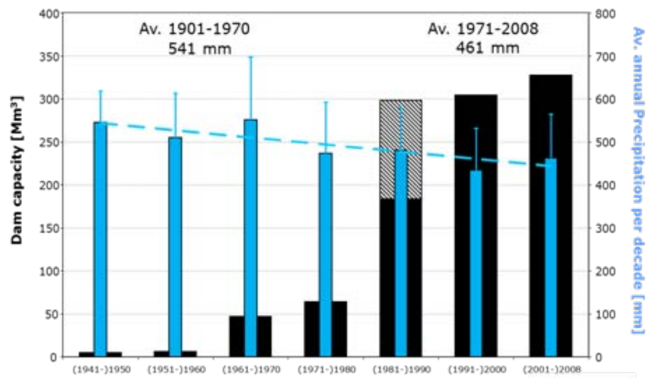

Figure 1
Installed dam capacity and corresponding average precipitation per decade (prepared from WDD statistics) (Hochstrat and Kazner, 2009)

parks, gardens and public greens. Most crops irrigated are trees such as citrus and olive or fodder crops.

A small proportion of reuse is used for groundwater recharge. Near the city of Paphos, the Ezousa aquifer is recharged artificially with 1,620 to 2,430 acre-feet (2-3 Mm^3) reclaimed water per year, which is re-abstracted for irrigation. Investigations by Christodoulou (2007) showed that the aquifer would be able to store a total of 4,000 ac-ft (5 Mm^3) from the municipal wastewater treatment plant.

Currently, the contribution of recycled water to irrigation water supplied through the Government Water Works makes up to about 10 percent of the demand which equals 10,500 to 12,200 ac-ft (13-15 Mm^3). The use of recycled water was a substantial benefit during the extreme drought of 2008 (WDD 2010a). After full implementation of planned schemes, the reclaimed water flow will amount to 48,000 ac-ft per year (59 Mm^3/yr) in 2012-2014 and increase further through 2025, as summarized in **Table 1** (WDD, 2008). The annual water recycling is expected to use 42,000 ac-ft (52 Mm^3) by 2012-2014 which equals 28.5 percent of today's agricultural water demand (WDD, 2008a).

Table 1 Estimated volumes of treated wastewater (WDD, 2008 and 2008a)

	2012	2015	2025
	Mm^3/yr		
Municipal wastewater treatment plants	46	51	69
Rural wastewater treatment plants	13	14	16
Total	**59**	**65**	**85**
Annual water recycling	52		

Water Quality Standards and Treatment Technology

Cyprus Regulation K.D.269/2005 specifies the reclaimed water quality criteria produced from agglomerations with less than 2,000 population equivalent. **Table 2** summarizes the tiered approach valid for different irrigation applications.

For agglomerations of more than 2,000 populationequalivant (p.e.), the quality characteristics (**Table 3**) and use of the treated effluent are specified within the Wastewater Discharge Permits, issued by the Ministry of Agriculture for the Sewerage Boards and the Water Development Department (WDD, 2008).

The prevailing treatment technology until recently was conventional activated sludge treatment with secondary clarifiers followed by sand filtration and chlorination. However, most new projects under planning (new wastewater treatment plants as well as extension of existing ones) are beginning to consider advanced technologies such as membrane application, e.g. bioreactor technology (Larnaca, Limassol, and Nicosia) or reverse osmosis.

Project Funding and Management Practices

Costs for construction and operation of municipal wastewater collection and treatment infrastructure are funded by the local communities through the sewerage rates. Tertiary treatment and reclaimed water distribution networks are financed and operated by the government, through the Water Development Department. Customers are charged different prices for reclaimed water depending on the end use (cf. **Table 4** Selling rates of the treated effluent (WDD, 2008).

Table 2 Cyprus guidelines for irrigation urban reclaimed water from agglomerations with population less than 2000 population equivalent (K.D.P. 269/2005)

No	Type of Crops	BOD mg/L	SS mg/L	Fecal coli-forms/100ml	Intestinal worms/L ***	Treatment required
1	All crops [a]	[A] 10*	10*	5* 15**	Nil	Tertiary and disinfection
2	Amenity areas of unlimited access and vegetables eaten cooked [b]	10 15**	10* 15**	50* 100**	Nil	Tertiary and disinfection
3	Crops for human consumption and amenity areas of limited access	20* 30*	30* 45**	200* 1000*	Nil	Secondary, disinfection and storage >7 days or Tertiary and disinfection.
4	Fodder crops	20* 30**	30* 45**	1000* 5000**	Nil	Secondary, disinfection and storage >7 days or Tertiary and disinfection.
		[B] -	-	1000* 5000**	Nil	Stabilization-maturation ponds with total retention time >60 days
5	Industrial crops	50* 70**	-	3000* 10000**	-	Secondary and Disinfection
		[B] -	-	3000* 10000**	-	Stabilization-maturation ponds with total retention time >60 days

* These values must not be exceeded in 80% of samples per month (Min. number of samples = 5).
** Maximum value allowed
*** Once a year (Summer Season)
(A) Mechanized methods of treatment (activated sludge etc.)
(B) Stabilization ponds
(a) Irrigation of leafy vegetables, bulbs and corms eaten uncooked is not allowed
(b) Potatoes, beetroots, colocasia

Table 3 Reused effluent quality characteristics included in the discharged permits for agglomerations with population above 2000 p.e. (WDD, 2008)

Parameter	Maximum permitted value	Frequency of analyses
BOD5 (mg/l)	10	1/15 days
COD (mg/l)	70	1/15 days
Suspended solids (mg/l)	10	1/15 days
Conductivity (μS/cm)	2200	1/15 days
Total Nitrogen (mg/l)	15*	1/15 days
Total Phosphorous (mg/l)	10**	1/15 days
Chlorides (mg/l)	300	1/ month
Fat and oil (mg/l)	5	1/month
Zinc (mg/l)	1***	2/year
Copper (mg/l)	0.1	2/year
Lead (mg/l)	0.15	2/year
Cadmium (mg/l)	0.01	2/year
Mercury (mg/l)	0.005	2/year
Chromium (mg/l)	0.1	2/year
Nickel (mg/l)	0.2	2/year
Boron (mg/l)	1	2/year
E. Coliforms	5/100 ml	1/15 days
Eggs of intestinal worms	Nothing/l	4/year
Residual Chlorine (mg/l)	1****	1/15 days
pH	6.5-8.5	3/week

* for discharge in sensitive areas and into the sea maximum level 10 mg/l
** for discharge in sensitive areas and into the sea maximum level 2 mg/l
*** for discharge into the sea maximum level 0.1 mg/l
**** for sensitive areas and discharge into the sea 0.5 mg/l

Proven Benefits of Reclaimed Water Use

For example, the Larnaca recycling scheme materializes substantial benefits for the farmers.

Instead of importing silage from abroad, fodder crops are now produced locally with recycled water, which results in cost advantages of up to 1.5 million EUR per year. With a lack of other conventional water resources, this is a viable way of sustaining local agriculture. Acceptance of and confidence in the use of reclaimed water among the user group grew through testimonials and evident positive results for crop productivity (Ioannidou et al., 2011). Another example of increasing confidence is the case of Limassol, where 100 percent of reclaimed water is reused in agriculture, with demand not exceeding substantially existing supply.

Challenges

Due to seasonal demand of water for irrigation and limited storage capacity, certain amounts of effluents are discharged to the sea during the winter months. It poses a challenge to establish both treatment technology and acceptance for utilizing these volumes for building up strategic reserves or restoring over-pumped aquifers. In addition, treated wastewater standards must be revised in order to address a wider variety of substances of concern, such as micro-pollutants.

Table 4 Selling rates of treated effluent from tertiary treatment plants (WDD, 2008)

A/A	Use	Existing selling Rate of Tertiary Treated Effluent Euro Cent/m^3	Suggested selling rate of fresh not filtered water from governmental water works Euro Cent/m^3
1	a. For irrigation divisions for agricultural production	5	15
	b. For persons for agricultural production	7	17
2	For sports	15	34
3	For irrigation of hotels green areas and gardens	15	34
4	For irrigation of golf courses	21	34
5	For pumping from an underground aquifer recharged by treated effluent	8	
6	For over consumption for items 1 to 5	Increase by 50%	56
7	For municipal parks, green areas etc. for rural communities where a plant has been built within its limits and the quantity does not exceed the approved quantity of more than 10%		

In view of the expected growth in wastewater availability and reclamation a long term Strategic Plan for sustainable nationwide water reuse should be designed and implemented.

An Environmental Impacts Study on the Strategic Plan should be issued. Continuous monitoring of the quality and review of the standards regulating the water reclamation and reuse should be incorporated in the strategic plan.

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Implementing Non-conventional Options for Safe Water Reuse in Agriculture in Resource Poor Environments

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Ghana-Agriculture

Project Background

There is increasing water scarcity and contamination of water sources with untreated wastewater in urban environments in many low income countries (Raschid-Sally and Jayakody, 2008). This is because many cities in low-income countries lack the capacity to effectively collect and treat wastewater. In Ghana, urban vegetable farming which has been relying on these water sources over the years for irrigation water is the most affected in terms of benefits and risks. In many cases, farmers have no other option other than using the contaminated water sources for irrigation, which in most cases are more affordable, reliable and enables cultivation of vegetables throughout the year. Risk assessments done in major cities in Ghana shows high fecal contamination levels in irrigation water and vegetables grown with this water potentially leading to an annual loss of 12,000 disability adjusted life years (DALY) per year (Amoah et al., 2005; Razak and Drechsel, 2010). This is equally a concern for authorities who have encouraged research on safe irrigation practices to address the challenge, as recommended in Ghana's national irrigation policy.

Comprehensive wastewater treatment coupled with strict implementation of water quality standards in wastewater irrigated agriculture could significantly reduce health risks. However, this conventional approach is at least for now not feasible in most low-income countries in sub-Saharan Africa, where only less than 1 percent of wastewater produced is treated. Monitoring water quality is also difficult due to the nature of the practice: informal, small-scale, with a large number of farmers spread all over cities. The WHO (2006) recommendation in these situations targets alternative, locally feasible strategies for risk reduction at any point between wastewater generation and the consumption of contaminated food. This multiple-barrier approach is known from the HACCP approach where treatment cannot meet water quality thresholds.

Non-Conventional Options for Risk Reduction

Some options for risk reduction, which have mostly been tested in Ghana, are shown in **Table 1**. These options can easily be combined for optimum reduction in contamination. For example, water treatment at the farm level can be combined with good irrigation techniques, better handling at markets and vegetable washing in households for higher cumulative reduction in contamination.

Project Implementation Considerations

A participatory approach was adopted in this study where key stakeholders such as urban vegetable farmers, vegetable sellers, street-food vendors, and local authorities (agriculture, health) were involved throughout the project. For example, farmers were involved in identifying most suitable options, developing criteria for assessment, testing them in their farms, while extension staff suggested materials for knowledge sharing.

Factors that can Enhance Adoption

1. ***Identify economic or social incentives for behavior change:*** Social marketing might help (learning from hand wash campaigns) where market incentives are lacking. For farmers, tenure security, credit access and media recognition could provide incentives.
2. ***Enabling farmers to see and understand the invisible risk:*** If we can visualize impacts that safer practices could have on risk reduction, it will influence farmers risk perceptions and encourage adoption of safe practices. Microbial contamination cannot easily be visualized and physical indicators that farmers use such as smell, odor, and color might not necessarily correlate with microbial contamination. Developing parameters for routine monitoring will be important as laboratory assessments are not feasible for many of these farmers.

Table 1 Non-conventional health-protection control measures and associated pathogen reductions

Control Measure	Pathogen Reduction (log units)	Notes
A. Wastewater treatment	6−7	Reduction of pathogens depends on type and degree of treatment selected.
B. On-farm options		
Crop restriction (i.e., no food crops eaten uncooked)	6−7	Depends on (a) effectiveness of local enforcement of crop restriction, and (b) comparative profit margin of the alternative crop(s).
On-farm water treatment:		
(a) Three-tank system	1−2	One pond is being filled by the farmer, one is settling and the settled water from the third is being used for irrigation.
(b) Simple sedimentation	0.5−1	Sedimentation for ~18 hours.
(c) Simple filtration	1−3	Value depends on filtration system used.
Method of wastewater application:		
(a) Furrow irrigation	1−2	Crop density and yield may be reduced.
(b) Low-cost drip irrigation	2−4	Reduction of 2 log units for low-growing crops, and reduction of 4-log units for high-growing crops.
(c) Reduction of splashing	1−2	Farmers trained to reduce splashing when watering cans used (splashing adds contaminated soil particles on to crop surfaces which can be minimized).
Pathogen die-off (cessation)	0.5−2 per day	Die-off between last irrigation and harvest (value depends on climate, crop type, etc.).
C. Post-harvest options at local markets		
Overnight storage in baskets	0.5−1	Selling produce after overnight storage in baskets (rather than overnight storage in sacks or selling fresh produce without overnight storage).
Produce preparation prior to sale	1−2	(a) Washing salad crops, vegetables and fruits with clean water.
	2−3	(b) Washing salad crops, vegetables and fruits with running tap water.
	1−3	(c) Removing the outer leaves on cabbages, lettuce, etc.
D. In-kitchen produce-preparation options		
Produce disinfection	2−3	Washing salad crops, vegetables and fruits with an appropriate disinfectant solution and rinsing with clean water.
Produce peeling	2	Fruits, root crops.
Produce cooking	5−7	Option depends on local diet and preference for cooked food.

Sources: Amoah et al. (2011).

3. ***Innovative knowledge sharing:*** In this project, various initiatives were used to facilitate empirical knowledge exchanges between key stakeholders and scientists. Research findings were synthesized to make farmer-friendly training and extension materials, translated into different local languages and presented in various forms like illustrated flip charts, books, radio and video and demonstrated in farmer field schools and markets.

4. ***Involving authorities:*** Local authorities and relevant government ministries should be involved from the start. In Ghana, the project involved local authorities, the Ministry of Food and Agriculture and other relevant agencies such as the food safety regulators. This is necessary because these agencies set policies and regulations for waste reuse, hence help in institutionalization of safe practices. They also have a mandate of offering extension services to farmers.

5. ***Linking with other food safety projects:*** Wastewater reuse represents only one contamination pathway affecting farm households and food safety in general. For best impact, campaigns on safer irrigation options or vegetable washing in markets could be combined e.g. with hand-wash campaigns.

The here described activities were piloted in different cities in Ghana to test their feasibility but await final implementation.

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Reuse Applications for Treated Wastewater and Fecal Sludge in the Capital City of Delhi, India

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India-Delhi

Project Background or Rationale

Based on current urbanization trends, the gap between water supply of 24.5 billion gallons per day (bgd) (95 billion liters per day [bld]) and demand of 48.8 bgd (189 bld) is expected to increase sharply by 2030 (McKinsey Report, 2010). Currently, 78 percent of the urban population in India has access to safe drinking water; however, only 38 percent receive sanitation services (CPCB, 2009). The cost of inadequate sanitation is estimated at $53.8 billion USD per year (World Bank, 2010). With a grim forecast for water availability and sanitation, India is exploring options for water saving, harvesting, recycling, and reuse of wastewater within cities.

The capital city of Delhi, with its population of nearly 15 million, requires a water supply of over 1.1 bgd (4300 million liters per day [mLd]) presently. Municipal sewage generation is estimated at 981 mgd (3,800 mLd), with a treatment capacity of about 594 mgd (2,300 mLd). A total of 30 sewage treatment plants (STPs) situated in 17 locations process 61 percent of wastewater generated in the city at varying degrees. Sewage is collected and transported through a network of pipes and sewage pump stations, and treatment occurs at primary, secondary, and tertiary levels, depending on the design capacity.

This case study describes reuse applications of treated wastewater generated at the Okhla STP, and the utilization of its by-products by communities close to the city for soil conditioning and energy needs.

Capacity and Type of Reuse Application

The Okhla STP is situated at Okhla, Mathura Road, New Delhi. Its current treatment capacity for sewage is 164 mgd (636 mLd), and is managed by the Delhi Jal Board (Delhi Water Board). The STP was developed in five phases between 1937 and 1990:

- Phase I – 14.2 mgd (55 mLd)
- Phase II – 18.8 mgd (73 mLd)
- Phase III – 35.1 mgd (136 mLd)
- Phase-IV – 43.4 (168 mLd)
- Phase V – 52.9 mgd (205 mLd)

The treatment involves a conventional activated sludge process and is being managed by the Delhi Jal Board (DJB, 2010). A flow diagram of the water treatment plant, and performance evaluation of 5 treatment units are shown in **Figure 1** and **Table 1**, respectively.

A raw sewage inlet chamber is common for all the units, after which liquid sewage is screened and conveyed to the five units for treatment. Figure 1 depicts the key steps in the treatment process. In its entirety, the STP receives around 140.6 mgd (545 mLd) of sewage at present for treatment at all five units. The different units have been upgraded in stages to optimize its capacity for treatment, and increase the reuse potential of its by-products.

At present, 40.8 mgd (158 mLd) of treated effluent is being issued to the Badarpur Thermal Power Station (705 MW) for cooling purposes, 23.2 mgd (90 mLd) for Central Public Works Department for horticulture, 11.6 mgd (45 mLd) to Minor Irrigation Department for irrigation (through gravity flow), and the rest is discharged into Agra canal, which reaches the Yamuna river (dilution of pollution). The government departments are charged a nominal fee for accountability. It is estimated that over 300 farmers (Jaitpur area) utilize the treated water for vegetable (cucumber, brinjal, tomato, cabbage, raddish, green leafy vegetables etc.) production. Private users pay up to INR 1.25 for 258 gallons (1000 L) of treated water, which is recommended for gardening and agriculture only. For industrial use the charge rate currently is INR 4.00 for 258 gallons (1000 L). At present the biogas is being issued to a small community living around the STP.

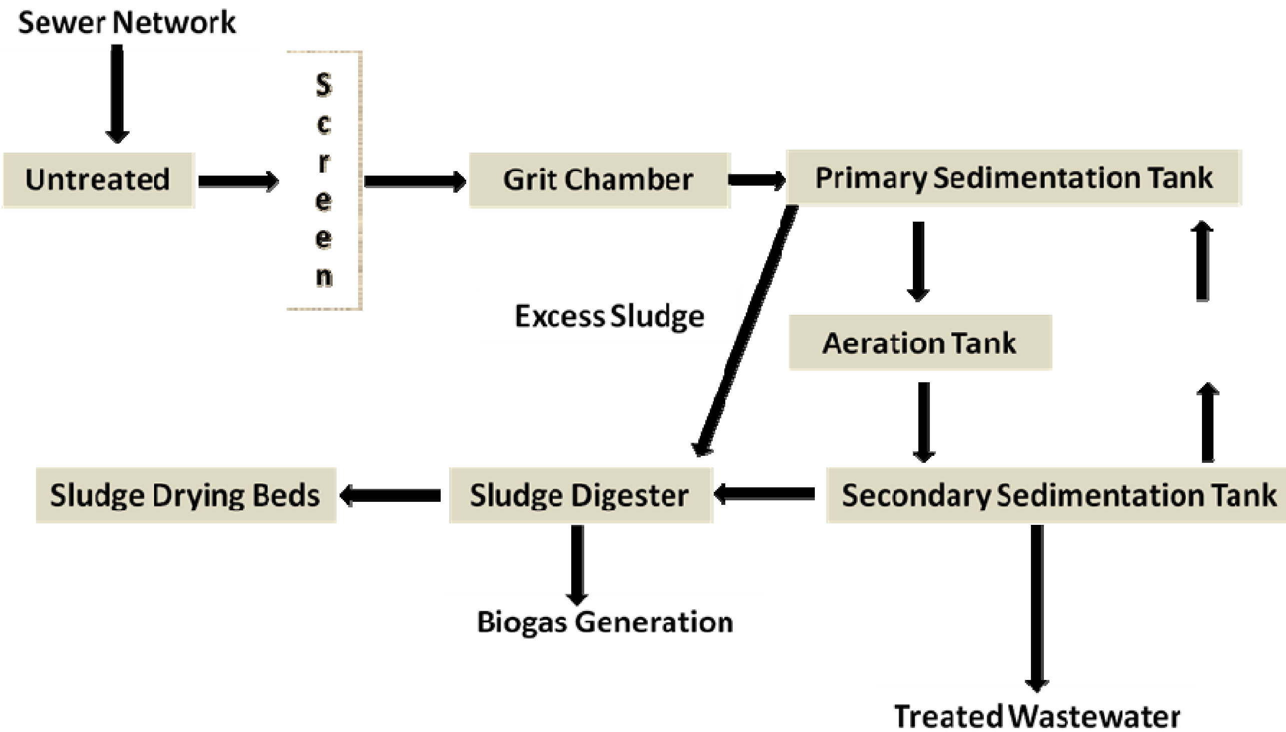

Figure 1
Flow diagram depicting the wastewater treatment pathway at the Okhla STP

Table 1 Performance evaluation of five sewage treatment units at Okhla STP

Phase	Capacity mLd	Flow mLd	Influent Quality					Effluent Quality					% Reduction		
			pH	TSS mg/L	COD mg/l	BOD mg/l	Con	pH	TSS mg/L	COD mg/L	BOD mg/L	Con	TSS mg/L	COD mg/L	BOD mg/L
I	54.55	39.09	7.3	498	517	204	1440	7.8	21	54	10	1460	95.8	89.56	95.1
II	72.73	40.91	7.4	291	486	207	1510	7.7	83	108	48	1400	71.5	77.78	76.8
III	136.38	136.98	7.4	647	551	222	1480	7.6	76	153	45	1470	88.3	72.23	79.7
IV	168.2	159.11	7.3	480	515	249	1590	7.8	32	62	12	1540	93.3	87.96	95.2
V	204.57	181.84	7.3	480	515	249	1590	7.7	27	51	19	1530	94.4	90.1	92.4

TSS = Total suspended solids; COD = Chemical oxygen demand; BOD = Biological oxygen demand; Con = Conductivity

In an attempt to reduce energy costs and earn carbon credits, the Jal Board is also planning for power generation from biogas. Improved business models for sludge disposal are also being discussed. The Jal Board subjects its process management to outside audit to assess operational capacity and pollution removal efficiency.

Water Quality Standards and Treatment Technology

Treated effluent from the plant is meeting design standards for BOD and suspended solids, which are set by the Central Pollution Control Board (CPCB), as shown in **Table 2** (CPCB, 1986).

The current percent reduction in pollution levels for purpose of horticulture, irrigation, and cooling is considered to be acceptable. The activated sludge process that is used for treatment is described elsewhere (CPCB, 2007).

Institutional and Management Practices

Installation of the Okhla STP spans over a long period (1937 to 1990). Infrastructure evaluation and upgrades have taken place at various times with funds received from different sources. The most recent support was received from USAID in 2005 for a feasibiltiy study to assess the reuse applications.

Currently the Delhi Jal Board is responsible for the infrastructure and day-to-day operational management of its SPTs, treatment processes, flow measurements, and distribution of treated water, as well as by-products with the support of a number of government and private stakeholders who serve as service partners. Education and awareness-raising are also a part of the activities of the Board, especially on the reuse applications. When services are provided to the beneficiary partners, it is advertised the public domain.

Augmentation of the capacity of the STP is being considered with an additional plant at 35.2 mgd (136.38 mLd) under Yamuna Action Plan II, which is under implementation with JBIC funding.

Successes and Lessons Learned

Wastewater reuse applications are becoming popular among the public in part due to increased demand caused by shortages of water and increased domestic energy needs. Alternative uses for recycled water are recognized by government authorities (Delhi Jal Board and City Administration), while attempts are also being made to explore different treatment processes. It is envisaged that by popularizing alternative uses for treated water, the city's drinking water supply will be conserved.

However, quantitative information is not available for citation, presently. There is an increased demand for by-products like bio-gas and sludge manure, which can generate revenue for maintenance and upgrading the system. With the emergence and use of new technologies for reuse applications, staff training and capacity building in relevant institutions are important. At the same time, regular re-evaluation of private and public partnerships is also crucial. Health risk assessments on the use of treated wastewater, especially for crop production can be easily formalized, considering that the water quality data are available at the time of discharge.

Table 2 Water quality standards for India

	DO (mg/L)	BOD (mg/L)	Total coliform (MPN/100 mL)	pH	Free ammonia (mg/L)	Conductivity	SAR	Boron (mg/L)
Class A	6	2	50	6.5-8.5	NA	NA	NA	NA
Class B	5	3	500	6.5-8.5	NA	NA	NA	NA
Class C	4	3	5000	6.5-8.5	NA	NA	NA	NA
Class D	4	NA	NA	6.5-8.5	1.2	NA	NA	NA
Class E	NA	NA	NA	6.5-8.5	NA	2.25	26	2

Class A: Drinking water source without conventional treatment
Class B: Water for outdoor bathing
Class C: Drinking water with conventional treatment
Class D: Water for wildlife and fisheries
Class E: Water for recreation and aesthetics, irrigation and industrial cooling
Source: CPCB, 2000

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V Valley Integrated Water Resource Management: the Bangalore Experience of Indirect Potable Reuse

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India-Bangalore

Project Background or Rationale

To bridge the ever increasing gap between the demand and supply of drinking water to its customers in Bangalore, the Bangalore Water Supply and Sewerage Board (BWSSB) has plans for non-conventional solutions to increase water supply. In this context, based on sufficient availability of treated wastewater and feasibility of diverting the treated wastewater to indirect potable use, BWSSB initiated a group of "Water Recycle and Reuse" projects under two broad initiatives:

1. Integrated water management in Vrishabhavathi Valley (V Valley) – an area of Bangalore

2. Integrated water management - lakes projects

This case study describes the development of new projects in V Valley to address water requirements. The lake projects are not described in this case.

Under the V Valley projects, drinking water supply will be indirectly augmented by water reuse. Secondary treated wastewater will be further refined through advanced treatment processes including membrane treatment and granular activated carbon (GAC) and discharged to a receiving river feeding a water reservoir that is a source for one of the drinking water treatment plants in Bangalore. This indirect potable reuse scheme will augment BWSSB's existing water supply sources, which are currently insufficient to meet current and projected demands.

History of Water Supply in Bangalore

Bangalore, the capital city of the state of Karnataka is today ranked the sixth largest city in India and is one of the fastest growing metropolitan cities in the world. The 2011 census population for Bangalore was about 8.4 million. As Bangalore is perched on rocky strata without a substantial groundwater aquifer, the city relies entirely on surface water for supply. The Arkavathy River was historically the main water supply source for the city, providing 39.3 mgd (149 mLd) under two water supply schemes, the Hesarghatta and Tippegondanahalli (TG Halli) water supply schemes, which were developed in multiple stages (1896, 1957, 1964, and 1993).

BWSSB was constituted in 1964 to provide for the drinking water supply and sewage disposal needs of the city. The Cauvery Water Supply Scheme implemented by the Board quadrupled the available piped water supplies to the city by developing the Cauvery River as an additional source. This scheme was planned in three stages (1974, 1982 and 1995). At the end of stage III, the total water available to Bangalore was 178 mgd (675 mLd). Reduction in rainfall duration and intensity and encroachment in the Arkavathy River's catchment area has resulted in decline in the volume of water received in the TG Halli reservoir.

Despite this dramatic overall increase in supply, the total present supply from both the Arkavathy and Cauvery Rivers, 222 mgd (840 mLd), provides a net per capita consumption of 26 gpd (100 Lpd), well below the national standard of 40 gpd (150 Lpd). To address shortfalls, Stage-IV of the Cauvery Water Supply Scheme has begun, which involves two phases. In Phase I, a new drinking water plant drawing Cauvery River water over a distance of 62 mi (100 km) was commissioned in 2002 to treat 79 mgd (300 mLd) of water. In Phase II, a new treatment plant at the same location is being constructed to treat 145 mgd (550 mLd) of Cauvery River water that is expected to be completed by December 2012.

In addition, eight urban local bodies and 110 villages around Bangalore have recently been merged forming Bruhat Bangalore Mahanagar Palike (BBMP – Greater Bangalore Municipal Corporation) which has resulted in increase in water demand on Bangalore City. The progressively widening gap between availability of freshwater and the demand is indicated in **Table 1**.

Table 1 Current and projected water demand and availability of fresh water for the BWSSB

Year	Population million	Demand MLd	Available mLd	Shortfall mLd
2001	5.4	870	540	310
2007	7.5	1219	840	379
2015	8.8	1720	1500[1]	220
2021	10	2125	1500	615
2036	12.5	2550	1500	1050

[1] In 2015, the projected available water (1500 mLd) is based on an increase of 148 mgd (560 mLd) which will be withdrawn from the Cauvery River under the Stage IV Phase II expansion (expected to be completed in December 2012). At this threshold, the maximum withdrawal (off take) sanctioned by the Government of Karnataka (GOK) is fully utilized and there will be no other conventional water sources to develop.

Capacity and Type of Reuse Application

To address projected shortfalls, a range of solutions are being developed. It is feasible to harness 53 mgd (200 mLd) wastewater for indirect potable reuse in Bangalore after appropriate advanced treatment in the V Valley by 2015. As a first stage in the overall V Valley reuse scheme, 36 mgd (135 mLd) will be treated for reuse. Based on the technical and economic performance of this scheme, further refinements will be made and a second phase is planned to reuse the remaining 17 mgd (65 mLd).

WQ Standards and Treatment Technology

Under the V Valley Reuse Scheme, water that has gone through tertiary treatment and disinfection with chlorine at V Valley sewage treatment plant (STP) will be pumped to the Tavarekere advanced treatment facility. There, the water will pass through ultrafiltration (UF) membranes and granular activated carbon (GAC) adsorption filter followed by low dose of terminal chlorination. It is anticipated that there is not a need for a dechlorination facility, as chlorine concentrations are expected to be non-detect by the time the water flows through the initial portion of the engineered wetland. However, there is a provision to add a dechlorination facility if chlorine levels are a problem in the future. This treatment scheme will achieve less than 1 mg/L biochemical oxygen demand (BOD) and total organic carbon (TOC), and below Detectable Level for fecal coliforms (FC) and total coliforms (TC). The highly

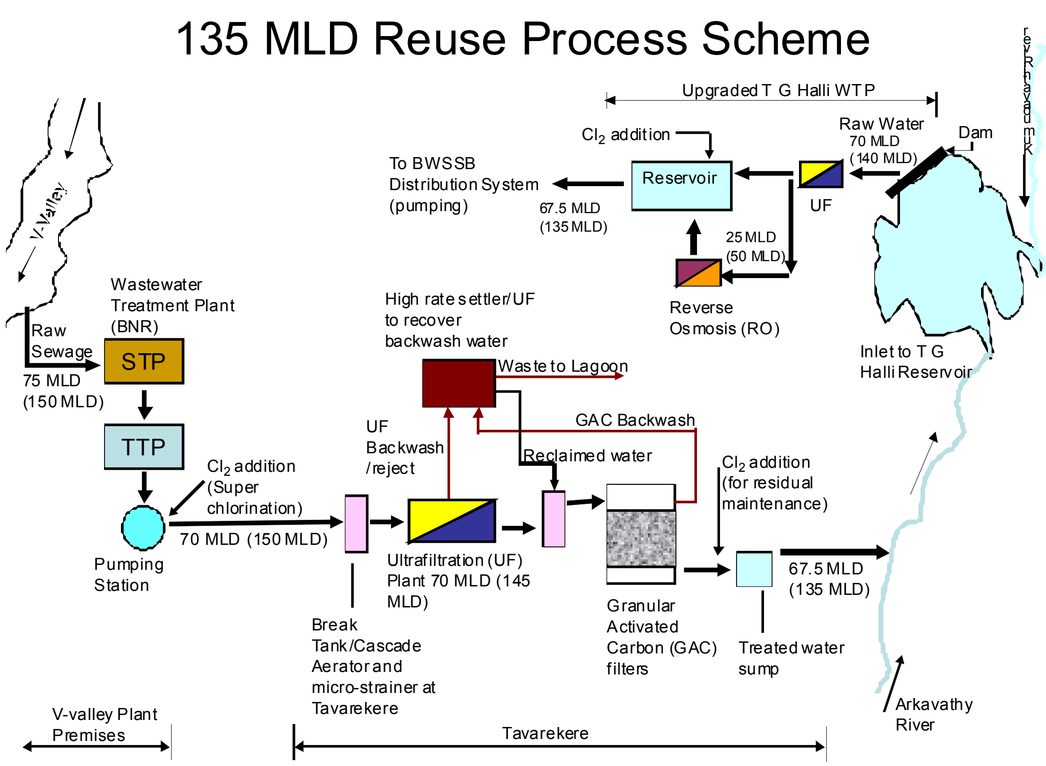

Figure 1
Proposed V Valley reuse scheme (Phase 1)

treated water will then be discharged into the Arkavathy River which feeds the TG Halli reservoir. The water will not result in polluting or degrading the quality of water present in the TG Halli reservoir. On the contrary, the quality of the TG Halli reservoir is likely to improve with respect to TOC and FC. This type of indirect potable reuse scheme follows in the path of similar projects around the world.

To get better understanding of what water quality is achievable and to understand public perception, BWSSB initiated a one year long pilot study (conducted from 2009 to 2010) that mimicked the actual treatment process that will be adopted for the full-scale plant. The pilot study included a 13,200 gpd (50 kL/day) membrane pilot followed by a 11,900 gpd (45 kL/day) GAC filter, pictured in **Figure 2**.

Figure 2
During the pilot study, water quality testing was conducted

The pilot plant data (**Table 2**) provided encouragement and clarified that indeed the water quality from this tertiary treated plant was superior to that of existing Arkavathy river water quality.

The 2004 EPA *Guidelines for Water Reuse* was used as a guidance document in the pilot studies and designs, as there are currently no national or state treatment standards for reuse in India.

Project Funding and Management Practices

Based on the pilot study data, BWSSB completed detailed design (30 percent completion level) to implement the plant on PPP mode Design Finance (60 percent) Build & Operate concept. The operation will be for a period of 15 years. With the design and bidding documents complete, BWSSB approached both the Government of India under the Jawaharlal Nehru National Urban Renewal Mission (JnNURM) for viability gap funding and the State of Karnataka. Considering the importance of the project, both the Governments budgeted and approved a total of 41 million USD (2000 million rupees), which was equivalent to 30 percent of overall project cost. The remaining 70 percent would come from the Contractor through a PPP mode.

Table 2 Results of water reuse pilot study: Quality of water leaving V Valley STP and leaving the tertiary treatment plant, as compared to existing water quality in the Arkavathy River and the TG Halli Reservoir; values are averages over a 12-month period (December 2009 – January 2010).

	Concentration			
Parameter	Effluent from secondary treatment (V Valley Plant)	Effluent from tertiary Treatment (Tavarekere Plant)[1] (reclaimed water, which is discharged to river)	Arkavathy River (7 km upstream of Reservoir)	TG Halli Reservoir (values at the reservoir intake to WTP)
BOD mg/L	22	1.6	12	9
COD mg/L	65	8	27	22
Sulfate mg/L	25	13	86	27
Magnesium mg/L	28	19	63	16
Phosphate mg/L	1.8	0.6	2.8	1.4
Ammonia mg/L	25	5	8	8
TDS mg/L	450	228	320	300 N/A
Fecal coliforms #/100 mL	> 1600	2	> 1600	> 1600 N/A
E. coli MPN/ 100 mL	> 400	3	> 600	> 600 N/A

[1] Reclaimed water that is discharged to river
N/A indicates data was not collected

Present BWSSB planning activities include:

- Improvements in V Valley STP to achieve nutrients removal from the current volume of 36 mgd (135 mLd), pumping of tertiary treated water to Tavarekere to undergo advanced treatment, including plans for UF and GAC adsorption.
- Construction of a 36 mgd (135 mLd) capacity drinking water treatment plant at TG Halli (which draws from the reservoir) based on UF membrane treatment followed by reverse osmosis (RO) membrane treatment for a portion of the flow. RO is included as a provision in case TDS levels start increasing in the reservoir over time due to water reclamation. RO will be employed to maintain the finished water TDS below 500 mg/L. This phase also includes pumping and distribution of the drinking water from TG Halli to Bangalore and installation of 10 mi (16 km) of new pipeline.

Institutional/Cultural Considerations

No matter how great are the technological advancements and availability of treatment technologies for advance treatment, projects tend to fail unless consumers have bought into the concept. This is especially true for reuse projects due to the apathy of consumers towards the word “reuse.” Public outreach and involvement is crucial for the acceptance of even a very well planned reuse project. A health effect study to ensure the health and safety of indirect potable reuse must be conducted in a rigorous and defensible manner.

Based on the 1-year pilot study data, BWSSB is planning to conduct a number of workshops and open discussion forums, which will not only have consumer participation but participation from politicians as well as local leaders. The workshops and public outreach programs were started in late 2011. In addition to this, BWSSB is also developing a media campaign on the importance of recycle and reuse and how reuse is beneficial to the city for its future. School kids have been targeted to become more active in this campaign.

Successes and Lessons Learned

The successful implementation of pilot plant and data analysis presented to decision makers helped to gain momentum on possibility of adding a new and first of its kind planned-indirect potable reuse project in Bangalore, India, thereby increasing the water availability to city of Bangalore.

City of Nagpur and MSPGCL Reuse Project

Authors: Uday G. Kelkar, PhD, P.E., BCEE (NJS Consultants Co. Ltd) and Kalyanaraman Balakrishnan (United Tech Corporation)

India-Nagpur

Project Background or Rationale

The primary goal of this project is to establish a wastewater recycle and reuse project in India that is both economically feasible and beneficial to the City of Nagpur as well as the Maharashtra State Power Generation Corporation (MSPGCL – a public sector unit of Govt. of Maharashtra, India). The project will also reduce the freshwater demand for non-potable applications and increasing the quantity of fresh water available for the City of Nagpur's use.

Nagpur, the second capital of Maharashtra, is at the geographic center of India, with all major national and state highways passing through the city. Nagpur is located geographically between Latitude 210 9' North and Longitude 790 6' East (Survey of India Top sheet No. 55 O/4) at an altitude of 1017 ft (310 m) above MSL. The soil type around Nagpur is mostly black cotton with very high fertility and rich in organic contents. Major cash crops are orange, cotton, sugarcane, and chili. Maximum, average, and minimum rain fall values are 78 in (1990 mm), 47 inches (1200 mm) and 24 inches (600 mm) respectively. The maximum temperature reaches 118 degrees F (47.8 degrees C) in May and minimum is 43 degrees F (6 degrees C) in mid December.

The current population of Nagpur is 2.35 million. The city presently receives freshwater from three different sources, the Kanhan River, Pench River and Gorewada reservoir tank, for a total of 124 mgd (470 mLd) of water at the rate of 35-40 gallons/cap./day (135-150 L/cap./day) . At present, 124 mgd (470 mLd) of water supply in the city generates about 100 mgd (380 mLd) (approx. 80 percent recovery) of sewage that is partially treated and discharged into natural water courses – drains and Nallas.

Maharashtra State Power Generation Corporation (MSPGCL, formerly known as MSEB) has two existing thermal power stations (TPS) to the north of Nagpur City at a distance of about 7 miles (12 kilometers). One TPS of 840MW capacity is at Khaperkheda, and the other TPS of 1100MW is at Koradi. The power stations are approximately 1 mile (1.5 km) away from each other. Due to growing power demand by the State of Maharashtra, MSPGCL has planned for three new power stations – one at Khaperkheda and two at Koradi, each with 500MW capacity. Coal linkage for the proposed power stations was established earlier and MSPGCL was in the process of securing water linkage for the power stations. MSPGCL had the existing allocation from Pench River for 45,000 ac-ft/yr (55 Mm^3/year). With the addition of three new power stations, MSPGCL was looking for a total additional water requirement of 47,000 ac-ft/yr (58 Mm^3/year) starting in 2015, when the new power plants come on-line. The existing percent consumption of water for various uses at the power station is shown in **Figure 1**.

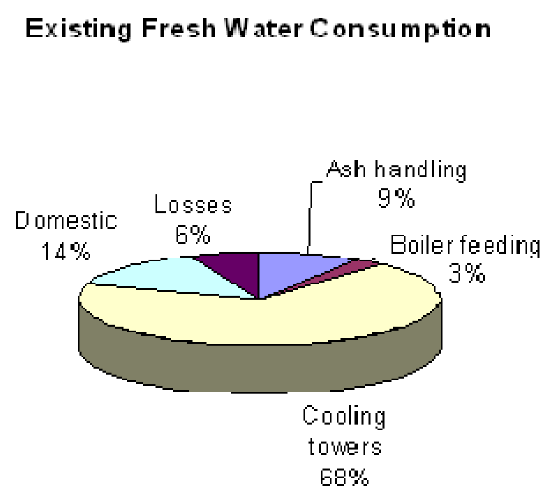

Figure 1
Percent consumption of water by type of use for the power station

Following a request from MSLGCL, the Irrigation department of Government of Maharashtra, increased the water allocation of 45,000 ac-ft/yr (55 Mm^3/year) to 54,000 ac-ft/yr (67 Mm^3/year) with a max. to 60,000 ac-ft/yr (75 Mm^3/year) within 10 percent variation). However, this was projected to be insufficient for all three units, and there was no additional freshwater allocation available for MSPGCL from any other source.

Project Funding and Management Practices

To resolve the issue of water availability for MSPGCL, USAID, through its project titled Water Energy NEXUS Phase - II (WENEXA - Phase II), initiated a feasibility study that included demand assessment and evaluation of alternate water sources, including but not limited to use of high quality tertiary treated water from the city of Nagpur's wastewater plant. The project also implemented a six month long pilot plant (**Figure 2**) to showcase achievable output water quality and get buy-in from both Nagpur Municipal Corporation (NMC) as well as MSPGCL that reuse is effective and feasible. The pilot plant was constructed by M/s. Triveni Engineering and Industries Ltd., using Memcor/ Siemens ultrafiltration unit that received secondary treated wastewater from the NMC's existing Bhandewadi STP.

Figure 2
Pilot setup for Nagpur water reuse scheme

The pilot study also helped gain public acceptance as well as support from State Government of Maharashtra, which issued a policy paper on reuse of wastewater for non-potable applications as a means of conserving freshwater for the city.

The water quality requirements, when compared with the tertiary-treated wastewater quality from the pilot plant and existing fresh water quality from the Pench Reservoir, indicated that the reclaimed water can be used for a number of applications at the power plant, including ash handling without further treatment, and can be used for cooling tower with the addition of a disinfectant. Based on the pilot plant study, the total reuse potential at the plant by 2015 was determined to be 69,000 ac-ft/yr (84.64 MM^3/yr) (**Figure 3**).

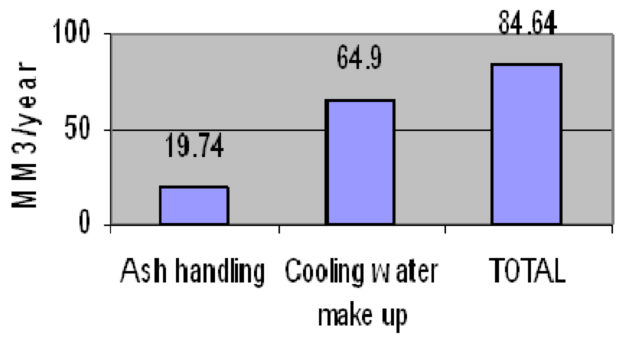

Figure 3
Total reuse potential at the power plant for ash handling and cooling water make-up by 2015

Comparative assessment between the available fresh water sources and reuse water indicated that MSPGCL can construct the reuse plant by 2014 at a capital cost of 2000 million rupees (200 Crores – 10 million equal to 1 Crore) while the cost of constructing a new dam and construction of new pipeline from a fresh water source could cost 3500 million (350 Crores) rupees and could take more than 10 years to get completed as the construction of new dam would have to go through various requirements and clearances through Ministry of Environment and Forest (MOEF) and address the issue of submergence and re-settlement of farmers. In addition, with the lower capital cost, the reuse project showcases an environmental friendly solution, solving NMC's wastewater treatment and discharge issues.

Based on the study results, pilot plant data and the potential for getting good quality reclaimed water in short period of time, MSPGCL signed a Memorandum of Understanding (MOU) with Nagpur Municipal Corporation (NMC) in support of NMC's Water Reuse Project, and to supply treated water from municipal sewage plant as the water linkage to meet additional demand of Mahagenco's proposed expansion plan. In addition, MSPGCL agreed to pay NMC 150 million rupees (15 crores) every year for the next 15 years as royalty fee. In addition, MSPGCL agreed to construct a new sewage treatment plant with tertiary treatment capability with the capability to pump the treated water to its thermal power stations. Based on this agreement, NMC being a municipality, approached the central Government and received a grant for a sum of 800 million rupees towards the project under the Jawaharlal Nehru National Urban Renewal Mission (JnNURM), while the remainder of the cost 1200 million rupees will be borne by MSPGCL.

Institutional/Cultural Considerations

The use of pilot plant data and results were helpful in getting both government officials and the public at large to get acceptance for the use of reclaimed water for non-potable applications. In addition to conducting pilot studies, the team also conducted a number of workshops and willingness surveys. The results of these activities helped the Government of Maharashtra to develop a policy paper in support of water reuse (**Figure 4**).

Statement of Support for Water Reclamation
(NAGPUR REGION)

Nagpur Municipal Corporation (NMC), Urban Development Department, Water Supply & Sanitation Department, Environment Department, Water Resources Department, Government of Maharashtra (GoM) adopt the following joint statement of support for water reclamation

Whereas, water reuse is defined as the beneficial use of treated wastewater for non-potable use as power plants, Industrial Cooling, Washing, Irrigation, Landscaping, Gardening, Recreation, Construction and other uses

Whereas, the NMC to make water reuse an important element of Master Plan for Nagpur Water Supply

Whereas, NMC & GoM discourage to use potable water for non-potable application by institutions, wherever the reclaimed water is available for reuse

Whereas, amount of wastewater generation in Nagpur to increase from 380 Mld per year in 2005 to over 747 Mld in 2031

Whereas, the demand assessment survey 2005 reported that water reuse potential in greater Nagpur region is appx. 245 Mld by 2011 and that the major constraints to achieving these levels of reuse appear to be funding, institutional and regulatory disincentives, the permitting process, and public acceptance; and

Whereas, a world wide extensive experience with water reclamation provides reasonable assurance that the potential public health risk associated with water reclamation in Nagpur are minimal, provided all regulations pertaining to water quality, monitoring, reporting and reliability are adhere to; and

Whereas, NMC & GoM agencies to frame the water reuse law and regulations to be fully protective of human health and require a specific level of water quality and treatment corresponding to each beneficial use of reclaimed water; and

Whereas, NMC & GoM agencies to setup the mechanism for monitoring and reliability requirements to further assure that use of reclaimed water is safe; and

Now therefore, be it resolved on Wednesday the 14th day of December, 2005, the undersigned agencies support the pursuit and development of State and local water reclamation policies that will reduce constraints and promote water reclamation. Specifically, the agencies will work to overcome and reduce institutional and regulatory disincentives and funding constraints and to promote public acceptance of water reclamation. The agencies will co-operate to develop specific policies and resource commitments that will enable the Nagpur Municipal Corporation to meet the water reclamation goals and to help satisfy the greater Nagpur region overall water need.

Principal Secretary
Urban Development Dept.
Govt. of Maharashtra

Principal Secretary
Water Supply & Sanitation Dept.
Govt. of Maharashtra

Principal Secretary
Environment Dept.
Govt. of Maharashtra

Principal Secretary
Water Resources Dept.
Govt. of Maharashtra

Municipal Commissioner
Nagpur Municipal Corporation, Nagpur

Figure 4
Government of Maharashtra published a written policy paper in support of water reuse

Successes and Lessons Learned

Based on the USAID study, public workshops, and pilot plant results, the project was finalized. The full scope of the project is given in **Table 1**:

The project is now under contract finalization with the selected contractor, who will have to construct the plant and other ancillary parts in a 24 month period and then operate the plant over the next 10 years as part of an operation and management contract.

Table 1 Scope of Work for Nagpur Reuse Scheme

Sr. No.	Module	Description
1	A	Construction of Kolhapur type collection weir, intake structure, sump and pump house, and miscellaneous works
2	B	Construction of sewage treatment plant (for primary and secondary treatment)
3	C	Construction of micro filtration tertiary treatment plant
4	D	Construction of tertiary water sump, pump house, transmission main up to Koradi 8.60 Kms, storage tank at Korado, and other miscellaneous works
5	E	Interconnectivity arrangement from Bhandewadi, i.e., sump, pump house, transmission main up to Pioli Nadi 7.62 Kms or up to Koradi T.P.S.

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Managing Irrigation Water with High Concentrations of Salts in Arid Regions

Authors: Alon Ben-Gal, PhD, and Uri Yermiyahu, PhD (Agricultural Research Organization, Gilat Research Center, Israel); Sirenn Naoum, PhD, Mohammad Jitan, PhD, Naeem Mazahreh, PhD, and Muien Qaryouti, PhD (National Center for Agricultural Research and Extension, Jordan)

Israel/Jordan-Brackish Irrigation

Project Background or Rationale

Agricultural development of the Middle East is contingent upon use of high amounts of low-quality irrigation water. Available water sources for irrigation, including reclaimed wastewater, often contain high levels of salts, including ions specifically toxic to plants such as sodium (Na) and boron (B).

Under a study made possible through support provided by The Middle East Regional Cooperation Program, US Agency for International Development, Grant M24-014, water management, both in terms of leaching requirements (water applied to remove salts from root zone) and in terms of understanding crop response to stress conditions caused by salinity-excess B combinations, was evaluated. Ultimately the results of this investigation provided growers with decision making tools for irrigation with low-quality water under arid conditions.

Capacity and Type of Reuse Application

Field and lysimeter experiments were conducted in arid regions of Jordan and Israel to investigate the response of vegetable crops, irrigated with saline water, to irrigation levels and to elevated concentrations of B. The experiments included bell pepper (Capsicum annum), melon (Cucumis melo L.), green beans (Phaselous vulgaris L.), and tomatoes (Lycopersicon esculentum). Water application rates were studied in greenhouses at the Al-Karameh experimental station in the mid Jordan Valley. For each crop, four irrigation water rates were used (80, 100, 120 and 140 percent return of potential evapotranspiration ETp). Irrigation water had electrical conductivity (EC) of 2.4 dSm-1. In Israel, salinity-water combinations were investigated in studies on bell pepper in the Arava Valley. Tomatoes and peppers were evaluated for salinity-B interactions. For peppers in Jordan, irrigation water had B solutions at concentrations of 0.046, 0.37, 0.74, and salinity levels of 5, 15, 25, and 35 millimolar (mM) NaCl. Tomatoes in Israel were irrigated with water having EC of 1, 3, 6, and 9 dS m-1 and B levels of 0.028, 0.185, 0.37, 0.74, 1.11, and 1.48 mM.

The project utilized state-of-the-art lysimeter facilities in Jordan (Karameh) and in Israel (Gilat, Arava Valley). In addition to growth and yield, data collected included actual plant-scale transpiration and amount and quality of water leached out of the root zone, thus facilitating environmental as well as agronomic and economic considerations.

Water Quality Standards and Treatment Technology

The quality of water in experiments was designed to represent across-the-scale expected qualities of reclaimed municipal wastewater. Salt and B concentrations in wastewater are mostly a function of their concentrations in background water and additions from human sources. Typical wastewater treatment, up to tertiary processes, does not remove dissolved salts. Less intensive treatments schemes (aeration ponds) actually concentrate these salts due to evaporation. Only desalination would remove or reduce salinity and such treatment of wastewater is currently considered highly uneconomical.

Leaching Requirements

When salinity is negligible, yield increases as a function of increased application of water to a crop, up until the point that the demand for evapotranspiration is satisfied. When salts are present, they depress water uptake and growth and therefore, additional water application is accompanied by a positive yield response. The mechanism for this is leaching of salts from the soil and maintenance of relatively salt-free environment for root activity.

Figures 1 and 2 show that while total yield is limited by source water salinity and sensitivity of the crop, as salinity increases, so does the marginal effect of increasing water application rate over ET requirements. In other words, when the water is salty, higher application means higher yield. In **Figure 1**, Relative total biomass production of peppers (Yield normalized to maximum yield) is graphed as a function of irrigation application level for three irrigation water salinity (ECIW) levels. Symbols are experimental measurements from two seasons (open symbols fall, closed symbols spring) and lines are results from an analytical model (Ben-Gal et al., 2008; Shani et al., 2007) The results from this figure show that the highest yields reached with non-saline water are impossible when salts are present but can be approached—under the condition that leaching requirements are satisfied.

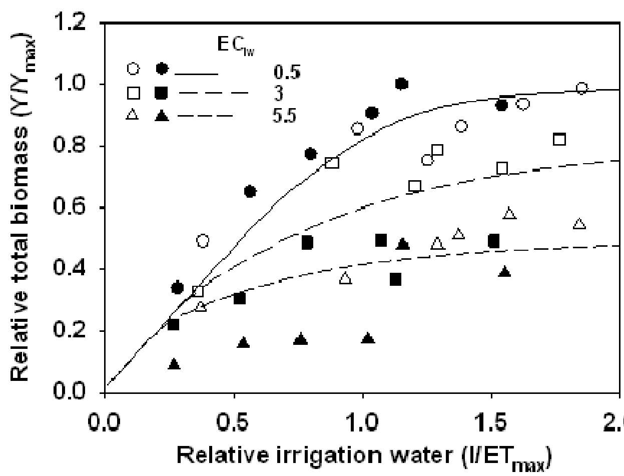

Figure 1
Relative total biomass production of peppers

Figure 2 displays fruit yield of three crops grown in Jordan irrigated with increasing rates of brackish (EC = 2.4 dSm-1 water) where ETp is potential evapotranspiration). Pepper is more sensitive to irrigation water salinity than melon which is more sensitive than beans as seen in slopes of water response curves in Figure 2 as application over 100 percent ETp is reached.

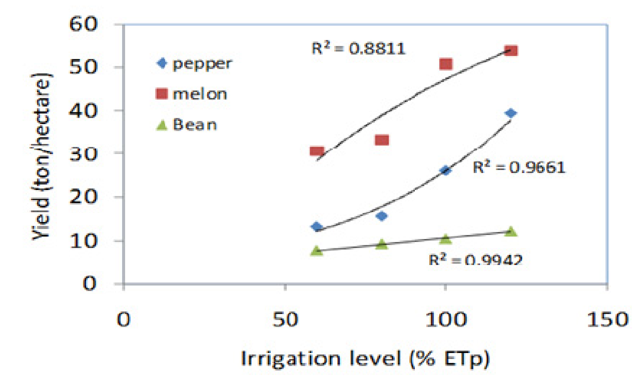

Figure 2
Fruit yield of three crops grown in Jordan

Salinity-boron interactions

Tomato and pepper were found to have decreased plant growth, yields and transpiration in response to either boron (**Figure 3**) or salinity. **Figure 3** shows Dry Matter (DM) g plant-1 accumulation in organs of bell pepper (Capsicum annum.cv. Saphir) as affected by soil boron in Karameh Jordan.

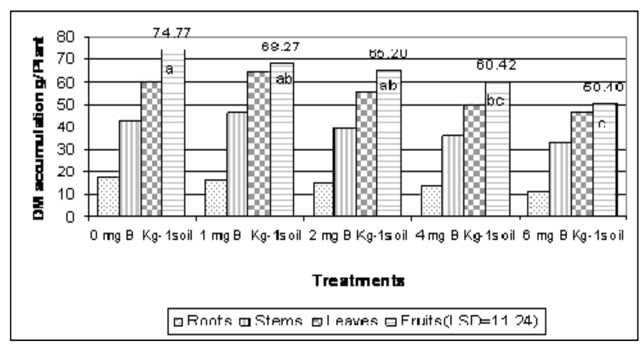

Figure 3
Dry matter (DM) g plant[1] accumulation in organs of bell pepper

A number of modeling approaches were applied to experimental results to investigate the nature of salinity-boron interactions on crop production. For both tomatoes and peppers, an antagonistic relationship for excess B and salinity was found (**Figure 4**). In other words, toxic effects on growth and yield were less severe for combined B toxicity and salinity than what would be expected if effects of the individual factors were additive. (Ben-Gal and Shani, 2002; Yermiyahu et al, 2008).

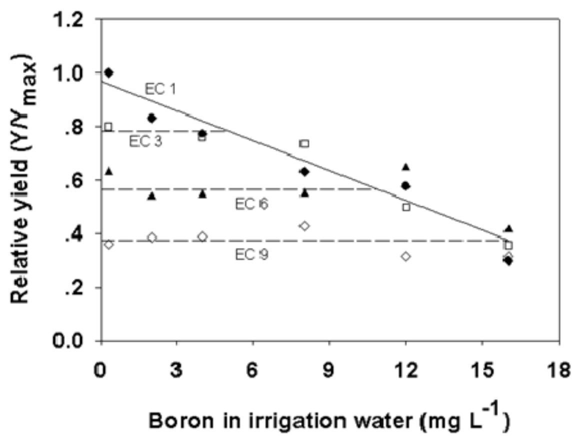

Figure 4
Biomass production of tomatoes

Figure 4 presents biomass production of tomatoes as a function of boron in irrigation water for varied salinity conditions where EC is electrical conductivity of irrigation water. Symbols shown in the figure are experimental measurements, Yotvata, Israel, lines depict dominant factor modeling approach (Ben-Gal and Shani, 2002).

Project Funding and Management Practices

This work was made possible through support provided by The Middle East Regional Cooperation Program, US Agency for International Development, Grant M24-014.

Institutional/Cultural Considerations

Irrigation water salinity decreases transpiration and biomass production of horticultural crops. The extent of the salinity response is dependent upon the level of leaching of salts from the root zone. Application of saline water to the soil exceeding the quantity used by the crop for transpiration, succeeds in improving conditions for water uptake and growth (Figures 1, 2, 5). The addition of such water has higher relative benefit as the salinity of the water and the sensitivity of the crop increase. Lysimeter, field, and modeled experimental results in dry regions of Jordan and Israel suggested that potential economic benefits from increased yields exist for irrigation application rates reaching more than 200 percent of the ETp for a high value but relatively salt sensitive crop like bell pepper. Leaching fractions were seen to increase as a result of reductions in transpiration caused by increases in salinity.

Decision making by growers benefits from consideration of soil-crop-climate specific predictions of yield as a function of irrigation water quality and quantity (**Figure 5**). For example, a farmer in the Jordan Valley irrigating with EC 3 water cannot expect to reach greater than 70 percent of the potential yield for a pepper crop even with exorbitant rates of water application. By choosing a more tolerant melon crop, the farmer can achieve 90 percent of potential yield with the same water that yielded 70 percent peppers. Figure 5 presents a compensation presentation of Iso-yield curves for irrigation water salinity (EC) and applied irrigation water quantity relative to climate demand (I Tp-1) for pepper and melon crops. Curves were computed using the ANSWER model (Shani et al., 2007). Isolines show 10 percent increases in relative yield.

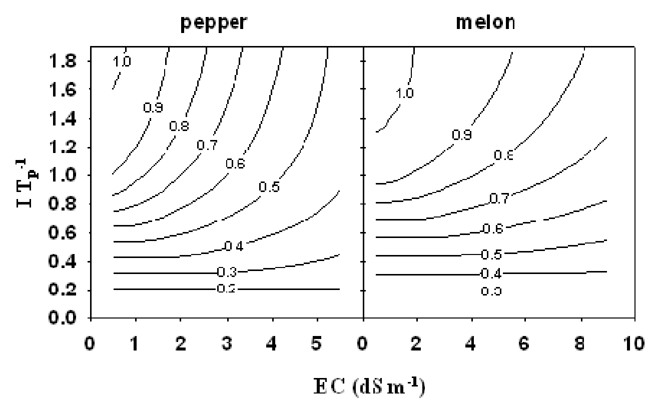

Figure 5
Compensation presentation of Iso-yield curves for irrigation water salinity

Successes and Lessons Learned

This investigation found that irrigation of horticultural crops with brackish water can be economically feasible as long as sufficient excess water is applied to control root zone conditions.

It was also found that the combined effects of simultaneous high salinity and excess boron were less than those predicted by combining the expected individual effects of each stress causing factor. This opens the door for utilization of water sources that otherwise would be considered unacceptable.

In spite of these successes, the results indicate that irrigation with saline water under arid conditions is problematic. Sustainable cultivation must provide for collection and disposal of the leached salts and water or alternatively, reduce the leaching. Reduced leaching is only possible through cultivation of highly tolerant crops or via the reduction of water salinity prior to irrigation (Ben-Gal et al 2008, Shani et al., 2007). In the case of wastewater reuse, it may be preferable to reduce salinity and boron in source water, prior to its reaching the wastewater stream, and long before its use for irrigation, rather than loading the environment with these problematic salts. Many sources of B (detergents, sea water) can be avoided or treated in source water using available legislative and technological tools. Desalination technology is becoming increasingly attractive and offers an elegant way to remove salts in source (municipal) water where they can be best managed and to leave agriculture with water that will lead to higher yields and lower environmental impact (Ben-Gal et al., 2009).

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Irrigation of Olives with Recycled Water

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Israel/Palestinian Territories/Jordan-Olive Irrigation

Project Background or Rationale

There is increasing use of low quality water for olive grove irrigation in the Mediterranean, due to scarcity of fresh water.

The aims of the present study were: 1) to evaluate the effect of irrigation with recycled wastewater (RWW) on tree growth, fruit, and oil yield and quality; 2) to assess the contribution of RWW to plant nutrition and; 3) to quantify nitrate and chloride losses when using RWW.

Capacity and Type of Reuse Application

A 4-year field study comparing two olive cultivars, Barnea and Leccino, was conducted within a 20 ha commercial high density (900 trees/ha) olive orchard. Three treatments were tested: A) fresh water with standard fertigation (drip irrigation using water amended with fertilizer (potassium and nitrogen), B) RWW with standard fertigation, and C) RWW with reduced fertigation (accounting for the potassium and nitrogen available in the RWW). The RWW was secondary-treated domestic wastewater from the City of Jerusalem and fresh water originated from the local costal aquifer. Water composition is presented in **Table 1**. Annual average irrigation application was 470 mm (18.5 inches). The total annual amount of nutrients arriving with the RWW were substantial, equaling some half of the recommended fertilization dosages.

Diagnostic leaves sampled in July each year were tested for macro elements and salts. Trunk circumference was measured once a year. Upon reaching the appropriate ripeness level, fruit was harvested and yield, fruit size, water, and oil content were measured. Oil was extracted, tested for free fatty acid content, peroxide level and polyphenol content, and evaluated for organoleptic attributes by a trained panel.

Table 1 Composition of fresh water and RWW. Values represent the 4-year average and standard deviation (2006-9, n=18)

Constituent	Units	RWW	Fresh Water
pH		7.7 (0.3)	7.5 (0.2)
EC	ds m^{-1}	1.65 (0.13)	0.9 (0.2)
NH_4-N	mg L^{-1}	4.8 (6.8)	0.0 (0.0)
NO_3-N		15.2 (3.9)	3.4 (2.2)
Total N		19.9 (6.0)	3.4 (2.2)
K		29.6 (2.2)	4.4 (2.8)
P		5.8 (1.8)	0.0 (0.0)
Cl		323 (30)	168 (56)
Na		198 (25)	81 (28)
SAR		4.9 (0.8)	4.2 (1.9)

Results

Diagnostic leaves. Mineral concentration in diagnostic leaves serves as a benchmark for salinity and nutritional status of olive trees. The measured concentrations of N, P, and K in the leaves obtained from trees receiving the three treatments were within a range considered normal (Therois, 2009), indicating adequate nutritional status across the treatments. There were no significant differences in leaf concentration of Na and Cl across the treatments, indicating that the additional application of these elements from RWW application did not accumulate in leaves.

Tree growth, fruit and oil yield. For both cultivars in each year, no significant differences were found between treatments for the parameters: trunk diameter, fruit number, average fruit weight oil content, water content, fruit yield, and oil yield. Fruit from "'Barnea" trees had higher oil content (ranging from 19.2 to 26.6 percent) than "'Leccino"' (ranging from 17.8 to 20.5 percent). Multiplying olive fruit yield by oil content provided oil yield per tree which ranged from 4.6 to 9.3 lb (2.1 to 4.2 kg) (1686-3372 lb/ac or 1890-3780 kg/ha) in the "'On" years (2006, 2008) in "Leccino." The "Barnea" trees had similar oil yields, ranging from 4.4 to 9.7 lb/tree (2.0 to 4.4 kg/tree) (1606-3533 lb/ac or 1800-3960 kg/ha).

Oil quality. Oil quality (free fatty acid level, polyphenol content and peroxide level) did not differ significantly among the treatments. Organoleptic assessments to grade the oil taste (bitterness, pungency and fruitiness) did not reveal any negative attributes in any of the tested oils. In respect to positive attributes, fruitiness and pungency were similar among the different treatments. Bitterness, on the other hand, was much lower (~ 1 on a 10-point scale with 10 being a very intense taste) in oil obtained from trees receiving RWW with standard fertigation (condition B) compared to oil from trees receiving fresh water (bitterness level of 6.5) (control condition). However, this effect was reduced when the fertigation regime was adjusted (condition C), with bitterness value reduce to 5.

Bacteriological tests. Total bacteria count in the RWW was 17,000 per 100 ml and <1 for the fresh water. No Salmonella bacteria were found in the two types of water. No differences were found between bacteria counts in oil obtained from trees irrigated with fresh water and those irrigated with RWW water.

Soil salinity. While similar amounts of water were applied, the RWW treatments loaded the soil profile with 1.75 times more Cl then the fresh water treatment. Additionally, significantly more nitrates were transported out of the root zone in the RWW with standard fertigation in comparison to the RWW with reduced fertigation and fresh water treatments for both cultivars. This implies that consideration of nutrients originating with the RWW is vital for its sustainable utilization.

The result of this experiment, together with our previous findings on negative effects of over fertilization on productivity (Erel et al., 2008) and oil quality (Dag et al., 2009), have inspired the olive experts of Israel's agricultural extension service to adjust their fertilization recommendations. The new recommendations take the amount of N and K in the RWW into account when planning fertilization regimes.

Project Funding and Management Practices

The research was supported by grant M26-062 of the USAID Middle East Regional Cooperation Program, as well as by grant 203-0620 from the Chief Scientist of the Israeli Ministry of Agriculture and Rural Development.

Institutional/Cultural Considerations

Due to overall scarcity of water in Israel, water available for irrigation of olive orchards is limited to recycled wastewater and brackish groundwater. In the past, some sectors restricted use of RWW due to religious objections, but the necessity for water combined with modernization and education have overcome these and other obstacles for utilization of recycled water across all sectors. Consumers in Israel generally do not object to the use of RWW. The opposite is actually the case, as water recycling is perceived as "green" and promoting resource conservation. Moreover, the people in Israel are keenly aware that fresh water is very scarce and tend to object its allocation to the agricultural sector.

Successes and Lessons Learned

Irrigation of olives with RWW did not affect tree nutritional status, growth, productivity or oil quality. RWW can be used safely with no negative effects on the oil produced, but fertilization regimes need to be adjusted in order to consider nutrients delivered with RWW to avoid negative effects of over fertilization. In this way, contamination of water resources from nutrient leaching can be minimized and the RWW can provide an additional benefit from reduced fertilizer costs (Segal et al., 2011).

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Advanced Wastewater Treatment Technology and Reuse for Crop Irrigation

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Israel/Jordan-AWT Crop Irrigation

Project Background

Shortage of water in sub-humid and semi-arid regions like the southeast Mediterranean, leads to use of wastewater for agricultural irrigation. Most of the effluent used is derived from secondary wastewater treatment plants or from sources having even lower water quality. Secondary-treated wastewater still contains some pathogens, organic compounds, and salts. Irrigation with this water induces, in a shorter or longer term, increased soil salinity that damages soils and crops. Sustainable agricultural production requires high water quality. Membrane treatment is a promising technology for the environmentally friendly removal of pollution agents and for rendering wastewater into a resource for unlimited use (J. Hagin et al., 2007; and J. Hagin et al., 2010). This project was carried out as a collaboration between researchers from the Technion – Israel Institute of Technology, Al-Quds University in Jerusalem, and the National Center for Agricultural Research and Extension in Jordan.

Application of Membrane Technologies

Advanced membrane treatment technologies based on ultra filtration (UF) and two stage reverse osmosis (RO) yield effluent of suitable quality for unrestricted irrigation.

Operation of the UF, mainly flow rate and water recovery, was monitored continuously. Steady UF performance required weekly cleaning by a NaOH solution, periodic acidic (HCl) cleaning for removal of inorganic scaling and backwash cycles. The operation included chlorination of the UF feed as an anti-biofouling agent, followed by dechlorination of the permeate prior to entering the RO membranes, to prevent damage.

During the lengthy operation, changes in quality of the secondary effluent (organic matter and suspended solids) resulted in parallel decrease of UF performance. Adjustments of the filtration-backwash cycle compensated fully for the performance decrease. This showed the system's ability to operate at varying and reduced feed quality.

Water recovery from the UF system was up to 88 percent. Recycling the rejected UF concentrate to the feed tank contributed an additional 6-9 percent to the UF water recovery. The UF operated at a flux of 93.78 gallons/ ft^2/hr (33 l/m^2/hr) and the permeability was about 0.89 gallons/ft^2/psi/hr (40 l/m^2/bar/hr).

The first RO stage (RO1) receives the UF permeate. It operated at a feed rate of about 1,717 gallons/hr (6.5 m^3/hr) under 88.2 psi (6 bar) pressure, at a recovery ratio of about 50 percent, and a pH of 6.5. Osmotic backwash is executed automatically every 60 minutes by shutting down the pressure pump for 1 minute. Scaling, organic fouling, and phosphate precipitation were negligible.

The second RO stage (RO2) received the RO1 brine. The RO2 membrane feed rate is about 607.6 gallons/hr (2.3 m^3/hr), 449.1 gallons/hr (1.7 m^3/hr) fresh feed (RO1 brine), and the rest is recycled concentrate operated at a pressure of 102.9 psi (7 bar) and a pH of 6.5. Osmotic backwash is automatic, the same as for the RO1 membrane.

Measurements indicated a long-term reduction in RO2 membrane performance. Calculations of mass balance showed that 33 percent of the inflow phosphate and 15 percent of the calcium were precipitated on the membrane. The pH control was not sufficient for steady operation, and chemical precipitation was required. Phosphate in the RO1 brine precipitated on the RO2 membrane as a complex calcium-phosphate. Phosphate removal was achieved by injecting ferric chloride into the RO1 brine pipe, forming a solid strengite—$FePO_4.2H_2O$, thus preventing its precipitation on the membrane (Katz and Dosoretz, 2008).

The RO2 stage extracted additional water from the rejected brine stream of the RO1 stage and its addition improved total system recovery to up to about 85 percent.

The overall operational cost of the pilot plant, following the process improvements, is estimated at \$0.55-0.60/m^3.

Crop Irrigation with Treated Wastewater

Secondary treated effluents, permeates of RO and mixtures of RO and UF membranes permeates were used for irrigation on a number of crops on several Palestinian, Jordanian and Israeli sites.

Irrigation using secondary-treated effluent induced significantly higher soil salinity, expressed as electrical conductivity (EC), than RO permeate, or UF and RO permeates combined (**Tables 1 and 2**). In addition, increased dripper clogging was noted.

In experiments running for several years at the same site, a significant decrease in crop yield was measured in plots irrigated by secondary-treated effluent compared to those irrigated by membrane-treated water (**Table 3**).

Biological tests of membrane treated irrigation water did not show any fecal coliform contamination.

Table 1 Electrical conductivity (EC) in soil, Jordanian site after 2 seasons of irrigation

	Irrigation water quality			
	Depth (cm)	Sec. treat. effluent	UF permeate	Mix UF-RO 50-50
EC (dS/m)	0-20	3.24	2.83	1.14
	20-40	3.01	2.71	0.99

Table 2 Electrical conductivity (EC) and Sodium adsorption ratio (SAR) values in soil samples after 6 years irrigation with various water streams, Arad site, Israel

Water Quality:	Sec effl.	UF permeate	UF-RO 70-30	UF-RO 30-70	RO permeate
EC, dS/m	16	9	6	5	2
SAR	25	20	16	12	3

Table 3 Crop yields (tons per hectare) for plots irrigated with different blends of reclaimed water at the Arad site, Israel

Irrigation Water	Watermelon	Garlic	Corn grain
Sec. treat. effluent	28	24	7.8
UF permeate	36	30	10.7
UF- RO 70-30	34	30	10.1
UF- RO 30-70	44	32	10.3
RO permeate	50	37	11.3

Measurement of pharmaceuticals, aspirin, paracetamol, X-ray contrast media, diatrizoate and carbamazepine and their degradation products, showed their complete removal by RO membranes.

Successes and Lessons Learned

The project's results provide guidelines for large-scale, economically and technically feasible operation of wastewater treatment systems, regional and worldwide. They indicate the potential of adding a substantial amount of quality water (up to 600,000 m^3) to the regional resources for irrigation and aquifer recharge. The overall conclusion and recommendation to water authorities, for maintaining an adequate water supply to agriculture and ensure production sustainability, is to construct membrane systems on a large scale at secondary treatment sites in the entire region.

Project Funding

The project is a cooperative Palestinian-Jordanian-Israeli project, coordinated by the Grand Water Research Institute, Technion and generously supported by the U.S. Agency for International Development – MERC Program, the Peres Center for Peace and other foundations.

Institutional/Cultural Considerations

The project created an excellent basis for Palestinian-Jordanian-Israeli cooperation. Over the years, professional and personal ties have developed between the investigators. Investigators at the participating institutes acquired a deeper understanding and greater experience regarding the processes and performances of membrane systems. This makes them experts in consulting authorities for large-scale wastewater treatment systems.

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Treatment of Domestic Wastewater in a Compact Vertical Flow Constructed Wetland and its Reuse in Irrigation

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Israel/Peru-Vertical Wetlands

Project Background or Rationale

The quantity of freshwater available worldwide is declining, and there is a pressing need for alternative sources, such as reuse of treated wastewater. In heavily populated areas, the most common strategy to treat domestic wastewater (DWW) for disposal or reuse is via intensive, centralized, often sophisticated and expensive systems. This approach is often unsuitable in developing countries, in lightly populated areas, or on remote farms where on-site (decentralized) treatment by low-cost low-tech systems should be considered. Treatment by constructed wetlands (CW) is recognized as an economically favorable option, even in the most developed countries (IWA, 2000).

Reuse of treated DWW for irrigation may involve certain risks of soil pollution due to salinization, boron accumulation, hydrophobicity (e.g., caused by detergents), pathogens and other pollutants. Particularly in on-site scenarios, variability in water quantity and quality might negatively impact treatment efficiency. Thus, any treatment system has to address these issues and consistently produce effluents that comply with defined quality guidelines.

In our approach to decentralized DWW treatment and reuse in irrigation we have developed a small footprint CW (**Figure 1**) — the recirculating vertical flow constructed wetland (RVFCW) (Gross *et al*., 2008; Sklarz *et al*., 2009; Zapater *et al*., 2011). The diversity and dynamics of the RVFCW bacterial community were analyzed to enhance our understanding of the treatment efficiency and stability (Sklarz *et al.,* 2011), and a mathematical model that can be used as a tool to design and operate these systems was formulated (Sklarz *et al*., 2010). Lastly, possible effects of irrigation with RVFCW effluent on soil properties were assessed (Sklarz, 2009). This research was carried

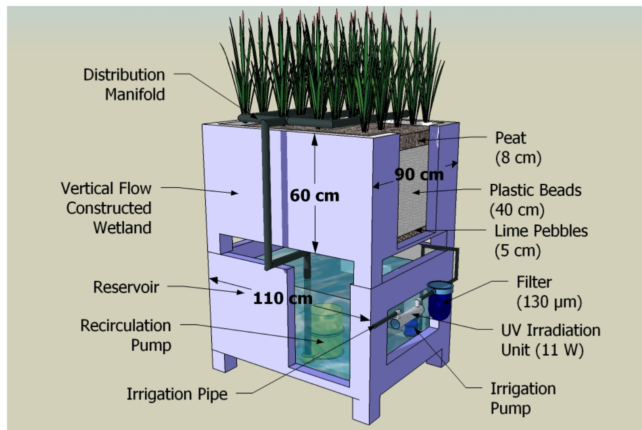

Figure 1
Schematic representation of the field RVFCW

out in Israel at the Zuckerberg Institute for Water Research at Ben Gurion University of the Negev.

Two similar 130 gallon (500 L) RVFCWs were used in the study. The systems consist of a three-layer bed (a thin upper-layer of organic soil planted with macrophytes, a middle thicker layer of high surface porous medium, and a thin lower-layer of limestone gravel) and a reservoir located beneath the bed. Wastewater is introduced in batches to the bed, percolates through it and trickles down into the reservoir, allowing for passive aeration; from the reservoir the water is recirculated back to the bed with a small pump until the effluent quality meets the relevant regulation (i.e., according to its use and the country standards).

Prior to irrigation, the treated DWW passes through a standard 130-micron filter to prevent clogging of the irrigation system and enhance the efficiency of the subsequent UV disinfection treatment. The high oxygen levels in the water allow for the conversion of nitrogen in the DWW to nitrate and minimize its loss, a desirable added value in that it lowers the need for crop fertilizer (**Table 1**).

Table 1 Quality of the raw DWW after primary sedimentation and of the RVFCW effluent after 6 h of treatment. Values shown are the arithmetic mean values (except where noted as geometric mean) and standard errors for samples from July 2007 to March 2008.

Parameter (mg L^{-1})	Raw (influent) Mean (SE)	Effluent Mean (SE)	Israeli Standard*
TSS	103 (11)	6.8 (1.0)	10
BOD_5	178 (19)	6.2 (0.9)	10
COD	200 (13)	18 (2.6)	100
TN	36 (2)	27 (1.1)	25
NH_4^+-N	29 (2.4)	1.3 (0.4)	20
NO_2^--N	BD**	0.62 (0.1)	
NO_3^--N	0.3 (0.0)	23 (0.9)	
DO	0.2 (0.1)	8.2 (0.2)	
pH	7.4 (0.0)	7.6 (0.1)	
EC (mS cm^{-1})	0.96 (0.1)	0.94 (0.1)	1.4
E. coli (CFU 100 mL^{-1})	1×10^6	5.4***	10

*Unrestricted irrigation (Inbar, 2007)
**Below detection
***Geometric mean

An irrigation experiment was conducted in which barrels 32 gallon (120 L) were filled with a naive sandy loamy soil and irrigated daily, at a rate of 2.6 gpd (10 l/d) , with one of four types of water: fresh water (FW), FW amended with 7:3:7 (N:P:K) fertilizer (FW+F), settled raw-DWW and RVFCW-treated-DWW after UV light disinfection. No further treatment was applied to the soil. Periodically, 20-inch (50-cm) deep soil cores were removed and analyzed. After three years, the physicochemical characteristics (pH, electrical conductivity, organic and water contents, and macro- and micro- elements) and bacterial community of the soil irrigated with the treated DWW were similar to those of the soils irrigated with FW+F but differ from soils irrigated with raw-DWW (data not shown). This may imply changes in the biochemical processes in the soil irrigated with raw-DWW.

The treatment efficiency under extreme variations in quality of the DWW was tested in a set of experiments using 8 gallon (30 L) bench-scale systems. In this study we assessed the resilience and recovery capacity of the RVFCW upon exposure to possible disturbances, which included high and low water pH, interruption of water recirculation, and high concentrations of *E. coli*, surfactants (i.e., detergents) and bleach. The effects of these disturbances were short-lived and recovery was observed within 24 hours, attesting to the robustness of the RVFCW (data not shown).

Capacity and Type of Reuse Application

The RVFCW is modular, enabling more units to be attached, serially or in parallel. Thus, the system can be up-scaled to serve a small community or a neighborhood. The required water quality will dictate the DWW load and the retention time, as well as the recirculation rate. Interestingly, the experimental results demonstrate that the size of the unit does not significantly affect the system's efficiency (Sklarz *et al.*, 2010). Different volumes were treated in the different experiments, ranging from 0.03 to 4 m^3/d (80 to 1,060 gpd). A typical hydraulic load is 0.5 m^3 m^{-2} d^{-1} and the retention time to meet high water quality standards for unrestricted DWW reuse in irrigation (Inbar, 2007) is about 5 hours, which corresponds to potential organic load capacity of over 270 g COD m^{-2} d^{-1} and 120 g BOD_5 m^{-2} d^{-1}.

Water Quality Standards and Treatment Technology

When treated with the UV disinfection unit, the effluent of the RVFCW consistently met the stringent Israeli standards for reuse in irrigation of <10 CFU *E. coli* 100 mL^{-1} (Inbar, 2007).

Project Funding and Management Practices

Funds from Ben-Gurion University of the Negev and USAID supported this research.

Institutional/Cultural Considerations

Based on the pilot results, the RVFCW was chosen for installation in two low-income Bedouin communities. The first, designated "Project Wadi Attir," aims to develop and demonstrate a model for sustainable, community-based organic farming, adapted to a desert environment (The Sustainability Laboratories, n.d.). The treated wastewater will be used for unrestricted landscape and possibly fodder irrigation. Construction has started and the site is expected to start operating during 2012. In the second community, installation of several units is planned in the Egyptian Bedouin village of St. Catharine in the Sinai desert (funding is expected via a UN project). The initiation of this project is unclear due to the current political situation in Egypt. The water will be used for unrestricted irrigation mainly of the local fruit trees and gardens. The choice of the RVFCW was interesting, considering the electricity requirements for recirculation in places where electricity is often scarce and not always reliable. The use of solar energy could be an alternative, should electricity supply become problematic. The justification for using the RVFCW, and not gravity-based systems, was the high treatment efficiency, the low maintenance, and the low footprint, particularly important in areas with high evaporation rates. Moreover, two-dozen units have been installed by private households throughout Israel for onsite graywater reuse, and have been operated successfully for more than three years for unrestricted ornamental garden irrigation.

Successes and Lessons Learned

We demonstrated that it is possible to safely reuse DWW by simple low-cost low-tech treatment means. The system design must consider the unique conditions associated with on-site DWW reuse, such as high variability in water quality and quantity, and exposure to short events of extreme conditions. The system can produce treated DWW of very high quality for unrestricted reuse such as for urban, agriculture and landscape irrigation.

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A Membrane Bioreactor (MBR) Used for Onsite Wastewater Reclamation and Reuse in a Private Building in Japan

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Japan-Building MBR

Project Background or Rationale

In Japan, about 2,500 urban buildings reuse wastewater and harvest roof runoff for various purposes. In several large cities including Tokyo, regulations require a wastewater reuse system or a runoff harvest system to be installed in a new building if the total floor area of the building exceeds a certain size. A sample of 2,500 buildings with reuse/harvest systems found that 25.9 percent are public office buildings, 12.5 percent are private office buildings, and 15.7 percent are schools. Reclaimed wastewater and/or harvested rainwater are used for a variety of purposes. The water is most commonly used for toilet flushing, but can also be used for landscape irrigation, cooling, car cleaning and fire protection.

A treatment system for wastewater reclamation in an individual building should be compact, easy to maintain and resistant to fluctuation of inflow. Low production of odor and sludge is also an important requirement for such a system. Membrane bioreactors (MBRs) can meet these criteria and are therefore often used for onsite wastewater reclamation. An example of an MBR system used for onsite wastewater reclamation/reuse system in a private building is shown (**Figures 1 and 2**).

Figure 1
A business complex building in Tokyo in which the MBR system was installed (Photo credit: Drico. Ltd.)

Figure 2
View of the MBR system installed (Photo credit: Drico. Ltd.)

Capacity and Type of Reuse Application

The MBR system was installed in a business complex building in Tokyo in 2007. Treatment capacity of the system is 180,000 gallons per day (680 m^3/day) and reclaimed water is used solely for the purpose of toilet flushing. Wastewater reclaimed for toilet flushing includes graywater from restaurants, graywater from offices, and blowdown from a cooling tower system. Black water from the toilet is not recycled and is prohibited by regulations. **Figure 3** presents the flow of water in the wastewater reuse system.

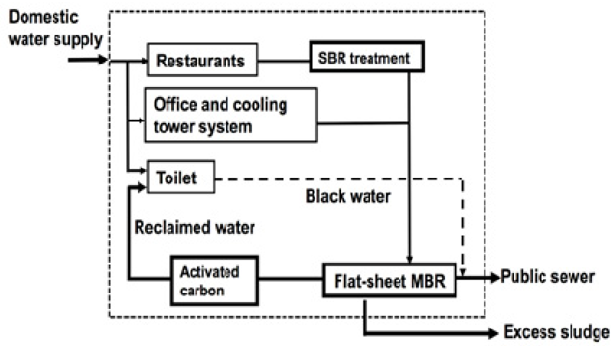

Figure 3
Wastewater reuse system flow diagram

Treatment Technology

Both hollow fiber membranes and flat-sheet membranes can be used in MBRs. Due to the ease of maintenance, flat-sheet membranes are often preferred in applications to small-scale systems such as onsite wastewater reclamation. The MBR system in this study used 1,800 flat-sheet membrane elements submerged in the reaction tank. The material of the membrane is chlorinated polyethylene with a nominal pore size of 0.4 μm.

Compared to the MBRs used in municipal wastewater treatment (i.e., large-scale treatment), mixed liquor suspended solids (MLSS) concentration in the reactor tends to be higher (15-20 g/L) in the case of MBRs used for onsite wastewater treatment. Graywater from restaurants contains substantial amounts of oil/grease, which can cause operational problems in MBRs. Thus, this heavily contaminated graywater is treated by sequencing batch reactors (SBRs) before being mixed with the other wastewater. Effluents from MBRs are used for toilet flushing only after the addition of chlorine, as mandated by the government.

In this particular MBR in Tokyo, they use activated carbon adsorption to remove color from the reclaimed water before the chlorine is added. Conditions of the system (e.g., trans-membrane pressure in the MBR) are continuously monitored by an automatic system.

Water Quality

Quality requirements for reclaimed water used for toilet flushing are summarized in **Table 1**. The averaged data obtained with the system are shown in **Table 2**. Design water quality in the effluent from the treatment system is also shown in the parenthesis in **Table 2**. It should be noted that quality of wastewater in **Table 2** represents the mixture of graywater from offices, blowdown from the cooling tower system, and effluents from the SBRs treating restaurants wastewater.

Table 1 Quality requirements for reclaimed water used for toilet flushing

Parameter	Requirement
pH	5.8-8.6
Odor	Not abnormal
Color and transparency	Almost colorless and transparent
E. coli	Must not be detected
Residual chlorine (mg/L)	0.1 (free) 0.4 (combined)
BOD (mg/L)	<20
COD (mg/L)	<30

Table 2 Water quality observed in the treatment system

Parameter	Raw Wastewater	Effluent
pH	6-8	7.7 (6-8)
Odor		Not abnormal
E. coli		Not detected
BOD (mg/L)	215	<1.0 (<10)
SS (mg/L)	215	<1.0 (<5)
n-Hex (mg/L)	43	<1.0 (5)
Color (color unit)		4 (<10)
Turbidity (turbidity unit)		<1 (<2)

Project Funding

The regulations for the construction of new buildings require a wastewater reuse system or a runoff harvest system to be installed. This policy driven water reuse intervention places the financial burden on the project developer.

Successes and Lessons Learned

The customer is satisfied with the net reduction of domestic water supply. Performance of the MBR system has been satisfactory as shown in Table 2. Operation and maintenance of the MBR were found to be very easy. Withdrawal of sludge and chemical cleaning of the membrane were carried out every 30 days and every 4 months, respectively, and have been sufficient to maintain stable operation of the system. When possible, use of graywater from restaurants as a source for reclamation should be prevented because of the difficulty in treatment. Unfortunately, the amount of “clean” graywater produced in the building is not sufficient to cover the amount needed for toilet flushing. To fill the gap, graywater produced in restaurants is also included as the source of reclaimed water at the cost of pretreatment.

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Water Reuse and Wastewater Management in Jordan

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Jordan-Irrigation

Introduction

Water management has long been recognized as one of the most critical issues for the sustainability of the Hashemite Kingdom of Jordan. According to Jordan's Water Strategy (2009), the country's annual per capita water availability is less than 40,000 gallons per year (150 m^3/yr). Available water supply is less than demand, and with continuing population growth, per capita availability is projected to continue declining in the coming years.

Jordan's Water Strategy states that "Wastewater is not managed as 'waste' but is collected, treated, managed, and used in an efficient and optimized manner." Beneficial use of reclaimed water is recognized as a crucial water management component and controlled use of reclaimed water has grown significantly during the past decade.

Institutional Arrangement and Regulations

The use of treated municipal wastewater is regulated through the water reuse standard JS893:2006, issued by the Institution for Standards and Metrology. The current standard was issued in 2006, replacing previous standards from 1995 and 2002. The standards allow irrigation of agricultural crops that will not be eaten raw. The standards also specify requirements for the use of reclaimed water for groundwater recharge to the aquifer not connected to drinking water sources, but planned groundwater recharge with reclaimed water has not yet been implemented in Jordan. The use of reclaimed water for other purposes such as cooling and fire fighting is permitted on a case-by-case basis, when confirmed with appropriate studies. Water reuse is planned concurrently with the construction of wastewater treatment plants. The Water Authority of Jordan (WAJ) is responsible for the management of the water and wastewater systems and for managing the supply of treated effluent for reuse purposes.

Promoting Water Reuse Practice

WAJ has been contracting with farmers to provide them with reclaimed water for agricultural irrigation; larger scale sites of this kind include As-Samra, Madaba, Ramtha, Akeder, and Mafraq, among others. As of 2009, about 1,900 acres (760 hectares) are irrigated with reclaimed water under contracts with WAJ.

As-Samra, located approximately 19 miles (30km) northwest of Amman, is the largest wastewater treatment plant in Jordan, with 70 mgd (267,000 m^3/d) treatment capacity. A lagoon treatment system was built in 1985, and replaced by an activated sludge plant with partial funding from USAID. The new plant came online in 2008 to provide better effluent quality. As of 2008, the treatment plant received approximately 58 mgd (220,000 m^3/d) (MWI, 2010), and treated effluent is discharged to the Zarqa River, which flows into the King Talal Reservoir where it is mixed with surface water. The water from the reservoir is used for irrigation in the Jordan Valley for various food crops including vegetable crops, citrus and bananas.

It is worth noting that fodder crop irrigation is the dominant application for all other water reuse schemes in Jordan, with the exception of trees such as date palm and olive. This is partly due to the high dependency on imported livestock feed. It is also due to the reluctance of farmers to use reclaimed water for food crops that may be exported to neighboring countries as those countries may have some reservations about importing such crops.

Water Reuse Project Case Study

USAID has been supporting the efforts to promote water reuse in Jordan. The water reuse pilot project at Wadi Mousa is an example of a USAID-funded project that promotes sustainability of local communities through the beneficial use of reclaimed water.

A demonstration pilot program for the use of reclaimed water for irrigation was first established in Wadi Mousa in 2002 as a 17 acres (6.9 ha) demonstration site at the time of the Wadi Mousa wastewater treatment plant (WWTP) upgrade; it was later expanded to approximately 90 acres (37 ha) to include the use of reclaimed water by a local community. The wastewater treatment plant has a treatment capacity of 0.9 mgd (3400 m^3/d) and consists of preliminary treatment (coarse screen and grit removal), activated sludge (oxidation ditch), final clarifiers, polishing ponds and disinfection. Effluent from the treatment plant is transferred to the irrigation water storage pond within the WWTP boundary, and reclaimed water is distributed through an irrigation water pump station and an irrigation water distribution main. As of 2010, the plant inflow is approximately 0.5 mgd (2000 m^3/d). Reclaimed water quality is routinely monitored by the plant engineer and consistently meeting Jordanian Standards for all reuse applications.

During the USAID Reuse for Industry, Agriculture and Landscaping Project (RIAL: 2004-7), the pilot program was further expanded, and reclaimed water was used to irrigate alfalfa, olive, fruit trees and other tree crops. The pilot has been operated by the Sad Al-Ahmar Association, a water reusers' association established in 2002 with the support of USAID to ensure sustainability of the project. Currently, the association is operated with support from the Hashemite Fund for the Development of Jordan Badia (HFDB). The Association represents the local community, from which 40 farmers (34 men, six women) work directly with the pilot program. Each farm unit was allocated 0.75 to 1.1 acres (0.3 to 0.45 ha), and cropping patterns were identified with the technical support of the project team. The pilot program demonstrated that reclaimed water use can be practiced safely and introduce stable income into local communities. By the winter of 2006-7, total area used for reclaimed water irrigation was over 130 acres (52 ha), and the net income per farm ranged from $3100 to $4600 per year, depending on the type of crops irrigated (in 2007 dollars; RIAL Completion Report: 2008). The net income accounted for the costs of maintaining the Association and the irrigation system. Alfalfa was the dominant crop grown with reclaimed water; olive trees were also grown at the pilot site. Most of the harvested olives were consumed by the farmers; indirect economic benefits to farmers were achieved through the reduction in their food expenses.

The RIAL project also demonstrated the beneficial use of reclaimed water for landscaping and industry in Amman and Aqaba. In Aqaba, reclaimed water has been used for industries (mainly cooling for potash operations) and the city's landscaping areas. Aqaba WWTP, constructed by USAID funds, consists of a lagoon treatment train and tertiary treatment process with oxidation ditch, clarifier, filtration and disinfection. Reclaimed water from the lagoon system is used for agricultural irrigation, whereas tertiary-treated reclaimed water is used for landscape irrigation and industrial applications. The industrial use provided mutual economic benefits for both Aqaba Water Company (which will finance the system after the conclusion of USAID's funding period) and the industry, and saved about 1,200 ac-ft/yr or 400 Mgal/year (1.5 million m^3/year) of fresh water that could then be dedicated for domestic and commercial uses. A pilot program was also established at the Jordan University of Science and Technology (JUST) to investigate the effects of reclaimed water irrigation on various agricultural crops and landscaping plants. Plans to support additional water reuse schemes are underway with various USAID Office of Water Resources and Environment projects, including the Water Reuse and Environmental Conservation Project. Currently the focus is to promote efficient reclaimed water irrigation to promote income generation for local communities, and industrial water management and pollution prevention through the integration of efficient use and reuse of water in industrial sectors. An analysis of lessons learned from previous demonstration projects will be used to establish sustainable and self-sustaining programs for the livelihood enhancement of local communities.

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Cultural and Religious Factors Influence Water Reuse

Author: Tom A. Pedersen (CDM Smith)

Jordan-Cultural Factors

Project Background or Rationale

Although global water resources are theoretically adequate to meet all human needs, water scarcity is the reality for many in arid and semi-arid areas around the world. When freshwater supplies are insufficient to meet ecosystem and human demand, water stress or water scarcity results. According to the United Nations (2007), water stresses occurs when the water supply drops below 450,000 gallons per person per year (gallons/person/yr) [1,700 cubic meters per person per year (m^3/person/yr)], and water scarcity results when supplies drop below 264,170 gallons/person/yr (1,000 m^3/person/yr). Further, the United Nations (2007) has estimated that 40 percent of the world's population will live in water scarce regions of the globe by 2025. Per capita water supply in Jordan is expected to fall to 24,040 gallon/person/yr (91 m^3/person/yr) by 2025 should the current population growth trend be maintained putting Jordan in the category of having an absolute water shortage (Hashemite Kingdom of Jordan Geography and Environment, 2012).

Maplecroft (2012) ranks the Hashemite Kingdom of Jordan as 10th among the 17 countries in the world having extreme water risk as measured by their water stress index. The index is based on the ratio of domestic, industrial, and agricultural water consumption, against renewable supplies of water from precipitation, rivers, and groundwater.

Jordan is undertaking aggressive programs to address its current and future water needs and key among these is the use of treated wastewater effluent in agricultural production. Cultural and religious factors have been shown to have significant bearing on the success of wastewater reuse projects in Jordan, as in other Islamic cultures.

Culture and Religion

As stated in *Water – The Epic Struggle for Wealth, Power, and Civilization,* "Everyone understands that water is essential to life. But many are only just now beginning to grasp how essential it is to everything in life – food, energy, transportation, nature, leisure, identity, culture, social norms, and virtually all the products used on a daily basis. With population growth and economic development driving accelerated demand for everything, the full value of water is becoming increasingly apparent to all." (Solomon, 2010)

The World Bank (2012) reports that wastewater use in agriculture is increasing especially in areas of water scarcity, increasing population, and where demand for food is on the rise. The expanding recognition of wastewater has nutrient value along with irrigation value is leading to increased acceptance for use in agricultural production. Although wastewater can be a reliable source of irrigation water, the World Health Organization (WHO) cautions that wastewater is always a public health risk and WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater (2006a) employ an approach integrating risk assessment and risk management to control water-related diseases.

The WHO guidelines recognize that in addition to technical issues, cultural and religious factors are important to the success of wastewater irrigation practice. WHO reports that societal concerns related to use of untreated human excreta range from abhorrence to acceptance (WHO, 2006b). In Africa, the America's and Europe excreta use is generally regarded with "disaffection," whereas in Asia its use is accepted and in keeping with Chinese and Japanese "traditions of frugality." In Islamic societies however, direct contact with excrement is abhorred however its use after treatment would be acceptable if the treatment were to remove impurities. Further, in Islamic countries it has been judged that wastewater can be used for irrigation provided that the impurities present in raw wastewater are removed (WHO, 2006a).

Islamic Fatwas

Fatwas are Islamic religious rulings of a scholarly opinion on a matter of Islamic law issued by a recognized religious authority in Islam (About Islam). A fatwa is based in knowledge and wisdom and those issuing the fatwas must supply evidence from Islamic sources for their opinions. However, it is not uncommon for scholars to come to different conclusions regarding the same issue. WHO (2006a) cites the 1978 Council of Leading Islamic Scholars of Saudi Arabia issuing a fatwa concerning the use of wastewater in Islamic Societies which stated “Impure wastewater can be considered as pure water and similar to the original pure water, if its treatment using advanced technical procedures is capable of removing its impurities with regard to taste, colour and smell, as witnessed by honest, specialized and knowledgeable experts.”

The following question was posed to the World Fatwa Management and Research Institute website in 2007: “From the Islamic point of view, is the reuse of treated wastewater permissible for irrigation of crops or park areas?” The response reads in part: “If water treatment restores the taste, color, and smell of unclean water to its original state, then it becomes pure and hence there is nothing wrong to use it for irrigation and other useful purposes” (INFAD, 2012).

Jordan RIAL Projects

The United States Agency for International Development’s (USAID) Reuse in Industry, Agriculture and Landscaping (RIAL) projects have engaged farmers in the successful use of treated wastewater in agricultural production. The projects have been successful because they have addressed not only technical and economic, but institutional and cultural issues as well (USAID, 2008). The RIAL projects pioneered the first Water User Association (WUA) in Jordan for operation, maintenance and management of a wastewater-based irrigation system and the introduction of urban wastewater use for the first time Jordan.

The Wadi Mousa WUA is comprised of women and men who work together on developing cropping patterns and schedules, equitable water distribution agreements, and utilize commonly-owned machinery and equipment. WUA pay their water fees to sustain a viable, independent, and productive irrigation system and they work with system operators and with the Petra Regional Authority in planning new activities (Abu Awwad, 2006).

The RIAL projects have shown that wastewater can be safely used in agricultural irrigation. Social acceptance of these practices have no doubt been furthered by the understanding of the benefits derived from the wastewater and the acceptance of its use in this Islamic culture through the issuances of fatwas allowing wastewater use in agriculture.

Figure 1
Irrigated alfalfa field in Wadi Mousa, Jordan (Photo credit: Tom Pedersen, CDM Smith)

Successes and Lessons Learned

The RIAL projects have demonstrated multiple benefits from well-managed reuse projects including environmental improvement as wastewater is no longer discharged into streams and wadis, increased farmer income, and a resultant enhancement of the quality of life.

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Water, Wastewater, and Recycled Water Integrated Plan for Tijuana, Mexico

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Mexico-Tijuana

Project Background or Rationale

The municipalities of Tijuana and Playas de Rosarito, with a combined population of more than 1.3 million people, represent one of the largest metropolitan areas in Mexico, having at the same time one of the highest population growth rates in the country. Water resources in the region, however, have always been a challenge. The accelerated growth, coupled with the scarcity of water resources in the area, require significant investments to assure water supply for this area. Significant challenges exist for the provision of water and sanitation services in the area, and deficits for the next 20 years are projected to occur if no action is taken.

Recognizing the need for immediate planning, the Comisión Estatal de Servicios Públicos de Tijuana (CESPT) developed a Water, Wastewater and Reclaimed Water Integrated Plan (Master Plan) for Tijuana and Playas de Rosarito. This master plan was developed to address the short-term improvements necessary to correct existing system deficiencies and long-term upgrades necessary to meet future growth through the year 2020.

Capacity and Type of Reuse Application

The Technical Committee selected a water supply alternative that resulted in a capital improvement program of more than $1 billion U.S. dollars. This alternative includes the construction of a desalination facility, additional wastewater treatment plants, rehabilitation and expansion of the water and the wastewater collection network, effluent conveyance and disposal lines, and wastewater advanced treatment and recycling, including aquifer recharge. In addition to the facilities listed in the CIP, the plan includes guidelines for aggressive industrial pretreatment programs.

Eight wastewater treatment options were identified based on the discharge limits established by the existing regulations and on the specific discharge quality goals established as part of the master plan. These technologies include: natural systems (lagoons), mechanized lagoon systems, conventional activated sludge, trickling filters, extended aeration, a combination of trickling filters and activated sludge, and sequencing batch reactors.

Based on a comparison of the advantages and disadvantages of these options, conventional activated sludge was pre-selected for the development of alternatives. For reuse options, additional treatment was necessary and selected for specific projects depending on discharge and/or reuse requirement.

The wastewater treatment plants “La Morita” and “Monte de los Olivos” combined effluent was recommended for indirect potable reuse, with a capacity of 21 mgd (930 L/s). Additionally, 14 mgd (600 L/s) were recommended for indirect potable reuse from the “Alamar WWTP”. About 20 mgd (900 L/s) additional were recommended for nonpotable reuse in different parts of the city.

Water Quality Standards and Treatment Technology

The water quality goals for the project varied according to the reuse options for the different plants. Plants that would discharge treated effluent into the Rodriguez reservoir, which can supply potable water, required quality goals and standards much higher than reuse for non-potable uses.

Plants discharging to the Rodriguez reservoir were conceptually designed to have conventional activated sludge followed by microfiltration/reverse osmosis (MF/RO). This advanced treatment requirement is necessary due to the indirect potable use scheme of the plants. The plants with effluent destined for non-potable uses were conceptually designed for conventional activated sludge followed with additional filtration and hypochlorite disinfection.

Project Funding and Management Practices

The master planning project was funded by the North American Development Bank, which in turn used funds from the U.S. Environmental Protection Agency (EPA). After the planning project, implementation of the different planning recommendations has proceeded with a number of different funding schemes. These include financing from foreign banks, funding from the national infrastructure bank in Mexico (Banobras), funding from the Mexican National Water Commission, funding from the North American Development Bank, and the EPA.

Any project financed in total or partially by U.S. funds has required environmental documentation in the United States under the National Environmental Policy Act (NEPA). EPA has developed environmental assessments to evaluate transboundary impacts (projects in Mexico that could have environmental impacts in the U.S. side of the border).

The projects are managed by the water and wastewater utility in Tijuana. The management of some projects requires the participation of the U.S. and Mexico sections of the International Boundary and Water Commission (IBWC).

Institutional/Cultural Considerations

The project's decision-making body was formed by agencies in Mexico and the United States. A binational technical committee was formed to oversee the master plan and make technical decisions and recommendations. This was necessary due to the funding scheme where U.S. funds were utilized for the planning project. On the Mexico side of the project, the federal government was involved, in addition to the local utility, to have a counterpart to EPA. Additionally, the project included significant involvement by the Border Environment Cooperation Commission and the North American Development Bank which are agencies with binational character.

For the implementation of projects, an additional level of institutional involvement has been added that includes the IBWC.

The planning project included significant public involvement in the United States and on the Mexico side of the border. Subsequent phases of implementation have continued to include community stakeholder participation through the environmental document process that has been required on both sides of the border.

A key consideration on the project recommendations was the "high-tech" and energy intensive nature of some of the projects recommended, namely the MF/RO plants. The recommendations were made due to the indirect potable reuse nature of some of the projects. Alternative plans included no indirect potable reuse, eliminating the need for MF/RO.

Successes and Lessons Learned

The recommendations from the study were accepted by the binational technical committee and the great majority of community stakeholders. The success of the project was due to the high level of bi-national cooperation transparency in the decision-making process. While conducting a project with a multi-agency technical committee is more challenging than dealing with one agency only, the benefit is that the recommendations from the plan are more likely to be accepted and supported.

The non-potable water reuse options recommended in the plan have proceeded successfully with environmental documentation, design, and construction. While indirect potable reuse options requiring MF/RO have not proceeded, a successful element of the project and the associated environmental documentation is that no secondary effluent is being discharged in Rodriguez reservoir, which supplies potable water to the city's residents.

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The Planned and Unplanned Reuse of Mexico City's Wastewater

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Mexico-Mexico City

Project Background or Rationale

Mexico City is located in what used to be a closed basin, at an altitude of 7,350 feet (2,240 meters above sea level). The basin was artificially opened in 1857 to dispose of waste and stormwater. Mexico City is the capital of Mexico and comprises the Federal District plus 37 municipalities, and is home to 21.4 million people. Water availability in the basin is of the order 43,600 gallons/inhabitant/yr (165 m^3/inhabitant/ yr) and there is a water intensity use of 120 percent. Total demand for water is around 1,950 mgd (85,700 L/s). The local aquifer is overexploited by 120 percent (CONAGUA, 2010), leading to the subsidence of the soil in some places at a rate of up to 18 in/yr (40 cm/yr). In addition, water has to be imported from two other basins. One is located 62 mi (100 km) away, from which water is gravitationally transported, while the other is 81 mi (130 km) away, and water must pumped up a height of 3,600 ft (1,100 m). Despite these efforts, one million people in the city depend on the delivery of a limited amount of water in tankers, while the rest of the population receives water through the network intermittently and sometimes at a very reduced flow, rendering it necessary to have water storage tanks and pumping systems in the home (Jiménez, 2008).

To face the challenge of meeting a constantly increasing demand for water, the local water utilities which also manage wastewater have implemented different projects to reuse wastewater for municipal and industrial purposes, some of which have been in operation since 1956. In addition, the Federal Government has been responsible for a program of reuse of water in Mexico City and a second basin for agricultural irrigation since 1920 (Jiménez, 2010).

Capacity and Type of Reuse Application

At the present time, 6 mgd (260 L/s) of water are reused to supply different industries. It is problematic to sell treated wastewater to industry as it is more expensive than tap water and there are no compulsory rules to oblige companies to use reclaimed water. It is estimated that with a proper legal framework industrial reuse could be increased by an additional 23 mgd (1,000 L/s). Furthermore, 30 mgd (1,300 L/s) of water is supplied to power plants merely for cooling. Nearly 46 mgd (2,000 L/s) are used for irrigation of green areas, recharge of recreational lakes and agriculture; 27 mgd (1,200 L/s) are used for groundwater recharge and 4 mgd (175 L/s) for car washing. New car washing service centers are compelled to use reclaimed water. In addition, one treatment plant produces 14 mgd (600 L/s) for ecological purposes. Its effluent is being used to recharge a lake that was dried by the Spanish during the colonial period and was the source of particulate matter heavily polluting Mexico City's air. The last planned public projects began to operate at the end of the 1980s. In most of these cases, e.g. the power plant, the restored lake, some irrigated areas and recreational lakes, pipelines convey treated water to the facilities. The other projects receive effluent from water tankers. The amount of water reused from public plants represents 10 percent of the total supply. Additionally, although they are not formally registered, several dozen private wastewater treatment plants in sports clubs, golf courses and schools treat wastewater and reuse it for lawn irrigation or toilet flushing. Private reuse is not controlled by the government.

The remainder of the wastewater produced in Mexico City, amounting 1,370 mgd (60,000 L/s), is reused with no treatment for the irrigation of 220,000 acres (90,000 hectares) in the Tula Valley (**Figure 1**). This is located 62 mi (100 km) north of Mexico City. Reuse has been performed, although not always officially, for more than 110 years and as a result the infiltration of the water used for irrigation (estimated in more than 570 mgd (25,000 L/s) has created new groundwater sources. These sources are used to supply the 500,000 people living in the Valley with municipal water, using only chlorination for treatment. The water has proven to be of acceptable quality (Jiménez and Chavez, 2004)

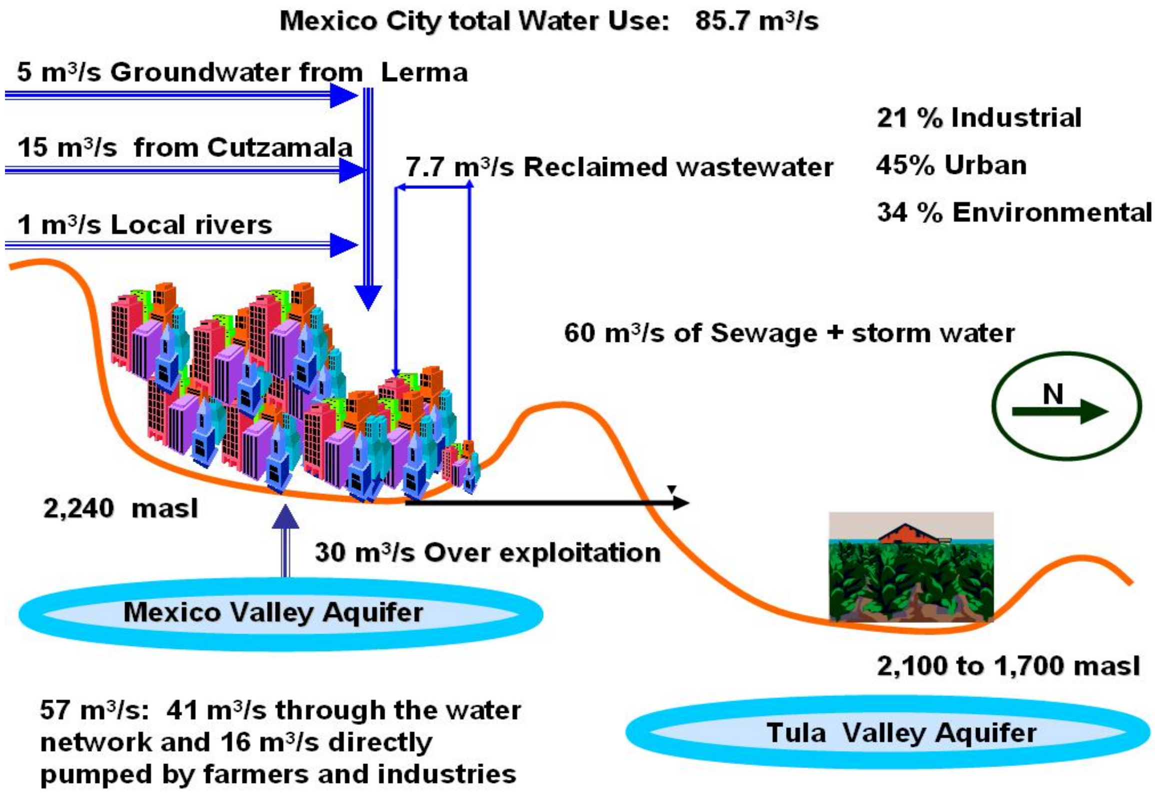

Figure 1
Use of water in Mexico City and the Tula Valley

thanks to several natural occurring treatment mechanisms that happen during its transport, storage, and infiltration into the soil. In fact, some pollutants such as heavy metals and emerging pollutants have been shown to remain in agricultural soils for several years or even decades (Siebe, 1995; Gibson et al., 2007; Duran et al., 2009).

Water Quality Standards and Treatment Technology

With regard to standards, the reuse of wastewater for agriculture has been regulated since the 1980s using criteria that were modified in 1986 (NOM-001-SEMARNAT 1986) to manage the quality of the treated water to control health risks, i.e., by limiting the fecal coliform content to 103 MPN/100 mL and 1 helminth egg/L for non-restricted irrigation or 5 helminth eggs/L for restricted irrigation. In addition, a higher content of BOD was allowed in order to improve the quality of agricultural soils while the amount of heavy metals was limited using values set out by the EPA, 2004 *Guidelines for Water Reuse*. There is no standard for the reuse of water for industrial purposes.

For public reuse, water standard NOM-003-SEMARNAT-1997 is in use, but this only covers restrictions for biological pollutants. To regulate the infiltration of reused water to groundwater, a relatively new standard (NOM-014-CONAGUA-2003) has been adopted. This basically only requires compliance with the Mexican drinking water standard prior to infiltration.

The planned reuse of wastewater for industrial and municipal purposes is always performed after at least secondary treatment coupled with filtration. The effluent produced has proven to be adequate for most uses, other than for the recharge of recreational lakes, notably the Xochimilco Lake, which is currently suffering from eutrophication. The power plant provides tertiary treatment to a secondary effluent at its own cost to avoid the formation of deposits in its cooling towers. To recharge the aquifer, treatment up to the tertiary level is provided, to remove suspended solids and organic matter. No data has been published with regard to effluent quality or its impacts on groundwater.

The massive reuse of wastewater for agricultural irrigation in the valley is performed with no treatment at all, although plans to treat the wastewater and its financing have been in place since the mid 1990s.

Project Funding and Management Practices

All investments for public projects have been through public funding. All but two wastewater treatment plants providing water to industries have been operated by private companies since the mid 2000s. Public reuse projects are managed by the water utilities of Mexico City and the municipalities, while the reuse of water on agricultural fields outside the Mexico City basin is operated by the federal government.

Institutional/Cultural Considerations

In general, society is aware of the reuse of water and considers it a positive practice. In fact, in the city there are many examples of people, forced by the lack of water, reusing wastewater from showers, or the washing of clothes for lawn irrigation or the manual flushing of toilets with graywater.

Successes and Lessons Learned

The main lessons learned are that relatively low risk practices for reuse have been readily accepted by a society that suffers from lack of water. However, possible future reuse projects, either in the form of new sources of water from the Tula Valley or the direct reuse of wastewater in Mexico City for drinking purposes, probably will not be accepted as easily for many reasons. Perhaps it is time for Mexico City to begin to plan to control, its urban growth.

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Maneadero Aquifer, Ensenada, Baja California, Mexico

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Mexico-Ensenada

Project Background or Rationale

The Maneadero aquifer, one of four aquifers supplying water to the City of Ensenada, is located in the Mexican state of Baja California, where the annual average temperature is 63 degrees F (17 degrees C) and precipitation is 12 in/yr (299 mm/yr). Groundwater is extracted for supplying approximately 100,000 habitants and to irrigate 16,600 acres (6,714 hectares) of a variety of crops, most of which are exported to the United States. Overexploitation is calculated at 16,000 ac-ft/yr (20 Mm^3/y) and has caused severe deterioration of groundwater due to saline intrusion (Daesslé et al., 2005). Ensenada is growing at a rate of 3.7 percent (INEGI, 1997) and so is the demand on water supply. Thus, there is the need for short-term strategies for the efficient use of water and the sustainability of the aquifer.

Ensenada has the advantage of being one of the few Mexican cities to treat all of its wastewater. A study conducted by Mendoza-Espinosa et al. (2004) determined that the El Naranjo wastewater treatment plant produces 5,000 gpm (316 L/s) of secondary effluent that can be safely used for agriculture irrigation yet it is being discharged to the ocean. In contrast, in central Mexico wastewater with little or no treatment is being used for the irrigation of crops for human consumption (Jiménez, 2005).

In order to explore and integrate water management alternatives such as water markets, reuse and seawater desalination, an optimization model was employed (Medellín-Azuara et al., 2007). The study indicated that reclaimed water for irrigation and aquifer recharge is the most economically promising alternative options to meet future water needs. Seawater desalination and new aqueducts are not economically viable alone, but may also have some utility if combined with other options for the region.

Only recently has there been Mexican legislation for planned artificial recharge through the standard NOM-014-CONAGUA-2003 (DOF, 2009). Studies by Reynoso-Cuevas et al. (2011) demonstrated that reclaimed water complies with this norm, and could represent an alternative for stopping saline intrusion.

Capacity and Type of Reuse Application

The city of Ensenada has five wastewater treatment plants (WWTP), providing treatment to approximately 9,500 gpm (600 L/s) of wastewater. The main WWTP is called El Naranjo and has a treatment capacity of 8,000 gpm (500 L/s). It is located approximately 8 mi (13 km) north of the Maneadero aquifer. A 25-ft (7.6 m) pipe was built in 2008 connecting El Naranjo with a holding tank of 530,000 gallons (2,000 m^3) at a cost of $4.8 million U.S. dollars. The reclaimed water is intended to be used for crop irrigation although it could also be used for artificial aquifer recharge.

Water Quality Standards and Treatment Technology

According to Mexican legislation for wastewater disposal, for “land application” of wastewater (effectively crops irrigation) practically no treatment is necessary, hence its extensive use in Central Mexico. However, according to Mexican water reclamation standards, the reclaimed water must comply with standards similar to those required by California Law (Title 22) and suggested in EPA guidelines. The new Mexican norm for aquifer recharge requires that for direct recharge reclaimed water must basically comply with potable water standards; for indirect recharge, tests must be undertaken to demonstrate that the soil percolation would guarantee the safety and protection of the groundwater. Currently the city of San Luis Rio Colorado in the state of Sonora is the only Mexican city where artificial recharge of a local aquifer has been implemented. Ensenada has the potential for becoming the second city to achieve this goal.

Studies by Reynoso-Cuevas et al. (2011) demonstrated that Ensenada’s wastewater does not appear to have high concentration of trace organic chemical contaminants like phenol and 10 of its derivatives, 16 polycyclic aromatic hydrocarbons and 7 aroclor. The concentration below analytical detection limits of these compounds indicates that their concentrations are not significant and/or that they are transformed to other metabolites through conventional wastewater treatment process. Risk minimization should certainly be the main element in the development of groundwater recharge project; results suggest that a combination of controls, such as wastewater treatment processes, water quality, recharge methods, recharge site and integral monitoring, would guarantee the success of the recharge operation and preserve a chemically safe groundwater. There is the potential for using the treated wastewater for direct injection to the aquifer although the high levels of total dissolved solids (TDS) in the aquifer 1.0-26.0 gl-1 (Daessle et al. 2011) remains the biggest challenge for aquifer recharge. Its removal via membrane systems will probably be required. In view of the high salinity of the aquifer, the National Water Commission could grant a special permit even if the 1.0 gl-1 TDS limit is exceeded in percolation water and only if a minimum distance of 0.62 mile (1 km) exists between the recharge site and the sites of drinking water extraction; further hydrogeological studies are being carried out by the authors to determine any potentially adverse effects to the aquifer.

Project Funding and Management Practices

Funding for Ensenada's WWTPs and the construction of the pipe that connects the Naranjo WWTP with Maneadero has been provided by a combination of federal and state funds. Comisión Estatal de Servicios Públicos de Ensenada (CESPE) has provided funds since 1999 for Universidad Autonoma de Baja California (UABC) for the continuous monitoring of the quality of its WWTPs. All specific research studies have been conducted by direct involvement of UABC researchers. Government official expect farmers to provide their own investment in order to connect to the current holding tank and, therefore, to be in a position to use reclaimed water for irrigation. On the other hand, it is unclear who would provide funds if reclaimed water is to be used for the artificial recharge of the Maneadero aquifer.

Although it has been demonstrated that water has an economic value (Medellín-Azuara et al., 2009) it appears that the availability of water, although of low quality due to high TDS as a result of saline intrusion is still economically viable even when reverse osmosis is needed to obtain irrigation water suitable for crops. As TDS in the groundwater continue to increase, it may reach a point when this will be no longer viable and, thus, reclaimed water could be preferred for irrigation.

Institutional/Cultural Considerations

Farmers are unwilling to irrigate crops with high-quality reclaimed water because they believe that the United States will block them for exporting their produce. Several meetings have been undertaken promoted by the academic sector in order to facilitate information about reuse schemes in the United States, particularly in California. Nevertheless, farmers are reticent as they believe that even if they comply with U.S. standards for crop irrigation, farmers' organizations in the U.S. may block their produce arguing health risks. Moreover, the actual cost for farmers of the reclaimed water has not been clearly established. Hence, the actual implementation of the reuse scheme has not been reached.

Successes and Lessons Learned

As with many water reclamation projects, the scientific and technical aspects can be dealt with. In the Maneadero case, this has been done slowly but surely, often by own initiative of the academic sector. Federal and state governments have invested in wastewater treatment plants and in reclamation facilities. However, the actual implementation of the reclamation schemes has been hindered by economic/cultural reasons, as farmers are not willing to pay for reclaimed water, opting for the continuous extraction of underground water. Farmers also worry that their product will not be able to be exported to the United States if farmers unions in the U.S. find out that it is being irrigated with reclaimed water, despite its compliance with U.S. norms. It appears that this deadlock can only be resolved by continuing to reach consents between the government and farmers in which the academic sector can continue be a facilitator and, by all means, undertaking the research to guarantee the adequate implementation of water reclamation schemes.

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Tenorio Project: A Successful Story of Sustainable Development

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Mexico-San Luis Potosi

Project Background or Rationale

In San Luis Potosi, Mexico, wastewater is considered as an asset rather than as a disposable waste. In the late 1990s, the State Government of San Luis Potosi decided to implement an Integral Plan for Sanitation and Water Reuse to stop the use of raw wastewater in agriculture and foster the substitution of groundwater for reclaimed water for all non-potable uses. Currently, the state has built seven wastewater treatment plants (WWTPs) to treat 70 percent of wastewater and 100 percent of the treated wastewater is reused. The project has not only economical benefits but also a positive impact for the local community, in terms of public health and environment enhancement.

The reuse program and the industrial users funding/ payments gave the system economical viability while the augmented water resources become available for potable use. The largest WWTP and reuse operation (irrigation and industry) of the system is the Tenorio Project, a tangible example of how to build and operate a sustainable reuse system, water governance, balance between treatment and supply costs and water rates, performance and reliability.

Capacity and Type of Reuse Application

The Tenorio plant has a total capacity of 24 mgd (90,720 m^3/d). The infrastructure consists of primary treatment enhanced with chemicals and a natural engineered polishing system in a 13.7 mgd wetland for agricultural irrigation of fodder crops.

The treatment required for industrial reuse was designed to supply make-up water for cooling towers in the "Villa de Reyes" Power Plant, focusing on saving groundwater for the surrounding population. The industrial reuse relies on a 10.3 mgd treatment process using activated sludge with nutrient removal, tertiary treatment with lime softening, and sand filtration and ion exchange for silica and hardness removal.

The reuse system is comprised of a complex distribution system with several pumping stations, an irrigation network and a 24 mile (39 km) conveyance system with an equalization tank to adjust to the industrial hourly demand.

Water Quality Standards and Treatment Technology

The reclaimed water for irrigation meets standards established by Mexican Regulation. These standards (**Table 1**) require guaranteed values in terms of biochemical oxygen demand (BOD), total suspended solids (TSS), and fecal coliform, which were largely exceeded by the treatment chosen.

For the industrial reuse application, the standards were established as per the requirements of the Power Plant operation. The water quality should guarantee at least the same concentration cycles in the cooling towers obtained with the groundwater. Therefore, the most significant parameters were silica, hardness and phosphate content as well as conductivity. However, the Power Plant also set limits in BOD, TSS, ammonia, fecal coliform, and ferruginous bacteria, in order to avoid the increase in cost of conditioning products to prevent development of algae and bacteria. To meet the latest standards and to prevent biofilm growth in the distribution system, a non oxidant biocide control was implemented as a complement of the original treatment.

Table 1 Main water quality standards for agricultural and industrial reuse 2007-2011

Parameter	Raw Wastewater*	Tenorio Tank Effluent to Reuse in Agriculture**	Criteria for Agricultural Reuse	Reclaimed Water to Power Plant*	Criteria for Industrial Reuse in Power Plant
TSS mg/L	188 (±76)	28.8 (±10.6)	30	3.58 (±3.06)	10
BOD_5 mg/L	275 (±99.5)	31 (±7.3)	40	2.87 (±2.05)	20
COD mg/L	518 (±259)	84 (±19)	Not required	15.8 (±14.45)	60
P_{TOTAL} mg/L	8.7 (±3.9)	6.5 (±0.2)	15	1.3 (±0.9)	2
TKN mg/L	32.6 (±9.6)	22.3 (±5.1)	25	1.5 (±3.87)	15
Fecal Coli /100 mL	$4.8.10^9 (\pm 1.3.10^2)$	161 (±402)	1000	18.4 (±16.6)	70
Total hardness mg/L	111.3 (±19.3)	Not measured	Not required	105.6 (±24.2)	120
Silica mg/L	104 (±20.3)	Not measured	Not required	64.9 (±9.3)	65

Project Funding and Management Practices

The WWTP, the 24 mile (39 km) distribution system of treated water, an irrigation system for 1236 acre (500 Ha) and 37 mile (59 km) of sewer pipes required a total investment of $67 million USD (May 2004). To guarantee reliability and long term operation, the project was built with a BOOT (build-own-operate-transfer) scheme and with 18 years of operation. The Mexican Federal Government provided 40 percent of the capital costs as a grant, while private funding provided the remaining 60 percent. Investment and operational costs are recovered by the collection of three tariffs: one for the private return of the investment, and the other two for the fixed and variable operational costs.

The Power Plant demand for reclaimed water allowed the San Luis Potosi State Water Commission (CEA) to undertake the investment risks. The income generated from this industrial reuse practically covers the total operation cost of the WWTP. Water reuse also accounts for an overall reduction of groundwater extractions, contributing to the aquifer sustainability.

Economic benefits to the Power Plant are also accomplished by a lower cost and more reliable quality of water coming from the WWTP. The fee collected for this reclaimed water is 0.23 USD/1000gal (0.85 USD/m^3).

Institutional/Cultural Considerations

Industrial and economic development in San Luis Potosi has always been related to water availability and water conservation efforts. Since 1961, water withdrawal from the two main aquifers (San Luis Potosi and Jaral-Villa de Reyes) has been strongly restricted and farmers used non-treated wastewater for irrigation purposes.

This particular project treats 43 percent of the total wastewater, and it is the first one in Mexico which makes possible the production of different qualities of treated water for multipurpose planned water reuse.

Local farmers considered themselves as the rightful owners of all the untreated water available. Farmers strongly opposed to any type of water treatment under the belief that it would reduce the nutrient content that served as fertilizer for their crops. CEA has negotiated with them the supply of better quality water and convinced them of the sanitary and economical benefits gained by using properly treated water.

Successes and Lessons Learned

In terms of public outreach, through local educational projects and participation in national forums, the Tenorio Project has already demonstrated how the economic and environmental benefits of reclaimed water are helping the city, farmers, and industry. Wastewater reuse provides industry with a water source which is 33 percent cheaper than groundwater. The high-quality water used for irrigation makes it possible for farmers to diversify crop production and reduce morbidity rate of intestinal and skin diseases.

At the same time, the significant restoration of the ecosystem in the Tenorio Tank, that initially received wastewater without treatment, was one the major successes of the project. The Tank functions as an artificial wetland that polishes and improves water quality. At present, migratory birds returned to nest in the surroundings of the wetland.

After 6 years of operation, this Project accounts for a net reduction of groundwater extractions of at least

40,000 ac-ft (48 million m^3). Within the next 2 years, the system will be expanded with an additional treatment train with an RO unit. This expansion will allow the Villa de Reyes Power Plant to replace 100 percent of its water demand with reclaimed water and the San Luis Potosí water availability will be increased by 10 mgd when the power station transfers all their groundwater rights to the city, for potable use.

Figure 1
Aerial view of Tenorio Tank, WWTP, and land irrigated with reclaimed water (Photo credit: Degremont)

Figure 2
Tenorio Tank with different species of migratory birds (Photo credit: Degremont)

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Faisalabad, Pakistan: Balancing Risks and Benefits

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Pakistan-Faisalabad

Project Background or Rationale

The International Water Management Institute (IWMI) started a program in 2000 that aimed to quantify both the risks and benefits of wastewater use in Pakistan. For this purpose the city of Faisalabad was selected for a 5-year study program. This city was selected for a number of reasons: 1) over 6,200 ac (2,500 ha) of land is irrigated with domestic wastewater, and 2) even though a waste stabilization pond (WSP) was present, farmers preferred to use untreated wastewater. At the start of the study different cost (health risks) and benefits were identified for which separate studies were designed.

Capacity and Type of Reuse Application

The WSP in Faisalabad is located in a predominantly agricultural area and has been in operation since January 1998 and was constructed with the aid of an international grant. It covers an area of almost 250 ac (100 ha) and consists of six parallel anaerobic ponds and two series each comprising one facultative pond and two maturation ponds. The plant was designed for a wastewater flow of 24 mgd (90,000 m^3/d) with an average influent biochemical oxygen demand (BOD) of 380 mg/L. BOD removal at the design stage, based on a total hydraulic retention time (HRT) of 16.5 days and calculated following standard procedures, was determined to be 80 mg/L. This would result in an effluent with BOD in compliance with the Pakistan Environmental Protection Agency's standard for the disposal of municipal and industrial wastewater effluents which is set at ≤80 mg/L.

Wastewater is pumped on a 24-hour basis from the main sewerage network into a primary drain bringing wastewater to the WSP. Local farmers, following extensive legal cases and now with permission from the local Water and Sanitation Authority (WASA), have installed five permanent outlets in the primary drain to convey untreated wastewater to their existing irrigation networks. Farmers were reluctant to use treated effluent as they claimed it was unsuitable for use in agriculture as it was much lower in nutrients and much higher in salinity (as a result of massive evaporation from the WSP) than untreated wastewater.

Approximately 290 farming households paid annual fees totaling USD $7,500 (440,000 Pakistan rupees) to the WASA to use wastewater. The main crops cultivated with wastewater were fodder, wheat, and vegetables. The vegetables included: spinach, cauliflower, eggplant, chilies, and tomatoes.

Farmer Perception and WSP Performance

A 1-year study showed a strong increase in salinity from untreated wastewater to final effluent with a clear decline in nitrogen concentration, thereby confirming farmer perceptions. The performance of the WSP was poor and did not comply with WHO and FAO guidelines for irrigation water. The poor performance of the WSP could be attributed to a combination of factors: poor design, the extreme climatic conditions, which causes evaporation exceeding 0.4 in/day (10 mm/day) during several months of the year. Also the large quantities of untreated wastewater that were diverted for agricultural irrigation by farmers meant that the hydraulic retention time was more than doubled due the reduced amount of raw wastewater inflow.

Water Quality

The water used for irrigation was untreated wastewater with high concentrations of *E. coli* (geometric mean: 1.8x107 CFU/100 mL) and helminth eggs (over 950 eggs/L) and exceed international standards, though no official wastewater use standards were adopted by the state of Pakistan.

Risks to Farmers

The health risks of wastewater use in agriculture were investigated through a cross-sectional study. The study showed an increased risk of intestinal nematode infection, and in particular hookworm infection, in wastewater farmers (OR = 31.4, 95% CI 4.1-243) and their children (OR = 5.7, 95% CI 2.1-16) when compared to farming households using regular (non-wastewater) irrigation water, though the prevalence of infections was low (Ensink, 2005). In addition an increased risk of *Giardia intestinalis* infections was found within the wastewater farming communities, though the large majority of infections were found to be asymptomatic (Ensink, 2006). The study further found elevated levels of heavy metals in soil irrigated by untreated wastewater but levels remained within permissible guidelines set by international agencies. No elevated levels of heavy metals were found in edible parts of agricultural produce (Ensink, 2008).

Farmer Benefits

During the study farmers using different types of irrigation water (untreated wastewater, and 'normal' [non-wastewater] irrigation water) were followed. Crop choice, crop yields, water use and fertilizer applications were monitored for all selected farmers for the duration of a year. Farmers using untreated sewage were found to grow crops of higher value (predominantly vegetables), have a higher cropping intensity per hectare and finally and most important only applied fertilizer through wastewater, with minimal amounts of chemical fertilizer. On average a farmer using untreated wastewater had an income that was US$ 600/ha higher than a farmer that used normal irrigation water (Ensink, 2007)

Risks to Consumers

The risk to consumers were quantified in a year-long study in which produce grown on untreated wastewater was analyzed for the presence of *E. coli* and helminth eggs. At time of harvest one batch of sample was collected from the fields and the same batch of vegetables was followed up and collected at the local market the next day. The study found that slow growing vegetables had the highest levels of contamination, though in general contamination levels were low with on average 1.9 *E. coli*/gram of produce. Higher concentrations of *E. coli* (14.3 *E. coli* g-1) were recovered from the vegetables collected from the market, with the results of the survey suggesting that unhygienic post harvest handling was the major source of produce contamination (Muhktar, 2008).

The construction of WSP has been suggested to pose a risk to urban populations as the large reservoirs could provide breeding sites to disease vectors. The WSP in Faisalabad was found to generate large amounts of mosquitoes; most notably the vectors of malaria, Japanese encephalitis, dengue, and lymphatic filariasis (Ensink, 2007). However mosquito breeding was predominantly associated with emergent grasses and the absence of grids within the WSP. Removal of grasses and the reinstallation of the grids reduced mosquito breeding to almost zero (Ensink, 2007)

Benefits to Consumers

A comparative analysis of food prices found that locally grown wastewater irrigated cauliflower was almost 50 percent cheaper than produce irrigated with non-wastewater water brought into the city (Ensink, 2007).

Risks and Benefits to Downstream Water Users

A nationwide survey in Pakistan found that only 2 percent of all cities with a population of over 10,000 inhabitants had wastewater treatment facilities, and in those that did have wastewater treatment facilities at maximum 50 percent of all wastewater received some form of treatment. In addition in 80 percent of all cities in Pakistan untreated wastewater seemed to occur, and occurred in all cities that had a sewerage systems (Ensink, 2004).

As a result of natural occurring salinity approximately 50 million people in Pakistan rely on irrigation canals for their domestic water supply, including drinking (Van der Hoek, 2001). In the absence of wastewater treatment, wastewater is disposed of untreated into irrigation canals and rivers, thereby exposing downstream water users to unknown health risks.

Lessons Learned

The Faisalabad case study shows that wastewater use for crop production is a practice with many benefits. It sustains livelihoods of poor peri-urban farming families, contributes to urban food security, helps in solving the urban sanitation problem by preventing pollution of surface water, and makes optimal use of the resources (water and nutrients). The health risks associated with wastewater use in agriculture to farmers and consumers of produce can be reduced by proper irrigation water management and implementation of existing public health measures, even when wastewater treatment is not feasible. It is therefore paramount that when wastewater treatment facilities are planned, farmers' views need to be taken in consideration.

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Friends of the Earth Middle East's Community-led Water Reuse Projects in Auja

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Palestinian Territories-Auja

Project Background or Rationale

The Village of Auja is located adjacent to the Jordan River just north of the City of Jericho. It is a small community of 4,500 residents, well known in Palestinian society due to the nearby Auja Spring, where an estimated 9 million cubic meters (m^3) (7,300 ac-ft) of water annually flows out of the desert rocks. The oasis created by the Auja Spring attracts thousands of visitors each year.

In close partnership with the community and the Auja Municipality, Friends of the Earth Middle East (FoEME) established its Jordan Valley Environmental Education Center with guest house facilities in 2010 (**Figure 1**). The center has quickly become a central institution of Auja and a focal point for environmental awareness for visitors and students about the geology, fauna, flora, water resources, and cultural heritage of Wadi Auja and the Jordan Valley as a whole.

Figure 1
FoEME's Auja Environmental Education Center

Capacity and Type of Reuse Application

The center was designed at the outset to include educational demonstration model water reuse installations including a graywater treatment system. These systems reduce water consumption, save costs and scarce resources, provide a source of irrigation water for the center's trees, and serve as educational models in action for visitors to the center.

The center's graywater reuse system treats graywater generated by the guest house and center's kitchen and bathroom sinks and showers for reuse in irrigating trees in the center's grounds. The system includes two parallel filtration systems, with 10 containers each, connected in a series (**Figure 2**). The system acts as a series of constructed wetlands, whereby in the first 8 containers gravel and phragmites (similar to bamboo) filters the graywater, followed by a gravel and sand composite in the 9th container, and finally an all sand-filled container for the last stage. The treated water is held in a 35.3-ft^3 (1-m^3) storage container, where an automatic pump pushes the treated water through the drip-irrigation system at the center. At full capacity the system can treat an estimated 8,000 gallons (30 m^3) of water a day.

Figure 2
Graywater reuse system

Project Funding and Management Practices

The water reuse system cost approximately $5,000 US and was funded by the U.S. Agency for International Development (USAID) and other donors as part of their support for the Auja Environmental Education Center. It has been operational for a year and is quickly becoming a model installation for water reuse projects for private homes in Auja and throughout the West Bank.

To ensure the project's replication and sustainability, FoEME produced a graywater installation manual (**Figure 3**) and led a training course at the center in which dozens of area residents were training in the installation and maintenance of graywater systems (**Figure 4**).

Figure 3
FoEME's graywater system installation manual in Arabic

Figure 4
Graywater workshop for youth at Auja Center

Institutional/Cultural Considerations

Trainings, seminars, and workshops at the Auja Center have involved a total of 384 people with an additional 3,318 youth and adults receiving an environmental education experience as part of their visit to the Auja EcoCenter in the last 6 months. Building on the success of this wastewater solution for the Palestinian community of Auja, Osprey Foundation agreed to support the installation of graywater systems at homes throughout the community of Auja.

Successes and Lessons Learned

Building on the success of this wastewater solution for the Palestinian community of Auja, Osprey Foundation agreed to support the installation of graywater systems at homes throughout the community of Auja.

Assessing Water Reuse for Irrigation in Huasta, Peru

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Peru-Huasta

Project Background

The rural community of Huasta is located in the southern portion of the district of Huasta, within the Bolognesi province of the Ancash region Peru (**Figure 1**). A key organization within Huasta is the Campesina Community. The Campesina Community may be thought of as a "Homeowners Association," where members collectively decide how community resources (land, agriculture, livestock etc.) will be utilized, managed, and distributed to participating members.

Figure 1
Location of Huasta, Peru

As a proactive response to the persistent dry summers, five communities (including Huasta) have formed the Tres Cuencas Commonwealth for the sole purpose of collectively mitigating water issues within these communities. This collaborative effort initiated by the communities themselves has presented a unique opportunity for Engineers without Borders Greater Austin Chapter (EWB-AUS) to get involved. The five communities in the commonwealth are populated with indigenous Andeans, who are traditional small-scale farmers and ranchers who live closely in shared residences with their neighbors. Residents live in courtyard-type dwellings where the kitchen and common areas are shared. Houses in Huasta are typically set up with a central courtyard that connects the sleeping rooms, kitchen, and washing area. Huasta has a central plumbing system with flush toilets implemented in combination with the community wastewater treatment plant built approximately 6 years ago.

The community of Huasta has a vested interest in improving water availability in the area, as it is a driver for economic success. The community owns a number of livestock, primarily cows whose milk is sold regionally to produce cheese. Since cows require grass to graze on throughout the year, and the summer months provide little to no rainfall, limited water resources are further stressed during the dry season. The President of the community and a representative from the agricultural water committee identified water for irrigation in the dry season as their major concern for continuing to expand their dairy production. Members of the community own parcels of land that are permitted for use for grazing animals.

Type of Reuse Application

The municipality of Huasta and the Campesina Community conveyed their interest in a water reclamation project to EWB-AUS during the initial program assessment in August 2011. They were particularly interested in the idea as it would increase the area of productive land in the community and draw from a currently unused resource. The project may also improve on current flood irrigation techniques and promote water conservation gains through an enclosed pipe to transport irrigation water for flood, spray, and/or drip irrigation systems.

The purpose of the follow-up assessment trip in January 2012 was to determine the feasibility of utilizing reclaimed water from the community wastewater treatment plant to irrigate a 0.405-ac (1-ha) community-owned pasture. This land is currently not served by the community's irrigation network as it is at a higher elevation than the canals that provide water during the dry season (from June-August). The current treatment train at the wastewater treatment plant (WWTP) (**Figure 2**) consists of a headworks grate at the influent inlet, three sedimentation basins in parallel, two clean out tanks in parallel, followed by a sand filtration (currently bypassed) structure. EWB-AUS is currently analyzing viable and feasible options to improve water quality of the effluent including getting the sand/gravel filter bed operational, increasing the residence time at the sedimentation tanks, etc. From the plant inspection made in January of 2012, it was observed that if the treatment structures are operated as intended, the water quality of the effluent will be satisfactory for irrigating a grass field which will be used to graze the community livestock.

Figure 2
Existing WWTP

WQ Standards

To our knowledge, two levels of reuse regulations exist for Peru, the first stipulates minimum requirements for WWTP effluent. The other Peruvian rule defines reuse requirements for watering animals. But no national regulation exists for irrigation reuse.

Also, the World Health Organization (WHO) recommends treatment processes for restricted and unrestricted irrigation. The team was guided by the WHO Guidelines for the Use of Wastewater in Agriculture to ensure that the existing WWTP meets or exceeds the requirements for non-contact irrigation (WHO, 1989).

Project Funding and Management Practices

Funding for the EWB-Peru project for travel, materials, installation, etc. has and will be raised by the local EWB-AUS. Also, if the reuse project proceeds as planned, a wastewater committee will be formed consisting of the local Campesino Community members. This committee will be expected to collect community tax, as applicable, and will be the decision making authority over the long-term operation and maintenance of the reuse system. The committee's role is crucial for this project's sustainability. The project team travelling this summer is planning to educate the proposed committee on importance of maintaining the WWTP and the impact of operation/maintenance of the plant on the effluent quality. As a part of this workshop, the members of the wastewater committee will be trained in monitoring the effluent quality for bacterial population and biochemical oxygen demand (BOD).

The project is currently managed by EWB-AUS members working in conjunction with The Mountain Institute (TMI), a local non-profit organization in Peru for coordination and input from the community in the decision making process of the project.

Stakeholder Involvement

Existing effluent water quality data was collected by the team and presented to the community and the local municipality (**Figure 3**). Since the bacterial population in the effluent is exponentially higher than recommended levels, the travel team accepted the request from the community to create a maintenance and monitoring plan for the WWTP to improve treatment and effluent quality. Currently, EWB-AUS is working on preparing a maintenance plan and monitoring kit designed to train the local community members to properly operate and maintain the WWTP.

Figure 3
Community meeting

Successes and Lessons Learned

The positive outcome from the assessment trip was identifying the need to educate the community on the importance of the operation and maintenance of the WWTP. The fate of the reuse project depends on the results from the continued plant monitoring against WHO standards (mainly bacteria and BOD) that is to be performed by the Huasta community. The feasibility of the reuse project depends upon the data collected from monitoring. EWB-AUS will continue to work with the community of Huasta throughout this project.

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Wastewater Treatment and Reuse for Public Markets: A Case Study in Sustainable, Appropriate Technology in the Philippines

Authors: Mary Joy Jochico (USAID) and Ariel Lapus (USAID PWRF Project)

Philippines-Market

Project Background or Rationale

Public markets in the Philippines and around Asia pose significant challenges for wastewater treatment due to the relatively high strength of the discharges and variability of flows. The Muntinlupa Public Market, located in Muntinlupa City in the southern part of Metro Manila, is one of the largest public markets in the metropolitan area with 1,448 stalls and 24 hours a day operation (**Figure 1**). Wastewater generated at Philippine public markets tends to be very high strength and land available for treatment is generally quite small, necessitating a unique solution.

Figure 1
Location of water reuse – the Muntinlupa City public market

With support for planning and design provided by the United States Agency for International Development (USAID) through the Local Initiatives for Affordable Wastewater Treatment (LINAW) project, the city constructed a treatment facility that began operating in February 2006. In addition to treating wastewater from the public market, the system incorporates a water recycling system that allows reuse of the treated effluent for flushing toilets, watering plants and street cleaning. In addition to Muntinlupa, the LINAW project is assisting six cities in the Philippines to build wastewater treatment facilities for public markets using appropriate, low-maintenance technologies

Capacity and Type of Reuse Application

The wastewater generated from the public market contains high levels of organic matter (more than 600 mg/L biochemical oxygen demand [BOD]) and solids classifying it as high-strength wastewater. The wastewater is from the market comfort rooms (sinks and toilets) and from cleaning/rinsing of fish, meat, poultry, vegetables, etc. The treatment system that was designed for the Muntinlupa Public Market Wastewater Treatment Facility is an innovative combination of anaerobic and aerobic treatment coupled with filtration to meet local discharge standards. Since the available land area for the treatment system was very small, the solution was to place the 5,646 ft^2 (160 m^3) treatment system underneath a parking lot. The water recycling system treats 0.055 mgd (210 $m^{3/}$day) of wastewater per day, of which 50 percent is discharged to Laguna de Bay Lake, and 50 percent is reused for flushing toilets, watering plants, and street cleaning. This technology is being applied elsewhere in the Philippines and is suitable for other locations in the region.

Water Quality Standards and Treatment Technology

The technology is low-cost and low-maintenance, costing a third less to construct and nearly half of the monthly operation and maintenance costs of a conventional (activated sludge) plant. The system is an anaerobic baffled reactor coupled with a sequencing batch reactor, followed by media filtration and disinfection. Wastewater enters the tank from the bottom of the first zone of the anaerobic baffled reactor (ABR) where a granular sludge blanket is formed. As the wastewater flows upwards through the sludge blanket, organic particles are trapped and degraded by the anaerobic bacteria present in the sludge blanket. With each pass through subsequent chambers, the wastewater is further treated. When it arrives in the sequencing batch reactor (SBR), atmospheric oxygen is mixed with the flow to produce a highly treated oxygenated effluent. The final step is secondary clarification followed by disinfection using chlorine injection to meet local discharge standards. **Figure 2** shows the final stage of treatment - filtration through coco-peat, a waste product from coconut husk processing. Another project was demonstrated in the public market in which a container of ‘coco-peat,’ is used as a wastewater treatment filter. This is now being replicated for wastewater treatment in two schools in Muntinlupa City.

Figure 2
The public market was also the demonstration site of the use of "coco-peat" for wastewater filtration

The Philippine Revised Effluent Regulations of 1990 (DAO-35) sets national requirements for treated wastewater discharge into various receiving water body classes. New or proposed industries and wastewater treatment plants that will discharge to Class C (inland waters) must meet the following effluent standards (in addition to other limits for toxic compounds), as shown in **Table 1**.

Table 1 Philippine DAO-35 Class C wastewater discharge requirements

Parameter	Unit	Class C Requirements
Color	Pt-Co units	< 150
Temperature (max rise in degree Celsius in RBW)	°C rise	<3
pH (range)		6.5 – 9.0
COD	mg/L	< 100
Settleable Solids (1-hour)	mg/L	< 0.5
5-Day 20°C BOD	mg/L	< 50
Total Suspended Solids	mg/L	< 70
Total Dissolved Solids	mg/L	—
Surfactants (MBAS)	mg/L	< 5.0
Oil/Grease (Petroleum Ether Extract	mg/L	< 5.0
Phenolic Substances as Phenols	mg/L	< 0.1
Total Coliforms	MPN/100mL	< 10,000

All required parameters are being met by the system.

Project Funding and Management Practices

The system was installed over a 7-month period and cost 6.8 million Philippine pesos (P) ($130,000). The ongoing operating costs are P 27,000 per month, but an overall savings of P 15,000 per month is realized because of lower overall water consumption at the market.

Muntinlupa City formed a Lake Management Office (LMO) whose function is to manage and protect a portion of the nearby lake. Covering a total area of 14,589 ac (5,904 ha), the LMO took over operations of monitoring and controlling pollution of the lake area, implement environmental laws, regulating structures in the lake community and serving the fishermen who relied on the lake for their livelihood; The Local Government passed Local Ordinance No. 02-070 which stipulates proper disposal of wastewater and gives strict sanctions/fines for noncompliance.

Two employees regularly monitor the operation of the facility and report any problems that will occur during the operation to the Muntinlupa Public Market Cooperative.

Cost recovery is through a daily charge of $0.10 to individual stall owners. Mr. John Emmanuel Pabilonia, LINAW Team Leader for Muntinlupa City, confirmed that since its operation in 2006 Muntinlupa City has fully recovered the cost of the construction and the fees sustain the operation and maintenance of the facility.

Institutional/Cultural Considerations

As part of this project, a demonstration was done to help inform the public and policy makers about the unique solution and application of water reuse. The public market also hosted a demonstration project to show the public how a container full of coco-peat is used as a filter for final treatment in some wastewater treatment schemes being installed in two schools in Muntinlupa City (**Figure 2**). As part of the start-up of the system, former Muntinlupa City Mayor Jaime Fresnedi was asked to inaugurate the public market wastewater treatment plant by turning on a faucet of treated water for reuse (**Figures 3 and 4**).

The LGU's key partners include USAID's Local Initiative for Affordable Wastewater Project and the public market cooperative as direct stakeholder.

Successes and Lessons Learned

This project was able to demonstrate that proper incentives and identifying economic drivers can motivate local governments to prioritize environmental protection. In the case of Muntinlupa City, capital investment for environmental protection was not necessarily a high priority of the local government but with increased awareness on the environmental and health impacts of pollution along with the technical assistance that showed that capital investments can be recovered through user charges, the local government willingly paid for the construction of the wastewater treatment plant.

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Figure 3
LINAW Team Leader for Muntinlupa City John Emmanuel Pabilonia and former Muntinlupa City Mayor Jaime Fresnedi inspect the construction of the public market treatment facility.

Figure 4
Former Muntinlupa City Mayor Jaime Fresnedi, with former Environment Secretary Elisea Gozun (behind the Mayor) inaugurates the public market wastewater treatment plant by turning on a faucet of treated water for reuse.

Use of Wastewater in Urban Agriculture in Greater Dakar, Senegal: "Adapting the 2006 WHO Guidelines"

Author: Seydou Niang, PhD (Cheikh Anta Diop University of Dakar)

Senegal-Dakar

Background

Although the city of Dakar, Senegal, is located in a developed zone of favorable micro-climate and hydrology, its ecosystem is very sensitive (permeable sandy soil, shallow groundwater level). Furthermore, in the coastal aquifer (Thiaroye) northeast of Dakar City (**Figure 1**), severe problems concerning groundwater quality occur: 1) salinization due to seawater intrusion or dissolution of salts in the unsaturated zone, and 2) degradation from anthropogenic contamination (septic tanks leaking, latrines, urban agriculture). An important increase in nitrate concentration and salt load are the most pronounced impacts (Pfeifer and Niang, 2009).

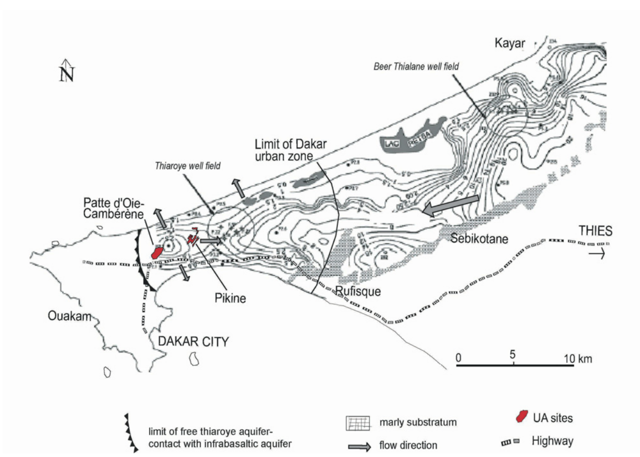

Figure 1
Hydrogeology and field situation (Pfeifer and Niang, 2009)

The scarcity of good quality freshwater resources in and around the city has led local populations to make greater use of wastewater in urban agriculture. Reuse of wastewater helps to sustain the city's thriving agriculture sector. Indeed, urban agriculture in and around Dakar is critical to the city's economy and livelihoods, ensuring more than 70 percent of the city's fresh vegetable supply and employing thousands of people (Ndiaye, 2009).This greater use of wastewater nonetheless imposes costs. Irrigation with wastewater, enhances salt accumulation in soils that releases to the shallow groundwater (Kass et al., 2005; Leal et al., 2009; Vengosh, 2003) and leads to microbiological contamination of crops, soils, groundwater and increases health risks for farmers, handlers and consumers (Ndiaye, 2009).

Project Rationale

This project sought to understand 1) how livelihoods and health of the local population could be improved through analysis of microorganisms and parasites from their source (wastewater, manure) to the markets where the produced vegetables are sold, and 2) how current urban agricultural practices (such as amendments, irrigation, use of pesticide) influence the environment, in particular the soil and groundwater quality.

The main result of the study was to provide policy makers with new guidelines based on the recommendations of WHO in 2006. The goals of these guidelines are, in terms of microbiological reduction, 6-7 $\log_{10}$ pathogen reduction through sets of measures:

- Wastewater treatment with 3-4 $\log_{10}$ pathogen reduction
- Die off (delay between last irrigation and harvesting) with 3-4 $\log_{10}$ pathogen reduction
- Washing of produce with 1 $\log_{10}$ pathogen reduction

Capacity and Type of Reuse Application

The main wastewater reuse site in urban agriculture in Dakar is Pikine. Of Pikine's total cultivated area of approximately 120 acres (50 ha), about 40 acres (16 ha) makes use of raw wastewater for irrigation. Usually, farmers divert wastewater from the sewage using pipes to load narrow wells located in their plot (**Figure 2**). From that well, they use water cans to irrigate crops such as lettuce, which grow rapidly—a crop characteristic that is important to farmers without secure land tenure. This practice of raw wastewater reuse for irrigation is being reduced due to upgrades/expansion of the city sewage system performance.

Water Quality Standards and Treatment Technology

In Senegal, the law which regulates wastewater use in agriculture is the Hygiene Code. It stipulates in its article 41 (Law N° 8371 of July 5, 1983) that dumping of rubbish or discharge of wastewater is forbidden on all lands where fruits and vegetables consumed raw are grown, where the edible parts are grown in contact with the rubbish or wastewater. Organic fertilizers, manure, and compost cannot be utilized within one month before harvesting. Fruits and vegetables should be soil free. If washing of fruits or vegetables is necessary, only potable water can be used, which then must be properly drained for disposal. (Gaye and Niang, 2010).

Figure 2
Loading narrow well with raw wastewater (Gaye and Niang, 2010)

This law, inspired by the 1992 WHO guidelines, needs to be updated based on the new WHO vision that now considers epidemiological risks instead of focusing on the calculation of microbiological concentration levels in irrigation water and vegetables. Currently, WHO recommends a set of measures to reduce risks related to the use of wastewater in urban agriculture.

Using the 2006 WHO guidelines, the study tested the viability of using three types of lagoon systems. The first treatment line is a combination of four ponds of 530 gallons (2 m^3) in series: two stabilization ponds, one pond planted with Cattail, and an immerged gravel filter pond. A surface and subsurface inverse vertical flow system circulates the water through the system. The second treatment line, with the same number and size of ponds, consists of one stabilization pond followed by three reed-planted ponds with free water surface and surface water flow. The third treatment line has one stabilization pond and three planted filters with *Vetivera* sp. For *E. coli*, all treatment lines achieved 4 log units reduction, and for *Ascaris* eggs 100 percent removal was achieved everywhere (Niang *et al*. 2009).

Institutional/Cultural Considerations

The local land tenure situation constitutes the biggest obstacle to investments of farming improvements and expansion. While there is one Council Order that provides some protection for local access to land, farmers often lack clear legal right to specific plots. As a result, plots are often taken and used for housing; therefore, farmers are reluctant to make medium to long-term investments.

A clear policy statement by public health officials concerning the use of wastewater under certain conditions will help farmers secure a more formalized status rather than potentially being in violation of the law.

As farmers are placed under the stress of losing their plot because of housing or their harvest because of hygiene issues, they prefer fast growing crops like lettuce.

Successes and Lessons Learned

In applying the 2006 WHO guidelines to Pikine, the following results were achieved:

- Treatment of wastewater with the three lagooning systems showed total removal of parasites and achieved 3-4 log unit reduction of *E. coli*.
- A two-day delay between last irrigation and harvesting of lettuce achieved 77 percent reduction of roundworm eggs on lettuce (from 35 eggs/g to 8 eggs/g) and 1 log unit reduction for *E. coli*.
- Twenty-six percent of farmers who were provided with masks, gloves, and boots had

roundworm infection compared 50 percent of farmers who did not use protective equipment.

- For disinfection of lettuce with bleach at the household level, 42 women have been involved in the test. We advised the use of one capsule (cap of the bottle) of bleach at 8° (around 6 mL = 0.2 fluid ounces) in 2.6 gallons (10L) of tap water (7.6 mg Cl/L) as a solution for disinfection of lettuce being soaked for 30 minutes before rinsing with tap water. The results have shown only 12 percent of women had lettuce still contaminated with *E. coli*.

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The Multi-barrier Safety Approach for Indirect Potable Use and Direct Nonpotable Use of NEWATER

Author: Harry Seah, MSc and Chee Hoe Woo, MSc (PUB Singapore)

Singapore-NEWater

Project Background or Rationale

Singapore, being a small island city-state of about 270 square miles (700 square km) and a population of 5 million, has no natural aquifers or groundwater, and relies on rainfall from catchments and raw water imported from the neighboring Johor state in Malaysia. These sole water sources, however, are subject to the vagaries of nature, leaving Singapore vulnerable to water shortages.

In order to achieve a sustainable and robust water supply to meet increasing water demand, Singapore has diversified its water sources, termed the 4 National Taps, namely:

- Imported water from Johor, Malaysia
- Local catchment water
- NEWater
- Desalinated water

NEWater, high grade reclaimed water of drinking water standards, is key to achieving water sustainability in Singapore because of the multiplier effect through infinite recycling within the water system.

Capacity and Type of Reuse Application

Currently, NEWater is supplied from five NEWater factories in Singapore, with total capacities of 122 mgd (554,600 m^3/day). The total capacities of the NEWater factories are projected to reach some 192 mgd (873,000 m^3/day) by 2020.

Because it is ultra clean, NEWater is ideal for industry use, such as wafer fabrication processes. NEWater is mostly used for direct nonpotable use (DNU) into wafer fabrication and electronics industries, where the necessary water quality is more stringent than that for drinking, as well as in commercial and institutional complexes for air-conditioning cooling purposes. This frees up potable water for domestic use.

In addition, NEWater supplements Singapore's potable water supply via planned indirect potable use (IPU). Planned IPU involves blending NEWater with raw reservoir water, and then subjecting the blended water to the same conventional water treatment process as raw reservoir water to produce potable water.

In February 2003, the Public Utilities Board (PUB), the national water agency of Singapore began pumping 2 mgd of NEWater into reservoirs for IPU. It was increased progressively to about 2.5 percent of total potable water consumption in 2011.

Treatment Technology and Water Quality Standards

NEWater is produced from treated used water (wastewater) that is purified further using advanced membrane technologies and ultraviolet (UV) disinfection, making the water ultra-clean and safe to drink.

The U.S. Environmental Protection Agency (EPA) Primary and Secondary Drinking Water Standards (Safe Drinking Water Act) and WHO Drinking Water Quality Guidelines are the benchmarks set for NEWater quality.

Project Management Practice

To ensure that NEWater is of a quality safe for IPU, the multiple safety barrier approach is rigorously adopted through enforcement, plant design, plant operation, plant maintenance and water quality monitoring.

This approach is audited bi-annually by an External Audit Panel comprised of 2 experts from the local tertiary institution and 5 overseas experts of international standing, and also by an Internal Audit Panel.

The multi safety barrier approach starts from thesource and extends to taps in households in the following stages:

- Source control at the industries to ensure the used water received at the water reclamation plants (WRPs)[1] will be fully treated and provides a consistent good quality secondary effluent as feedwater for NEWater production;
- More than 85 percent of used water is used from domestic sources to provide additional safety through dilution
- Comprehensive secondary wastewater treatment is used to provide consistent good quality effluent for NEWater production
- Microfiltration (MF)/Ultrafiltration (UF) process, reverse osmosis (RO) process, and ultraviolet (UV) disinfection in NEWater production
- Natural attenuation in surface reservoirs
- Conventional water treatment process of coagulation, flocculation, sand filtration and disinfection

The approach is further enhanced by a Sampling and Monitoring Programme (SAMP), which covers the entire delivery chain of NEWater to determine the suitability of NEWater for IPU and DNU; and a strict operating philosophy.

The SAMP is comprised of a comprehensive physical, chemical and microbiological sampling and analysis of water samples. To-date, 300 parameters are monitored including emerging contaminants of concern listed in the USEPA Priority List of Contaminants.

The operating philosophy adopted in NEWater factories is based on operating with reference to the baseline performance of the plants. Such mode of operation is to maintain the water quality of the treated permeate close to the expected baseline readings, which are well within the WHO Drinking Water Guidelines and EPA Drinking Water Standards, during the daily operations.

NEWater Quality

Since the operation of the first membrane (demonstration) plant began in year 2000 to produce NEWater, water analysis through grab sampling and on-line monitoring has shown consistently that NEWater quality is of drinking water standards, even as the membrane ages over the expected life span of 5 years.

Table 1 shows the NEWater quality of selected parameters, out of the 300 parameters currently monitored for NEWater under the SAMP.

Institutional/Cultural Considerations

An important part of the NEWater success story is its high public acceptance. This was achieved through a long and extensive public education program done in various phrases.

Before NEWater's launch, extensive briefings were held for critical groups, which comprised of community leaders, business communities and government agencies. An educational tour was also organized to bring the media from Europe and the United States to observe the various places where water reuse has been practiced for many years. A documentary on the technology of NEWater and the water reuse experience of other countries was also produced and televised.

Successes and Lessons Learned

NEWater is the product of years of investment in used water infrastructure and research on water technologies. Countries interested in water reuse on a municipal scale would need to have a comprehensive used water infrastructure in place.

Accurately pricing the reclaimed water is also crucial for the reuse program's long term financial sustainability.

[1] Water Reclamation Plants in Singapore refer to treatment plants that provide secondary treatment to wastewater, via the activated sludge process.

Table 1 Quality of NEWater since year 2000

Parameter	Unit	Analytical Methods	Detection Limits	Value
Physical Parameter Controls				
TOC	µg/L	Sievers 820 TOC Analyser	20	40 to 100
SS	Mg/L	USEPA 160.2	2.5	<2.5
Turbidity	NTU	USEPA 180.1	0.1	<0.1
Trace Contaminants				
Total estrogen	µg/L	NGCMS_1124	0.003	<0.003
Estrones (E1)	µg/L	NGCMS_1124	0.001	<0.001
17β-estradiol (E2)	µg/L	NGCMS_1124	0.001	<0.001
Ethinylestradiol (EE2)	µg/L	NGCMS_1124	0.001	<0.001
Ibuprofen	µg/L	LC-MS/MS	0.005	<0.005
Naproxen	µg/L	LC-MS/MS	0.005	<0.005
Gemfibrozil	µg/L	LC-MS/MS	0.005	<0.005
N-nitrosodimethylamine (NDMA)	ng/L	PTV-GC/MS	2	<2 to 10
1,4 Dioxane	µg/L	USEPA 8270C	1	<1
Methyl Tertiary Butyl Ether (MTBE)	µg/L	USEPA 8260B	5	<5
Polychlorinated biphenyls (PCBs)	µg/L	USEPA 8082	0.2	<0.2

Public acceptance is crucial to the success of such projects. It is thus critical to translate complex technical jargon into terms that are easily understood by the public. In order to sustain people's acceptance of NEWater, the NEWater Visitor Centre was set up in early 2003 to for the visitors to appreciate the philosophies and technologies used in the production of NEWater.

Moving forward, the production costs of NEWater can be further lowered through the adoption of new technologies, such as using membrane bioreactors (MBR), which will consume less energy, and will result in lower costs.

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Turning Acid Mine Drainage Water into Drinking Water: The eMalahleni Water Recycling Project

Author: Jay Bhagwan (Water Research Commission)

South Africa-eMalahleni Mine

Project Background or Rationale

Population growth, rising service levels and economic development means that in many parts of South Africa, demand for water is growing faster than the supply available.

In a first for South Africa, a pioneering public-private partnership (PPP) between eMalahleni Local Municipality and two leading coal mining companies (BHP Billiton and Anglo Coal) has led to the establishment of a major mine water reclamation plant. Acidic, saline, underground water from four nearby coal mines is treated and purified to drinking water standards and supplied to the Municipality.

This type of collaboration between two large mining corporations has few precedents in South Africa, and highlights the growing importance attached to responsible environmental management. This innovative partnership has averted a water supply crisis in eMalahleni. At the same time, a major water contamination problem and environmental hazard has been transformed into a valuable resource which meets the needs of a range of users, safely and reliably.

Capacity and Type of Reuse Application

The eMalahleni Municipality is the main user and now receives 4.2 million gallons (16 megalitres) of safe, treated drinking water each day from the reclamation plant to boost domestic water supplies. Since April 2009, this amount increased to 5.3 million gallons (20 megalitres) per day. The outcome of this solution is based on ten years of research by Anglo Coal into water quality management options identifying a range of possible treatment technologies. No less than 13 different treatment technologies to remove heavy metals and sulphates were evaluated in demonstration projects. In 2004, Anglo Coal short-listed seven technologies for further evaluation, and after extensive investigation, opted for a technology that relied on advanced membrane desalination. The key advantages of this technology were low life-cycle costs, a high rate of water recovery (greater than 99 percent), and waste streams suitable for reprocessing and reuse.

A 31,700 gallons (120 m^3/day) pilot plant began in 2005 to test the technology rigorously over a three month trial. Its performance exceeded expectations and Anglo Coal moved swiftly to develop a much larger plant, able to deliver 5.3 million gallons (20 megalitres) a day of potable water, with further capacity to provide safe industrial-grade water for routine mining operations.

Water Quality Standards and Treatment Technology

The treatment process is designed to produce water quality, which meets South African National Standard for Drinking Water Quality (SANS 0241 Class 0 potable water) and uses the High Recovery Precipitating Reverse Osmosis (HiPRO) process from which low salinity product water is generated by the membrane process. This design's chief characteristic is that it makes use of Reverse Osmosis to concentrate the water and produce supersaturated brine from which the salts can be released in a simple precipitation process. The project's schematic is shown in **Figure 1**.

This technology offers the following key advantages:

- Very high recovery
- Simple system configuration
- Easy operation
- Low operating costs
- Low capital costs
- Minimum waste

The plant is designed to treat 6.5 mgd (25 megalitres/day) of acid mine drainage (AMD) with a recovery consistently greater than 99 percent, producing potable water with a guaranteed total dissolved solids (TDS) of under 450 mg/L (SABS

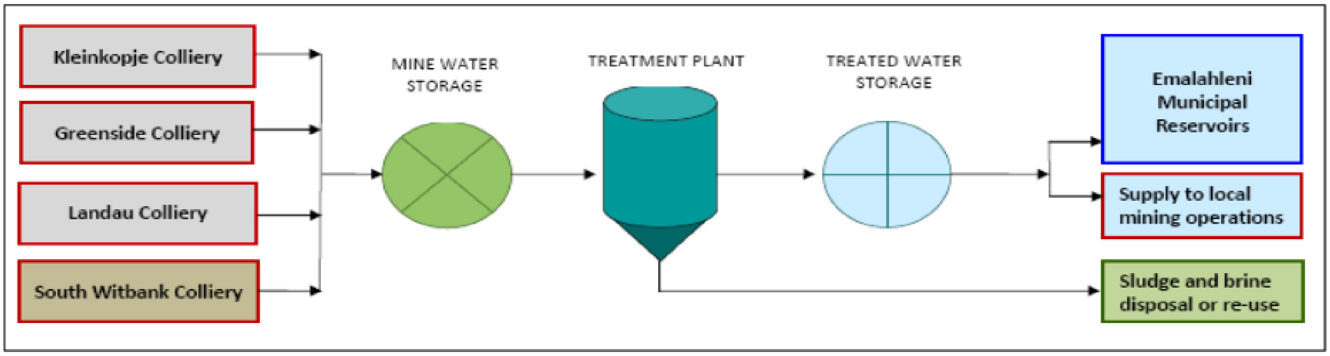

Figure 1
Schematic diagram of key component of the reclamation approach (Source: Gunther and Mey 2006)

Class 0). The treated water is stored in two large concrete reservoirs before being pumped to a municipal reservoir for distribution to users in eMalahleni. Additional water is piped to a number of Anglo Coal sites for domestic use and for mining activities such as dust suppression.

By-products of the treatment process are 26,400 gallons (100 m^3) of brine and 100 tons (90,700 kg) of gypsiferous waste each day. Plastic-lined evaporation ponds are used to concentrate the brine further and Anglo Coal is exploring a number of cost-effective options for re-use. Gypsum-based wastes will be used in building construction, and the intention is to establish a market for gypsum-based building products on a large scale.

A second phase, completed in 2010, added a further 2.1 to 2.6 mgd (8-10 megalitres/day) of industrial quality water for use on nearby mines and plans are in place to increase the capacity to 13 mgd (50 megalitres/day).

Project Funding and Management Practices

Financing of this option of treating acid mine water was way beyond the means of the municipality, and any proposed alternatives for augmentation had a long lead period before any water was supplied. The fact that the client eMalahleni Municipality realized this constraint and the constraint of managing such an advanced technology, the only lucrative option was this long term arrangement to purchase the water. The mines needed to continue to dewater to sustain its ongoing operation and where in a better position to raise the capital, based on the all-round benefits which were envisaged to accrue. The purchase of the treated water made the project viable for the mining companies, while meeting the municipality's urgent need for additional water supplies. Ingwe Collieries owns South Witbank Colliery, where mining activities ended in 1969. In 2005, BECSA's Ingwe Collieries entered a Joint Venture with Anglo Coal to develop the R296 million eMalahleni Water Reclamation Plant.

Successes and Lessons Learned

The water reclamation plant and project offers a number of direct benefits. For the municipality, over and above an additional assured supply of clean water, perhaps the three most important benefits are cost-effectiveness, delivery of safe drinking water that requires no further treatment, and the technical expertise and financial resources of two major mining companies who funded the plants' capital cost of nearly US $43 million. For the mines, there is a small financial loss in subsidizing this treated water of the cost of treatment is US $1.50 per 264 gallons ($m^3$) and sold to the Municipality for USm$1.00 per 264 gallons ($m^3$). However the environmental and social gains are much higher in that they have avoided serious future environmental damage.

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Durban Water Recycling Project

Author: Jay Bhagwan (Water Research Commission)

South Africa-Durban

Project Background or Rationale

Water supply sources within South Africa are becoming ever more limited, while the need for alternative solutions is becoming increasingly more important with reuse becoming more attractive over traditional solutions.

The city of Durban in the Ethekweni municipality, located on the east coast of South Africa, was faced with the challenge of sewage capacity constraints and the high cost of constructing a new outflow or marine outfall pipeline. They put together plans to increase capacity by building a duplicate sewer line, but found that the costs of wastewater disposal would be too high. The other option available was effluent recycling for reuse. However, even this option posed a financial and technical management challenge. The solution that emerged is an example of a Public Private Partnership (PPP) that harnesses the synergies of the partners to achieve an outcome that is unprecedented in the water industry in South Africa. The projects demonstrate innovative approaches to the sustainable development of water resources, minimization of water consumption and environmental pollution, and the achievement of technically challenging water and wastewater treatment goals. The result was the construction of a secondary waste water treatment plant and a water recycling plant, aimed at treating and supplying treated effluent to a level which was acceptable to an industrial recipient (Mondi Paper Mills) funded and managed through a partnership with the private sector Veola Water Services (VWS). This demonstrated that by pooling resources and expertise in a PPP, and by focusing on long-term sustainability goals, all participants can benefit, including the environment.

The Durban Water Recycling Project demonstrates that innovative approaches to water resource management, environmental management, wastewater treatment technology and institutional arrangements can yield exceptional results.

Capacity and Type of Reuse Application

The resulting solution was a plant consisting of an upgrade of the existing activated sludge process from 12.9 mgd to 19.9 mgd (50 megaliters/d to 77 megaliters/d), the construction of a new 12.3 mgd (47.5 megaliters/d) tertiary plant (**Figure 1**), refurbishment of the high level storage tank and the installation of the reclaimed water reticulation system. This solution produced treated effluent (12.1 mgd or 47 megaliters/d) for reuse in industrial application. Mondi uses the reclaimed water for the production of fine paper and is extremely sensitive to processed water quality and its impact on paper brightness.

Figure 1
Construction of the Durban Wastewater Recycling Plant (Photo credit: Ethekweni Metro Water Services)

Water Quality Standards and Treatment Technology

The technology produces reuse water of a quality which has to comply with 32 contractually specified parameters based on regulatory requirements. The activated sludge process is a conventional design and serves to remove 95 percent of the incoming COD and 98 percent of the incoming ammonia loads. Typically, activated sludge plant effluent COD and ammonia concentrations are 15 mg/L and 0.2 mg/L respectively. The first step in the tertiary treatment process is lamella settling. Poly Aluminum Chloride (PAC) is placed in the water leaving behind the lamella settlers and is employed for the removal of iron. The final reclaimed water achieves iron levels of 0.04 mg/L, which is five times lower than the South African standards for class 1 potable water (SABS 241:1999). The dual media filtration step is the last solids removal barrier in the process. Iron precipitate is removed in the dual media filter. The final step is ozonation used to break up the remaining non-biodegradable organic compounds, including color causing compounds. Mondi Paper's reclaimed water specification includes 23 parameters that are measured in the South African potable standard (SABS 241:1999) of these parameters; Mondi's specification meets or exceeds the potable standard for 77 percent of the parameters for class 1 potable water. In practice, VWS operationally meets or exceeds the Class 1 potable standard for 96 percent of the parameters. The Class 1 potable water standard gives the water quality levels that are known to be acceptable for lifetime human consumption.

Project Funding, Management Practices, and Benefits

The preliminary and primary wastewater treatment process is comprised of screening, degritting and primary settling operations; performed by Ethekweni Metro Water Services (EMWS). Meanwhile, the effluent from the primary settling tank is fed to the activated sludge plant operated by VWS. The funding of the capital for upgrade and new technologies, as well as the risks of meeting the water quality is undertaken by VWS under a 20 year production, operation and transfer concession. The incentive rested on the fact that the industry partner was prepared to accept a treated effluent water quality at a tariff, which was attractive and with offered high supply assurance. For the private sector it was a financially viable proposition, and for the municipality there were significant benefits to be achieved.

For EWS, the project has delayed capital investment for the increased marine outfall pipeline capacity; it also has delayed capital investment for future bulk potable water supply infrastructure. There was no capital investment and risks associated with the recycling plant; and a long term revenue stream from a levy raised on the production of recycled water was created thereby reducing cost of water services to Durban's citizens.

For Mondi the benefits were a 50 percent reduction on normal industrial water tariffs, representing a significant cost saving in Mondi's paper production. The project provided a higher assurance of water supply for the functioning of Mondi and greater security in terms of additional water requirements.

Successes and Lessons Learned

The success of the project demonstrated a true partnership between the public and private sectors and the success of the partnership lies in the mobilization of the inherent strengths of both sectors. Some of these key outcomes are as follows:

At operational capacity 12.3 mgd/47.5 megaliters/d) the reclamation plant will meet 7 percent of the city's current potable water demand and will reduce the city's treated wastewater output by 10 percent. EWS currently treats 121.3 mgd (470 megaliters/d) of wastewater. Of this volume, approximately 200 51.6 mgd (megaliters/d) is discharged into the sea as screened and degritted wastewater. The reclamation project reduces the city's total treated wastewater discharge by 10 percent and reduces the partially treated load on the marine environment by up to 24 percent. Further, the volume of potable water saved on a daily basis afforded the opportunity to extend supply to up to 220,000 households in the greater Durban area.

Individually the water treatment steps employed in the Durban Water Recycling process are relatively standard in terms of water industry technologies. Together, however, the treatment steps create a highly specialized process, tailored specifically to meet the quality requirements of the main client, Mondi Paper Mills. The treatment of raw wastewater from both domestic and industrial sources to a potable standard, within the financial pressures of the business environment, is a significant technical achievement.

This 20-year concession project was the first PPP of its kind in South Africa. Within the South African context, the project broke new ground in its approach to manage and implement water projects and may be regarded as model for future PPPs in South Africa, and possibly elsewhere. The acceptance of PPPs and the involvement of the private sector in business opportunities for the provision of water services in South Africa are enhanced by the success of the Durban Water Recycling Project.

This project has also changed the way industry in South Africa views wastewater. Sewage is no longer regarded simply as a waste product, but a beneficial resource spurring many new initiatives which have unlocked innovation and technology.

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Risk Assessment for *Legionella* sp. in Reclaimed Water at Tossa de Mar, Costa Brava, Spain

Authors: Rafael Mujeriego, PhD (Universidad Politécnica de Cataluña) and Lluis Sala, (Consorci Costa Brava)

Spain-Costa Brava

Project Background or Rationale

Tossa de Mar is a Mediterranean coastal resort city in southern Costa Brava (Girona, NE Spain) and member of Consorci Costa Brava (CCB), the water supply and sanitation agency for Costa Brava. Tossa de Mar's population goes from 6,000 people in winter to 60,000 people in summer. Its drinking water use is 264 mgd (1 m^3/year), of which 20 percent comes from local sources and the remainder from external sources: 52 percent is groundwater from the Tordera river aquifer and 28 percent is desalinated water from Blanes desalination plant, both located 9 miles (15 km) southwest. Tossa de Mar was one of the leading cities in Costa Brava to recognize the benefits of turning wastewater into reclaimed water. Reclaimed water is now a new municipal water resource for non-potable use, with lower production and conveyance energy requirements than the conventional sources.

Capacity and Type of Reuse Application

The water reclamation plant (WRP) of Tossa de Mar has a capacity of 0.22 mgd [35 m^3/hr (840 m^3/day)] upgradable to 0.89 mgd (140 m^3/hr). The current WRP capacity represents 13 percent of the potable water use during the peak tourist season. It includes: coagulation-flocculation, lamella settling, rapid sand filtration, and a combined disinfection process with sodium hypochlorite and UV light. Reclaimed water is stored in a 185,000 gallon (700 m^3) tank, where it is further chlorinated and mixed, and then pumped to the reclaimed water distribution system. Reclaimed water use for street cleansing and public garden irrigation began in 2003 by water tanks loading at a hydrant located at the doorstep of the WRP. By 2007 a reclaimed water distribution system was already in operation. The pipeline was brown in color with a blue plastic film that says "Atención: Agua no potable". By mid 2011, the distribution system had reached a length of 3.5 miles (5.7 km) after an investment of US $477,000 (365,000 €) from municipal and regional government sources. The distribution system provides reclaimed water to the main municipal services and landscape areas, fire hydrants, and other publicly-owned facilities, such as the county's dog shelter (**Figure 1**) as well as to public spaces in new residential areas. In addition, landscape irrigation with reclaimed water at the Sa Riera Park is indirectly supplying recharge water flows to the local stream, avoiding its total summer desiccation and protecting its fragile aquatic ecosystems.

Figure 1
Reclaimed water use at Tossa de Mar dog shelter (Photo credit: Lluis Sala)

Water Quality Standards and Treatment Technology

Spanish water reclamation and reuse regulations are established by Royal Decree 1620/2007. Reclaimed water quality is defined by four main parameters: parasitic helminth eggs, *E. coli*, suspended solids, and turbidity. Other micro-biological parameters, like *Legionella* sp. and physico-chemical parameters are applicable to specific uses of reclaimed water. Compliance is determined by the 90 percentile (P90) of the series of water quality parameters recorded during a water reuse period. Applicable limits for current reclaimed water uses in Tossa de Mar are those for unrestricted urban use (Quality Use 1.2) with SS, turbidity, parasitic helminths and *E. coli* P90 concentration limits below 20 mg/L, 10 NTU, 1 egg/10L and 200 cfu/100mL, respectively. Future mid-term plans include the supply of reclaimed water for irrigation of private gardens, which requires compliance with quality limits for unrestricted residential use (Quality Use 1.1): P90 values below 10 mg/L for SS, 2 NTU for turbidity, 1 egg/10L for parasitic helminths and absence of *E. coli* (cfu/100 mL).

Since 2007, CCB is conducting an extensive assessment of the overall *Legionella* infection risk posed by the use of reclaimed water for irrigation of urban and private gardens, following the Technical Guidelines for the Prevention and Control of Legionellosis established by the Spanish Ministry of Public Health and Consumer Affairs. These technical guidelines are used to assess such public health risk, based not only on the microbiological quality of the water (concentration of total aerobic bacteria, TAB < 105 cfu/mL), but also on several other parameters and characteristics of the materials used in the distribution and application system, such as pipelines and sprinklers, among others. The upper limit of this index is 100 and anything below 60 is considered to be a "low infection risk" condition.

The studies conducted since 2007 indicate that: 1) TAB concentrations increase as water flows away from the point at the WRP where sodium hypochlorite is applied; 2) changes in TAB concentrations along the network system provide valuable information on how to manage the regrowth process and to maintain the network within the safety limits required by the Technical Guidelines; and 3) the overall infection risk resulting for spray irrigation in urban areas, considering the most unfavorable points of use (sprinklers) and under the most unfavorable microbiological conditions recorded, is just below 60 units, the limit officially set for "low infection risk" conditions.

This monitoring program also provided useful information for determining whether re-chlorination is needed and where to apply it. Furthermore, Tossa de Mar complies with the requirements of Royal Decree 865/2003 (2003) relative to the prevention and control of Legionellosis, by systematically cleaning and disinfecting all the sprinklers under its responsibility, whether they use drinking or reclaimed water.

Project Funding and Management Practices

The investment completed so far amounts to US $477,000 (365,000 €), which was provided by the Catalan Water Agency (CWA), CCB, Girona's provincial government and the city of Tossa de Mar. Operation and maintenance of the water reclamation plant has been assured by CCB, while operation and maintenance of the reclaimed water distribution system has been assured by the city's technical services. CCB is completing the official permitting process necessary to become a wholesale reclaimed water producer and supplier as prescribed by CWA. At that time, CCB will be able to establish the appropriate supply contracts with cities, which will be responsible for managing the technical and economic aspects of reclaimed water distribution to end users. In the event that CCB becomes a wholesale supplier, the responsibilities will be the same, as delegated under Spanish Water Reuse Regulations (RD 1620/2007).

Institutional/Cultural Considerations

The use of reclaimed water in Tossa de Mar was prompted by the severe drought of the late 1990s and early 2000s. The high quality of reclaimed water and the clear benefits of its use for non-potable uses quickly raised a very positive perception from local and seasonal residents. Since then, CCB has promoted a high quality branding through CCB's website, municipality website, and Facebook page, of the non-potable use of reclaimed water in Tossa de Mar. Technical personnel wear white lab coats while conducting the on-site water testing and sampling, which has improved the citizen's perception of the high microbiological and aesthetic quality of reclaimed water (**Figure 2**).

Figure 2
Reclaimed water quality monitoring in Tossa de Mar (Photo credit: Lluis Sala)

Successes and Lessons Learned

Water scarcity and the favorable assessment of the energy balance of the municipal water cycle were the main factors for the project development. The quick and effective response of municipal services in close collaboration with CCB and the CWA were instrumental for the project success. The high reclaimed water quality, its high quality branding, the systematic follow-up studies and the educational programs implemented have all contributed to assure a very positive perception and acceptance from local and seasonal residents. The very favorable results of the *Legionella* risk assessment study have paved the way for the extension of the use of reclaimed water to irrigation of private gardens and possibly the supply of reclaimed water for toilet flushing in the very near future.

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Sam Pran Pig Farm Company: Using Multiple Treatment Technologies to Treat Pig Waste in an Urban Setting

Authors: Pruk Aggarangsi, PhD (Energy Research and Development Institute-Nakornping, Chiang Mai University, Thailand)

Thailand-Pig Farm

Project Background or Rationale

In Thailand, there are numerous pig farms which must treat the pig effluent in order to meet the standards set by the Pollution Control Department (PCD) of Thailand's Ministry of Natural Resources and Environment (MNRE) (MNRE, 2005). This case study illustrates the use of Upward-flow Anaerobic Sludge Blanket (UASB) reactors as adopted by one pig farm, the Sam Pran Pig Farm, in Nakhon Pathom Province, located approximately 40 miles (65 km) southwest of Bangkok.

Capacity and Type of Reuse Application

The Sam Pran Pig Farm Company raises between 5,000 and 8,000 pigs at a time, ranging from 22 to 220 pounds (10 to 100 kg) each, with an average size of 130 lbs (60 kg). The pig farm has 18 single level, open pig stables with an average size 45 ft by 280 ft (13.5 m by 85 m). The pigs generate solid fecal matter at a rate of 860 lb/day (390 kg/day) and liquid waste including urine, stable wash water and fecal liquid run off at a rate of 29,000 gallons (110 m^3/day). All waste generation is collected daily.

The farm utilizes two sets of channel digesters (CDs) each integrated with a UASB reactor plus additional subsequent treatment steps (including aeration and water hyacinth ponds) to process wastewater. These reactors produce biogas (methane and carbon dioxide) via an anaerobic decomposition process that eliminates more than 90 percent of the biochemical oxygen demand (BOD) and chemical oxygen demand (COD). The system also removes most solids from the wastewater. The waste is converted into fertilizer, biogas and water for washing the pig barns.

Figure 1
Composition of the system at Sam Pran (from top to bottom): channel digester and solids drying beds for use as fertilizer, aeration tank, water hyacinth pond, and biogas-fueled generator.

Treatment Technology

The top industrial uses of UASBs include treatment of wastewater from breweries, distilleries, other beverage and fermentation operations, the food processing industry, and pulp and paper operations. While UASBs are generally used in many applications for rapid treatment of wastewater with high BOD, the treatment system for Sam Pran farm is specially designed by Chiang Mai University to cope with specific pig waste. The system consists of one channel digester with serial-integrated UASB module running at 6-7 days Hydraulic Retention Time (HRT).

Wastewater Treatment System Performance

After a 6-month system stabilization period, the performance of the system was measured. The system produced 440-880 lbs (200-400 kg) per day of fertilizer, 7,000 to 14,000 cubic feet (200-400 m3) biogas per day (which produces 300-600 kW.h per day of electricity) and 26,400 gallons (100 m3) per day of recycling water acceptable for washing the pig barns. The performance of the treatment system is designated in **Table 1**.

Project Funding and Management Practices

In 2004 when Sam Pran farm initialized the project, a total investment cost of the digester, approximately 3.0 million THB ($100,000 USD), 20 percent is funded by Energy Conservation Fund through Livestock biogas subsidizing program by Thailand Ministry of Energy. The farm owner has to cover the rest of the investment including the land and electricity generation equipment.

Institutional/Cultural Considerations

The project seems to be a best model in practice for collaboration between community, local government and academia to find and implement the best solution to this difficult waste management problem.

Successes and Lessons Learned

Sam Pran farm founded their business more than 30 years ago in the area designated as the pig raising community away from the residential area. The growth of city's population forced an expansion of the residential area in all directions. Currently, Sam Pran farm is located in the city's municipal area. Thus, the farm has to conform to strict regulations in terms of effluent and odor control in order to continue their business. Anaerobic digesters were their only option in both the technical aspect and land use effectiveness.

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Table 1 Performance of installed CMU CD+UASB System in Sam Pran Farm

Parameters	Digester Influent	Flow Leaving UASB towards Aeration Tank	Final Discharge	Thailand Waste Water Standard
pH	7.1	7.7	7.8	5.5-9.0
BOD^5 (mg/L)	3,245	86	327	100
TCOD (mg/L)	1,513	306	65	400
TKN (mg/L)	463	397	261	200
TSS (mg/L)	812	150	59	200

TKN = Total Kjehldahl nitrogen (i.e. the combination of organically bound nitrogen and ammonia in wastewater)

Evaluating Reuse Options for a Reclaimed Water Program in Trinidad, West Indies

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Trinidad and Tobago-Beetham

Project Background or Rationale

The island of Trinidad is the most southern island of the Caribbean and covers an area of approximately 1,841 mi^2 (4,768 km^2). Trinidad's economy is primarily energy based and there are industrial estates concentrated in the southern section of the island. The Beetham Wastewater Treatment Plant (WWTP) effluent could therefore provide a supply that is not severely affected by seasonal variation, as well as reduce the demand on high quality potable water in applications where appropriately treated, non-potable supply could suffice. There is also a thriving agricultural sector with large farms located throughout the island.

The island has experienced continued economic growth over recent years and consequently there was an increasing demand for water. This steady increase in water demands prompted the Government of the Republic of Trinidad and Tobago (GORTT) together with its Water and Sewerage Authority (WASA) to capitalize on the valuable resource available from the Beetham WWTP, which is located towards the northwestern section of Trinidad just east of the capital city of Port of Spain.

Capacity and Type of Reuse Application

The Beetham WWTP is the largest wastewater treatment plant in Trinidad. The plant treats approximately 21 mgd (80 ML/d) of wastewater collected from Trinidad's capital city Port of Spain and its environs. The wastewater entering the plant undergoes preliminary treatment comprising screening and grit removal. It then receives secondary treatment from an activated sludge process that incorporates nitrogen removal. Conventional gravity clarifiers provide solid-liquid separation and the clarified effluent undergoes ultraviolet disinfected before it is discharged to the Black River that flows to the Gulf of Paria.

The Beetham WWTP, which was commissioned in 2005, consistently meets its effluent design criteria. **Table 1** summarizes the average effluent quality for the period 2005 to 2010 together with the plant's design criteria.

Table 1 2005 - 2010 average WWTP influent, effluent data compared to design criteria

Parameter	Influent	Effluent	Design Criteria
Flow, ML/d	78	75	80
pH	7.2	7.7	6-9
TSS, mg/L	163	4	20
BOD, mg/L	125	2	20
COD, mg/L	301	18	-
NH_4-N, mg/L	15.4	0.2	-
Total P, mg/L	2.9	1.7	-
Residual Chlorine, mg/L			0.01
Fecal Coliform, #/100 mL		85	200

The flow data from the Beetham WWTP over the period July 2005 to December 2010 indicated that the plant maintained an average effluent flow near its design capacity of 21 mgd (80 ML/d) throughout the dry season. This is in contrast to the monthly average rainfall records as shown in **Figure 1**.

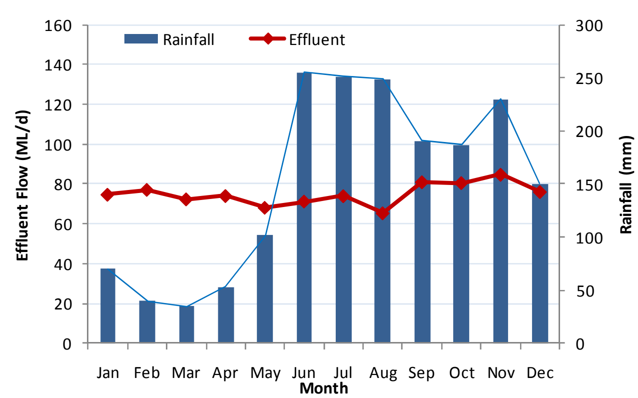

Figure 1
Average WWTP effluent flow and monthly average rainfall

The projected water demand for 2015 shows domestic users as having the greatest demand of 195 mgd (736 ML/d)followed by industry at 65 mgd (245 ML/d) and then irrigated agriculture at 7 mgd (27 ML/d) (WRA, 2001; WASA, 2007). The options therefore focused on reuse applications in urban, agricultural, industrial and indirect potable reuse.

Water Quality Standards and Treatment Technology

Currently there are no local reuse water quality standards or regulations for Trinidad and hence, standards for the Beetham Reuse Project were adopted from the United States, specifically the states of California and Florida. These states were selected because they have significant reuse programs in place and well established regulations to govern these programs.

Project Funding and Management Practices

Based on the reuse possibilities and the required treatment level, reuse options were developed that considered the location of the end users, the route taken to deliver the reclaimed water, and the water quality requirements of the end users. Four general options were formulated as follows:

Option 1: Reclaimed Water (RW) delivered to industrial users via marine routes

Option 2: RW delivered to primarily industrial end users plus some agricultural end users via marine route and then overland

Option 3: RW delivered to primarily industrial end users plus some agricultural end users via overland routes

Option 4: RW delivered to agricultural, industrial and other end users via overland routes

Three end uses were evaluated within each option as follows:

a. Unrestricted urban reuse, medium quality industrial

b. Food crop irrigation, indirect water supply augmentation, general purpose industrial

c. Aquifer recharge by injection

Life-cycle cost analyses were performed for the 12 alternations. Two funding mechanisms were evaluated, private equity in the form of build-own-operate-transfer (BOOT) contract, and funding by GORTT. Non-monetary decision variables also included technical, social, and environmental factors that would influence the reuse program implementation. These were ranked using a numerical scoring system.

The highest rated option, based on a benefit to cost ratio, was a multi-user concept that would provide reclaimed water for food crop irrigation, indirect potable water augmentation, and general purpose industrial use.

Institutional/Cultural Considerations

While reclaiming WWTP effluent for reuse purposes is new to Trinidad, it appears the concept would be acceptable to the general public based on a short-term project in which secondary effluent was dyed, chlorinated, and used for urban irrigation during a significant drought in 2009. However, the program has not moved forward. One of the biggest issues keeping the program from being implemented is the outdated water rates that undervalue potable water such that a true comparison with alternative sources cannot be made.

Successes and Lessons Learned

Implementation of the Beetham Reuse Program was put on hold in 2011 for several reasons including the high cost of distributing reclaimed water to the potential end users and the election of a new government that had different priorities and approaches for solving the water shortage problem. It appears that the best chance for reviving the program would be to identify a major user near the WWTP that could be economically supplied with RW to meet their demands. The most promising user identified to date is the Trinidad and Tobago Electrical Commission. They are planning to build a new power plant about 1.2 miles (2 km) east of the WWTP and reclaimed water would be an ideal cooling medium for the new facility.

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Langford Recycling Scheme

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United Kingdom-Langford

Project Background or Rationale

Essex & Suffolk Water (ESW) is in the southern operating area of Northumbrian Water Limited (NWL) which supplies a population of approximately 1.5 million people with potable water. In response to a supply deficit, Essex & Suffolk Water identified the Langford Recycling Scheme (the Scheme) as a new resource. The scheme involves diverting the Chelmsford Sewage Treatment Works (CSTW) effluent from the Blackwater Estuary to the Langford Recycling Plant (LRP). The reclaimed water is then discharged in the River Chelmer at Scotch Marsh to be abstracted 8 km downstream for drinking water supply.

In April 2000, ESW was granted a permit by the UK Environment Agency (EA) to discharge reclaimed wastewater, originally from CSTW, into the river Chelmer at Scotch Marsh, Ulting. In addition, the Company was allowed to vary its abstraction license to benefit from this extra water. The granting of the permits effectively gave approval for the construction of the wastewater recycling plant for indirect potable reuse with an output of up to 10.5 mgd (40 ML/d). The scheme has been operating successfully since 2003, providing additional flow in the river Chelmer during the periods of low flow.

Capacity, Type of Reuse Application and Treatment Technology

The purpose of the recycling scheme is indirect potable reuse. Although the LRP is licensed to recycle up to 10.5 mgd (40 ML/d) the average daily output is normally between 5.3 to 6.6 mgd (20-25 ML/d). During drought periods, these volumes represent up to 70 percent of the raw water available in the River Chelmer at ESW's drinking Water's intake. The scheme is normally operated from April to November when the temperatures support the biological treatment process at the LRP. From October 2003 to November 2011, a total of 3.47 billion gallons (13,139.7 ML) of reclaimed water was produced for indirect potable reuse. The highest production was during the drought periods during 2005 to 2006 and 2010 to 2011.

The advanced treatment process at the LRP includes the following processes:

- Biological nitrification-denitrification
- Chemical phosphorus removal
- UV disinfection

The treated reclaimed water from the LRP is consistently much higher quality than the receiving river water in terms of chemical and bacteriological contaminants.

Water Quality Standards

The EA consent conditions for the LRP aim to protect the receiving stream water quality; the treated water quality standards are summarized in **Table 1**. The treated reclaimed water meets all established water quality standards (**Table 2**) and as such, the LRP is considered the tertiary stage of the CSTW. In addition, the following consent limits apply to the discharge: iron 2mg/L, copper 40mg/L, and nonylphenol 4.0 µg/L.

Environmental Impact

Environmental monitoring was conducted to assess the impact of reclaimed water discharge on the receiving stream. The monitoring program included weekly chemical and bacteriological sampling as well as monthly macrophytes, phytoplankton and invertebrate monitoring. In addition, the LRP final effluent and Clemsford effluent were tested for possible endocrine disruption effects using fish bioassays. Monthly algae and zooplankton surveys were carried out at the Hanningfield Reservoir

Environmental impact assessments on the estuary (a Ramsar site, a Site of Special Scientific Interest, a Special Area of Conservation and a Special Protection Area) from where the wastewater is diverted consisted mainly of studies on marine invertebrates and wildfowl that preyed upon them. The impact of increased water abstraction on siltation in a local port on the estuary was also evaluated. In order to mitigate the effect of diverting the wastewater, ESW carries out annual dredging at Maldon Port to reduce the impact of siltation.

Table 1 Water framework directive standards

Parameter	90 Percentile	95 Percentile	Maximum	Annual Mean
BOD		10 mg/L	20 mg/L	3.2mg/L
Ammonia		2 mg/L	7mg/L	0.28 mg/L
Suspended Solids		20 mg/L		3.1 mg/L
SRP			1,000 µg/L	255 µg/L
Total Nitrogen			15 mg/L	3.9mg/L
Dissolved Oxygen (percent saturation)	>70 %		>40%	89 %

Table 2 Urban wastewater treatment directive (UWWTD) standards

	UWWTD limit	Annual Average Removal Rate Limit	LRP Annual Mean Removal Rate
BOD	25mg/L	70-90%	96%
COD	125 mg/L	75%	85%
Total phosphorus	1000 µg/L	80%	96%
Total Nitrogen		70-80% and 57% by LRP only	83% total, 72% by LRP only

Project Funding and Management Practices

Funding for the studies, promotion and building of the LRP was through the UK water industry's normal regulated business planning process. The funding was obtained through price increases for potable water with this particular scheme having a low capital expenditure (CAPEX) cost but a higher than normal operational expenditure (OPEX) cost because the practice of using reclaimed water as a potable water source requires additional treatment that is not normally required for a conventional raw water source.

Institutional/Cultural Considerations

This is the first example of a planned indirect potable reuse scheme in Europe. There were no precedents that could be used for justification of the project and a great deal of effort was required to demonstrate to the government, regulators and the public the value and safety of the proposed project. The success of the final scheme was a result of significant stakeholder engagement with customer representative groups and customers. This included the purchase and fitting of a mobile information workshop that was taken to all areas that would receive the potable water.

Successes and Lessons Learned

Years of baseline and pilot plant data that demonstrated improvement to water quality were key to securing the reuse license. However, even with solid scientific information, public acceptance is not a given and early engagement and clear communication with project stakeholders was essential to project success. The solid science, regulatory coordination and public engagement were all important components of this project that promotes sustainable water use, enhances the aquatic environment through a reduction in polluting discharges and mitigates the impacts of drought.

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Water Reuse as Part of Holistic Water Management in the United Arab Emirates

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United Arab Emirates-Abu Dhabi

Project Background or Rationale

As a region, the Middle East and North Africa (MENA) is the driest in the world, with only 1 percent of the globe's freshwater resources. About 43 percent of wastewater generated in the MENA region is treated with a wide range in the percent of wastewater treated between countries (Qadir et al., 2010). While several countries in the region have very little wastewater treatment, other countries with the financial resources have a very high percentage of treatment and treat wastewater to very high quality for reuse. In countries that are dependent on desalination to supply major portions of their water demands, water reuse can be a relatively lower energy and cost alternative. As a region, approximately one quarter of all wastewater generated is treated and reused. The Abu Dhabi emirate has been one of the few leaders in the region with the commitment to implement substantial wastewater treatment and reuse programs utilizing over seventy percent of this resource.

Abu Dhabi's mean annual rainfall is extremely low—only 32 mm (1.25 inches) per year. Water resources in the United Arab Emirates (UAE) have traditionally been met through shallow groundwater wells. However, rapid economic development and population increases over the last three decades have dramatically increased the emirates' water demands. About 70 percent of the emirate's water comes from brackish groundwater. This non-renewable resource has been used predominantly to support expansions in agriculture. Salinization of some aquifer resources and soils has resulted (Murad et al., 2010 and Al-Katheeri et. al, 2008). The UAE's groundwater deficit is largely met by desalinated water (24 percent) and the reuse of treated wastewater for agriculture and landscape irrigation (6 percent).

To improve the current water situation, the emirate of Abu Dhabi has adopted a water resources master plan and a water reuse strategy to maintain the emirate's water security.

Water Reuse as Strategy in Abu Dhabi

Abu Dhabi Emirate is the largest of the seven emirates that compose the UAE. Abu Dhabi's urban population (1.4 million) is projected to increase by an average of 50 percent every seven years up to 2030. In 2003, water consumption in Abu Dhabi was 92.5 gallons (350 litres) per capita per day, among the highest rates in the world (Global Water Intelligence, 2009).

Water reuse has been practiced in Abu Dhabi for over a decade for landscape irrigation. As of 2010, reclaimed water adds about 6 percent to overall water supplies (EAD, 2010).

The formulation of *Abu Dhabi Water Resources Master Plan* (Pitman et al., 2009) published by the Environment Agency Abu Dhabi (EAD) in 2009 was a major strategic step towards achieving its vision for a sustainable future for Abu Dhabi. The plan identified existing total water availability and demand and projected forward to examine future conditions and options. To address the lack of renewable freshwater resources, the plan recommended water reclamation to minimize environmental costs of desalination, particularly energy consumption and greenhouse gas emissions.

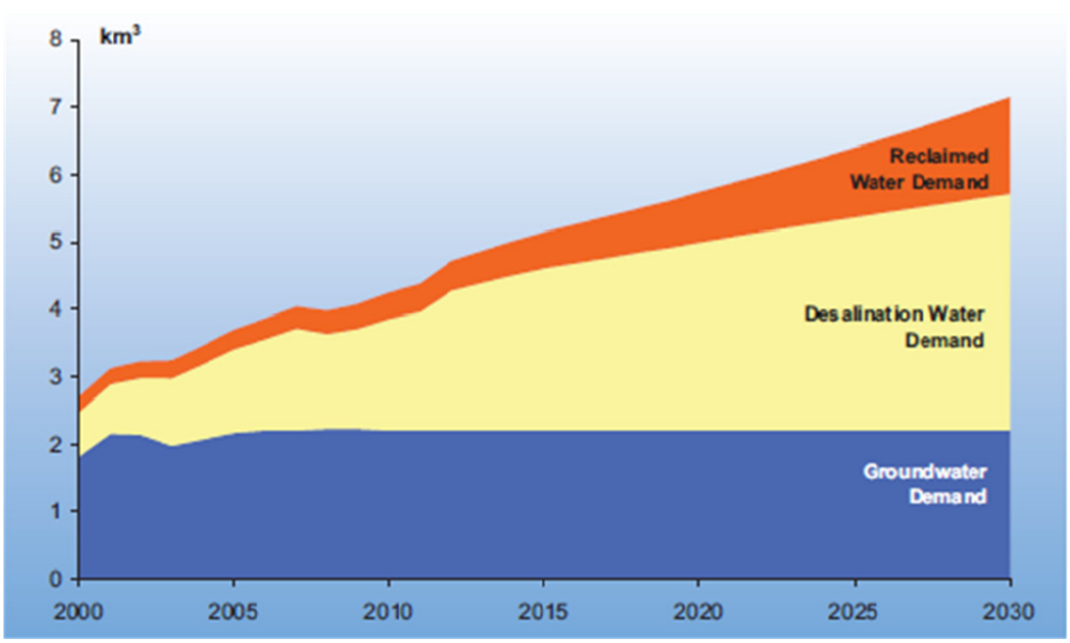
Taking the water resources planning process forward, EAD recently established a bold wastewater reuse strategy for the Emirate of Abu Dhabi (EAD, 2010) that was developed by the International Centre for Biosaline Agriculture (ICBA). This reuse strategy provides a roadmap for diversifying the application of recycled water in the emirate for agriculture, forestry, and amenities. The strategy identifies the opportunities for reuse in the emirate, technical aspects of reuse (including protecting public safety, and the incorporation of both decentralized and centralized systems). The strategy also addressed associated institutional and regulatory issues. Since reclaimed water is such a valuable resource in Abu Dhabi, the strategy specifically outlines licensing approaches and high efficiency farming to avoid profligate use of reclaimed water in agriculture.

The water reuse strategy also calls for several implementation components, including:

1. A survey of public acceptance
2. A wastewater market assessment to help design systems that achieve the best possible economic conditions
3. A commitment that the design and location of future wastewater treatment plants should take potential reuse as the starting point
4. A commitment to view water reuse as an element in a broader water management approach which also encompasses demand management, conservation, and a recognition of the economic value of water

International and local expertise was enlisted in ICBA's development of this master plan, from both the public and private sectors, involving all relevant agencies, including the Regulation and Supervision Bureau (RSB), the Abu Dhabi Sewage Services Company (ADSSC), and the Abu Dhabi Food Control Authority (ADFCA). This integrated approach to stakeholder involvement is key to the success of the strategy.

Matched with this policy commitment is a strong financial commitment to urban regeneration, including water and wastewater system improvements. The overall strategic vision for Abu Dhabi, Plan 2030, includes a planned total investment of over $1 trillion in infrastructure, with a commitment to state-of-the-art wastewater infrastructure (Stedman, 2010). Where wastewater treatment will be installed in Abu Dhabi, the focus will be on reuse, driven by the opportunities presented by water scarcity. Reclaimed water is expected to provide around 10-13 percent of overall water supplies by 2030, by progressively substituting reuse for expensive desalinated water and rapidly dwindling fresh groundwater supplies (EAD, 2010). The two main wastewater treatment plants that currently serve the emirate, at Mafraq and Al Ain, have been operating above design capacity. Four new large WWTP are currently being built in the Emirate of Abu Dhabi which will add a treatment capacity of 225 mgd (850,000 m^3/day) to serve more than 3 million inhabitants (Al Wathba Veolia Besix Waste Water, 2012). This new infrastructure has been designed with state-of- the-art technologies enabling 100 percent reuse of the wastewater treated for irrigation purposes. **Figure 1** shows the predicted water supply by sectors in UAE through 2030.



UAE Water Conservation Strategy, 2010. MOEW

Figure 1
Predicted water supply by sectors in UAE

Types of Reuse Applications

For over a decade, Abu Dhabi has implemented reuse for irrigation under the municipality's Sewerage Projects Committee, under the direction of His Highness Sheikh Zayed Bin Sultan Al Nahyan. An investment of around U.S. $149 M (547.5 M UAE Dirhams) has resulted in an irrigation system using reclaimed water from the Mafraq wastewater treatment facility to irrigate approximately a quarter of the island section of the city's area to create a green oasis in the city. This has generated fresh water savings and a series of ecological, social, and economic benefits. The greening of the city has enhanced the urban environment and offset pollution and carbon emissions. During peak summer demand, irrigation requirements surpass the volume of reclaimed water generated by Mafraq and is supplemented with valuable potable water. The city has initiated a series of studies to improve the system through data collection, modeling, system upgrades including strategic storage, landscape redesign, and data management (Shepherd, 2003).

Water reuse is also a key opportunity to achieving adequate long-term storage capacity. Artificial aquifer recharge on a large scale could be beneficial to help the emirate achieve emergency water supply storage. Existing pilot projects are examining the feasibility of aquifer recharge using reclaimed water (Al-Katheeri et al., 2008).

While under the new Abu Dhabi wastewater reuse strategy, reclaimed water will substitute about 10 percent of the emirate's water supply, projected demands will be 40 percent greater than potential supplies by 2025, requiring improvements in water use efficiency and careful targeting of highest added-value reuse (Shepherd, 2003).

Water Quality Standards and Treatment Technology

One important component of Abu Dhabi's approach has been the setting of clear regulatory standards for trade effluent discharge control, and recycled water and biosolid products and use by the regulator, the RSB. Two categories are defined with the strictest standards defined for end uses where the public are more exposed such as in flushing toilets and urban irrigated areas.

Project Funding and Management Practices

The emirate of Abu Dhabi has committed all the investment to set the national policies and water reuse strategy. In addition to significant commitments to the development of new infrastructure, $13 billion of private investment has also been attracted (GWI, 2009).

Successes and Lessons Learned

Coordinated efforts between the various agencies involved in water management in Abu Dhabi has shown clear leadership in making a strong commitment to including water reuse as part of its overall water resource strategic planning for the growth and sustainability of the emirate. Through the Abu Dhabi Technical Committee for Wastewater, activities between different institutions and users involved in reuse have been harmonize, and may become a focal point for water reuse advocacy, public education, and outreach (EAD, 2010). Also by including provisions for wastewater reuse infrastructure development at the outset of new developments, the most financially and environmentally sound solutions can be incorporated for both handling wastewater, but also addressing water demands.

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Wastewater Reuse in Thanh Tri District, Hanoi Suburb, Vietnam

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Vietnam-Hanoi

Project Background or Rationale

In Vietnam, a large number of urban and peri-urban farmers rely on wastewater for irrigated agriculture and aquaculture. In Hanoi alone, an estimated 658,000 farmers use wastewater to irrigate 108,178 ac (43,778 ha) of land (Raschid-Sally and Jayakody, 2008).

Thanh Tri is a peri-urban district located in the south of Hanoi, downstream of the To Lich River, one of the main streams contaminated with wastewater from urban areas. Irrigation systems designed to uptake water from the To Lich River have been in use in some communes of the district water since the 1960s and are used to irrigate hundreds of hectares of agricultural land.

In recent years, increased contamination from urban wastewater and industrial effluents has created problems for the traditional practice of wastewater reuse: loss of agriculture and aquaculture production affect the health of farmers and consumers. Thanh Liet commune in this district has designed a decentralized wastewater management system (DWMS) to accommodate wastewater reuse.

Capacity and Type of Reuse Application

To combat the negative impact of wastewater effluent on crops, productivity, public health and the increase of unusable land, the Local Agriculture Cooperative (LAC), in agreement with local farmers, decided to transfer large areas of low productivity agricultural land to fishponds by gathering farmers' fields and leasing them to fish raising men. In other words, the intervention does not seek to change the quality of the water itself, but instead change the type of reuse application to aquaculture, which is a safer use of the contaminated water.

The fishpond areas in Thanh Liet were originally used as a low land paddy for rice. Rice is less tolerant to contaminated water, so they shifted to other aquatic vegetables and fish ponds, which also have higher market values. Aquatic vegetables and fish production can generate 120 million Vietnamese dong (VND) per ha per year and 150 million VND/ha-yr ($5,760/ha-yr and $7,200/ha-yr), respectively which is three times higher than rice production. The total land area dedicated to aquaculture in Thanh Liet has increased over the last 10 years from about 25 to 85 hectares (60 to 210 acres) in 2011. More constructors are interested in this area since they could get substantial benefit from wastewater fed fishponds.

Institutional/Cultural Considerations

Thanh Liet commune area has a population of 241,000 people (2010) and is not yet covered by the service from Hanoi Sanitation and Drainage Company (SADCO). Therefore, the management of local sewerage and drainage system belongs to the commune's People's Committee (PC), who delegates the task to the LAC of the commune.

There is a policy for providing water for irrigation free of charge, creating a financial barrier for the LAC to invest in improving irrigation water quality and involving local farmers to the operations and maintenance (O&M) activities of the system.

Water Quality Standards and Treatment Technology

There are no official regulations for wastewater use in Vietnam, except for microbiological quality standards specifying a maximum total coliform count for effluent discharge to surface water.

Project Funding and Management Practices

For the construction of drainage canals and sewers along the roads of the commune, funding is mobilized from the city's budget, via the District PC. In some cases, local farmers contribute, especially for their household connection to the drainage lines. Under the management of the local PC, the Thanh Liet LAC is assigned the function to operate water supply, sewage, drainage and irrigation systems. They are also providing other agricultural services for farmers such as supply of fertilizers, seeding crops and fish fingerlings.

Institutional decentralization has created a strict separation of institutions at upper levels of management, causing difficulties for the LAC to integrate irrigation, drainage and sewage management at the local level. For instance, all of the wastewater collected by the centralized wastewater system in Hanoi is discharged to the upper level of the canals. The LAC is unable to collect the wastewater discharge fee to cover the cost of treatment; therefore the water from these canals is diverted to the local irrigation system without proper treatment.

Locations of fishponds are usually along the open drainage canals. One reason is the availability of leased land; since the soil is contaminated with wastewater and not suitable for growing crops, another reason is that fishermen could actively exploit the wastewater and do not solely depend on the LAC's pumping services. Meanwhile, the cropping land is about 250 ac (100 ha) of which only 25 ac (10.5 ha) is used for cultivating rice and the rest is for aquatic vegetables. These fields are located further from drainage canals to reduce the impact of wastewater since the quality of the wastewater is improved in terms of nutrients, pathogens, and heavy metal concentration after partial treatment in ponds with the presence of aquatic plant cultivation and long channels.

Farmers and fishermen experience the negative impacts from wastewater such as skin and worm diseases. They have carried out different measures to reduce perceived impacts. Fishermen are more proactive; they combine wastewater and groundwater to dilute the wastewater, and in addition, wastewater pumps provide more oxygen to boost wastewater treatment process through biochemical oxygen demand breakdown in the ponds. Farmers and fishermen wear protective clothes while working to reduce the exposure level to wastewater.

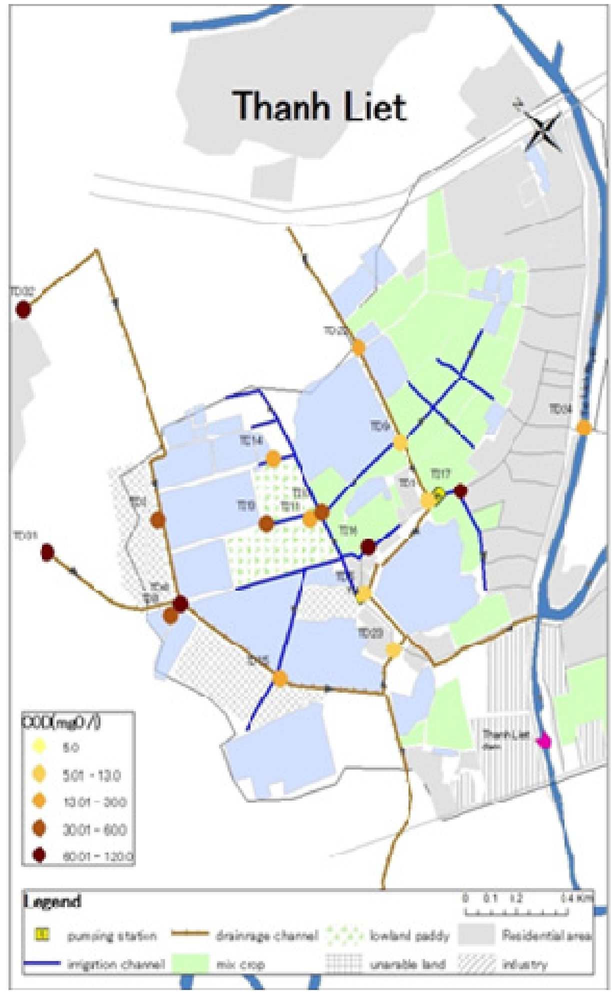

Figure 2
Chemical Oxygen Demand ($KMnO_4$) measured along the drainage channel in March 2011

Moreover, the farmers and fishermen are encouraged to participate in the agricultural extension training program organized by the LAC and the extension division of the district. The content of these training programs include the safe practice of wastewater reuse. Most of the crops and all fish products are required to be cooked before eating.

Figure 2
Farmer working in the field in protective clothing (Photo credit: Lan Huong Nguyen)

Successes and Lessons Learned

Through a combination of various activities, e.g., conjunctive use of wastewater and groundwater, protective gear, improving hygienic condition, and raising awareness among producers and consumers, the impact of wastewater reuse has been minimized to a certain level. The practice of wastewater reuse in Thanh Liet behaves as *spot market* with complex and unpredictable long-term outcomes.

Despite the numerous challenges, the DWMS of Thanh Tri could provide a concrete framework to build up an integrated system of wastewater reuse for irrigation at a local level where decentralized provision allows wastewater reuse to maximize resource recovery, i.e., where wastewater is collected and treated to the acceptable level for agriculture and aquaculture use in the area.

Finally, further studies on the measurements taken out by the Thanh Liet people and reinforced with scientific base are needed to support the management of LAC by providing information to set up guidelines, standards, and regulations of the reuse of wastewater for application in other areas of the country.

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Appendix F
Case Studies in 2004 Guidelines for Water Reuse

Section in 2004 Guidelines	U.S. Case Study Title	City	State
2.7.1	Water Reuse at Reedy Creek Improvement District	Orlando	FL
2.7.2	Estimating Potable Water Conserved in Altamonte Springs due to Reuse	Altamonte Springs	FL
2.7.3	How Using Potable Supplies to Supplement Reclaimed Water Flows can Increase Conservation	Hillsborough County	FL
2.7.4	Water Reclamation and Reuse Offer an Integrated Approach to Wastewater Treatment and Water Resources Issues in Phoenix	Phoenix	AZ
2.7.5	Small and Growing Community: Yelm, Washington	Yelm	WA
2.7.6	Landscape Uses of Reclaimed Water with Elevated Salinity	El Paso	TX
2.7.7	Use of Reclaimed Water in a Fabric Dyeing Industry	Santa Fe Springs	CA
2.7.8	Survey of Power Plants Using Reclaimed Water for Cooling Water	Multiple	US
2.7.9	Agricultural Reuse in Tallahassee, Florida	Tallahassee	FL
2.7.10	Spray Irrigation at Durbin Creek WWTP Western Carolina Regional Sewer Authority	Fountain Inn	SC
2.7.11	Agricultural Irrigation of Vegetable Crops: Monterey, CA	Monterey	CA
2.7.12	Water Conserv II: City of Orlando and Orange County, FL	Orange County	FL
2.7.13	The Creation of a Wetlands Park: Petaluma, CA	Petaluma	CA
2.7.14	Geysers Recharge Project: Santa Rosa, CA	Santa Rosa	CA
2.7.15	Advanced Wastewater Reclamation in California	Orange County	CA
2.7.16	An Investigation of Soil Aquifer Treatment for Sustainable Water	6 sites	AZ/CA
2.7.17	The City of West Palm Beach, Florida Wetlands-Based Water Reclamation Project	West Palm Beach	FL
2.7.18	Types of Reuse Applications in Florida	Statewide	FL
2.7.19	Regionalizing Reclaimed Water in the Tampa Bay Area	Tampa Bay FL	
3.8.1	Code of Good Practices for Water Reuse	Statewide	FL
3.8.2	Examples of Potable Water Separation Standards from the State of Washington	Statewide	WA
3.8.3	An Example of using Risk Assessment to Establish Reclaimed Water Quality Study		US
5.7.1	Statutory Mandate to Utilize Reclaimed Water: California	Statewide	CA
5.7.2	Administrative Order to Evaluate Feasibility of Water Reclamation: Fallbrook Sanitary District, Fallbrook, CA	Fallbrook	CA
5.7.3	Reclaimed Water User Agreements Instead of Ordinance: Central Florida	Orlando	FL
5.7.4	Interagency Agreement Required for Water Reuse: Monterey County Water Recycling Project, Monterey, CA	Monterey	CA
5.7.5	Public/Private Partnership to Expand Reuse Program: The City Of Orlando, Orange County and The Private Sector	Orlando	FL
5.7.6	Inspection of Reclaimed Water Connections Protect Potable Water Supply: Pinellas County Utilities, Florida	Pinellas County	FL
5.7.7	Oneida Indian Nation/Municipal/State Coordination Leads to Effluent Reuse: Oneida Nation, New York	Oneida	NY
5.7.8	Implementing Massachusetts' First Golf Course Irrigation System Utilizing Reclaimed Water: Yarmouth, MA	Yarmouth	MA

Section in 2004 Guidelines	U.S. Case Study Title	City	State
6.7.1	Unique Funding Aspects of the Town of Longboat Key Reclaimed Water System	Longboat Key	FL
6.7.2	Financial Assistance in San Diego County, California	San Diego	CA
6.7.3	Grant Funding Through the Southwest Florida Water Management District	SW Florida	FL
6.7.4	Use of Reclaimed Water to Augment Potable Supplies: An Economic Perspective (California)	LA/Orange Co.	CA
6.7.5	Impact Fee Development Considerations for Reclaimed Water Projects: Hillsborough County, FL	Hillsborough County	FL
6.7.6	How Much Does it Cost and Who Pays: A Look at Florida's Reclaimed Water Rates	Statewide	FL
6.7.7	Rate Setting for Industrial Reuse in San Marcos, TX	San Marcos	TX
7.5.1	Accepting Produce Grown with Reclaimed Water: Monterey, California	Monterey	CA
7.5.2	Water Independence in Cape Coral – An Implementation Update in 2003	Cape Coral	FL
7.5.3.1	Learning Important Lessons-San Diego, California	San Diego	CA
7.5.3.2	Public Outreach May not be Enough: Tampa, FL	Tampa	FL
7.5.4	Pinellas County, Florida Adds Reclaimed Water to Three R's of Education	Pinellas County	FL
7.5.5	Yelm, Washington, A Reclaimed Water Success Story	Yelm	WA
7.5.6	Gwinnett County, Georgia – Master Plan Update Authored by Public	Gwinnett County	GA
7.5.7	AWWA Golf Course Reclaimed Water Market Assessment		National US

Section in 2004 Guidelines	International Case Study by Country
8.5.1	Argentina
8.5.2	Australia
8.5.2.1	Aurora, Australia
8.5.2.2	Mawson Lakes, Australia
8.5.2.3	Virginia Project, South Australia
8.5.3	Belgium
8.5.4	Brazil
8.5.4.1	Sao Paulo, Brazil
8.5.4.2	Sao Paulo International Airport, Brazil
8.5.5	Chile
8.5.6	China
8.5.7	Cyprus
8.5.8	Egypt
8.5.9	France
8.5.10	Greece
8.5.11	India
8.5.12.1	Hyderabad, India
8.5.12	Iran
8.5.13	Israel
8.5.14	Italy
8.5.15	Japan
8.5.16	Jordan

Section in 2004 Guidelines	International Case Study by Country
8.5.17	Kuwait
8.5.18	Mexico
8.5.19	Morocco
8.5.20.1	Drarga, Morocco
8.5.20	Namibia
8.5.21	Oman
8.5.22	Pakistan
8.5.23	Palestinian National Authority
8.5.24	Peru
8.5.25	Saudi Arabia
8.5.26	Singapore
8.5.27	South Africa
8.5.28	Spain
8.5.28.1	Costa Brava, Spain
8.5.28.2	Portbou, Spain
8.5.28.3	Aiguamolls de l'Emporda Natural Preserve, Spain
8.5.28.4	The City of Victoria, Spain
8.5.29	Sweden
8.5.30	Syria
8.5.31	Tunisia
8.5.32	United Arab Emirates
8.5.33	United Kingdom
8.5.34	Yemen
8.5.35	Zimbabwe

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APPENDIX G
Abbreviations

Abbreviations for Names of States

Full name	Text abbreviation	Case Study Abbreviation
Alabama	Ala.	AL
Alaska	Alaska	AK
Arizona	Ariz.	AZ
Arkansas	Ark.	AR
California	Calif.	CA
Colorado	Colo.	CO
Connecticut	Conn.	CT
Delaware	Del.	DE
District of Columbia	D.C.	DC
Florida	Fla.	FL
Georgia	Ga.	GA
Hawaii	Hawaii	HI
Idaho	Idaho	ID
Illinois	Ill.	IL
Indiana	Ind.	IN
Iowa	Iowa	IA
Kansas	Kan.	KS
Kentucky	Ky.	KY
Louisiana	La.	LA
Maine	Maine	ME
Maryland	Md.	MD
Massachusetts	Mass.	MA
Michigan	Mich.	MI
Minnesota	Minn.	MN
Mississippi	Miss.	MS
Missouri	Mo.	MO
Montana	Mont.	MT
Nebraska	Neb.	NE
Nevada	Nev.	NV
New Hampshire	N.H.	NH
New Jersey	N.J.	NJ
New Mexico	N.M.	NM
New York	N.Y.	NY
North Carolina	N.C.	NC
North Dakota	N.D.	ND
Ohio	Ohio	OH
Oklahoma	Okla.	OK
Oregon	Ore.	OR
Pennsylvania	Pa.	PA
Rhode Island	R.I.	RI
South Carolina	S.C.	SC
South Dakota	S.D.	SD
Tennessee	Tenn.	TN
Texas	Texas	TX
Utah	Utah	UT
Vermont	Vt.	VT
Virginia	Va.	VA
Washington	Wash.	WA
West Virginia	W. Va.	WV
Wisconsin	Wis.	WI
Wyoming	Wyo.	WY

Abbreviations for Units of Measure

Abbreviation	Unit
ac	Acre
ac-ft	Acre-foot
ac-ft/yr	Acre-foot per year
bbl/yr	Barrels per year
BTU	British thermal unit
cfu	Colony forming units
cm	Centimeter
m^3	Cubic meter
m^3/d	Cubic meters per day
d	Day
°C	Degrees Celsius
°F	Degrees Fahrenheit
ft	Foot (feet)
gallon	Gallon
GJ	Gigajoules
gpd	Gallons per day
gpcd	Gallons per capita per day
gpm	Gallons per minute
g	Gram
ha	Hectare
hp	Horsepower
hr	Hour
ccf	Hundred cubic feet
in	Inch
J	Joules
kg	Kilogram (10^3 g)
kg/ha	Kilogram per hectare
km	Kilometer (10^3 m)
kPa	Kilopascal (10^3 Pa)
kW	Kilowatt (10^3 W)
kWh	Kilowatt hour
L	Liter
Lpcd	Liters per capita per day
L/s	Liters per second
MW	Megawatt (10^6 W)
MWhr	Megawatt hours

Abbreviation	Unit
m	Meter
m/s	Meters per second
µg	Microgram (10^{-6} g)
µg/L	Micrograms per liter
MCM	Million cubic meters
MCM/yr	Million cubic meters per year
mgd	Million (10^6) gallons per day
µm	Micrometer (10^{-6} m)
mi	Mile
mph	Miles per hour
mg	Milligram (10^{-3} g)
mg/L	Milligrams per liter
mL	Milliliter (10^{-3} l)
mm	Millimeter (10^{-3} m)
meq/L	Milliequivalent per liter
MAFY	Million acre feet per year
min	Minute
MPN	Most probable number
nm	Nanometer (10^{-9} m)
NTU	Nephelometric turbidity units
ppt	Parts per trillion
Pa	Pascal
pfu	Plaque forming unit
lb	Pound
lb/ac	Pounds per acre
psi	Pounds per square inch
s	Second
ft^2	Square foot
in^2	Square inch
km^2	Square kilometers
m^2	Square meter
mi^2	Square mile
TWh/yr	TWh/yr
W	Watt
yr	Year

Appendix C - CDPH 2011 Draft Regulation for Groundwater Recharge Reuse and Public Workshop Presentations

This draft regulation reflects the California Department of Public Health's (CDPH's) Drinking Water Program's current thinking on the regulation for replenishing groundwater with recycled municipal wastewater. To assist readability, this draft does not include some information and formatting required by the Administrative Procedures Act.

Any comments you have on this draft can be emailed to Mike McKibben at Michael.McKibben@cdph.ca.gov and Randy Barnard at Randy.Barnard@cdph.ca.gov.

November 21, 2011

Title 22, CALIFORNIA CODE OF REGULATIONS
DIVISION 4. ENVIRONMENTAL HEALTH
CHAPTER 3. RECYCLING CRITERIA
ARTICLE 1. DEFINITIONS

Section 60301.050. 24-hour Composite Sample.
"24-hour composite sample" means an aggregate sample derived from no fewer than eight discrete samples collected at equal time intervals or collected proportional to the flow rate over the compositing period. The aggregate sample shall reflect the average source water quality covering the composite of sample period.

Section 60301.080. Added Tracer.
"Added Tracer" means a non-reactive substance, either foreign to the receiving groundwater or at concentrations at least three orders of magnitude greater than the receiving groundwater, intentionally added to the water applied at a GRRP such that the first two percent of the tracer can be identified in the groundwater downgradient of the GRRP to determine the underground retention time of the water.

Section 60301.180. Department.
"Department" means the California Department of Public Health.

Section 60301.190. Diluent Water.
"Diluent water" means water, meeting the diluent requirements of this Chapter, used for reducing the recycled municipal wastewater contribution over time.

Section 60301.370. Groundwater.
"Groundwater" means water below the land surface in a saturated zone.

Section 60301.390. Groundwater Replenishment Reuse Project (GRRP).
"Groundwater Replenishment Reuse Project (GRRP)" means a project involving the planned use of recycled municipal wastewater that is operated for the purpose of replenishing a groundwater basin designated in the Water Quality Control Plan [as defined in Water Code section 13050(j)] for use as a source of municipal and domestic water supply, or a project determined as a GRRP by the RWQCB based on a project's existing or projected replenishment of the affected groundwater basin.

Section 60301.450. Indicator Compound.

"Indicator Compound" means an individual chemical in a GRRP's municipal wastewater that represents the physical, chemical, and biodegradable characteristics of a specific family of trace organic chemicals; is present in concentrations that provide information relative to the environmental fate and transport of those chemicals; is used to monitor the efficiency of trace organic compounds removal by treatment processes; and provides an indication of treatment process failure.

Section 60301.455. Intrinsic Tracer.

"Intrinsic Tracer" means a substance present in the recharge water at concentrations greater than the receiving groundwater such that the substance in the water applied at the GRRP can be readily detected at low concentrations in the groundwater downgradient of the GRRP and can be used to determine the underground retention time of the water.

Section 60301.575. Maximum Contaminant Level or MCL.

"MCL" means the maximum permissible concentration of a contaminant, as defined by the section 116275(c) and (d) of the Health and Safety Code or established by the U.S. Environmental Protection Agency.

Section 60301.625. Notification Level or NL.

"NL" means the concentration of a contaminant established by the Department pursuant to section 116455 of the Health and Safety Code.

Section 60301.670. Project Sponsor.

"Project sponsor" means an entity subject to water recycling requirements for a GRRP from a RWQCB and is, in whole or part, responsible for complying with the requirements of this Chapter.

Section 60301.680. Public Water System.

"Public Water System" has the same meaning as defined in section 116275(h) of the Health and Safety Code.

Section 60301.685. Recharge Water.

"Recharge Water" means recycled municipal wastewater or the combination of recycled municipal wastewater and diluent water that is applied at a GRRP facility.

Section 60301.690. Recycled Municipal Wastewater.

"Recycled Municipal Wastewater" means recycled water that is the effluent from the treatment of a wastewater of municipal origin.

Section 60301.705. Recycled Municipal Wastewater Contribution (RWC).

"Recycled Municipal Wastewater Contribution (RWC)" means the fraction equivalent to the quantity of recycled municipal wastewater applied at the GRRP divided by the sum of the quantity of recycled municipal wastewater and credited diluent water applied at the GRRP.

Section 60301.770. RWQCB.

"RWQCB" means Regional Water Quality Control Board.

Section 60301.780. Saturated Zone.

"Saturated zone" means an underground region or regions in which all interstices in, between, and below natural geologic materials are filled with water, with the uppermost surface of the saturated zone being the water table.

Section 60301.810. Spreading Area.

"Spreading area" means a natural or constructed impoundment with a depth equal to or less than its widest surface dimension used by a GRRP to replenish a groundwater basin with recharge water infiltrating and percolating through a zone that, in the absence of a GRRP, would be an unsaturated zone.

Section 60301.840. Subsurface Application.

"Subsurface Application" means the controlled application of recharge water to a groundwater basin(s) by a means other than surface application.

Section 60301.850. Surface Application.

"Surface Application" means the controlled application of recharge water to a spreading area.

Section 60301.855. Surrogate Parameter.

"Surrogate parameter" means a measurable physical or chemical property that has been demonstrated to provide a direct correlation with the concentration of an indicator compound, is used to monitor the efficiency of trace organic compounds removal by a treatment process, and/or provides an indication of a treatment process failure.

Section 60301.860. Total Nitrogen.

"Total nitrogen" means the sum of concentrations of nitrogen in ammonia, nitrite, nitrate, and organic nitrogen-containing compounds, expressed as nitrogen.

Section 60301.870. Total Organic Carbon (TOC).

"Total organic carbon (TOC)" means the concentration of organic carbon present in water.

Section 60301.910. Unsaturated Zone.

"Unsaturated Zone" means the volume between the land surface and the uppermost saturated zone.

ARTICLE 5.1. INDIRECT POTABLE REUSE: GROUNDWATER REPLENISHMENT - SURFACE APPLICATION WITHOUT FULL ADVANCED TREATMENT

~~**Section 60320. Groundwater Recharge.**~~

~~(a) Reclaimed water used for groundwater recharge of domestic water supply aquifers by surface spreading shall be at all times of a quality that fully protects public health. The State Department of Health Services' recommendations to the Regional Water Quality Control Boards for proposed groundwater recharge projects and for expansion of existing projects will be made on an individual case basis where the use of reclaimed water involves a potential risk to public health.~~

~~(b) The State Department of Health Services' recommendations will be based on all relevant aspects of each project, including the following factors: treatment provided; effluent quality and quantity; spreading area operations; soil characteristics; hydrogeology; residence time; and distance to withdrawal.~~

~~(c) The State Department of Health Services will hold a public hearing prior to making the final determination regarding the public health aspects of each groundwater recharge project. Final recommendations will be submitted to the Regional Water Quality Control Board in an expeditious manner.~~

Note: ~~Authority cited: Section 208, Health and Safety Code; and Section 13521, Water Code. Reference: Sections 13520 and 13521, Water Code.~~

Section 60320.100. General Requirements.

(a) A Groundwater Replenishment Reuse Project (GRRP) project sponsor utilizing surface application without continuous full advanced treatment of the entire recycled municipal wastewater stream prior to application shall meet the requirements of this Article. For the purpose of this Article, advanced treatment means treatment meeting the reverse osmosis and advanced oxidation process criteria in section 60320.201 of Article 5.2.

(b) Prior to operation of a new GRRP, or prior to permit renewal for an existing GRRP, the GRRP's project sponsor shall have a Department-approved plan describing the steps the project sponsor will take to provide an alternative source of potable water supply to all users of a producing drinking water well, or a Department-approved treatment mechanism the project sponsor will provide to all owners of a producing drinking water well, that as a result of the GRRP's operation, as determined by the Department:

(1) violates a California or federal drinking water standard;

(2) has been degraded to the degree that it is no longer a safe source of drinking water; or

(3) receives water that fails to meet section 60320.108.

(c) Prior to operating a new GRRP, the project sponsor shall collect at least two samples from each monitoring well approved pursuant to section 60320.126.

The samples shall be representative of water in each aquifer, taking into consideration seasonal variations, and be analyzed for the chemicals, contaminants, and characteristics in sections 60320.110, 60320.112, 60320.118 and 60320.120.

(d) A GRRP's recycled municipal wastewater shall be retained underground for a period of time no less than the retention time required pursuant to section 60320.108 and 60320.124. The GRRP shall be designed and operated in a manner that ensures water treated pursuant to this Article, beyond the boundary described in (e)(2), meets the recycled municipal wastewater contributions (RWC) requirements in section 60320.116.

(e) A GRRP's project sponsor shall provide the Department, RWQCB, and local well-permitting authorities a map of the GRRP site at a scale of 1:24,000 or larger (1 inch equals 2,000 feet or 1 inch equals less than 2,000 feet) or, if necessary, a site sketch at a scale providing more detail, that clearly indicates:

(1) the location and boundaries of the GRRP;

(2) the boundary representing the greatest of the horizontal and vertical distances reflecting the retention times required pursuant to section 60320.108 and section 60320.124; and

(3) the location of all monitoring wells established pursuant to section 60320.126, and drinking water supply wells within two years of the GRRP based on groundwater flow directions and velocities expected under GRRP operating conditions.

(f) Prior to operating a new GRRP, the project sponsor shall demonstrate to the Department and RWQCB that the project sponsor possesses adequate managerial and technical capability to assure compliance with this Article.

(g) Prior to replenishing a groundwater basin or an aquifer with recycled municipal wastewater, a new GRRP's project sponsor shall demonstrate that all treatment processes have been installed and can be operated by the project sponsor to achieve their intended function. A protocol describing the actions to be taken to meet this subsection shall be included in the engineering report submitted pursuant section 60323.

(h) In the engineering report required pursuant to section 60323, the project sponsor for a new GRRP shall include a hydrogeological assessment of the proposed GRRP's setting. The assessment shall include the following:

(1) the qualifications of the individual(s) preparing the assessment;

(2) a general description of geologic and hydrogeological setting of the groundwater basin(s) potentially directly impacted by the GRRP;

(3) a detailed description of the stratigraphy beneath the GRRP, including the composition, extent, and physical properties of the affected aquifers; and

(4) based on at least four rounds of consecutive quarterly monitoring to capture seasonal impacts;

(A) the existing hydrogeology and the hydrogeology anticipated as a result of the presence of the GRRP, and

(B) maps showing quarterly groundwater elevation contours, along with vector flow directions and calculated hydraulic gradients.

Section 60320.102. Public Hearing.

(a) A public hearing for a GRRP shall be held by the project sponsor prior to the Department's submittal of its recommendations to the RWQCB for the GRRP's initial permit and any time an increase in maximum RWC has been proposed but not addressed in a prior public hearing. Prior to a public hearing, the project sponsor shall provide the Department, for review and approval, the information the project sponsor intends to present at the hearing. The information shall also be provided on the Internet. Following the Department's approval of the information, the project sponsor shall place the information on the Internet and in a repository that provides at least thirty days of public access to the information prior to the public hearing.

(b) Prior to placing the information required pursuant to subsection (a) in a repository, the project sponsor shall:

(1) Notify the public of the following;

(A) the location and hours of operation of the repository,

(B) the Internet address where the information may be viewed,

(C) the purpose of the repository and public hearing,

(D) the manner in which the public can provide comments, and

(E) the date, time, and location of the public hearing; and

(2) At a minimum, notify the first downgradient potable water well owner and well owners whose drinking water source is within 10 years from the GRRP based on groundwater flow directions and velocities.

(c) Unless directed otherwise by the Department, the public notification made pursuant to subsection (b)(2) shall be by direct mail and the notification made pursuant to (b)(1) shall be by one or more of the following methods delivered in a manner to reach persons whose source of drinking water may be impacted by the GRRP:

(1) local newspaper(s) publication;

(2) mailed or direct delivery of a newsletter;

(3) conspicuously placed statement in water bills; or

(4) television and/or radio.

Section 60320.104. Lab Analyses.

(a) Analyses for contaminants having primary or secondary MCLs shall be performed by laboratories approved to perform such analyses by the Department utilizing Department-approved drinking water methods.

(b) Analyses for chemicals other than those having primary or secondary MCLs shall be described in the GRRP's Operations Plan prepared pursuant to section 60320.122.

Section 60320.106. Wastewater Source Control.
A project sponsor shall ensure that the recycled municipal wastewater used for a GRRP shall be from a wastewater management agency that:

(a) administers an industrial pretreatment and pollutant source control program;

(b) implements and maintains a source control program that includes, at a minimum;

(1) an assessment of the fate of Department-specified and RWQCB-specified chemicals and contaminants through the wastewater and recycled municipal wastewater treatment systems,

(2) chemical and contaminant source investigations and monitoring that focuses on Department-specified chemicals and contaminants,

(3) an outreach program to industrial, commercial, and residential communities within the portions of the sewage collection agency's service area that flows into the water reclamation facility subsequently supplying the GRRP, for the purpose of managing and minimizing the discharge of chemicals and contaminants at the source, and

(4) a current inventory of chemicals and contaminants identified pursuant to this section, including new chemicals and contaminants resulting from new sources or changes to existing sources, that may be discharged into the wastewater collection system; and

(c) is compliant with the effluent limits established in the RWQCB permit for the GRRP.

Section 60320.108. Pathogenic Microorganism Control.

(a) A project sponsor shall design and operate a GRRP such that the recycled municipal wastewater used as recharge water for a GRRP receives treatment that achieves at least 12-log enteric virus reduction, 10-log Giardia cyst reduction, and 10-log Cryptosporidium oocyst reduction. The treatment train shall consist of at least three separate treatment processes. For each pathogen (i.e., virus, Giardia cyst, and Cryptosporidium oocyst), a separate treatment process may be credited with no more than 6-log reduction and shall achieve at least 1-log reduction.

(b) Except for those portions treated with advanced treatment meeting the requirements of section 60320.201, the wastewater used as recycled municipal wastewater shall receive treatment to meet:

(1) the definition of filtered wastewater, pursuant to section 60301.320; and

(2) the definition of disinfected tertiary recycled water, pursuant to section 60301.230.

(c) For each month retained underground as demonstrated in subsection (f), the recycled municipal wastewater or recharge water will be credited with 1-log virus reduction. A GRRP meeting subsection (b)(1) and (2) or providing advanced treatment complying with section 60320.201, that also demonstrates at least six months retention underground pursuant to subsection (f), will be credited with 10-log Giardia cyst reduction and 10-log Cryptosporidium oocyst reduction.

(d) With the exception of log reduction through retention time underground, the project sponsor shall validate each of the treatment processes used to meet the requirements in subsection (a) for their log reduction by submitting a report for the Department's review and approval, or by using a challenge test approved by the Department, that provides evidence of the treatment process's log reduction. The report and/or challenge test shall be prepared by engineer licensed in California with at least five years of experience, as a licensed engineer, in wastewater treatment and public water supply, including the evaluation of treatment processes for pathogen control. With the exception of retention time underground and a soil treatment process, the project sponsor shall propose and include in its Operations Plan prepared pursuant to section 60320.122, on-going monitoring that verifies the performance of each treatment process's ability to achieve its credited log reduction.

(e) The project sponsor of a GRRP whose permit was issued prior to *[insert effective date]* shall demonstrate compliance with subsection (d) prior to the renewal of the GRRP's permit. The project sponsor of a new GRRP shall demonstrate compliance with subsection (d) prior to being issued a permit.

(f) To demonstrate the retention time underground in subsection (c), a tracer study utilizing an added tracer shall be implemented under hydraulic conditions representative of normal GRRP operations. The retention time shall be the time representing the difference from when water is applied at the GRRP to when the first two percent (2%) of such water arrives at the downgradient endpoint. The project sponsor for a new GRRP shall initiate the tracer study prior to the end of the third month of operation. The project sponsor for existing GRRP that hasn't already performed such a tracer study shall complete a tracer study demonstrating retention time underground prior to the renewal of the GRRP's permit.

(g) For the purpose of siting a GRRP location during project planning and until a GRRP's project sponsor has met the requirements of subsection (f), for each month of retention time estimated using the method in column 1, the recycled municipal wastewater or recharge water shall be credited with no more than the corresponding virus log reduction in column 2 of Table 60320.108.

Table 60320.108

Column 1	**Column 2**
Method used to estimate the retention time to the nearest downgradient drinking water well	**Virus Log Reduction Credit per Month**
Tracer study utilizing an intrinsic tracer, based on T_{10} (i.e. The time representing the difference from when water is applied at the GRRP to when the first ten percent arrives at the downgradient endpoint.)	0.67 logs
Numerical modeling consisting of calibrated finite element or finite difference models using validated and verified computer codes used for simulating groundwater flow.	0.50 logs
Analytical modeling using existing academically-accepted equations such as Darcy's Law to estimate groundwater flow conditions based on simplifying aquifer assumptions.	0.25 logs

(h) The protocol(s) used to establish the retention times in subsections (f) and (g) shall be approved by the Department.

(i) Based on changes in hydrogeological or climatic conditions since the most recent demonstration, the Department may require a GRRP's project sponsor to demonstrate that the underground retention times required in this section are being met.

(j) If the pathogen reduction in subsection (a) is not met based on the on-going monitoring required pursuant to subsection (d), within 24 hours of being aware the project sponsor shall immediately investigate the cause and initiate corrective actions. For failing to meet the pathogen reduction criteria longer than 4 consecutive hours or more than a total of 8 hours during any 7-day period, the Department and RWQCB shall be immediately notified. Failures of shorter duration shall be reported to the RWQCB no later than 10 days after the month in which the failure occurred.

(k) If the effectiveness of a treatment train's ability to reduce enteric virus is less than 9-logs, or Giardia cyst or Cryptosporidium oocyst reduction is less than 8-logs, the project sponsor shall immediately notify the Department and RWQCB, and discontinue application of recycled municipal wastewater at the GRRP.

Section 60320.110. Nitrogen Compounds Control.

(a) To demonstrate control of the nitrogen compounds, the project sponsor shall:

(1) Each week, at least three days apart as specified in the GRRP's Operations Plan, collect at least two samples (grab or 24-hour composite) representative of the recycled municipal wastewater or recharge water applied throughout the spreading area. Samples may be collected before or after surface application;

(2) Have the samples collected pursuant to paragraph (1) analyzed for total nitrogen, with the laboratory being required by the project sponsor to complete each analysis within 72 hours and have the result reported to the project sponsor within the same 72 hours if the result of any single sample exceeds 10 mg/L;

(3) If the average of the results of two consecutive samples collected pursuant to paragraph (1) exceeds 10 mg/L total nitrogen;

(A) notify the Department and the RWQCB within 48 hours of being notified of the exceedance by the laboratory,

(B) investigate the cause for the exceedances and take actions to reduce the total nitrogen concentrations such that continued and future exceedances don't occur, and

(C) initiate additional monitoring for nitrogen compounds as described in the GRRP's Operations Plan, including locations in the groundwater basin and spreading area, to identify elevated concentrations and determine whether such elevated concentrations exceed or may lead to an exceedance of a nitrogen-based MCL; and

(4) If the average of the results of four consecutive samples collected pursuant to paragraph (1) exceeds 10 mg/L total nitrogen, suspend the surface application of recycled municipal wastewater. Surface application shall not resume until corrective actions have been taken and at least two consecutive total nitrogen sampling results are less than 10 mg/L.

(b) Based on a GRRP's operation, including but not limited to the time the spreading area is out of service and utilization of a denitrification process, the project sponsor shall initiate additional monitoring for nitrogen compounds to identify elevated concentrations in the groundwater and determine whether such elevated concentrations exceed or may lead to an exceedance of a nitrogen-based MCL.

(c) The GRRP's project sponsor may apply for reduced monitoring frequencies for total nitrogen, nitrate, or nitrite if, for the most recent 24 months:

(1) the average of all results did not exceed 5 mg/L total nitrogen or one-half the nitrate, nitrite, and nitrate plus nitrite MCLs; and

(2) a result did not exceed 10 mg/L total nitrogen or 80 percent of the nitrate, nitrite, and nitrate plus nitrite MCLs.

(d) If the results of reduced monitoring conducted pursuant to subsection (c) exceed the total nitrogen, nitrate, nitrite, and nitrate plus nitrite concentrations in paragraph (c), the project sponsor shall revert to the GRRP's monitoring frequencies for total nitrogen, nitrate, and nitrite prior to implementation of the reduced frequencies. Reduced frequency monitoring shall not resume unless the requirements of subsection (c) are met.

Section 60320.112. Regulated Contaminants and Physical Characteristics Control.

(a) Each calendar quarter, as specified in the GRRP's Operations Plan, the GRRP's project sponsor shall collect grab samples representative of the applied recycled municipal wastewater and have the samples analyzed for:

(1) the inorganic chemicals in Table 64431-A, except for nitrogen compounds;

(2) the radionuclide chemicals in Tables 64442 and 64443;

(3) the organic chemicals in Table 64444-A;

(4) the disinfection byproducts in Table 64533-A; and

(5) lead and copper.

(b) Recharge water may be monitored in lieu of recycled municipal wastewater to satisfy the monitoring requirements in paragraph (a)(4) if the fraction of recycled municipal wastewater in the recharge water is equal to or greater than the average fraction for the quarter. If the fraction of recycled municipal waste water in the recharge water being monitored is less than the average fraction applied for the quarter, the reported value shall be amended to account for any dilution.

(c) Each year, the GRRP's project sponsor shall collect at least one representative grab sample of the recycled municipal wastewater and have the sample(s) analyzed for the secondary drinking water contaminants in Tables 64449-A and 64449-B.

(d) If a result of the monitoring performed pursuant to subsection (a) exceeds a contaminant's MCL or action level (for lead and copper), within 72 hours of notification of the result the project sponsor shall collect another sample and have it analyzed for the contaminant as confirmation.

(1) For a contaminant whose compliance with its MCL or action level is not based on a running annual average, if the average of the initial and confirmation sample exceeds the contaminant's MCL or action level, or the confirmation sample is not collected and analyzed pursuant to this subsection, the GRRP's project sponsor shall notify the Department and RWQCB within 24 hours and initiate weekly monitoring until four consecutive weekly results are below the contaminant's MCL or action level. If the running four-week average exceeds the contaminant's MCL or action level, the GRRP's project sponsor shall notify the

Department and RWQCB within 24 hours and, if directed by the Department or RWQCB, suspend application of the recycled municipal wastewater.

(2) For a contaminant whose compliance with its MCL is based on a running annual average, if the average of the initial and confirmation sample exceeds the contaminant's MCL, or a confirmation sample is not collected and analyzed pursuant to this subsection, the GRRP shall initiate weekly monitoring for the contaminant until the running four-week average no longer exceeds the contaminant's MCL.

(A) If the running four-week average exceeds the contaminant's MCL, the project sponsor shall describe the reason(s) for the exceedance and provide a schedule for completion of corrective actions in the next quarterly report submitted to RWQCB pursuant to section 60321, with a copy provided to the Department.

(B) If the running four-week average exceeds the contaminant's MCL for sixteen weeks, the project sponsor shall notify the Department and RWQCB within 48 hours and, if directed by the Department or RWQCB, suspend application of the recycled municipal wastewater.

(e) With the exception of color, if an annual result of the monitoring performed pursuant to (c) exceeds a contaminant's secondary MCL in Table 64449-A or the upper limit in Table 64449-B, the project sponsor shall initiate quarterly monitoring of the recycled municipal wastewater for the contaminant and, if the running annual average of quarterly results exceeds a contaminant's secondary MCL or upper limit, describe the reason(s) for the exceedance and any corrective actions taken in the next quarterly report submitted to RWQCB pursuant to section 60321, with a copy provided to the Department. The annual monitoring in (c) may resume if the running annual average of quarterly results does not exceed a contaminant's secondary MCL or upper limit.

(f) If four consecutive quarterly results for asbestos are below the detection limit for asbestos, monitoring for asbestos may be reduced to one sample every three years. Quarterly monitoring shall resume if asbestos is detected.

Section 60320.114. Diluent Water Requirements.

To be credited with diluent water used in calculating an RWC pursuant to section 60320.116, the GRRP shall comply with the requirements of this section and receive Department approval. For diluent water that is a Department-approved drinking water source, the GRRP's project sponsor is exempt from subsections (a) and (b). The GRRP's project sponsor shall:

(a) Monitor the diluent water quarterly for nitrate and nitrite and, within 72 hours of being informed by the laboratory of a nitrate, nitrite, or nitrate plus nitrite result exceeding an MCL, collect a confirmation sample. If the average of the two samples is greater than an MCL;

(1) notify the Department and the RWQCB within 48 hours of receiving the confirmation sample result,

(2) investigate the cause(s) and implement corrective actions, and

(3) each week, collect and analyze two grab samples at least three days apart as specified in an Operations Plan. If the average of the results for a two-week period exceeds the MCL, surface application of the diluent water shall not be used in the calculation of RWC until corrective actions are made. Quarterly monitoring may resume if four consecutive results are below the MCL.

(b) Conduct a source water evaluation per California-Nevada Section of American Water Works Association watershed sanitary survey handbook, or other Department approved evaluation, of the diluent water for Department review and approval that includes, but is not limited to:

(1) a description of the source of the diluent water;

(2) delineation of the origin and extent of the diluent water;

(3) the susceptibility of the diluent water to contamination;

(4) the identification of known or potential contaminants; and

(5) an inventory of the potential sources of diluent water contamination.

(c) Ensure diluent water does not exceed primary MCLs or notification levels and implements a Department-approved water quality monitoring plan for Department-specified contaminants to demonstrate compliance with the primary MCLs and notification levels. The plan shall also include:

(1) monitoring of any chemicals or contaminants in section 60320.120, based on the source water evaluation performed in (b); and

(2) actions to be taken in the event of non-compliance with a primary MCL or exceedance of a notification level.

(d) Develop a method for determining the volume of diluent water to be credited and demonstrate that the diluent water will be introduced in a manner such that the diluent water volume will not result in the GRRP's 120-month running monthly average RWC exceeding its maximum RWC at or beyond the boundary established pursuant to 60320.100(e)(2). The method shall be submitted to the Department for review and approval, and be conducted at a frequency specified in the engineering report prepared pursuant to section 60323. The method shall address all conditions that influence how and when the recycled municipal wastewater and diluent water arrive at all points along the boundary. The conditions must include, but are not limited to, temporal variability in the diluent water supply and regional groundwater gradients, the difference in the distribution of the recycled municipal wastewater and diluent water between individual aquifers where more than one aquifer is replenished, and the difference in travel-time when recycled municipal wastewater and diluent water are introduced at different locations and/or times.

(e) For credit prior to the operation of the GRRP, but not to exceed 120 months:

(1) demonstrate that the diluent water met the nitrate, nitrite, and nitrate plus nitrite MCLs, notification levels, and the water quality requirements in section 60320.112;

(2) provide evidence that the quantity of diluent water has been accurately determined and was distributed such that the proposed or permitted maximum RWC would not have been exceeded; and

(3) conduct a source water evaluation of the diluent water pursuant to subsection (c).

(f) In the Operations Plan prepared pursuant to 60320.122, include a description of:

(1) how the diluent water will be distributed in a manner that ensures that the maximum RWC will not be exceeded during normal operations; and

(2) the actions to be taken in the event the diluent water is curtailed or is no longer available.

Section 60320.116. Recycled Municipal Wastewater Contribution (RWC) Requirements.

(a) Each month, for each surface application facility used for replenishing a groundwater basin, the GRRP's project sponsor shall calculate the running monthly average (RMA) RWC based on the total volume of the recycled municipal wastewater and credited diluent water for the preceding 120 calendar months. For GRRPs in operation less than 120 months, calculation of the RMA RWC shall commence after 30 months of recycled water application, based on the total volume of the recycled municipal wastewater and credited diluent water introduced during the preceding months.

(b) The GRRP's RMA RWC, as determined in (a), shall not exceed the maximum RWC specified by the Department.

(c) The initial maximum RWC, based on the Department's review of the engineering report and information obtained as a result of the public hearing, shall not exceed 0.20.

(d) A GRRP may increase its maximum RWC, provided that:

(1) the increase has been approved by the Department and RWQCB;

(2) for the previous 52 weeks, the TOC 20-week running average, as monitored pursuant to section 62320.118, has not exceeded 0.5 mg/L divided by the proposed maximum RWC; and

(3) the GRRP has received a permit from the RWQCB that allows operation of the GRRP at the increased maximum RWC.

(e) In addition to the requirements in subsection (d), prior to operating a GRRP at an RWC greater than 0.50 or 0.75, which must be achieved sequentially, the project sponsor shall:

(1) provide a proposal to the Department prepared and signed by an engineer licensed in California with at least three years of experience in wastewater treatment and public water supply;

(2) submit an updated engineering report and Operations Plan; and

(3) provide evidence of compliance with section 60320.126(a).

(f) If the RMA RWC exceeds its maximum RWC, the GRRP's project sponsor shall:

(1) notify the Department and RWQCB in writing within 7 days of exceedance; and

(2) within 60 days, implement corrective action(s) and submit a report to the Department and RWQCB describing the reason(s) for the exceedance and the corrective action(s) taken to avoid future exceedances.

Section 60320.118. Total Organic Carbon and Soil Treatment Process Requirements.

(a) For each surface application facility used for replenishing a groundwater basin, the GRRP's project sponsor shall monitor TOC as follows:

(1) For recycled municipal wastewater, at least one 24-hour composite sample each week prior to application; or

(2) At least one sample each week in a manner yielding TOC values representative of the recycled municipal wastewater TOC concentrations after infiltration and percolation, and not influenced by diluent water, native groundwater, or other source of dilution as determined by;

(A) measuring undiluted percolating recycled municipal wastewater,

(B) measuring diluted percolating recycled municipal wastewater and adjusting the value for the diluent water effect, or

(C) using replenishment demonstration studies to develop a soil treatment factor that can be applied weekly to recycled municipal wastewater measurements leaving the treatment plant.

(b) Grab samples may be taken in lieu of the 24-hour composite samples required in subsection (a) if:

(1) the GRRP demonstrates that a grab sample is representative of the water quality throughout a 24-hour period; or

(2) the entire recycled municipal wastewater stream has been treated by reverse osmosis meeting the criteria in section 60320.201(a) and (b).

(c) Analytical results of the TOC monitoring performed pursuant to subsection (a) shall not exceed 0.5 mg/L divided by the RMA RWC based on:

(1) the 20-week running average of all TOC results; and

(2) the average of the last four TOC results.

(d) If the GRRP exceeds the limit in (c)(1), or its approved increased TOC limit obtained pursuant to section 60320.130(c), based on a 20-week running average, the GRRP's project sponsor shall:

(1) immediately suspend the addition of recycled municipal wastewater until at least two consecutive results, 3 days apart, are less than the limit;

(2) notify the Department and RWQCB within 7 days of suspension; and

(3) within 60 days, submit a report to the Department and RWQCB describing the reasons for the exceedance and the corrective actions to avoid future exceedances. At a minimum, the corrective actions shall include;

(A) a reduction of RWC sufficient to comply with the limit, and/or

(B) additional treatment demonstrated to the Department to remove TOC and chemicals or contaminants of concern to public health.

(e) If the GRRP exceeds the limit in (c)(2) or its approved increased TOC limit obtained pursuant to section 60320.130(c) based on the last four results, the GRRP shall, within 60 days, submit a report to the Department and RWQCB describing the reasons for the exceedance and the corrective actions taken to avoid future exceedances.

(f) Quarterly, a project sponsor shall monitor the GRRP's recycled municipal wastewater or recharge water prior to the soil treatment process and the water after the soil treatment process, but at a point no farther than 30 days downgradient of the treatment process. The monitoring shall include at least three indicator compounds based on the results of an occurrence study approved by the Department. If the monitoring results do not indicate a reduction of at least 90 percent in the concentration of indicator compounds by the soil treatment process, excluding the effects of dilution from diluent water that may be present, the project sponsor shall investigate the reason for the low reduction and report the indicator compound and investigative results within 90 days of receipt of the analytical results.

(g) If the result of the investigation in subsection (f) concludes that the 90 percent reduction could not be demonstrated because the concentration of indicator compounds prior to the soil treatment process wasn't sufficient, the project sponsor shall consult with the Department and comply with an alternative monitoring plan approved by the Department.

(h) To use one or more wastewater chemicals in lieu of TOC, approval from the Department shall be obtained. At a minimum, the chemical(s) used in lieu of TOC shall:

(1) be quantifiable in the wastewater, recycled municipal wastewater, groundwater, and throughout the treatment processes; and

(2) have identifiable treatment performance standards as protective of public health as the TOC standards in this Article.

Section 60320.120. Additional Chemical and Contaminant Monitoring.

(a) Each quarter, the GRRP's project sponsor shall sample and analyze the recycled municipal wastewater and the downgradient monitoring wells specified by the Department for the following:

(1) Priority Toxic Pollutants [chemicals listed in the Water Quality Standards, Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California, and 40 CFR Part 131, Federal Register 65(97), May 18, 2000, p. 31682] specified by the Department, based on the Department's review of the GRRP's engineering report;

(2) Chemicals with notification levels that the Department has specified, based on a review of the GRRP's engineering report and the affected groundwater basin(s); and

(3) Chemicals that the Department has specified, based on a review of the GRRP's engineering report, the affected groundwater basin(s), and the results of the assessment performed pursuant to subparagraph 60320.106(a)(2)(A).

(b) The project sponsor may reduce monitoring for the chemicals in subsection (a) to once each year following Department approval based on the Department's review of the most recent two years of results of the monitoring performed pursuant to subsection (a).

(c) Annually, the project sponsor shall monitor the recycled municipal wastewater for indicator compounds specified by the Department and RWQCB based on the following:

(1) a review of the GRRP's engineering report;

(2) the inventory developed pursuant to section 60320.106(a)(2)(D);

(3) the affected groundwater basin(s);

(4) an indicator compound's ability to characterize the presence of pharmaceuticals, endocrine disrupting chemicals, personal care products, and other indicators of the presence of municipal wastewater; and

(5) the availability of a test method for a chemical.

(d) A chemical or contaminant detected as a result of monitoring conducted pursuant to this section shall be reported to the Department and RWQCB no later than the quarter following the quarter in which the results are received by the GRRP's project sponsor. If a detection of a contaminant is from a monitoring well and exceeds a state notification level, the project sponsor shall monitor the well for the contaminant within 7 days of receipt of the initial result. If the average of the initial and the confirmation results exceed the notification level, as soon as possible but no later than 30 days after receipt of the confirmation result, the project sponsor shall notify the Department and RWQCB. Following notification, the Department may require the project sponsor to notify local agencies overseeing private drinking water wells and each public water system immediately downgradient of the GRRP of the notification level exceedance.

Section 60320.122. Operation Optimization and Plan.

(a) Prior to operation, a new GRRP shall have an Operations Plan submitted to and approved by the Department. An existing GRRP shall maintain, and make available to the Department or RWQCB for review upon request, an Operations Plan. At a minimum, the Operations Plan shall identify the operations, maintenance, analytical methods, monitoring necessary for the GRRP to meet the requirements of this Article, and the reporting of monitoring results to the Department and RWQCB. The project sponsor shall be responsible for ensuring that the Operations Plan is, at all times, representative of the current operations, maintenance, and monitoring of the GRRP.

(b) During the first year of operation for a new GRRP, or during the first year of operation after *[insert effective date]* for an existing GRRP, and at all times thereafter, all treatment processes shall be operated in a manner providing optimal reduction of all chemicals and contaminants including:

(1) microbial contaminants;

(2) regulated contaminants identified in section 60320.112 and the nitrogen compounds in section 60320.110; and

(3) nonregulated chemicals identified in section 60320.120.

(c) Within six months of optimizing treatment processes pursuant to (b) and anytime thereafter operations are optimized that result in a change in operation, each GRRP shall update their operations plan to include such changes in operational procedures and submit the operations plan to the Department for review.

Section 60320.124. Response Retention Time.

(a) The recycled municipal wastewater used by a GRRP shall be retained underground for a period of time sufficient to allow the GRRP's project sponsor ample response time to identify treatment failures and implement actions, including those required pursuant to section 60320.100(b), necessary for the protection of public health from inadequately treated recycled municipal wastewater or recharge water.

(b) The response time required in subsection (a) shall be approved by the Department, based on information provided in the engineering report required pursuant to section 60323. Regardless of the minimum response time identified in subsection (a), the retention time shall be no less than two months.

(c) To demonstrate the retention time underground is no less than the response time in subsection (b), a tracer study utilizing an added tracer shall be implemented under hydraulic conditions representative of normal GRRP operations. With Department approval, an intrinsic tracer may be used in lieu of an added tracer. For each month of retention time estimated utilizing the approved intrinsic tracer, the project sponsor shall receive no more than 0.67

months credit. The retention time shall be the time representing the difference from when water is applied at the GRRP to when the first ten percent (10%) of such water arrives at the downgradient endpoint. A project sponsor for new GRRP shall initiate the tracer study prior to the end of the third month of operation. The project sponsor for existing GRRP that hasn't already performed a tracer study shall initiate a tracer study prior to the renewal of the GRRP's permit.

(d) For the purpose of siting a GRRP location during project planning and until a GRRP's project sponsor has met the requirements of subsection (c), for each month of retention time estimated using the method in column 1, the recycled municipal wastewater or recharge water may be credited with no more than the corresponding response time in column 2 of Table 60320.124.

Table 60320.124

Column 1	**Column 2**
Method used to estimate the retention time	**Response Time Credit per Month**
Tracer study utilizing an intrinsic tracer, based on T_{10} (i.e. the time for ten percent (10%) of tracer concentration to reach the endpoint).	0.67 months
Numerical modeling consisting of calibrated finite element or finite difference models using validated and verified computer codes used for simulating groundwater flow.	0.50 months
Analytical modeling using existing academically-accepted equations such as Darcy's Law to estimate groundwater flow conditions based on simplifying aquifer assumptions.	0.25 months

(e) The protocol(s) used to establish the retention times in subsections (c) and (d) shall be approved by the Department.

(f) The Department may require the GRRP to demonstrate that the underground retention times required in this section are being met based on changes in hydrogeological or climatic conditions since the most recent demonstration.

Section 60320.126. Monitoring Well Requirements.

(a) Prior to operating a GRRP, a project sponsor shall site and construct at least two monitoring wells such that:

(1) at least one monitoring well is located;

(A) no less than two weeks, but no more than six months of travel through the saturated zone of the GRRP, and

(B) at least 30 days upgradient of the nearest drinking water source;

(2) in addition to the well(s) paragraph (1), at least one monitoring well is located between the GRRP and the nearest downgradient domestic water supply well; and

(3) samples from the monitoring wells in paragraphs (1) and (2) can be;

(A) obtained independently from each aquifer, initially receiving the water used as a source of potable water supply, that will receive the GRRP's recharge water, and

(B) validated as receiving recharge water from the GRRP.

(b) From each monitoring well in subsection (a)(1), and each monitoring well in subsection (a)(2) that has recharge water located within one year travel time of the well(s), the project sponsor shall collect two samples prior to GRRP operation (for a new GRRP) and at least one sample each quarter after operation begins. Each sample shall be analyzed for total nitrogen, nitrate, nitrite, the contaminants in tables 64449-A and B of section 64449, and any contaminants and chemicals specified by the Department and RWQCB based on the results of the recycled municipal wastewater monitoring conducted pursuant to this Article.

(c) If a result from the monitoring conducted pursuant to subsection (b) exceeds a nitrate, nitrite, or nitrate plus nitrite MCL, the project sponsor shall, within 24 hours, collect another sample and have it analyzed for the contaminant. If the average of the result of the initial sample and the confirmation sample exceed the contaminant's MCL, the project sponsor shall:

(1) within 24 hours of being notified by the laboratory of the confirmation sample result, notify the Department and RWQCB; and

(2) discontinue surface application of recycled municipal wastewater until corrective actions have been taken or evidence is provided to the Department and RWQCB that the contamination was not a result of the GRRP.

(d) For chemical analyses completed in a calendar month, the project sponsor shall ensure the laboratory submits results no later than the end of the following month using the Electronic Deliverable Format as defined in the Electronic Deliverable Format (EDF) Version 1.2i Guidelines & Restrictions dated April 2001 and Data Dictionary dated April 2001.

(e) The GRRP's project sponsor may reduce monitoring for the chemicals and contaminants in subsection (b) to once each year following Department approval based on the Department's review of the most recent two years of results.

Section 60320.128. Reporting.

(a) Annually, the project sponsor shall provide a report to the RWQCB and the Department. Public water systems having downgradient sources potentially affected by the GRRP and within 10 years groundwater travel time from the GRRP shall be notified by direct mail and/or electronic mail of the availability of the report. The report shall be prepared by an engineer licensed in California and experienced in the fields of wastewater treatment and public water supply. The report shall include the following:

(1) A summary of the GRRP's compliance status with the applicable monitoring requirements and criteria of this Article during the previous calendar year;

(2) For any violations of this Article during the previous calendar year;

(A) the date, duration, and nature of the violation,

(B) a summary of any corrective actions and/or suspensions of surface application of recycled municipal wastewater resulting from a violation, and

(C) if uncorrected, a schedule for and summary of all remedial actions;

(3) Any detections of monitored chemicals or contaminants, and any observed trends in the monitoring wells and diluent water supplies;

(4) Information pertaining to the vertical and horizontal migration of the recharge water plume;

(5) A description of any changes in the operation of any unit processes or facilities;

(6) A description of any anticipated changes, along with an evaluation of the expected impact of the changes on subsequent unit processes;

(7) The estimated quantity and quality of the recycled municipal wastewater and diluent water to be utilized for the next twelve months; and

(8) A summary of the measures taken to comply with section 60320.106 and the effectiveness of the implementation of the measures.

(b) Every five years from the date of the initial approval of the engineering report required pursuant to section 60323, the project sponsor shall update the report to address any project changes and submit the report to the RWQCB and the Department. The update shall include, but not be limited to:

(1) anticipated RWC increases, a description of how the RWC requirements in section 60320.116 will be met, and the expected impact the increase will have on the GRRP's ability to meet the requirements of this Article;

(2) evidence that the requirements associated with retention time in section 60320.108, if applicable, and section 60320.124 have been met; and

(3) a description of any inconsistencies between previous groundwater model predictions and the observed and/or measured values, as well as a description of how subsequent predictions will be accurately determined.

Section 60320.130. Alternatives.

(a) A project sponsor may use an alternative to a requirement in this Article if the GRRP's project sponsor has:

(1) demonstrated to the Department that the proposed alternative would assure at least the same level of protection to public health;

(2) received written approval from the Department prior to implementation of the alternative; and

(3) if required by the Department or RWQCB for the purpose of conducting a public hearing regarding the proposed alternative, disseminated information to the public, and received public comments, pursuant to subsections 60320.102(b) and (c).

(b) Unless specified otherwise by the Department, the demonstration in paragraph (a)(1) shall include the results of a review of the proposed alternative by an independent scientific advisory panel that includes a toxicologist, a registered engineering geologist or hydrogeologist, an engineer licensed in California with at least three years of experience in wastewater treatment and public drinking water supply, a microbiologist, and a chemist.

(c) The TOC limit specified in section 60320.118(c) may be increased if:

(1) The increased TOC limit is approved by the Department and RWQCB;

(2) The GRRP has been in operation for the most recent ten consecutive years;

(3) The project sponsor submits a proposal to the Department prepared and signed by an engineer licensed in California and experienced in the fields of wastewater treatment and public water supply. The proposal shall include the following, based on the most recent ten consecutive years of operation;

(A) GRRP operations, monitoring, and compliance data,

(B) Evidence that the GRRP has a history of compliance with the requirements of their RWQCB permit,

(C) Evidence that the water collected at all downgradient drinking water wells and monitoring wells impacted by the GRRP has met the primary drinking water standards specified pursuant to section 60320.126(b),

(D) Analytical or treatment studies requested by the Department to make the determination in subparagraph (C),

(E) Validation of appropriate construction and siting of monitoring wells pursuant to section 60320.126, and

(F) A study defining the water quality changes, including organic carbon characterization, as a result of the impact of the GRRP;

(4) The project sponsor has performed a health effects evaluation that assesses the health risks to consumers of water impacted by the GRRP, including any anticipated water quality changes resulting from the proposed increased TOC limit. The evaluation shall include the following;

(A) An exposure assessment that characterizes the quality of the water consumed and the quantity of contaminants and chemicals consumed,

(B) All available human epidemiologic studies of the population that has consumed water impacted by the GRRP,

(C) The results of laboratory animal studies and health risk assessments available in peer-reviewed literature pertaining to water impacted by the GRRP and anticipated water quality changes resulting from the proposed increased TOC, including studies or assessments where extrapolation of data may be relevant,

(D) A health risk assessment of the potential individual and cumulative effects of the regulated contaminants described in section 62320.112, and the chemicals or contaminants monitored pursuant to subsections 60320.120(a) and (c), that includes;

1. lifetime risks of cancer, and
2. risks of non-cancer effects, and

(E) A report detailing comments, questions, concerns, and conclusions of a review by an independent scientific peer review advisory panel that includes, as a minimum, a toxicologist, an epidemiologist, an engineering geologist or hydrogeologist registered in California, an engineer licensed in California with at least three years of experience in wastewater treatment and public water supply, a microbiologist, and a chemist.

ARTICLE 5.2. INDIRECT POTABLE REUSE: GROUNDWATER REPLENISHMENT - SUBSURFACE APPLICATION

Section 60320.200. General Requirements.

(a) A Groundwater Replenishment Reuse Project (GRRP) project sponsor utilizing subsurface application shall meet the requirements of this Article and continuously treat, with full advanced treatment meeting the criteria in section 60320.201, the entire recycled municipal wastewater stream prior to application.

(b) Prior to operation of a new GRRP, or prior to permit renewal for an existing GRRP, the GRRP's project sponsor shall have a Department-approved plan describing the steps the project sponsor will take to provide an alternative source of potable water supply to all users of a producing drinking water well, or a Department-approved treatment mechanism the project sponsor will provide to all owners of a producing drinking water well, that as a result of the GRRP's operation, as determined by the Department:

(1) violates a California or federal drinking water standard;

(2) has been degraded to the degree that it is no longer a safe source of drinking water; or

(3) receives water that fails to meet section 60320.208.

(c) Prior to operating a new GRRP, the project sponsor shall collect at least two samples from each monitoring well approved pursuant to section 60320.226. The samples shall be representative of water in each aquifer, taking into consideration seasonal variations, and be analyzed for the chemicals, contaminants, and characteristics in sections 60320.210, 60320.212, 60320.218 and 60320.220.

(d) A GRRP's recycled municipal wastewater shall be retained underground for a period of time no less than the retention time required pursuant to section 60320.208 and 60320.224. The GRRP shall be designed and operated in a manner that ensures water treated pursuant to this Article, beyond the boundary described in (e)(2), meets the recycled municipal wastewater contributions (RWC) requirements in section 60320.216.

(e) A GRRP's project sponsor shall provide the Department, RWQCB, and local well-permitting authorities a map of the GRRP site at a scale of 1:24,000 or larger (1 inch equals 2,000 feet or 1 inch equals less than 2,000 feet) or, if necessary, a site sketch at a scale providing more detail, that clearly indicates:

(1) the location and boundaries of the GRRP;

(2) the boundary representing the greatest of the horizontal and vertical distances reflecting the retention times required pursuant to section 60320.208 and section 60320.224; and

(3) the location of all monitoring wells established pursuant to section 60320.226 and drinking water supply wells within two years of the GRRP based

on groundwater flow directions and velocities expected under GRRP operating conditions.

(f) Prior to operating a new GRRP, the project sponsor shall demonstrate to the Department and RWQCB that the project sponsor possesses adequate managerial and technical capability to assure compliance with this Article.

(g) Prior to replenishing a groundwater basin or an aquifer with recycled municipal wastewater, a new GRRP's project sponsor shall demonstrate that all treatment processes have been installed and can be operated by the project sponsor to achieve their intended function. A protocol describing the actions to be taken to meet this subsection shall be included in the engineering report submitted pursuant section 60323.

(h) In the engineering report required pursuant to section 60323, the project sponsor for a new GRRP shall include a hydrogeological assessment of the proposed GRRP's setting. The assessment shall include the following:

(1) the qualifications of the individual(s) preparing the assessment;

(2) a general description of geologic and hydrogeological setting of the groundwater basin(s) potentially directly impacted by the GRRP;

(3) a detailed description of the stratigraphy beneath the GRRP, including the composition, extent, and physical properties of the affected aquifers; and

(4) based on at least four rounds of consecutive quarterly monitoring to capture seasonal impacts;

(A) the existing hydrogeology and the hydrogeology anticipated as a result of the presence of the GRRP, and

(B) maps showing quarterly groundwater elevation contours, along with vector flow directions and calculated hydraulic gradients.

Section 60320.201. Advanced Treatment Criteria.

Full advanced treatment is the treatment of an oxidized wastewater, as defined in section 60301.650, using a reverse osmosis and an oxidation treatment process that, at a minimum, meets the criteria of this section.

(a) A project sponsor shall select for use a reverse osmosis membrane that:

(1) has been determined, utilizing ASTM method D4194-03 (2008), that it achieves an average rejection of sodium chloride greater than or equal to 99.5 percent, with a 15 percent recovery; and

(2) through bench-scale testing, initially produces a permeate having TOC concentrations of 0.25 mg/L or less when using reverse osmosis influent consistent with the GRRP's expected influent.

(b) For the reverse osmosis treatment process, a project sponsor shall propose, for Department review and approval, on-going performance monitoring (e.g. conductivity or TOC) that indicates when the integrity of the process has been compromised. The proposal shall include at least one form of continuous monitoring, as well as the associated surrogate and/or operational parameter limits and alarm settings that indicate when the integrity has been compromised.

(c) To demonstrate a sufficient oxidation process has been designed for implementation, a project sponsor shall:

(1) Perform an occurrence study on the project's municipal wastewater to identify indicator compounds and select a total of at least nine indicator compounds, with at least one from each of the functional groups in subparagraphs (A) through (I) below. The project sponsor shall submit an occurrence study protocol, as well as the subsequent results and chosen indicator compounds, to the Department for review and approval.

(A) Hydroxy Aromatic
(B) Amino/Acylamino Aromatic
(C) Nonaromatic with carbon double bonds
(D) Deprotonated Amine
(E) Alkoxy Polyaromatic
(F) Alkoxy Aromatic
(G) Alkyl Aromatic
(H) Saturated Aliphatic
(I) Nitro Aromatic

(2) Utilize an oxidation process that achieves optimal removal of the indicator compounds selected in paragraph (1) such that removal is no less than;

(A) 0.5-log (69 percent) for each indicator compound representing the functional groups in paragraph (1)(A) through (1)(G), and

(B) 0.3-log (50 percent) for each indicator compound representing the functional groups in paragraph (1)(H) and (1)(I).

(3) Establish at least one surrogate or operational parameter that reflects the removal of at least five of the nine indicator compounds selected pursuant to paragraph (1) such that;

(A) at least one of the five indicator compounds represents at least one functional group in paragraph (1)(A) through (1)(G),

(B) at least one of the five indicator compounds represents at least one functional group in paragraph (1)(H) or (1)(I),

(C) at least one surrogate or operational parameter is capable of being monitored continuously, recorded, and have associated alarms, and

(D) a surrogate or operational parameter, including the parameter in (C), is identified that indicates when the process may no longer meet the criteria established in paragraph (2).

(4) Conduct pilot testing that includes confirmation the findings of the occurrence study in paragraph (1) and provides evidence that the requirements of paragraphs (2) and (3) can be met with a full-scale oxidation process. The pilot testing shall include challenge or spiking tests conducted to determine the removal differential under normal operating conditions utilizing, at minimum, the nine indicator compounds identified in paragraph (1). The project sponsor shall submit a pilot testing protocol, as well as the subsequent results, to the Department for review and approval.

(d) In lieu of demonstrating that a sufficient oxidation process has been designed for implementation pursuant to subsection (c), a project sponsor may conduct pilot testing demonstrating that the oxidation process will provide a 0.5-log (69 percent) reduction of 1,4-dioxane.

(1) The project sponsor shall submit a pilot testing protocol, as well as the subsequent results, to the Department for review and approval. The pilot testing shall include challenge or spiking tests, using 1,4-dioxane, to demonstrate the proposed oxidation process has been designed and will achieve the 0.5-log reduction under normal operation of the oxidation process.

(2) The project sponsor shall establish surrogate and/or operational parameters that reflect whether the 0.5-log 1,4-dioxane design criteria is being met. At least one surrogate or operational parameter shall be capable of being monitored continuously, recorded, and have associated alarms that indicate when the process no longer operates as designed.

(e) During the full-scale operation of the oxidation process designed pursuant to subsections (c) or (d), the project sponsor shall continuously monitor the surrogate and/or operational parameters established pursuant to (c)(3)(C) or (d)(2), as applicable. The project sponsor shall implement, in full-scale operation, the oxidation process as designed pursuant to subsections (c) or (d).

(f) Within 60 days after completing the initial 12-months of monitoring pursuant to subsection (e), the project sponsor shall submit a report to the Department and RWQCB that includes:

(1) the results of the monitoring performed in subsection (e);

(2) the removal differential of the indicator compounds;

(3) a description of the efficacy of the surrogate and/or operational parameters to reflect the removal differential of the indicator compounds; and

(4) a description of actions taken, or those that would be taken, if the indicator compound removal didn't meet the associated design criteria in (c) or (d), the continuous surrogate and/or operational parameter monitoring in (c)(3)(C) or (d)(2) failed to correspond to the differential indicator compound removal, or the surrogate and/or operational parameter established in (c)(3)(D) or (d)(2) was not met.

(g) Within 60 days after completing 12 months of operation of the reverse osmosis process, the project sponsor shall submit a report to the Department and RWQCB describing the effectiveness of the treatment, process failures, and actions taken in the event the on-going monitoring in subsection (b) indicated that process integrity was compromised.

(h) Each quarter, the project sponsor shall tabulate the percent of the quarter's monitoring, conducted pursuant to subsection (b) and (e), that did not meet the surrogate and/or operational parameter limits established to assure proper on-going performance of the reverse osmosis and oxidation processes. If the value is more than ten percent, within 30 days after the end of the quarter the project sponsor shall:

(1) submit a report to the Department and RWQCB describing the corrective actions planned or taken to reduce the percent to ten percent or less; and

(2) consult with the Department and, if required, comply with an alternative monitoring plan approved by the Department.

(i) Each month the project sponsor shall collect grab samples representative of the effluent of the advanced treatment process and have the samples analyzed for contaminants having MCLs and notification levels. After 12 consecutive months with no results exceeding an MCL or notification level, the project sponsor may apply for reduced monitoring frequency. The reduced monitoring frequency shall be no less than quarterly. Monitoring conducted pursuant to this subsection may be used in lieu of the monitoring (for the same contaminants) required pursuant to section 60320.212. The effluent of the advanced treatment process shall not exceed an MCL or notification level.

Section 60320.202. Public Hearing.

(a) A public hearing for a GRRP shall be held by the project sponsor prior to the Department's submittal of its recommendations to the RWQCB for the GRRP's initial permit and any time an increase in maximum RWC has been proposed but not addressed in a prior public hearing. Prior to a public hearing, the project sponsor shall provide the Department, for review and approval, the information the project sponsor intends to present at the hearing. The information shall also be provided on the Internet. Following the Department's approval of the information, the project sponsor shall place the information on the Internet and in a repository that provides at least thirty days of public access to the information prior to the public hearing.

(b) Prior to placing the information required pursuant to subsection (a) in a repository, the project sponsor shall:

(1) Notify the public of the following;

(A) the location and hours of operation of the repository,

(B) the Internet address where the information may be viewed,

(C) the purpose of the repository and public hearing,

(D) the manner in which the public can provide comments, and

(E) the date, time, and location of the public hearing; and

(2) At a minimum, notify the first downgradient potable water well owner and well owners whose drinking water source is within 10 years from the GRRP based on groundwater flow directions and velocities.

(c) Unless directed otherwise by the Department, the public notification made pursuant to subsection (b)(2) shall be by direct mail and the notification made pursuant to (b)(1) shall be by one or more of the following methods delivered in a manner to reach persons whose source of drinking water may be impacted by the GRRP:

(1) local newspaper(s) publication;
(2) mailed or direct delivery of a newsletter;
(3) conspicuously placed statement in water bills; or
(4) television and/or radio.

Section 60320.204. Lab Analyses.

(a) Analyses for contaminants having primary or secondary MCLs shall be performed by laboratories approved to perform such analyses by the Department utilizing Department-approved drinking water methods.

(b) Analyses for chemicals other than those having primary or secondary MCLs shall be described in the GRRP's Operations Plan prepared pursuant to section 60320.222.

Section 60320.206. Wastewater Source Control.

A project sponsor shall ensure that the recycled municipal wastewater used for a GRRP shall be from a wastewater management agency that:

(a) administers an industrial pretreatment and pollutant source control program;

(b) implements and maintains a source control program that includes, at a minimum;

(1) an assessment of the fate of Department-specified and RWQCB-specified chemicals and contaminants through the wastewater and recycled municipal wastewater treatment systems,

(2) chemical and contaminant source investigations and monitoring that focuses on Department-specified chemicals and contaminants,

(3) an outreach program to industrial, commercial, and residential communities within the portions of the sewage collection agency's service area that flows into the water reclamation facility subsequently supplying the GRRP, for the purpose of managing and minimizing the discharge of chemicals and contaminants at the source, and

(4) a current inventory of chemicals and contaminants identified pursuant to this section, including new chemicals and contaminants resulting from new sources or changes to existing sources, that may be discharged into the wastewater collection system; and

(c) is compliant with the effluent limits established in the RWQCB permit for the GRRP.

Section 60320.208. Pathogenic Microorganism Control.

(a) A project sponsor shall design and operate a GRRP such that the recycled municipal wastewater used as recharge water for a GRRP receives treatment that achieves at least 12-log enteric virus reduction, 10-log Giardia cyst reduction, and 10-log Cryptosporidium oocyst reduction. The treatment train shall consist of at least three separate treatment processes. For each pathogen (i.e., virus, Giardia cyst, and Cryptosporidium oocyst), a separate treatment process may be credited with no more than 6-log reduction and shall achieve at least 1-log reduction.

(b) For each month retained underground as demonstrated in subsection (e), the recycled municipal wastewater or recharge water will be credited with 1-log virus reduction.

(c) With the exception of log reduction through retention time underground, the project sponsor shall validate each of the treatment processes used to meet the requirements in subsection (a) for their log reduction by submitting a report for the Department's review and approval, or by using a challenge test approved by the Department, that provides evidence of the treatment process's log reduction. The report and/or challenge test shall be prepared by engineer licensed in California with at least five years of experience, as a licensed engineer, in wastewater treatment and public water supply, including the evaluation of treatment processes for pathogen control. With the exception of retention time underground, the project sponsor shall propose and include in its Operations Plan prepared pursuant to section 60320.222, on-going monitoring that verifies the performance of each treatment process's ability to achieve its credited log reduction.

(d) The project sponsor of a GRRP whose permit was issued prior to *[insert effective date]* shall demonstrate compliance with subsection (c) prior to the renewal of the GRRP's permit. The project sponsor of a new GRRP shall demonstrate compliance with subsection (c) prior to being issued a permit.

(e) To demonstrate the retention time underground in subsection (b) a tracer study utilizing an added tracer shall be implemented under hydraulic conditions representative of normal GRRP operations. The retention time shall be the time representing the difference from when water is applied at the GRRP to when the first two percent (2%) of such water arrives at the downgradient endpoint. The project sponsor for new GRRP shall initiate the tracer study prior to the end of the third month of operation. The project sponsor for existing GRRP that hasn't already performed such a tracer study shall complete a tracer study demonstrating retention time underground prior to the renewal of the GRRP's permit.

(f) For the purpose of siting a GRRP location during project planning and until a GRRP's project sponsor has met the requirements of subsection (e), for each month of retention time estimated using the method in column 1, the recycled municipal wastewater or recharge water shall be credited with no more than the corresponding virus log reduction in column 2 of Table 60320.208.

Table 60320.208

Column 1	**Column 2**
Method used to estimate the retention time to the nearest downgradient drinking water well	**Virus Log Reduction Credit per Month**
Tracer study utilizing an intrinsic tracer, based on T_{10} (i.e. The time representing the difference from when water is applied at the GRRP to when the first ten percent arrives at the downgradient endpoint.)	0.67 logs
Numerical modeling consisting of calibrated finite element or finite difference models using validated and verified computer codes used for simulating groundwater flow.	0.50 logs
Analytical modeling using existing academically-accepted equations such as Darcy's Law to estimate groundwater flow conditions based on simplifying aquifer assumptions.	0.25 logs

(g) The protocol(s) used to establish the retention times in subsections (e) and (f) shall be approved by the Department.

(h) Based on changes in hydrogeological or climatic conditions since the most recent demonstration, the Department may require a GRRP's project sponsor to demonstrate that the underground retention times required in this section are being met.

(i) If the pathogen reduction in subsection (a) is not met based on the on-going monitoring required pursuant to subsection (c), within 24 hours of being aware the project sponsor shall immediately investigate the cause and initiate corrective actions. For failing to meet the pathogen reduction criteria longer than 4 consecutive hours or more than a total of 8 hours during any 7-day period, the Department and RWQCB shall be immediately notified. Failures of shorter duration shall be reported to the RWQCB no later than 10 days after the month in which the failure occurred.

(j) If the effectiveness of a treatment train's ability to reduce enteric virus is less than 9-logs, or Giardia cyst or Cryptosporidium oocyst reduction is less than 8-logs, the project sponsor shall immediately notify the Department and RWQCB, and discontinue application of recycled municipal wastewater at the GRRP.

Section 60320.210. Nitrogen Compounds Control.

(a) To demonstrate control of the nitrogen compounds, the project sponsor shall:

(1) Each week, at least three days apart as specified in the GRRP's Operations Plan, collect at least two samples (grab or 24-hour composite) representative of the recycled municipal wastewater or recharge water applied. Samples may be collected before or after subsurface application;

(2) Have the samples collected pursuant to paragraph (1) analyzed for total nitrogen, with the laboratory being required by the project sponsor to complete each analysis within 72 hours and have the result reported to the project sponsor within the same 72 hours if the result of any single sample exceeds 10 mg/L;

(3) If the average of the results of two consecutive samples collected pursuant to paragraph (1) exceeds 10 mg/L total nitrogen;

(A) notify the Department and the RWQCB within 48 hours of being notified of the exceedance by the laboratory,

(B) investigate the cause for the exceedances and take actions to reduce the total nitrogen concentrations such that continued and future exceedances don't occur, and

(C) initiate additional monitoring for nitrogen compounds as described in the GRRP's Operations Plan, including locations in the groundwater basin, to identify elevated concentrations and determine whether such elevated concentrations exceed or may lead to an exceedance of a nitrogen-based MCL; and

(4) If the average of the results of four consecutive samples collected pursuant to paragraph (1) exceeds 10 mg/L total nitrogen, suspend the subsurface application of recycled municipal wastewater. Subsurface application shall not resume until corrective actions have been taken and at least two consecutive total nitrogen sampling results are less than 10 mg/L.

(b) The GRRP's project sponsor may apply for reduced monitoring frequencies for total nitrogen, nitrate, or nitrite if, for the most recent 12 months:

(1) the average of all results did not exceed 5 mg/L total nitrogen or one-half the nitrate, nitrite, and nitrate plus nitrite MCLs; and

(2) a result did not exceed 10 mg/L total nitrogen or 80 percent of the nitrate, nitrite, and nitrate plus nitrite MCLs.

(c) If the results of reduced monitoring conducted pursuant to subsection (b) exceed the total nitrogen, nitrate, nitrite, and nitrate plus nitrite concentrations in paragraph (b), the project sponsor shall revert to the GRRP's monitoring frequencies for total nitrogen, nitrate, and nitrite prior to implementation of the reduced frequencies. Reduced frequency monitoring shall not resume unless the requirements of subsection (b) are met.

Section 60320.212. Regulated Contaminants and Physical Characteristics Control.

(a) Each calendar quarter, as specified in the GRRP's Operations Plan, the GRRP's project sponsor shall collect grab samples representative of the applied recycled municipal wastewater and have the samples analyzed for:

(1) the inorganic chemicals in Table 64431-A, except for nitrogen compounds;

(2) the radionuclide chemicals in Tables 64442 and 64443;

(3) the organic chemicals in Table 64444-A;

(4) the disinfection byproducts in Table 64533-A; and

(5) lead and copper.

(b) Recharge water may be monitored in lieu of recycled municipal wastewater to satisfy the monitoring requirements in paragraph (a)(4) if the fraction of recycled municipal wastewater in the recharge water is equal to or greater than the average fraction for the quarter. If the fraction of recycled municipal waste water in the recharge water being monitored is less than the average fraction applied for the quarter, the reported value shall be amended to account for any dilution.

(c) Each year, the GRRP's project sponsor shall collect at least one representative grab sample of the recycled municipal wastewater and have the sample(s) analyzed for the secondary drinking water contaminants in Tables 64449-A and 64449-B.

(d) If a result of the monitoring performed pursuant to subsection (a) exceeds a contaminant's MCL or action level (for lead and copper), within 72 hours of notification of the result the project sponsor shall collect another sample and have it analyzed for the contaminant as confirmation.

(1) For a contaminant whose compliance with its MCL or action level is not based on a running annual average, if the average of the initial and confirmation sample exceeds the contaminant's MCL or action level, or the confirmation sample is not collected and analyzed pursuant to this subsection, the GRRP's project sponsor shall notify the Department and RWQCB within 24 hours and initiate weekly monitoring until four consecutive weekly results are below the contaminant's MCL or action level. If the running four-week average exceeds the contaminant's MCL or action level, the GRRP's project sponsor shall notify the Department and RWQCB within 24 hours and, if directed by the Department or RWQCB, suspend application of the recycled municipal wastewater.

(2) For a contaminant whose compliance with its MCL is based on a running annual average, if the average of the initial and confirmation sample exceeds the contaminant's MCL, or a confirmation sample is not collected and analyzed pursuant to this subsection, the GRRP shall initiate weekly monitoring for the contaminant until the running four-week average no longer exceeds the contaminant's MCL.

(A) If the running four-week average exceeds the contaminant's MCL, the project sponsor shall describe the reason(s) for the exceedance and provide a schedule for completion of corrective actions in the next quarterly report submitted to RWQCB pursuant to section 60321, with a copy provided to the Department.

(B) If the running four-week average exceeds the contaminant's MCL for sixteen weeks, the project sponsor shall notify the Department and RWQCB within 48 hours and, if directed by the Department or RWQCB, suspend application of the recycled municipal wastewater.

(e) With the exception of color, if an annual result of the monitoring performed pursuant to (c) exceeds a contaminant's secondary MCL in Table 64449-A or the upper limit in Table 64449-B, the project sponsor shall initiate quarterly monitoring of the recycled municipal wastewater for the contaminant and, if the running annual average of quarterly results exceeds a contaminant's secondary MCL or upper limit, describe the reason(s) for the exceedance and any corrective actions taken in the next quarterly report submitted to RWQCB pursuant to section 60321, with a copy provided to the Department. The annual monitoring in (c) may resume if the running annual average of quarterly results does not exceed a contaminant's secondary MCL or upper limit.

(f) If four consecutive quarterly results for asbestos are below the detection limit for asbestos, monitoring for asbestos may be reduced to one sample every three years. Quarterly monitoring shall resume if asbestos is detected.

Section 60320.214. Diluent Water Requirements.

To be credited with diluent water used in calculating an RWC pursuant to section 60320.216, the GRRP shall comply with the requirements of this section and receive Department approval. For diluent water that is a Department-approved drinking water source, the GRRP's project sponsor is exempt from subsections (a) and (b). The GRRP's project sponsor shall:

(a) Monitor the diluent water quarterly for nitrate and nitrite and, within 72 hours of being informed by the laboratory of a nitrate, nitrite, or nitrate plus nitrite result exceeding an MCL, collect a confirmation sample. If the average of the two samples is greater than an MCL;

(1) notify the Department and the RWQCB within 48 hours of receiving the confirmation sample result,

(2) investigate the cause(s) and implement corrective actions, and

(3) each week, collect and analyze two grab samples at least three days apart as specified in an Operations Plan. If the average of the results for a two-week period exceeds the MCL, subsurface application of the diluent water shall not be used in the calculation of RWC until corrective actions are made. Quarterly monitoring may resume if four consecutive results are below the MCL.

(b) Conduct a source water evaluation per California-Nevada Section of American Water Works Association watershed sanitary survey handbook, or other Department approved evaluation, of the diluent water for Department review and approval that includes, but is not limited to:

(1) a description of the source of the diluent water;
(2) delineation of the origin and extent of the diluent water;
(3) the susceptibility of the diluent water to contamination;
(4) the identification of known or potential contaminants; and
(5) an inventory of the potential sources of diluent water contamination.

(c) Ensure diluent water does not exceed primary MCLs or notification levels and implements a Department-approved water quality monitoring plan for Department-specified contaminants to demonstrate compliance with the primary MCLs and notification levels. The plan shall also include:

(1) monitoring of any chemicals or contaminants in section 60320.220, based on the source water evaluation performed in (b); and

(2) actions to be taken in the event of non-compliance with a primary MCL or exceedance of a notification level.

(d) Develop a method for determining the volume of diluent water to be credited and demonstrate that the diluent water will be introduced in a manner such that the diluent water volume will not result in the GRRP's 120-month running monthly average RWC exceeding its maximum RWC at or beyond the boundary established pursuant to 60320.200(e)(2). The method shall be submitted to the Department for review and approval, and be conducted at a frequency specified in the engineering report prepared pursuant to section 60323. The method shall address all conditions that influence how and when the recycled municipal wastewater and diluent water arrive at all points along the boundary. The conditions must include, but are not limited to, temporal variability in the diluent water supply and regional groundwater gradients, the difference in the distribution of the recycled municipal wastewater and diluent water between individual aquifers where more than one aquifer is replenished, and the difference in travel-time when recycled municipal wastewater and diluent water are introduced at different locations and/or times.

(e) For credit prior to the operation of the GRRP, but not to exceed 120 months:

(1) demonstrate that the diluent water met the nitrate, nitrite, and nitrate plus nitrite MCLs, notification levels, and the water quality requirements in section 60320.212;

(2) provide evidence that the quantity of diluent water has been accurately determined and was distributed such that the proposed or permitted maximum RWC would not have been exceeded; and

(3) conduct a source water evaluation of the diluent water pursuant to subsection (c).

(f) In the Operations Plan prepared pursuant to 60320.222, include a description of:

(1) how the diluent water will be distributed in a manner that ensures that the maximum RWC will not be exceeded during normal operations; and

(2) the actions to be taken in the event the diluent water is curtailed or is no longer available.

Section 60320.216. Recycled Municipal Wastewater Contribution (RWC) Requirements.

(a) Each month, for each subsurface application facility used for replenishing a groundwater basin, the GRRP's project sponsor shall calculate the running monthly average (RMA) RWC based on the total volume of the recycled municipal wastewater and credited diluent water for the preceding 120 calendar months. For GRRPs in operation less than 120 months, calculation of the RMA RWC shall commence after 30 months of recycled water application, based on the total volume of the recycled municipal wastewater and credited diluent water introduced during the preceding months.

(b) The GRRP's RMA RWC, as determined in (a), shall not exceed the maximum RWC specified by the Department.

(c) The initial maximum RWC will be based on the Department's review of the engineering report and information obtained as a result of the public hearing.

(d) A GRRP may increase its maximum RWC, provided that:

(1) the increase has been approved by the Department and RWQCB;

(2) for the previous 52 weeks the TOC 20-week running average, as monitored pursuant to section 62320.218, has not exceeded 0.5 mg/L; and

(3) the GRRP has received a permit from the RWQCB that allows operation of the GRRP at the increased maximum RWC.

(e) If the RMA RWC exceeds its maximum RWC, the GRRP's project sponsor shall:

(1) notify the Department and RWQCB in writing within 7 days of exceedance; and

(2) within 60 days, implement corrective action(s) and submit a report to the Department and RWQCB describing the reason(s) for the exceedance and the corrective action(s) taken to avoid future exceedances.

Section 60320.218. Total Organic Carbon Requirements.

(a) For each subsurface application facility used for replenishing a groundwater basin, the GRRP's project sponsor shall monitor the applied recycled municipal wastewater for TOC as follows:

(1) Prior to replenishment, at least one 24-hour composite sample each week.

(2) Grab samples may be taken in lieu of the 24-hour composite samples required in paragraph (1) if the GRRP demonstrates that a grab sample is representative of the water quality throughout a 24-hour period.

(b) Analytical results of the TOC monitoring performed pursuant to subsection (a) shall not exceed 0.5 mg/L based on:

(1) the 20-week running average of all TOC results; and

(2) the average of the last four TOC results.

(c) If the GRRP exceeds the limit in (b)(1), or its approved increased TOC limit obtained pursuant to section 60320.230(c), based on a 20-week running average, the GRRP's project sponsor shall:

(1) immediately suspend the addition of recycled municipal wastewater until at least two consecutive results, 3 days apart, are less than the limit;

(2) notify the Department and RWQCB within 7 days of suspension; and

(3) within 60 days, submit a report to the Department and RWQCB describing the reasons for the exceedance and the corrective actions to avoid future exceedances. At a minimum, the corrective actions shall include a reduction of RWC sufficient to comply with the limit.

(d) If the GRRP exceeds the limit in (b)(2), or its approved increased TOC limit obtained pursuant to section 60320.230, based on the last four results, the GRRP shall, within 60 days, submit a report to the Department and RWQCB describing the reasons for the exceedance and the corrective actions taken to avoid future exceedances.

(e) To use one or more wastewater chemicals in lieu of TOC, approval from the Department shall be obtained. At a minimum, the chemical(s) used in lieu of TOC shall:

(1) be quantifiable in the wastewater, recycled municipal wastewater, groundwater, and throughout the treatment processes; and

(2) have identifiable treatment performance standards as protective of public health as the TOC standards in this Article.

Section 60320.220. Additional Chemical and Contaminant Monitoring.

(a) Each quarter, the GRRP's project sponsor shall sample and analyze the recycled municipal wastewater and the downgradient monitoring wells specified by the Department for the following:

(1) Priority Toxic Pollutants [chemicals listed in the Water Quality Standards, Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California, and 40 CFR Part 131, Federal Register 65(97), May 18, 2000, p. 31682] specified by the Department, based on the Department's review of the GRRP's engineering report;

(2) Chemicals with notification levels that the Department has specified, based on a review of the GRRP's engineering report and the affected groundwater basin(s); and

(3) Chemicals that the Department has specified, based on a review of the GRRP's engineering report, the affected groundwater basin(s), and the results of the assessment performed pursuant to subparagraph 60320.206(a)(2)(A).

(b) The project sponsor may reduce monitoring for the chemicals in subsection (a) to once each year following Department approval based on the Department's review of the most recent two years of results of the monitoring performed pursuant to subsection (a).

(c) Annually, the project sponsor shall monitor the recycled municipal wastewater for indicator compounds specified by the Department and RWQCB based on the following:

(1) a review of the GRRP's engineering report;

(2) the inventory developed pursuant to section 60320.206(a)(2)(D);

(3) the affected groundwater basin(s);

(4) an indicator compound's ability to characterize the presence of pharmaceuticals, endocrine disrupting chemicals, personal care products, and other indicators of the presence of municipal wastewater; and

(5) the availability of a test method for a chemical.

(d) A chemical or contaminant detected as a result of monitoring conducted pursuant to this section shall be reported to the Department and RWQCB no later than the quarter following the quarter in which the results are received by the GRRP's project sponsor. If a detection of a contaminant is from a monitoring well and exceeds a state notification level, the project sponsor shall monitor the well for the contaminant within 7 days of receipt of the initial result. If the average of the initial and the confirmation results exceed the notification level, as soon as possible but no later than 30 days after receipt of the confirmation result, the project sponsor shall notify the Department and RWQCB. Following notification, the Department may require the project sponsor to notify local agencies overseeing private drinking water wells and each public water system immediately downgradient of the GRRP of the notification level exceedance.

Section 60320.222. Operation Optimization and Plan.

(a) Prior to operation, a new GRRP shall have an Operations Plan submitted to and approved by the Department. An existing GRRP shall maintain, and make available to the Department or RWQCB for review upon request, an Operations Plan. At a minimum, the Operations Plan shall identify the operations, maintenance, analytical methods, monitoring necessary for the GRRP to meet the requirements of this Article, and the reporting of monitoring results to the Department and RWQCB. The project sponsor shall be responsible for ensuring that the Operations Plan is, at all times, representative of the current operations, maintenance, and monitoring of the GRRP.

(b) During the first year of operation for a new GRRP, or during the first year of operation after *[insert effective date]* for an existing GRRP, and at all times thereafter, all treatment processes shall be operated in a manner providing optimal reduction of all chemicals and contaminants including:

(1) microbial contaminants;

(2) regulated contaminants identified in section 60320.212 and the nitrogen compounds in section 60320.210; and

(3) nonregulated chemicals identified in section 60320.220.

(c) Within six months of optimizing treatment processes pursuant to (b) and anytime thereafter operations are optimized that result in a change in operation, each GRRP shall update their operations plan to include such changes in operational procedures and submit the operations plan to the Department for review.

Section 60320.224. Response Retention Time.

(a) The recycled municipal wastewater used by a GRRP shall be retained underground for a period of time sufficient to allow the GRRP's project sponsor ample response time to identify treatment failures and implement actions, including those required pursuant to section 60320.100(b), necessary for the protection of public health from inadequately treated recycled municipal wastewater or recharge water.

(b) The response time required in subsection (a) shall be approved by the Department, based on information provided in the engineering report required pursuant to section 60323. Regardless of the minimum response time identified in subsection (a), the retention time shall be no less than two months.

(c) To demonstrate the retention time underground is no less than the response time in subsection (b), a tracer study utilizing an added tracer shall be implemented under hydraulic conditions representative of normal GRRP operations. With Department approval, an intrinsic tracer may be used in lieu of an added tracer. For each month of retention time estimated utilizing the approved intrinsic tracer, the project sponsor shall receive no more than 0.67 months credit. The retention time shall be the time representing the difference from when water is applied at the GRRP to when the first ten percent (10%) of such water arrives at the downgradient endpoint. A project sponsor for new GRRP shall initiate the tracer study prior to the end of the third month of operation. The project sponsor for existing GRRP that hasn't already performed a tracer study shall initiate a tracer study prior to the renewal of the GRRP's permit.

(d) For the purpose of siting a GRRP location during project planning and until a GRRP's project sponsor has met the requirements of subsection (c), for each month of retention time estimated using the method in column 1, the recycled municipal wastewater or recharge water may be credited with no more than the corresponding response time in column 2 of Table 60320.224.

Table 60320.224

Column 1	**Column 2**
Method used to estimate the retention time	**Response Time Credit per Month**
Tracer study utilizing an intrinsic tracer, based on T_{10} (i.e. the time for ten percent (10%) of tracer concentration to reach the endpoint).	0.67 months
Numerical modeling consisting of calibrated finite element or finite difference models using validated and verified computer codes used for simulating groundwater flow.	0.50 months
Analytical modeling using existing academically-accepted equations such as Darcy's Law to estimate groundwater flow conditions based on simplifying aquifer assumptions.	0.25 months

(e) The protocol(s) used to establish the retention times in subsections (c) and (d) shall be approved by the Department.

(f) The Department may require the GRRP to demonstrate that the underground retention times required in this section are being met based on changes in hydrogeological or climatic conditions since the most recent demonstration.

Section 60320.226. Monitoring Well Requirements.

(a) Prior to operating a GRRP, a project sponsor shall site and construct at least two monitoring wells such that:

(1) at least one monitoring well is located;

(A) no less than two weeks, but no more than six months of travel time from the GRRP, and

(B) at least 30 days upgradient of the nearest drinking water source;

(2) in addition to the well(s) paragraph (1), at least one monitoring well is located between the GRRP and the nearest downgradient domestic water supply well; and

(3) samples from the monitoring wells in paragraphs (1) and (2) can be;

(A) obtained independently from each aquifer initially receiving the water used as a source of potable water supply that will receive the GRRP's recharge water, and

(B) validated as receiving recharge water from the GRRP.

(b) From each monitoring well in subsection (a)(1), and each monitoring well in subsection (a)(2) that has recharge water located within one year travel time of the well(s), the project sponsor shall collect two samples prior to GRRP operation (for a new GRRP) and at least one sample each quarter after operation begins. Each sample shall be analyzed for total nitrogen, nitrate, nitrite, the contaminants in tables 64449-A and B of section 64449, and any contaminants and chemicals specified by the Department and RWQCB based on the results of the recycled municipal wastewater monitoring conducted pursuant to this Article.

(c) If a result from the monitoring conducted pursuant to subsection (b) exceeds a nitrate, nitrite, or nitrate plus nitrite MCL, the project sponsor shall, within 24 hours, collect another sample and have it analyzed for the contaminant. If the average of the result of the initial sample and the confirmation sample exceed the contaminant's MCL, the project sponsor shall:

(1) within 24 hours of being notified by the laboratory of the confirmation sample result, notify the Department and RWQCB; and

(2) discontinue surface application of recycled municipal wastewater until corrective actions have been taken or evidence is provided to the Department and RWQCB that the contamination was not a result of the GRRP.

(d) For chemical analyses completed in a calendar month, the project sponsor shall ensure the laboratory submits results no later than the end of the following month using the Electronic Deliverable Format as defined in the Electronic Deliverable Format (EDF) Version 1.2i Guidelines & Restrictions dated April 2001 and Data Dictionary dated April 2001.

(e) The GRRP's project sponsor may discontinue monitoring for the chemicals and contaminants in subsection (b) following Department approval based on the Department's review of the most recent two years of results.

Section 60320.228. Reporting.

(a) Annually, the project sponsor shall provide a report to the RWQCB and the Department. Public water systems having downgradient sources potentially affected by the GRRP and within 10 years groundwater travel time from the GRRP shall be notified by direct mail and/or electronic mail of the availability of the report. The report shall be prepared by an engineer licensed in California and experienced in the fields of wastewater treatment and public water supply. The report shall include the following:

(1) A summary of the GRRP's compliance status with the applicable monitoring requirements and criteria of this Article during the previous calendar year;

(2) For any violations of this Article during the previous calendar year;

(A) the date, duration, and nature of the violation,

(B) a summary of any corrective actions and/or suspensions of subsurface application of recycled municipal wastewater resulting from a violation, and

(C) if uncorrected, a schedule for and summary of all remedial actions;

(3) Any detections of monitored chemicals or contaminants, and any observed trends in the monitoring wells and diluent water supplies;

(4) Information pertaining to the vertical and horizontal migration of the recharge water plume;

(5) A description of any changes in the operation of any unit processes or facilities;

(6) A description of any anticipated changes, along with an evaluation of the expected impact of the changes on subsequent unit processes;

(7) The estimated quantity and quality of the recycled municipal wastewater and diluent water to be utilized for the next twelve months; and

(8) A summary of the measures taken to comply with section 60320.106 and the effectiveness of the implementation of the measures.

(b) Every five years from the date of the initial approval of the engineering report required pursuant to section 60323, the project sponsor shall update the report to address any project changes and submit the report to the RWQCB and the Department. The update shall include, but not be limited to:

(1) anticipated RWC increases, a description of how the RWC requirements in section 60320.216 will be met, and the expected impact the increase will have on the GRRP's ability to meet the requirements of this Article;

(2) evidence that the requirements associated with retention time in section 60320.208, if applicable, and section 60320.224 have been met; and

(3) a description of any inconsistencies between previous groundwater model predictions and the observed and/or measured values, as well as a description of how subsequent predictions will be accurately determined.

Section 60320.230. Alternatives.

(a) A project sponsor may use an alternative to a requirement in this Article if the GRRP's project sponsor has:

(1) demonstrated to the Department that the proposed alternative would assure at least the same level of protection to public health;

(2) received written approval from the Department prior to implementation of the alternative; and

(3) if required by the Department or RWQCB for the purpose of conducting a public hearing regarding the proposed alternative, disseminated information to the public, and received public comments, pursuant to subsections 60320.202(b) and (c).

(b) Unless specified otherwise by the Department, the demonstration in paragraph (a)(1) shall include the results of a review of the proposed alternative by an independent scientific advisory panel that includes a toxicologist, a registered engineering geologist or hydrogeologist, an engineer licensed in California with at least three years of experience in wastewater treatment and public drinking water supply, a microbiologist, and a chemist.

ARTICLE 5.3. INDIRECT POTABLE REUSE: GROUNDWATER REPLENISHMENT - SURFACE APPLICATION WITH FULL ADVANCED TREATMENT

A Groundwater Replenishment Reuse Project (GRRP) project sponsor utilizing surface application with continuous advanced treatment of the entire recycled municipal wastewater stream prior to application shall meet the requirements of Article 5.2, except that after one year of operation, the project sponsor may apply for a reduced monitoring frequency for any monitoring requirement.

ARTICLE 7. ENGINEERING REPORT AND OPERATIONAL REQUIREMENTS

Section 60323[1]. Engineering Report

(a) No person shall produce or supply ~~reclaimed water~~recycled municipal wastewater for ~~direct~~ reuse from a ~~proposed~~ water reclamation plant ~~unless he files an~~ without a Department approved engineering report.

(b) The report shall be prepared by a properly qualified engineer ~~registered~~ licensed in California and experienced in the field of wastewater treatment, and shall contain a description of the design of the proposed reclamation system. The report shall clearly indicate the means for compliance with these regulations and any other features specified by the regulatory agency.

(c) The report shall contain a contingency plan which will assure that no untreated or inadequately treated wastewater will be delivered to the use area.

[1] Section 60320 is an existing section. The text reflects the proposed amendments.

CDPH Groundwater Recharge Regulations

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Workshop Presenters

- Cindy Forbes—Southern California Branch Chief
- Bob Hultquist—Retired Annuitant, Recharge Specialist
- Brian Bernados—Technical Programs Branch, Recycled Water Unit
- Kurt Souza—Southern California Section Chief

Stakeholder Meeting Overview

- Historical Perspective
- *Existing Groundwater Recharge Projects*
- *2011 Draft Regulations and Time Schedule for Adoption*
- *Implementation Protocols*

Historical Perspective

- 1978—Existing Groundwater Recharge Regs become effective (Section 60320, Title 22). Consists of 3 paragraphs, broadly regulating GW Recharge. Lacks detail.
- 1986—DHS Groundwater Recharge Committee Formed to Develop Reg Package
- 1988—First Draft Proposed (Spreading Projects Only)
- 1989—Draft Considered Injection

Historical Perspective Cont.

- 2001, 2002—Changes involving type of organics treatment and TOC levels needed to deal with NDMA and 1,4—Dioxane
- 2002-2011--Additional tweaking made to the draft regulations made to deal with Chemicals of Emerging Concern (CECs)

Historical Perspective Cont.

- 2010 — Statutory changes:
  - Water Code was revised via SB 918
    - CDPH must adopt uniform water recycling criteria for groundwater recharge by December 31, 2013
    - CDPH must adopt uniform water recycling criteria for surface water augmentation by December 31, 2016

❖ No additional resources were provided to CDPH for these activities; the ability of CDPH to meet these deadlines is dependent upon the availability of funds from other parties.

CDPH – Division of Drinking Water and Environmental Management

- Regulates public water systems
- Sets standards for wastewater reuse to protect public health
  - “Water Recycling Criteria” in Title 22 of California Code of Regulations
- RWQCBs have the permitting and ongoing oversight authority of “Groundwater Recharge Reuse Project (GRRP)”

CDPH – SWRCB - RWQCB

- Due to the potential for confusion and duplication of effort between CDPH & RWQCBs, CDPH & SWRCB signed a Memorandum of Agreement (MOA) in 1996
- MOA delineates responsibilities of each agency in review and approval of RW projects

CDPH – SWRCB – RWQCB, cont.

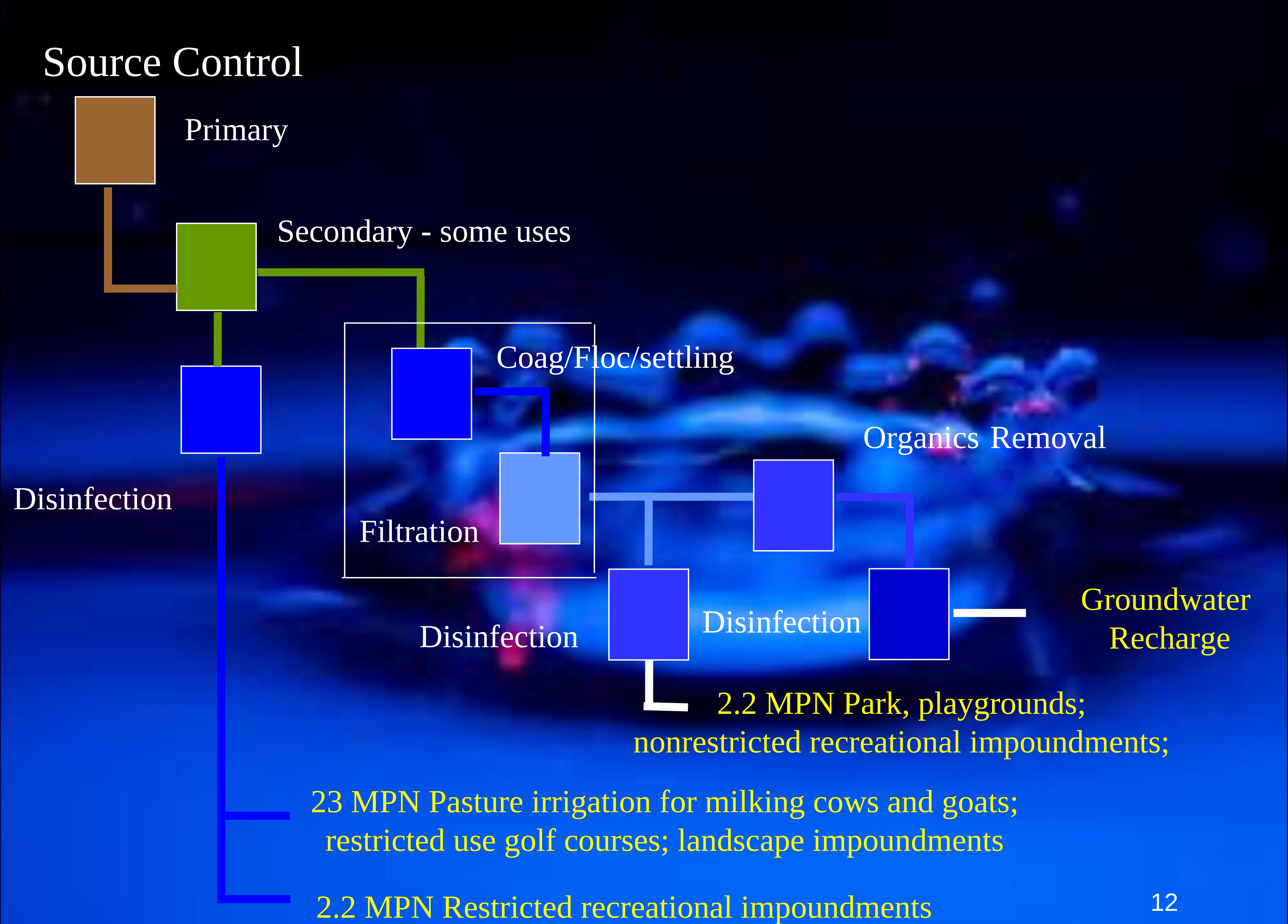
- CDPH requirements for permit approval are to be incorporated in RWQCB permit
- CDPH will meet with RWQCB staff and attend RWQCB hearings as necessary to explain any CDPH requirements or recommendations
- The two agencies agree to meet and try to resolve any differences

CDPH DDWEM
Drinking Water Program

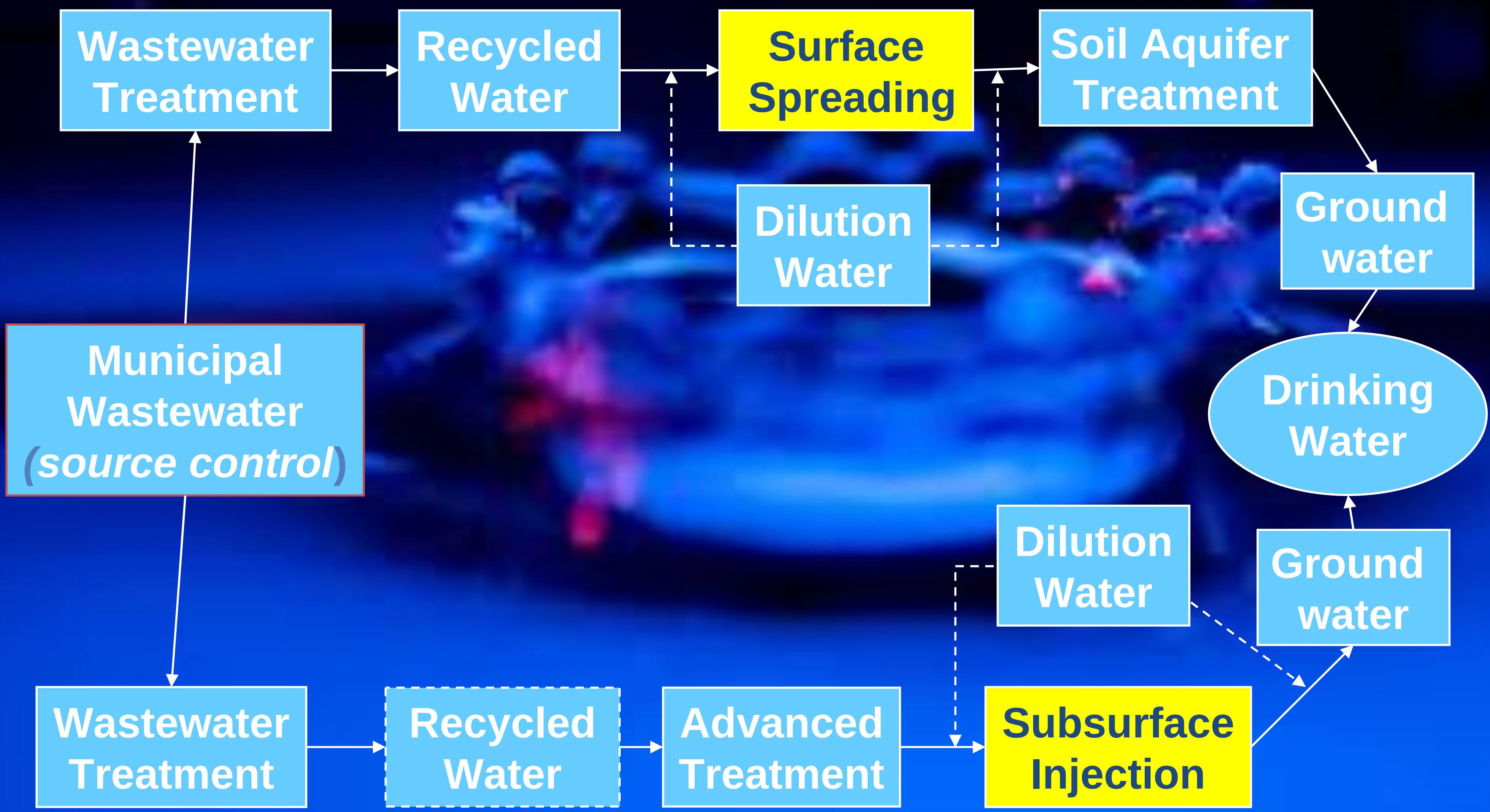
- Reviews recycled water proposals for compliance with Title 22 Criteria
- Provides requirements and recommendations to RWQCB for recycled water permits
- Coordinates with other agencies
- Interfaces with recycled water industry
- Reviews new and emerging technologies
- Collects fees from project applicants for CDPH reviews

Draft Recharge Criteria

- Recycled water from domestic sewage
- Aquifer designated as a drinking water source
- Indirect potable reuse
  - Effective natural barrier
  - Time to identify and respond to problems
- Multiple barriers for each type of contaminants
- Ongoing monitoring program in recycled water and groundwater
- Treatment processes required
- Source water control


Source Control
Primary
Secondary - some uses
Coag/Floc/settling
Organics Removal
Disinfection
Filtration
Disinfection
Disinfection
Groundwater Recharge
2.2 MPN Park, playgrounds; nonrestricted recreational impoundments;
23 MPN Pasture irrigation for milking cows and goats; restricted use golf courses; landscape impoundments
2.2 MPN Restricted recreational impoundments

Wastewater to Drinking Water through Groundwater Recharge



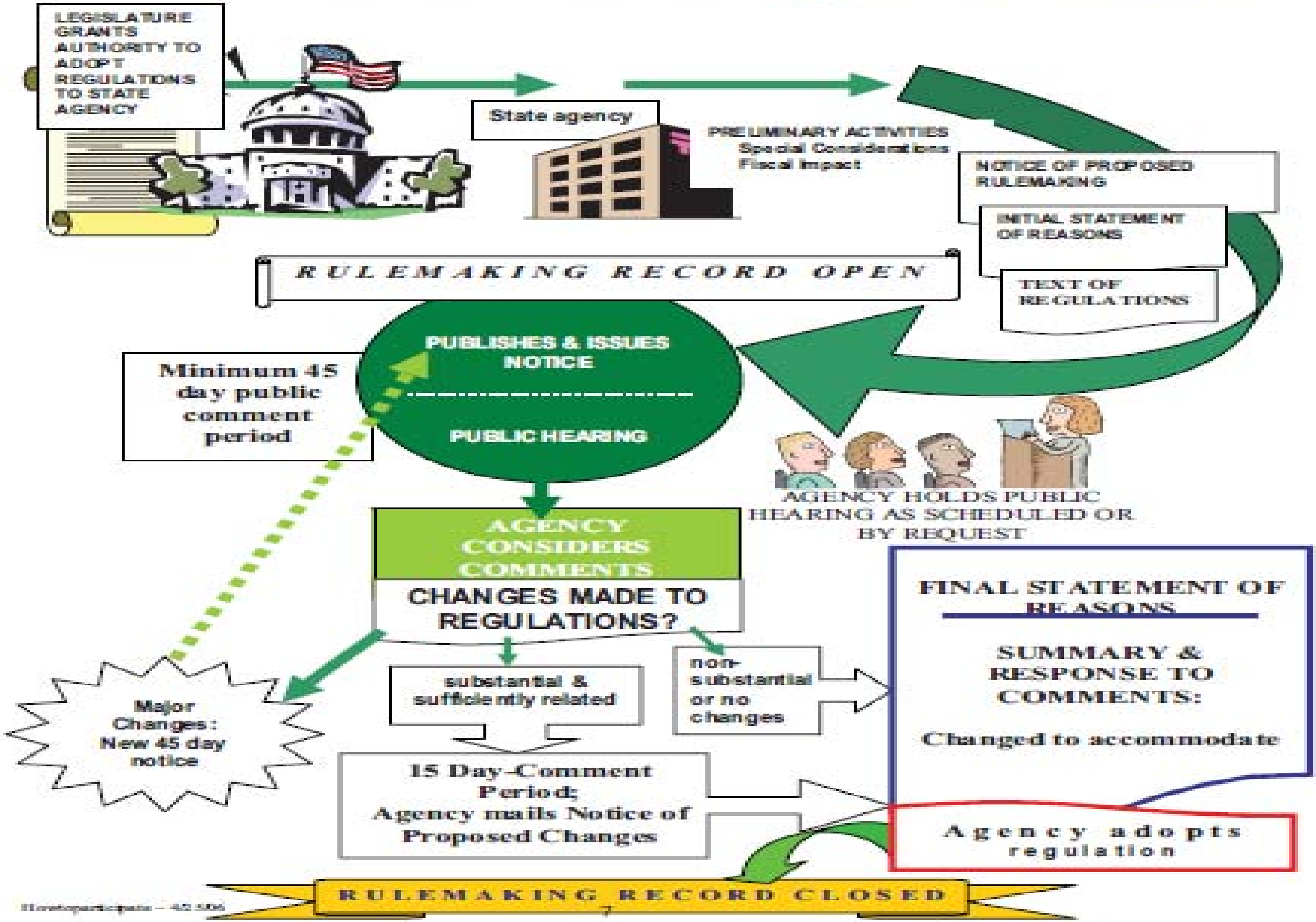
Groundwater Recharge Projects

- Montebello Forebay – County Sanitation Districts of Los Angeles County
- West Basin MWD
- Harbor Recycling Project
- Alamitos Barrier
- Inland Empire Utilities Agency
- Orange County Water District—GWRS

What’s Next?

- CDPH will consider comments received during the workshops and during the formal comment period. The comments will be reviewed to consider any needed changes.
- To meet our statutory deadline, we’re requesting comments be submitted no later than Jan 30, 2012.
- CDPH will complete the formal reg package and the formal reg process will then begin.

The Rulemaking Process



What's Next?

- Formal Reg development and process
  - Regulation Text (to enhance readability the current version does not include some information and formatting required by the APA), Transmittal Memos, Initial Statement of Reasons, Rulemaking Notices, cost estimating documents, etc.
  - These documents will undergo a rigorous review process by CDPH, Agency, OOR, attorneys, Budget Office, Department of Finance, etc.
  - All this occurs before entering the formal 45-day public comment period and subsequently being reviewed by the Office of Adminstrative Law and being adopted.

CALIFORNIA'S DRAFT CRITERIA FOR GROUNDWATER RECHARGE WITH RECYCLED WATER

Stakeholder Meetings

December 2011

Drinking Water Program

California Dept. of Public Health

Approach - General

- Present the overarching goals and principles behind the draft regulation
- Present the intent, approach, and supporting science for the individual sections
- Answer questions about intent and general approach

Presentation Outline

- Overview of Principals - Bob Hultquist
- General Requirements - Bob Hultquist
- Public Hearing, Lab Analysis & Source Control - Brian Bernados
- Pathogen Microorganisms - Bob Hultquist
- Nitrogen and Regulated - Brian Bernados
- Unregulated Chemical Control Overview, TOC, RWC & Diluent Water - Bob Hultquist

Short Break

Presentation Outline, cont.

- Unregulated Chemical Control Indicators, Surrogates and FAT - Brian Bernados
- Additional Constituents, Optimization and Operations Plan - Brian Bernados
- Response Time - Bob Hultquist
- Monitoring Well, Reporting - Bob Hultquist
- Alternatives, Engineering Report and Summary - Bob Hultquist

Principles

- Replenish groundwater (GW) basins used as drinking water sources
- Low tolerable risk
  - One in 10,000 (10^{-4}) annual risk of infection from Pathogenic Microorganisms
  - Drinking water standards
  - Unregulated chemical control
- No degradation of an existing water source
- Multiple barriers

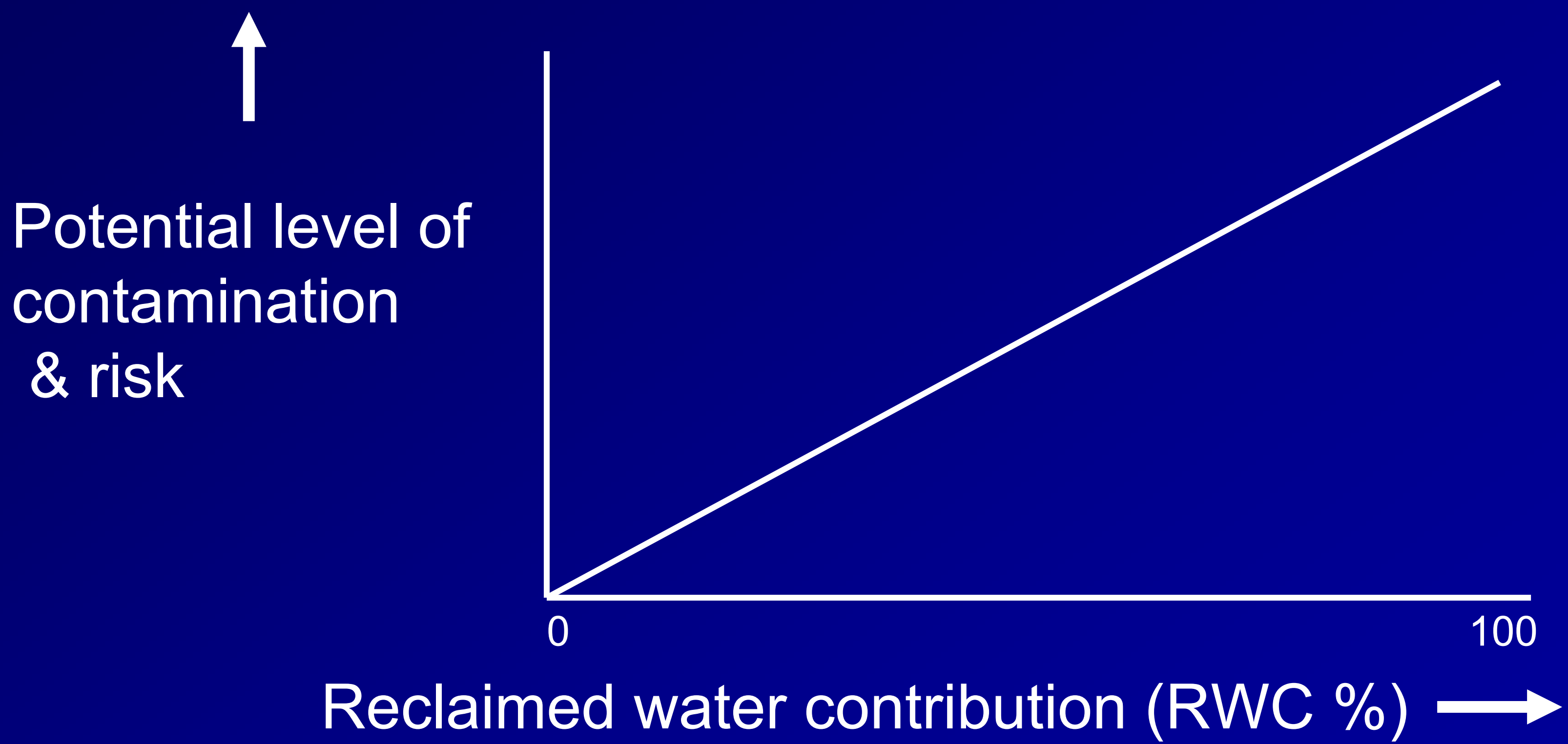
Groundwater Protection Challenges

- If there is contamination, it could persist
- Plumes may be difficult to track
- In a large aquifer, there may be numerous dispersed wells and it may not be feasible to provide treatment to each
- There may be individual residence wells or business wells

Indirect Potable Reuse

- Make a source of drinking water
  – not drinking water
  – not direct potable reuse
- Storage in an aquifer
- Some natural treatment
- Time to identify and respond to a treatment failure

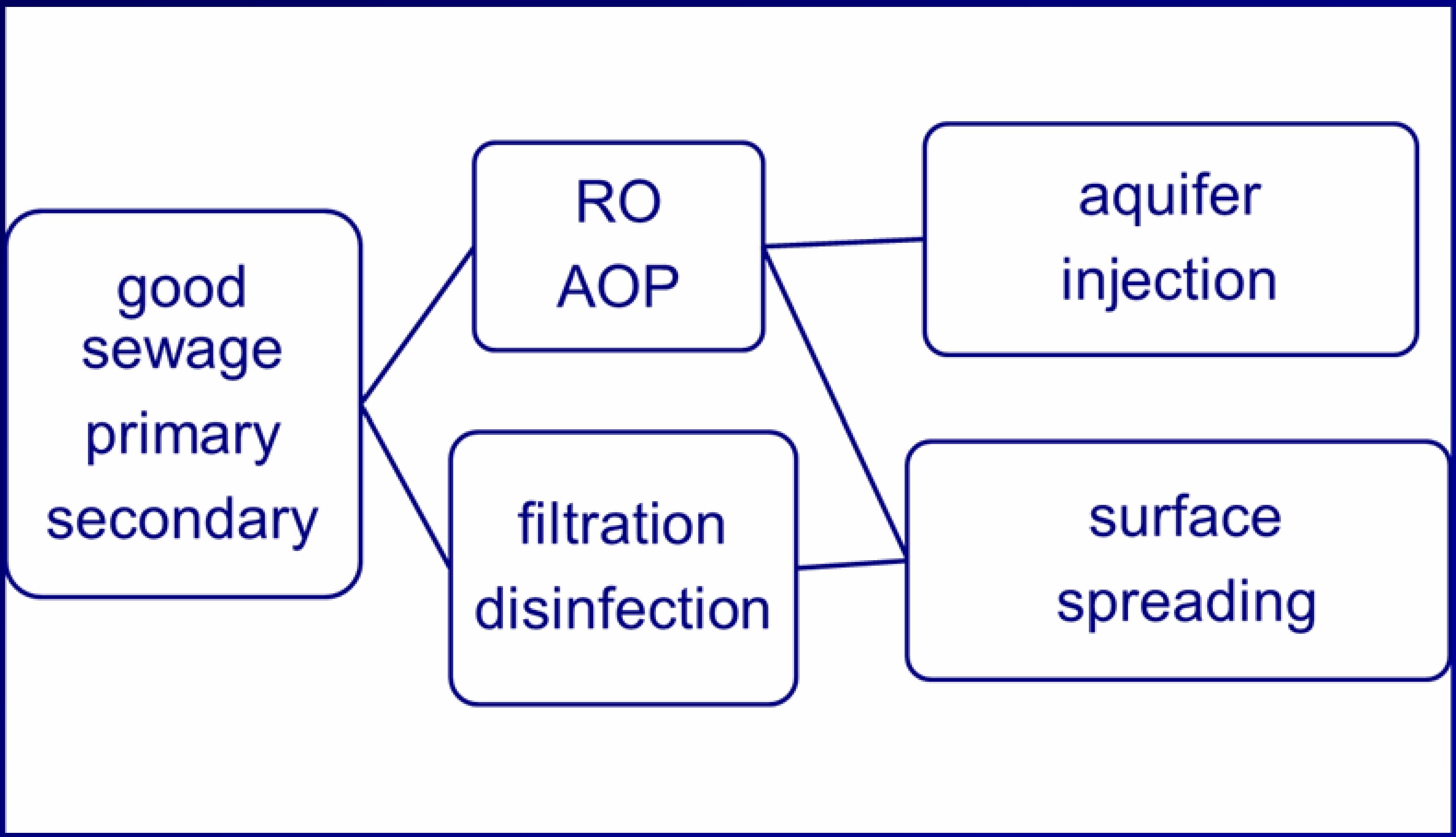
Degrees of Indirect Potable Reuse



Project Types

- Organize criteria by method of recharge to simplify identifying relevant requirements
- Surface spreading w/o full advanced treatment (FAT) – Article 5.1
  - Scheme relies on soil aquifer treatment (SAT)
- Subsurface application – Article 5.2 (FAT required)
  - FAT is continuous advanced treatment of the entire flow
- Surface spreading with FAT – Article 5.3

Schemes


good
sewage
primary
secondary
RO
AOP
filtration
disinfection
aquifer
injection
surface
spreading

Groundwater Replenishment Reuse Project (GRRP) 60301.390

- A GRRP is a project using recycled municipal wastewater
  - for the purpose of replenishment of groundwater that is designated a source of water supply in a Water Quality Control Plan, or
  - which has been identified as a GRRP by the RWQCB

General Requirements 60320.100 & 200

a. The type of project that must comply with the Article
b. Plan for alternative source of potable water or remedial treatment in case GRRP causes an unsafe source
c. Benchmark sampling
d. Hold recycled water underground long enough to meet requirements of pathogen barrier (if needed) and response time requirements

General Requirements - 2

e. Map showing
   - The GRRP facilities
   - Monitoring and drinking water wells
   - The boundary within which certain requirements are not met (more later)

f. New GRRPs demonstrate managerial and technical capacity to meet requirements

g. Commissioning tests

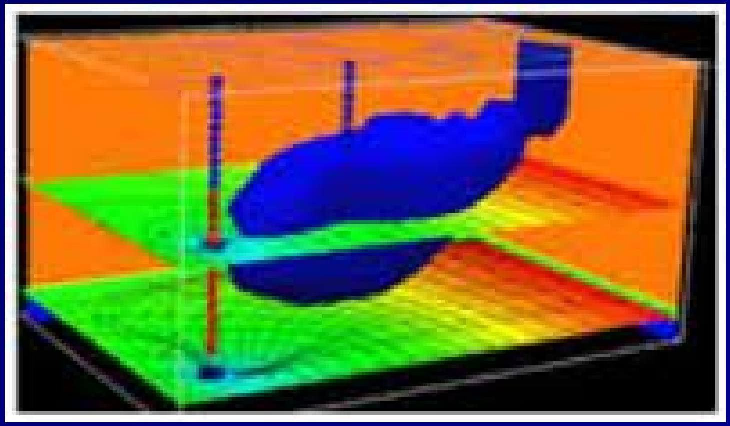
h. Hydrogeological assessment

Boundary for Groundwater recharge

- The boundary is the downgradient limit of the zone around the recharge site necessary to meet all requirements
  - The time required to provide the pathogen barrier (if needed)
  - The time to react to a treatment failure
  - The time to achieve effective soil-aquifer treatment
  - RWC compliance, if necessary

Boundary - 2

- The boundary may be complex in three-dimensions due to different water velocities in different aquifers



- Within the boundary, water may not be withdrawn as an unimpaired drinking water source

Public Hearing 60320.102 & 202

- Intent - to foster informed comment by the public
- Hearing held by the project sponsor prior to:
  - New project
  - A higher recycled water contribution
- Present information on the project
  - Made public before hearing
  - Must be provided via the Internet
  - Approved by the Department
- At least 30 days prior to the hearing, Post on the Internet and Notify public & down-gradient well-owners of the hearing

Lab Analyses 60320.104 & 204

- Department approved labs for constituents that have maximum contaminant levels (MCLs)
- That means labs accredited by the CDPH Environmental Lab Accreditation Program (ELAP)
- CDPH approved drinking water methods for MCLs assure low detection levels
- Analyses for chemicals without MCLs shall be described in the Operations Plan

Source water control 60320.106 & 206

- A pollutant source control program beyond typical industrial pretreatment that includes
  - an assessment of the fate of Department-specified contaminants,
  - contaminant source investigations and contaminant monitoring
  - an outreach program to industrial, commercial, and residential for the purpose of managing and minimizing the discharge of contaminants

    nodrugsdownthedrain.org
  - an up-to-date inventory of contaminants discharged into the wastewater collection system so that new contaminants of concern can be readily evaluated

Pathogenic Microorganism Control 60320.108 & 208

- Intent – ensure that pathogens will not exceed the tolerable risk dose in drinking water

- Approach - set a log reduction requirement from raw sewage to useable groundwater
  - 12-log Virus
  - 10-log *Giardia* cysts
  - 10-log *Cryptosporidium* oocysts

Pathogenic Microorganisms - 2

- Start from:
  - For virus and *Giardia* - Water Reuse (Asano et al, 2007) Table 3-9, high end of range
  - For *Cryptosporidium* use high (and rounded up) levels from studies in Melbourne and Norway
- End point is USEPA allowable drinking water density (modified for Cryptosporidium infectious dose and exposure)
  - One in 10,000 (10^{-4}) annual risk of infection goal

Multi-barrier Pathogen Control

- 3 separate barriers for reliability
- A project may select a set of treatment and retention time barriers to meet the log reduction value (LRV) required
- Title-22 Filtration/disinfection required only for surface spreading projects w/o FAT
- 1-log ≤ individual barrier LRV ≤ 6-log
  - Significant barriers
  - Barriers that can be validated

Barrier Validation

- Must validate each of the treatment processes used to meet log reduction, except for retention time underground
  - Demonstration report,
  - Or a challenge test
  - Either must provide evidence of the treatment process's log reduction.
- Operations Plan must specify on-going monitoring to verify performance of each treatment process's ability to achieve its credited log reduction

Barriers - 2

- Retention time barrier
  - 1-log virus reduction for each month of subsurface retention
    - Yates et al 1985
  - Verify with added or approved intrinsic tracer study
    - retention time is the time for first two percent (2%) to arrive
  - Limit on credit prior to added tracer study (see table)
  - For spreading projects,
    - full Log reduction requirement for *Cryptosporidium* and *Giardia* is met when 6-month retention it met

Methods to Determine LRV

Planning and Engineering Report Effort vs. LRV			
Method	General Accuracy	General Level of Effort	Log Virus per month
Formula (Darcy's)	Poor	limited info on aquifer	0.25
3-D model	Fair	A lot of info on aquifer	0.50
Intrinsic Tracer	Better	quantify existing indicators	0.67
Added Tracer	Best Available	track added Tracer (T_2)	1.0

Pathogenic Microorganisms - 3

- Failure to meet an LRV - consequences
  – Investigate, correct problem, and notify for a failure to meet the total log reduction
  – Shut down if the virus LRV is less than 9-log or the Giardia or Cryptosporidium LRVs are less than 8-log

Nitrogen Compound Control 60320.110 & 210

- Goal is to preclude exceeding the nitrite or nitrate MCL
- Collect 2 samples each week, at least 3 days apart
- Comply in effluent or in recharge water
- Limit =10 mg/L as N - average of 2 consecutive samples
  - If > 10 mg/L total N, consequences include:
    - Notify CDPH & RWQCB
    - Monitor, investigate and take actions
- If average of 4 consecutive samples >10 mg/L total N, suspend application
- Provisions allow for reduced monitoring in future

Regulated Chemicals 60320.112 & 212

- A chemical or physical drinking water standard must be met:
  - In the plant effluent
  - Or recharge water (accounting for dilution)
- Quarterly testing for chemicals with primary MCL
- Annual testing for chemicals with secondary MCL
- Consequences for exceeding standard:
  - 4 conditions specified
  - Including resampling to confirm
  - Responses to exceedance

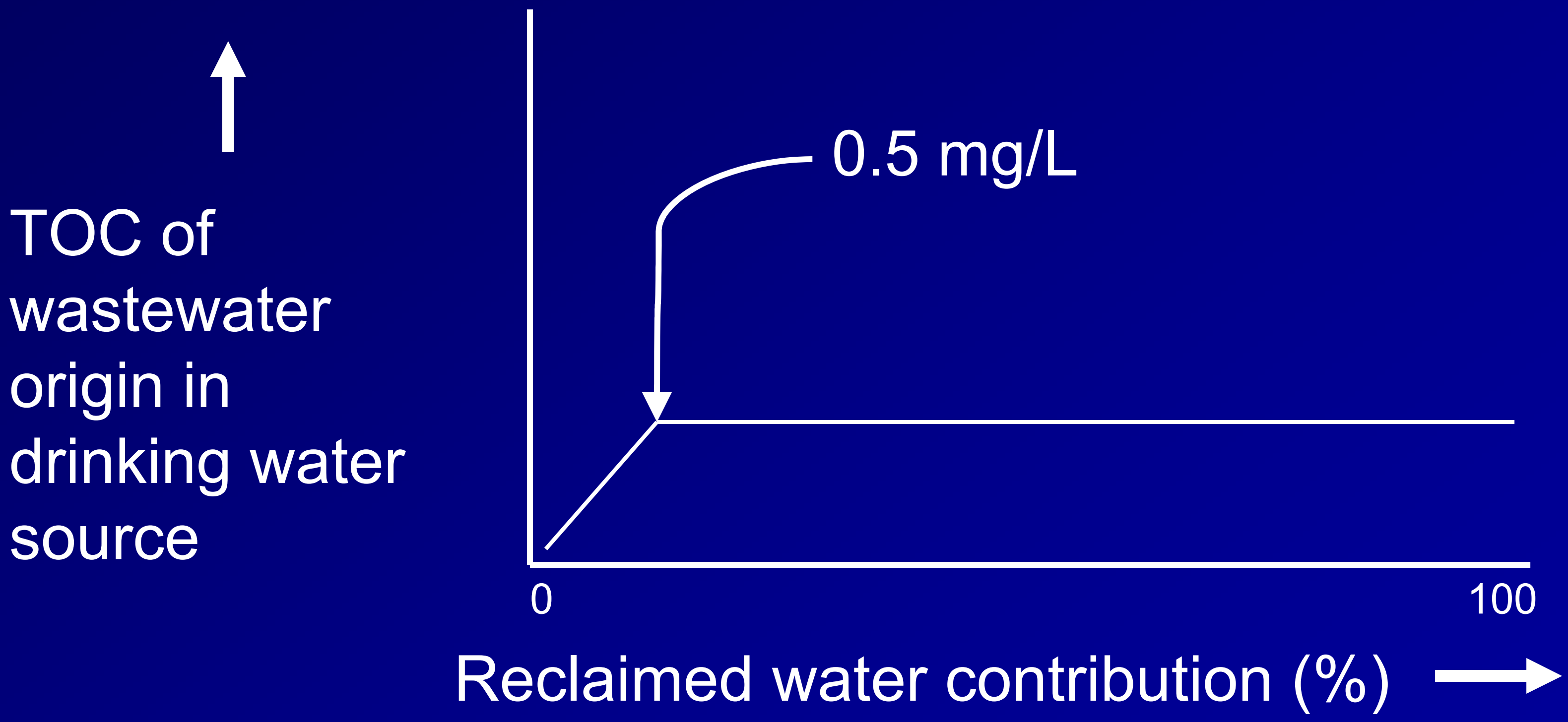
Unregulated Chemical Control Overview

- 60320.114 , 116, 118 and 201, 214, 216 & 218
- The Diluent Water, Recycled Water Contribution (RWC), Total Organic Carbon (TOC) and Soil Treatment Process (SAT) Requirements, and Advanced Treatment Criteria sections work in concert to limit the concentration of any potentially harmful unregulated or unknown chemical.
- TOC used as a surrogate for the unknown organic chemicals

Unregulated Chemical Control - 2

- A limit of 0.5 mg/L for TOC from recycled water in the groundwater ensures effective treatment and/or dilution is used
  - Ensure use of best RO membranes with excellent organic chemical removal
  - Gets soil treatment projects to a recycled water TOC comparable to projects found to be safe

TOC equation intent



Unregulated Chemical Control - 3

For spreading projects,

- Reclaimed water compliance calculation:

  TOC $\leq$ (0.5 mg/L) / (RWC)

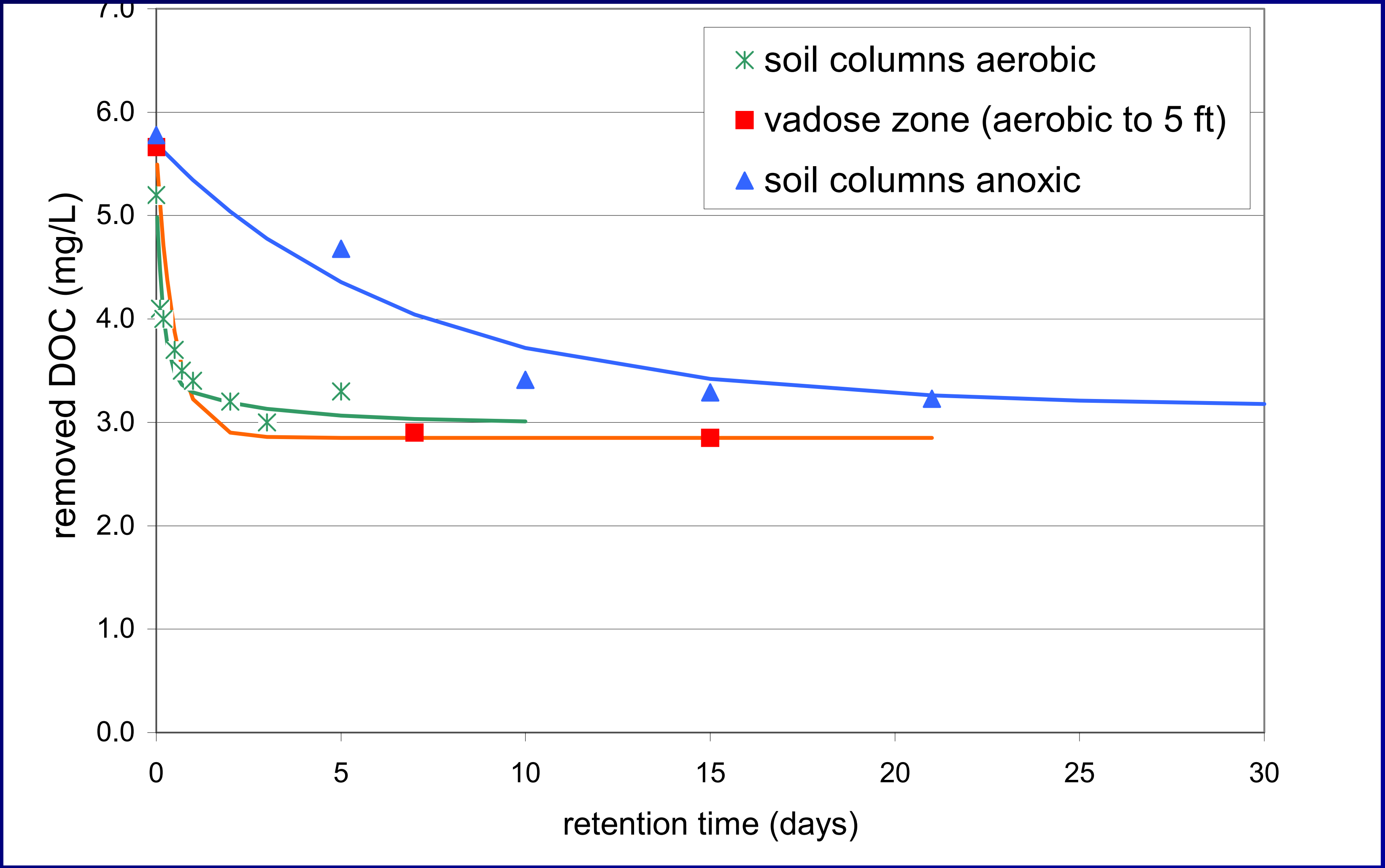
  allows a GRRP to balance treatment and dilution as needed to comply

- SAT alone cannot meet the 0.5 mg/L TOC level (due to the non-biodegradable TOC fraction) and must be supplemented with dilution

- Can treat a portion of the flow to reduce TOC and increase the RWC

FAT projects must meet 0.5 mg/L in the RW

Soil Treatment (Peter Fox)



Recycled Water Contribution 60320.116 and 216

$$\frac{\text{(reclaimed water flow)}}{\text{(reclaimed water + diluent water flow)}}$$

- RWC must be met each month using the previous 120 months of data
  - Chronic exposure threat
  - Extended drought
- RWC calculations begin after 30 months
- Meet RWC everywhere beyond the boundary

Recycled Water Contribution - 2

- The initial maximum RWC for a GRRP is set by CDPH based on information provided in the engineering report and as a result of the public hearing
- Initially, shall not exceed 0.20 for projects w/o FAT
- FAT project initial RWC as justified
- May increase the RWC above the initial value if:
  - Increase approved by CDPH and RWQCB
  - For previous 52 weeks, the 20-week running average TOC ≤ (0.5 mg/L)/(RWC proposed)
  - Receive permit from RWQCB

Recycled Water Contribution - 3

Spreading projects only

- Prior to operating a GRRP at an RWC greater than 0.50 or 0.75, project sponsor must:
  - Provide proposal to CDPH prepared & signed by PE with 3 years experience in RW & potable
  - For previous 52 weeks, the 20-week running average TOC ≤ (0.5 mg/L)/(RWC proposed)
  - Submit updated engineering report and Operations Plan
  - Show that monitoring wells are located properly and receiving recharge water

Diluent Water 60320.114 & 214

- Diluent water quality must meet primary MCLs and NLs
  - Use approved potable water source
  - Or GW or stormwater if a source water evaluation is done
- Quantity to be used in the RWC calculation must be identified such that:
  - The diluent and recycled water must be in the correct proportions (RWC) over the compliance averaging period

TOC and Soil Treatment 60320.118 & 218

- TOC $\leq$ (0.5 mg/l) / (RWC)
  - For spreading projects
    - In the recycled water, or
    - After soil treatment but not influenced by dilution (otherwise would benefit from dilution twice)
    - Mound or lysimeter
    - 3 options to avoid dilution confounding the result
  - In the recycled water for FAT projects
  - Not to exceed on 20 week running average or the average of the last 4 weekly TOC results

BREAK

Framework Using Indicators and Surrogates

- Goal is to develop a monitoring program of specific chemicals indicators and surrogates
- "Monitoring Strategies for CECs in Recycled Water Recommendations of a Science Advisory Panel Convened by the SWRCB"
- Work by Shane Snyder & Jorg Drewes
- WateReuse 03-014, Drewes, Sedlak, Snyder, Dickenson - "Development of Indicators and Surrogates for Chemical Contaminant Removal during Wastewater Treatment and Reclamation"
- Environmental Sci. Technol. 2009, 43, 6242–6247

Monitoring Strategies for CECs in Recycled Water Recommendations of a Science Advisory Panel Convened by the SWRCB

- “changes in bulk parameters do correlate with changes of indicator chemicals”
- “Thus, to ensure proper performance of unit operations regarding the removal of CECs, a combination of appropriate surrogate parameters and performance indicator CECs should be selected that are tailored to monitor the removal efficiency of individual unit processes”
- Defines surrogate/indicator framework

"The selection of a practical set of indicator compounds is driven by . . .

- ". . . treatment performance and less so by toxicological relevance.
- Thus, selecting multiple indicators representing a broad range of properties will allow accounting for compounds currently not identified ("unknowns") and new compounds . . .
- The underlying concept is that absence or removal of an indicator compound during a treatment process would also ensure absence or removal of unidentified compounds with similar properties."
- 2 phases: piloting/start-up and full-scale
- Suggests a 5-step process

Soil Treatment 60320.118 f

- Indicators of the effectiveness of SAT must be identified and measured
- Pick at least 3 relevant indicators based upon an occurrence study approved by CDPH
- Monitor quarterly
  - prior to SAT and
  - no more than 30 days downgradient
- If a 90% reduction (excluding the effect of dilution) is not demonstrated
  - investigate
  - and report

SAT - Indicator Compound Examples for Soil Treatment Process (from WRF 03-014)

SAT removes > 90% of these:

- Acetaminophen
- Atenolol
- Atorvastatin (Lipitor)
- Bisphenol A
- Caffeine
- DEET
- Diclofenac
- Erythromycin–H_2O
- 17β-Estradiol (E2)
- Estriol (E3)
- Estrone (E1)
- Fluoxetine (Prozac)
- Gemfibrozil
- Hydrocodone (Vicodin)
- Ibuprofen
- Iopromide
- Ketoprofen
- Metoprolol (Lopressor)
- Naproxen
- Nonylphenol
- Propranolol

Indicator Compounds For Verifying Location of Monitoring Wells

(from WRF 03-014)

SAT removes < 25% of these:

- Carbamazepine
- Dilantin
- Primidone
- TCEP
- TDCPP
- TCIPP

SAT removes more than 25% but < 50% of

- Chloroform

SAT removes more than 50% but < 90% of

- Meprobamate

Advanced Treatment Criteria

- Goal is to remove the organic chemicals that may pose a health threat
- Continuous treatment of the entire flow with Reverse Osmosis (RO) and Advanced Oxidation Process (AOP)
- RO permeate is free of almost all organics
- AOP used to degrade any that pass through RO (NDMA & 1,4-dioxane) including unknown chemicals and
- AOP provides multi barrier treatment
  - 1998 report by NRC - potable reuse should include multiple, independent barriers to organic chemical contaminants

Advanced Treatment 2008 vs. 2011

- 2008 advanced oxidation treatment to provide treatment equivalent to
  - a 1.2 log NDMA reduction <u>and</u>
  - a 0.5 log 1.4-dioxane reduction
  - Received comments regarding Ozone / H_2O_2
- 2011 advanced oxidation to provide
  - NDMA reduction to NL <u>and</u>
  - 1.4-dioxane reduction to NL
  - 2 options to design AOP
  - Ozone may be more attractive in some cases

Section 60320.201 a

- “A GRRP shall use a reverse osmosis membrane that:”
- (1) “utilizing ASTM method D4194-03 (2008), achieves an average rejection of NaCl > or = 99.5 % with a 15% recovery”
- “(2) through bench-scale testing conducted pursuant to section 60320.200(g), initially produces a permeate having TOC concentrations of 0.25 mg/L or less.”

Section 60320.201 b
Potential RO Surrogates

- "on-going performance monitoring (e.g. conductivity or TOC) that indicates when the integrity of the process has been compromised. "
- Online continuous
  – Conductivity
  – Low-level TOC
  – UV absorbance
  – Sulfate
  – Nitrate
  – Ammonia
  – Sucralose?

RO Effectiveness

- RO is effective at removing large and/or ionic compounds via:
  - Size exclusion
  - Electrostatic repulsion
  - Adsorption phenomena
- Most CECs are large organic molecules with a MW > 250 and are well removed; however,
- RO is less effective at removal of small non-ionic, neutral compounds
  - NDMA
  - chloroform
  - 1,4-dioxane

Indicators Detected After RO (a Few Times @ Very Low Levels:)

- 4-nonylphenol
- Bisphenol-A
- Carbamazepine
- DEET
- Estradiol
- Gemfibrozil
- Ketoprofen
- Musk ketone
- Primidone
- Triclocarban
- Acetaminophen
- Caffeine
- Clofibric acid
- Diclofenac
- Galaxolide
- Ibuprofen
- Meprobamate
- Oxybenzone
- Sulfamethoxazole
- TCEP
- other fire retardants TDCPP & TCIPP

Advanced Oxidation Process (AOP)

- AOP can reduce organics that pass RO
- Especially 2 contaminants with NLs
  - NDMA reduction
    - NDMA has a small MW of 74
    - Concentration varies, but always detected
    - Passes through RO and requires AOP
  - 1,4-dioxane reduction
    - 1,4-dioxane has MW of 88
    - Passes through RO and requires AOP

UV AOP & 1,4-dioxane

- While NDMA is generally photoliable, 1,4-dioxane is not, so UV can not photolyze 1,4-dioxane well
- The addition of H_2O_2, creates hydroxyl radicals to meet the 0.5-log reduction of 1,4 dioxane, which is photostable.
- BUT what is the optimum dose?
- It is currently difficult to quantify hydroxyl radicals, as they are very reactive and short-lived.
- Recent research has shown chloramine residual may be a surrogate

2 Options for AOP 60320.201 c & d

- Similar to the previous approach
  - – Design using 0.5-log reduction of 1,4-dioxane to determine the equipment size and dose for AOP
- OR new approach based on SWRCB SAP
  - – Utilize an oxidation process that achieves optimal removal of many indicator compounds.
  - – Establish at least one surrogate or operational parameter that reflects the removal of at least five of the nine indicator compounds selected . . .
  - – Uses chemical structures and functional groups of indicator compounds

First Option for AOP 60320.201 c

- Based upon latest research, such as
- Environ. Sci. Technol. 2009, 43, 6242–6247
- *Applying Surrogates and Indicators to Assess Removal Efficiency of Trace Organic Chemicals during Chemical Oxidation of Wastewaters*
- By Dickenson, Drewes, Sedlak, Wert & Snyder
- "Potential surrogate parameters and indicator compounds, identified by reviewing previous publications and classified by their structural properties, were tested in pilot- and full-scale treatment systems."

AOP Removal> 90% of Most Indicator Compounds Removal Categories / Structure

(A) Hydroxy Aromatic

Acetominophen, Bisphenol A, Estrone, Triclosan

(B) Amino/Acyl amino Aromatic

Atorvastatin, Sulfamethoxazole

(C) Nonaromatic C=C

Carbamazepine, Codeine, OTNE

(D) Deprotonated Amine

Atenolol, Caffeine, Diclofenac, Trimethoprim

(E) Alkoxy Polyaromatic – Naproxen, Propranolol

(F) Alkoxy Aromatic – Gemfibrozil, Hydrocodone

(G) Alkyl Aromatic

DEET, Dilantin, Ibuprofen, Primidone

AOP <90% Removal of Some Indicator Compounds
Removal Categories / Structure

Typical Expected Intermediate Removal 50-90% using ozone

- (H) Saturated Aliphatic
  - Iopromide
  - Meprobamate
- (I) Nitro Aromatic
  - Musk ketone
  - Musk xylene

For UV / H_2O_2

- Removal of Meprobamate is 20-50%

AOP Optimal Removal

- 0.5-log (69%) for each indicator in the functional groups in (1)(A) through (1)(G) – [good removal], and
- 0.3-log (50%) for each indicator in the functional groups in (1)(H) and (1)(I) [intermediate removal].
- at least one surrogate or operational parameter that reflects the removal of 5 of 9 indicator groups
  - at least one of the five indicators represents at least one functional group in (1)(A) through (1)(G),
  - at least one of the five indicators represents at least one functional group in (1)(H) or (1)(I),
  - at least one surrogate or operational parameter is monitored continuously

Example Application of surrogate/indicator framework to an treatment processes

Step 1 - Conduct occurrence study of indicators in the feedwater; one for each of the 9 groups.

[e.g., Acetominophen, Atorvastatin, Carbamazepine, Caffeine, Naproxen, Gemfibrozil, DEET, Meprobamate, Musk ketone]

Step 2 - Define conditions for proper operation

[size, dose, flow, etc.]

Step 3 - identify those surrogate or operational parameters with a measurable removal –

[e.g., UVA_{254}, fluorescence, chloramine residual, or ozone residual]

Example Application of surrogate/indicator framework to an overall treatment train

Step 4 – Submit test protocol.

Conduct piloting by spiking or monitor for detectable indicators (5 of 9 groups) to determine the removal differentials under normal operating conditions.

[e.g., DEET, Meprobamate, Caffeine, Acetominophen, BPA]

Step 5 - Confirm operational conditions of full-scale, monitor surrogate / operational parameters; and monitor differential of selected indicator on a regular basis

[for good or intermediate removal depending on functional group]

2nd Option for AOP 60320.201 d

- Conduct pilot testing demonstrating that AOP will provide a 0.5-log (69%) reduction of 1,4-dioxane.
- Submit pilot testing protocol to CDPH for review. Pilot testing shall include challenge or spiking tests, using 1,4-dioxane, to demonstrate the 0.5-log reduction
- Establish surrogate and/or operational parameters that show the 0.5-log 1,4-dioxane design criteria is being met.
  - Dose
  - Chloramine residual
  - other
- At least one surrogate or operational parameter shall be capable of being monitored continuously

60320.201 e, f, and g

e) During the full-scale operation of the AOP, continuously monitor the surrogate and/or operational parameters established.

f) Within 60 days after completing 12-months of monitoring submit a report on AOP
   - Monitoring results
   - Removal differential of indicators
   - Efficacy of the surrogate and/or operational parameters to reflect the removal differential of the indicator compounds
   - actions taken, etc.

g) Similar type of report on RO performance

60320.201 h and i

h) Quarterly, tabulate the % that did not meet the surrogate and/or operational parameter limits that assure proper performance of RO and AOP. If > 10%, within 30 days after the end of the quarter:

1) submit a report describing the corrective actions planned or taken
2) consult with CDPH and, if required, comply with an alternative monitoring plan approved by CDPH

i) Monthly collect grab samples after RO/AOP and analyze for all MCLs & NLs. If no exceedances, may apply for less monitoring after 12 mo.

Additional Constituent Monitoring 60320.120 & 220

Recycled municipal wastewater & monitoring wells

- Quarterly for chemicals
  - Priority Toxic Pollutants,
  - Chemicals with notification levels,
  - Any specified by CDPH based on source control
  - May reduce to annual after review of 2 years data
- Annually for constituents indicating the presence of municipal wastewater as specified by the Department

Operation Optimization and Plan 60320.122 and 220

- Intent – to assure that the facilities are operated:
  - To achieve compliance with requirements
  - In a manner consistent with the project engineering report and findings of fact
  - To achieve optimal reduction of contaminants
  - Identify monitoring and analytical methods
- An operations plan must be up-to-date and receive approval

Response Retention Time 60320.124 & 224

- Intent – that inadequately treated recycled water not enter a potable water system in the event of a treatment failure
- Between the recharge and extraction of the water, sufficient time must elapse to allow for:
  - The identification of any treatment failure
  - A response that will protect the public from exposure to inadequately treated water
    - Provide alternative source of water
    - Remedial treatment at the wellhead

Response Time - 2

- The time is the aggregate of the period:
  - Between treatment verification samples or measurements
  - To make the measurement or analyze the sample
  - To evaluate the results
  - To make a decision
  - To activate the response
  - For the response work

Response Time - 3

- Retention time
  - Verify with added tracer study
  - Limit on credit prior to added tracer study
- Minimum 2 months
  - Less than 2 months is not credible given the uncertainty in the failure identification, SAT monitoring, response effectiveness, and institutional procedures
  - This is not direct potable reuse
  - Should not infer that 2 months will be readily approved

Methods to Determine Retention Time to drinking water wells

Planning and Engineering Report Effort vs. Time			
Method	General Accuracy	General Level of Effort	Time multiplier
Formula (Darcy's)	Poor	limited info on aquifer	0.25
3-D model	Fair	A lot of info on aquifer	0.50
Intrinsic Tracer	Better	quantify existing indicators	0.67
Added Tracer	Best Available	track added tracer	1.0

Monitoring Well 60320.126 & 226

- Location/construction
  - 2 weeks to 6 months travel time in the saturated zone downgradient to give chemical/physical processes a chance to work
  - 30 days upgradient of well to give some warning
  - Be able to sample each aquifer
  - Must be getting recycled water
- Monitoring
  - Benchmark and each quarter for listed chemicals plus others specified by CDPH

Reporting 60320.128 & 228

- Intent – to assure that the CDPH, Water Boards, and Public Water Systems with proximate wells are informed of the state of compliance with requirements
- Annual report on compliance and exceptions
- Updated Engineering Report every five years

Alternatives 60320.130 & 230

- Intent - to accommodate unforeseen or yet to be approved methods of meeting the intent of a requirement
- Demonstrate "at least the same level of protection to public health"
- May be proposed for ANY requirement
- Evaluation by an independent panel of experts probably required

Engineering Report
60323

- Intent – that the CDPH and Water Boards will have sufficient information to evaluate and permit the recharge project
- A report that:
  - Describes the project facilities and shows how each requirement will be met
  - Includes a contingency plan that assures that inadequately treated wastewater will not be delivered to the use area

Articles in Summary

- 5.1 Surface Spreading w/o FAT – SAT
  – RWC critical
- 5.2 Subsurface – FAT
  – 100% RWC possible
- 5.3 Surface with FAT
  – 100% RWC possible
  – Possible reduced monitoring
  – Other regulatory benefits?

ANCRONYMS

AOP	advanced oxidation process
CDPH	California Department of Public Health
CEC	compound of emerging concern
FAT	full advanced treatment
GRRP	Groundwater Replenishment Reuse Project
GW	groundwater
LRV	log reduction value
MCLs	maximum contaminant levels
MW	molecular weight
NL	notification level
NRC	National Research Council
RO	reverse osmosis
RWC	recycled water contribution
RWQCB	Regional Water Quality Control Board
SAT	soil aquifer treatment
T_2	The retention time when the first two percent (2%) of recharge water arrives at the downgradient endpoint.
TOC	total organic carbon
UV	ultra-violet

Groundwater Recharge Implementation

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Implementation – How to Get a Project Reviewed and Approved

- Timeline of Events
  - Discussion of concept of a project
  - Pre-Meetings
  - Pilot Studies
  - Technical Memos
  - Engineering Report
  - Public Hearing
  - Findings of Facts
  - RWQCB Permit
  - Operations, Maintenance and Monitoring Plan
  - Ongoing Compliance Monitoring Reports

Pre-Meeting

- Applicant will need to contact local District office to set up an introductory meeting.
- Local Office will invite: Regional Engineer, District Engineer, local staff, Technical Section.
- CDPH project team will be formed
  - CDPH team will include, RE, DE, Branch Chief, local staff engineer, Technical Section representatives

Pre-Meeting

- Applicant will need to have similar meeting with the RWQCB.
- Future meetings will include CDPH project team and RWQCB.
- All Correspondence from CDPH will be signed by Regional Engineer.
- All Correspondence from the Proponent should be directed to RWQCB and RE.

Pilot Studies and Tech Memos

- Pilot Studies may be needed
  - Study protocols must be reviewed by CDPH.
- Technical Memos will be reviewed by CDPH project team and RWQCB.

Engineering Report

- Prepared by the Applicant
- Complete documentation of proposed project
- Reviewed by CDPH project team and RWQCB

Public Hearing

- Applicant will hold a public hearing
  - Discuss the components of the project
  - CDPH will attend and discuss regulations
- Findings of Fact
  - CDPH will finalize a Findings of Fact following the Public Hearing and submit to the RWQCB.

RWQCB Permit

- CDPH will review and comment on the draft RWQCB permit and any amendments
- CDPH will attend the RWQCB Board meeting when project is presented

OMMP and Ongoing Monitoring

- Operations, Maintenance and Monitoring Plan (OMMP) will be produced by the Applicant
  - Reviewed by CDPH Project team
  - Include Start up plan
- Ongoing Monthly Monitoring Reports
  - Reviewed by RWQCB and CDPH (Local District office)

Thank you for your attention

Questions

Appendix D - Demands Assumptions

Assumptions Used to Determine Recycled Water Demand

For SB and GWD, RW estimates were provided.	

For MWD, AFY per acre factors were used:	
Customer Type	**AFY/acre**
Irrigation	2.5
Agriculture	1.8

For CVWD AG Users - AFY per acre factors were used:	
Customer Type	**AFY/acre**
avocado	1.19
avocado / Cate School	1.19
avocado / lemons	1.19
avocado / lemons / cherimoyas	1.19
avocado / sparse	1.19
cherimoyas	2.00
cherimoyas / avocado	2.00
cherimoyas / avocado / lemons	2.00
cherimoyas / passion fruit / bananas	2.00
cherimoyas / passion fruit / zapote	2.00
field crops	1.38
field crops / mixed crops	1.38
field crops / mixed crops / scrub	1.38
field crops / vines	1.38
golf driving range	1.50
horse facilities / pasture	1.50
horse facilities / polo field	1.50
lemons	0.82
lemons / avocado / cherimoyas	0.82
lemons / avocado / cherimoyas / persimmons	0.82
park / sports field	1.50
passion fruit	2.00
passion fruit / avocado / cherimoyas	2.00
persimmons / sparse	2.00
roses	1.50

Assumptions Used to Determine Recycled Water Demand

For LCMWC and CVWD Urban Users, a percentage for used:	
Customer Type	**% Reuse of Customer Total Demand**
Irrigation	90%
Schools	50%
Industrial	50%
Commercial	50%
COMMERCIAL (MISC)	50%
HOTELS	50%
INDUSTRIAL, MISC	50%
IRRIGATED FARMS, MISC	90%
LIGHT MANUFACTURING	50%
NURSERIES,GREENHOUSES	90%
ORCHARDS, IRRIGATED	90%
PARKS	90%
RECREATIONAL OPEN (MISC)	90%

Appendix E - Potential Recycled Water Customers

Santa Barbara South Coast Regional Reuse Study
Potential Recycled Water Demands

Id	Agency	Customer	Type	Avg. Demand (AFY) Near-Term	Long-Term	Data Source
CVWD_1	CVWD	HOTEL	Commercial	0	8	2007-11 Water Records, %RW
CVWD_2	CVWD	ORCHARD, IRRIGATED	Irrigation - Recreation	0	6	2007-11 Water Records, %RW
CVWD_3	CVWD	HOTEL	Commercial	0	8	2007-11 Water Records, %RW
CVWD_5	CVWD	IRRIGATED FARM	Irrigation - Recreation	0	5	2007-11 Water Records, %RW
CVWD_7	CVWD	COMMERCIAL	Commercial	0	14	2007-11 Water Records, %RW
CVWD_8	CVWD	LIGHT MANUFACTURING	Commercial	0	7	2007-11 Water Records, %RW
CVWD_9	CVWD	INDUSTRIAL	Commercial	0	6	2007-11 Water Records, %RW
CVWD_10	CVWD	LIGHT MANUFACTURING	Commercial	0	3	2007-11 Water Records, %RW
CVWD_11	CVWD	INDUSTRIAL	Commercial	0	3	2007-11 Water Records, %RW
CVWD_12	CVWD	SCHOOL	Commercial	0	4	2007-11 Water Records, %RW
CVWD_13	CVWD	RECREATIONAL OPEN	Irrigation - Recreation	0	8	2007-11 Water Records, %RW
CVWD_14	CVWD	PARK	Irrigation - Recreation	0	10	2007-11 Water Records, %RW
CVWD_15	CVWD	SCHOOL	Commercial	0	6	2007-11 Water Records, %RW
CVWD_16	CVWD	HOTEL	Commercial	0	6	2007-11 Water Records, %RW
CVWD_17	CVWD	HOTEL	Commercial	0	2	2007-11 Water Records, %RW
CVWD_18	CVWD	HOTEL	Commercial	0	7	2007-11 Water Records, %RW
CVWD_19	CVWD	COMMERCIAL	Commercial	0	22	2007-11 Water Records, %RW
CVWD_20	CVWD	COMMERCIAL	Commercial	0	2	2007-11 Water Records, %RW
CVWD_21	CVWD	LIGHT MANUFACTURING	Commercial	0	1	2007-11 Water Records, %RW
CVWD_22	CVWD	LIGHT MANUFACTURING	Commercial	0	2	2007-11 Water Records, %RW
CVWD_23	CVWD	LIGHT MANUFACTURING	Commercial	0	1	2007-11 Water Records, %RW
CVWD_24	CVWD	LIGHT MANUFACTURING	Commercial	0	2	2007-11 Water Records, %RW
CVWD_25	CVWD	LIGHT MANUFACTURING	Commercial	0	1	2007-11 Water Records, %RW
CVWD_26	CVWD	PARKS	Irrigation - Recreation	0	2	2007-11 Water Records, %RW
CVWD_27	CVWD	PARKS	Irrigation - Recreation	0	2	2007-11 Water Records, %RW
CVWD_28	CVWD	PARKS	Irrigation - Recreation	0	2	2007-11 Water Records, %RW
CVWD_29	CVWD	RECREATIONAL OPEN	Irrigation - Recreation	0	2	2007-11 Water Records, %RW
			Subtotal	**0**	**142**	
C1	Carp-Ag	avocado	Agriculture	0	76.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C2	Carp-Ag	field crops	Agriculture	0	56.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C3	Carp-Ag	avocado	Agriculture	0	50.4	CVWD Landuse, LT projected irrg. (AFY/acre)
C5	Carp-Ag	cherimoyas	Agriculture	0	40.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C8	Carp-Ag	avocado / sparse	Agriculture	0	35.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C9	Carp-Ag	avocado	Agriculture	0	34.8	CVWD Landuse, LT projected irrg. (AFY/acre)
C10	Carp-Ag	avocado	Agriculture	0	34.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C11	Carp-Ag	cherimoyas	Agriculture	0	33.2	CVWD Landuse, LT projected irrg. (AFY/acre)

Santa Barbara South Coast Regional Reuse Study
Potential Recycled Water Demands

Id	Agency	Customer	Type	Avg. Demand (AFY) Near-Term	Avg. Demand (AFY) Long-Term	Data Source
C12	Carp-Ag	avocado	Agriculture	0	33.0	CVWD Landuse, LT projected irrg. (AFY/acre)
C13	Carp-Ag	avocado	Agriculture	0	32.0	CVWD Landuse, LT projected irrg. (AFY/acre)
C14	Carp-Ag	cherimoyas / passion fruit / zapote	Agriculture	0	31.8	CVWD Landuse, LT projected irrg. (AFY/acre)
C15	Carp-Ag	avocado	Agriculture	0	30.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C17	Carp-Ag	avocado	Agriculture	0	30.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C20	Carp-Ag	field crops / mixed crops	Agriculture	0	26.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C23	Carp-Ag	avocado	Agriculture	0	26.0	CVWD Landuse, LT projected irrg. (AFY/acre)
C25	Carp-Ag	field crops / mixed crops	Agriculture	0	25.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C26	Carp-Ag	horse facilities / polo field	Agriculture	0	25.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C27	Carp-Ag	avocado	Agriculture	0	25.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C28	Carp-Ag	avocados	Agriculture	0	24.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C29	Carp-Ag	avocado	Agriculture	0	24.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C30	Carp-Ag	avocado	Agriculture	0	24.4	CVWD Landuse, LT projected irrg. (AFY/acre)
C31	Carp-Ag	avocado	Agriculture	0	24.2	CVWD Landuse, LT projected irrg. (AFY/acre)
C33	Carp-Ag	cherimoyas	Agriculture	0	23.7	CVWD Landuse, LT projected irrg. (AFY/acre)
C35	Carp-Ag	avocado	Agriculture	0	23.4	CVWD Landuse, LT projected irrg. (AFY/acre)
C36	Carp-Ag	avocado	Agriculture	0	23.2	CVWD Landuse, LT projected irrg. (AFY/acre)
C37	Carp-Ag	avocado	Agriculture	0	22.7	CVWD Landuse, LT projected irrg. (AFY/acre)
C40	Carp-Ag	horse facilities / pasture	Agriculture	0	21.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C42	Carp-Ag	avocado	Agriculture	0	21.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C43	Carp-Ag	lemons	Agriculture	0	21.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C44	Carp-Ag	avocado	Agriculture	0	20.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C46	Carp-Ag	avocado	Agriculture	0	20.4	CVWD Landuse, LT projected irrg. (AFY/acre)
C48	Carp-Ag	avocado	Agriculture	0	20.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C49	Carp-Ag	passion fruit	Agriculture	0	19.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C50	Carp-Ag	avocado	Agriculture	0	19.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C51	Carp-Ag	lemons	Agriculture	0	19.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C53	Carp-Ag	avocado	Agriculture	0	19.0	CVWD Landuse, LT projected irrg. (AFY/acre)
C57	Carp-Ag	avocado	Agriculture	0	18.7	CVWD Landuse, LT projected irrg. (AFY/acre)
C58	Carp-Ag	avocado	Agriculture	0	18.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C59	Carp-Ag	avocado	Agriculture	0	18.4	CVWD Landuse, LT projected irrg. (AFY/acre)
C61	Carp-Ag	field crops / mixed crops	Agriculture	0	18.2	CVWD Landuse, LT projected irrg. (AFY/acre)
C62	Carp-Ag	avocado	Agriculture	0	17.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C64	Carp-Ag	avocado	Agriculture	0	17.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C65	Carp-Ag	avocado / Cate School	Agriculture	0	17.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C67	Carp-Ag	avocado	Agriculture	0	17.4	CVWD Landuse, LT projected irrg. (AFY/acre)

Santa Barbara South Coast Regional Reuse Study
Potential Recycled Water Demands

Id	Agency	Customer	Type	Avg. Demand (AFY) Near-Term	Avg. Demand (AFY) Long-Term	Data Source
C68	Carp-Ag	cherimoyas	Agriculture	0	17.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C69	Carp-Ag	horse facilities / polo field	Agriculture	0	17.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C72	Carp-Ag	avocado	Agriculture	0	16.4	CVWD Landuse, LT projected irrg. (AFY/acre)
C73	Carp-Ag	avocado	Agriculture	0	16.4	CVWD Landuse, LT projected irrg. (AFY/acre)
C74	Carp-Ag	field crops	Agriculture	0	16.2	CVWD Landuse, LT projected irrg. (AFY/acre)
C75	Carp-Ag	avocado	Agriculture	0	16.2	CVWD Landuse, LT projected irrg. (AFY/acre)
C76	Carp-Ag	lemons / avocado / cherimoyas	Agriculture	0	16.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C80	Carp-Ag	avocado	Agriculture	0	15.8	CVWD Landuse, LT projected irrg. (AFY/acre)
C82	Carp-Ag	avocado	Agriculture	0	15.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C84	Carp-Ag	horse facilities / polo field	Agriculture	0	15.4	CVWD Landuse, LT projected irrg. (AFY/acre)
C87	Carp-Ag	avocado	Agriculture	0	14.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C88	Carp-Ag	avocado	Agriculture	0	14.8	CVWD Landuse, LT projected irrg. (AFY/acre)
C89	Carp-Ag	avocado	Agriculture	0	14.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C90	Carp-Ag	avocado	Agriculture	0	14.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C92	Carp-Ag	field crops	Agriculture	0	14.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C93	Carp-Ag	avocado	Agriculture	0	14.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C94	Carp-Ag	avocado	Agriculture	0	14.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C102	Carp-Ag	avocado	Agriculture	0	13.7	CVWD Landuse, LT projected irrg. (AFY/acre)
C103	Carp-Ag	avocado	Agriculture	0	13.7	CVWD Landuse, LT projected irrg. (AFY/acre)
C108	Carp-Ag	avocado	Agriculture	0	13.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C109	Carp-Ag	avocado	Agriculture	0	13.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C111	Carp-Ag	avocado	Agriculture	0	13.2	CVWD Landuse, LT projected irrg. (AFY/acre)
C114	Carp-Ag	avocado	Agriculture	0	13.0	CVWD Landuse, LT projected irrg. (AFY/acre)
C116	Carp-Ag	avocado	Agriculture	0	12.7	CVWD Landuse, LT projected irrg. (AFY/acre)
C117	Carp-Ag	field crops	Agriculture	0	12.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C118	Carp-Ag	lemons	Agriculture	0	12.4	CVWD Landuse, LT projected irrg. (AFY/acre)
C120	Carp-Ag	public - Carpinteria Cemetery District	Agriculture	0	12.2	CVWD Landuse, LT projected irrg. (AFY/acre)
C121	Carp-Ag	avocado	Agriculture	0	12.2	CVWD Landuse, LT projected irrg. (AFY/acre)
C122	Carp-Ag	avocado	Agriculture	0	12.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C123	Carp-Ag	avocado	Agriculture	0	12.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C124	Carp-Ag	avocado	Agriculture	0	12.0	CVWD Landuse, LT projected irrg. (AFY/acre)
C128	Carp-Ag	avocado	Agriculture	0	11.7	CVWD Landuse, LT projected irrg. (AFY/acre)
C129	Carp-Ag	cherimoyas	Agriculture	0	11.7	CVWD Landuse, LT projected irrg. (AFY/acre)
C131	Carp-Ag	avocado	Agriculture	0	11.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C132	Carp-Ag	avocado	Agriculture	0	11.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C135	Carp-Ag	avocado	Agriculture	0	11.3	CVWD Landuse, LT projected irrg. (AFY/acre)

Id	Agency	Customer	Type	Avg. Demand (AFY) Near-Term	Avg. Demand (AFY) Long-Term	Data Source
C136	Carp-Ag	park / sports field	Agriculture	0	11.2	CVWD Landuse, LT projected irrg. (AFY/acre)
C137	Carp-Ag	avocado	Agriculture	0	11.2	CVWD Landuse, LT projected irrg. (AFY/acre)
C138	Carp-Ag	lemons / avocado / cherimoyas / persimmons	Agriculture	0	11.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C139	Carp-Ag	avocado	Agriculture	0	11.0	CVWD Landuse, LT projected irrg. (AFY/acre)
C140	Carp-Ag	avocado	Agriculture	0	11.0	CVWD Landuse, LT projected irrg. (AFY/acre)
C142	Carp-Ag	avocado	Agriculture	0	10.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C144	Carp-Ag	avocado	Agriculture	0	10.7	CVWD Landuse, LT projected irrg. (AFY/acre)
C145	Carp-Ag	avocado	Agriculture	0	10.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C147	Carp-Ag	avocado	Agriculture	0	10.4	CVWD Landuse, LT projected irrg. (AFY/acre)
C149	Carp-Ag	avocado	Agriculture	0	10.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C150	Carp-Ag	avocados / sparse	Agriculture	0	10.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C151	Carp-Ag	avocado	Agriculture	0	10.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C152	Carp-Ag	field crops / mixed crops	Agriculture	0	10.0	CVWD Landuse, LT projected irrg. (AFY/acre)
C153	Carp-Ag	field crops / mixed crops	Agriculture	0	9.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C155	Carp-Ag	cherimoyas	Agriculture	0	9.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C157	Carp-Ag	cherimoyas	Agriculture	0	9.7	CVWD Landuse, LT projected irrg. (AFY/acre)
C159	Carp-Ag	avocado	Agriculture	0	9.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C160	Carp-Ag	? avocado	Agriculture	0	9.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C161	Carp-Ag	avocado	Agriculture	0	9.4	CVWD Landuse, LT projected irrg. (AFY/acre)
C162	Carp-Ag	field crops / mixed crops	Agriculture	0	9.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C164	Carp-Ag	avocado	Agriculture	0	9.2	CVWD Landuse, LT projected irrg. (AFY/acre)
C169	Carp-Ag	field crops / mixed crops / scrub	Agriculture	0	9.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C170	Carp-Ag	avocado	Agriculture	0	9.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C171	Carp-Ag	avocado	Agriculture	0	9.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C172	Carp-Ag	avocado / sparse	Agriculture	0	9.0	CVWD Landuse, LT projected irrg. (AFY/acre)
C173	Carp-Ag	avocado	Agriculture	0	9.0	CVWD Landuse, LT projected irrg. (AFY/acre)
C174	Carp-Ag	avocado	Agriculture	0	8.8	CVWD Landuse, LT projected irrg. (AFY/acre)
C176	Carp-Ag	avocado	Agriculture	0	8.7	CVWD Landuse, LT projected irrg. (AFY/acre)
C177	Carp-Ag	cherimoyas	Agriculture	0	8.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C179	Carp-Ag	avocado	Agriculture	0	8.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C180	Carp-Ag	avocado / Cate School	Agriculture	0	8.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C181	Carp-Ag	avocado	Agriculture	0	8.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C182	Carp-Ag	cherimoyas / avocado	Agriculture	0	8.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C184	Carp-Ag	persimmons / sparse	Agriculture	0	8.2	CVWD Landuse, LT projected irrg. (AFY/acre)
C185	Carp-Ag	avocado	Agriculture	0	8.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C186	Carp-Ag	cherimoyas	Agriculture	0	8.1	CVWD Landuse, LT projected irrg. (AFY/acre)

Santa Barbara South Coast Regional Reuse Study
Potential Recycled Water Demands

Id	Agency	Customer	Type	Avg. Demand (AFY) Near-Term	Avg. Demand (AFY) Long-Term	Data Source
C187	Carp-Ag	avocado / sparse	Agriculture	0	7.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C188	Carp-Ag	avocado	Agriculture	0	7.8	CVWD Landuse, LT projected irrg. (AFY/acre)
C190	Carp-Ag	horse facilities / pasture	Agriculture	0	7.7	CVWD Landuse, LT projected irrg. (AFY/acre)
C192	Carp-Ag	avocado	Agriculture	0	7.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C194	Carp-Ag	avocado	Agriculture	0	7.4	CVWD Landuse, LT projected irrg. (AFY/acre)
C196	Carp-Ag	avocado	Agriculture	0	7.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C197	Carp-Ag	avocado	Agriculture	0	7.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C198	Carp-Ag	field crops / vines	Agriculture	0	7.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C199	Carp-Ag	lemons	Agriculture	0	7.2	CVWD Landuse, LT projected irrg. (AFY/acre)
C200	Carp-Ag	avocado	Agriculture	0	7.2	CVWD Landuse, LT projected irrg. (AFY/acre)
C201	Carp-Ag	avocado	Agriculture	0	7.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C202	Carp-Ag	avocado	Agriculture	0	7.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C203	Carp-Ag	avocado / sparse	Agriculture	0	7.0	CVWD Landuse, LT projected irrg. (AFY/acre)
C205	Carp-Ag	avocado / lemons / cherimoyas	Agriculture	0	7.0	CVWD Landuse, LT projected irrg. (AFY/acre)
C206	Carp-Ag	avocado / lemons	Agriculture	0	6.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C208	Carp-Ag	horse facilities / pasture	Agriculture	0	6.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C209	Carp-Ag	avocado	Agriculture	0	6.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C210	Carp-Ag	avocado	Agriculture	0	6.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C211	Carp-Ag	avocado	Agriculture	0	6.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C214	Carp-Ag	avocado	Agriculture	0	6.8	CVWD Landuse, LT projected irrg. (AFY/acre)
C215	Carp-Ag	lemons	Agriculture	0	6.8	CVWD Landuse, LT projected irrg. (AFY/acre)
C218	Carp-Ag	avocado	Agriculture	0	6.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C219	Carp-Ag	cherimoyas / avocado / lemons	Agriculture	0	6.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C220	Carp-Ag	avocado	Agriculture	0	6.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C223	Carp-Ag	avocado	Agriculture	0	6.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C224	Carp-Ag	field crops / mixed crops	Agriculture	0	6.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C225	Carp-Ag	avocado	Agriculture	0	6.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C226	Carp-Ag	avocado	Agriculture	0	6.4	CVWD Landuse, LT projected irrg. (AFY/acre)
C228	Carp-Ag	cherimoyas / avocado / lemons	Agriculture	0	6.4	CVWD Landuse, LT projected irrg. (AFY/acre)
C229	Carp-Ag	avocado	Agriculture	0	6.4	CVWD Landuse, LT projected irrg. (AFY/acre)
C231	Carp-Ag	horse facilities / pasture	Agriculture	0	6.2	CVWD Landuse, LT projected irrg. (AFY/acre)
C232	Carp-Ag	avocado	Agriculture	0	6.2	CVWD Landuse, LT projected irrg. (AFY/acre)
C235	Carp-Ag	horse facilities / pasture	Agriculture	0	6.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C238	Carp-Ag	avocado	Agriculture	0	6.0	CVWD Landuse, LT projected irrg. (AFY/acre)
C239	Carp-Ag	field crops	Agriculture	0	5.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C241	Carp-Ag	horse facilities / pasture	Agriculture	0	5.9	CVWD Landuse, LT projected irrg. (AFY/acre)

Santa Barbara South Coast Regional Reuse Study
Potential Recycled Water Demands

Id	Agency	Customer	Type	Avg. Demand (AFY) Near-Term	Long-Term	Data Source
C242	Carp-Ag	avocado	Agriculture	0	5.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C243	Carp-Ag	avocado	Agriculture	0	5.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C244	Carp-Ag	roses	Agriculture	0	5.9	CVWD Landuse, LT projected irrg. (AFY/acre)
C246	Carp-Ag	avocado	Agriculture	0	5.8	CVWD Landuse, LT projected irrg. (AFY/acre)
C247	Carp-Ag	avocado	Agriculture	0	5.8	CVWD Landuse, LT projected irrg. (AFY/acre)
C249	Carp-Ag	lemons	Agriculture	0	5.8	CVWD Landuse, LT projected irrg. (AFY/acre)
C250	Carp-Ag	avocado	Agriculture	0	5.7	CVWD Landuse, LT projected irrg. (AFY/acre)
C252	Carp-Ag	field crops / mixed crops	Agriculture	0	5.7	CVWD Landuse, LT projected irrg. (AFY/acre)
C255	Carp-Ag	cherimoyas / passion fruit / bananas	Agriculture	0	5.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C256	Carp-Ag	?avocado	Agriculture	0	5.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C257	Carp-Ag	avocado	Agriculture	0	5.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C259	Carp-Ag	horse facilities / pasture	Agriculture	0	5.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C260	Carp-Ag	avocado	Agriculture	0	5.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C262	Carp-Ag	avocado	Agriculture	0	5.6	CVWD Landuse, LT projected irrg. (AFY/acre)
C263	Carp-Ag	avocado	Agriculture	0	5.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C264	Carp-Ag	field crops / vines	Agriculture	0	5.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C265	Carp-Ag	cherimoyas	Agriculture	0	5.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C266	Carp-Ag	cherimoyas	Agriculture	0	5.5	CVWD Landuse, LT projected irrg. (AFY/acre)
C269	Carp-Ag	avocado	Agriculture	0	5.4	CVWD Landuse, LT projected irrg. (AFY/acre)
C270	Carp-Ag	avocado	Agriculture	0	5.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C271	Carp-Ag	avocado	Agriculture	0	5.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C272	Carp-Ag	avocado / sparse	Agriculture	0	5.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C273	Carp-Ag	avocado	Agriculture	0	5.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C274	Carp-Ag	lemons	Agriculture	0	5.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C275	Carp-Ag	avocado	Agriculture	0	5.3	CVWD Landuse, LT projected irrg. (AFY/acre)
C278	Carp-Ag	avocado	Agriculture	0	5.2	CVWD Landuse, LT projected irrg. (AFY/acre)
C283	Carp-Ag	avocado	Agriculture	0	5.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C284	Carp-Ag	avocado	Agriculture	0	5.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C285	Carp-Ag	avocado / sparse	Agriculture	0	5.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C286	Carp-Ag	avocado	Agriculture	0	5.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C287	Carp-Ag	avocado	Agriculture	0	5.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C288	Carp-Ag	passion fruit / avocado / cherimoyas	Agriculture	0	5.1	CVWD Landuse, LT projected irrg. (AFY/acre)
C289	Carp-Ag	cherimoyas	Agriculture	0	5.1	CVWD Landuse, LT projected irrg. (AFY/acre)
			Subtotal	**0**	**2,458**	
GWD_1	GWD	UCSB Sierra Madre Appartments	Irrigation - Recreation	0.5	0.5	GWD provided estimate, Near-term
GWD_2	GWD	Westar Associates	Irrigation - Recreation	10.4	10.4	GWD provided estimate, Near-term

Santa Barbara South Coast Regional Reuse Study
Potential Recycled Water Demands

Id	Agency	Customer	Type	Avg. Demand (AFY) Near-Term	Long-Term	Data Source
GWD_3	GWD	Rincon Palms Hotel	Irrigation - Recreation	0.7	0.7	GWD provided estimate, Near-term
GWD_4	GWD	Haskell's Landing	Irrigation - Recreation	13.5	13.5	GWD provided estimate, Near-term
GWD_5	GWD	El Colegio RW Medians Phase 1	Irrigation - Recreation	0.2	0.2	GWD provided estimate, Near-term
GWD_6	GWD	El Colegio RW Medians Phase 2	Irrigation - Recreation	0.2	0.2	GWD provided estimate, Near-term
GWD_7	GWD	Caltrans US101 at Cathedral Oaks Road	Irrigation - Recreation	1.2	1.2	GWD provided estimate, Near-term
GWD_9	GWD	Married Student Housing	Irrigation - Recreation	0	2.0	GWD provided estimate, potential conversion
GWD_11	GWD	East side of Storke, N. of Santa Felicia	Irrigation - Recreation	0	0.5	GWD provided estimate, potential conversion
GWD_12	GWD	East side of Sorke, N. of Santa Felicia	Irrigation - Recreation	0	0.5	GWD provided estimate, potential conversion
GWD_14	GWD	DMV Camino Real Shopping Center	Irrigation - Recreation	0	0.6	GWD provided estimate, potential conversion
GWD_15	GWD	Pacific Oaks/Davenport Rd.	Irrigation - Recreation	0	0.8	GWD provided estimate, potential conversion
GWD_16	GWD	Condo Complex: 7300 Block of Calle Real	Irrigation - Recreation	0	0.3	GWD provided estimate, potential conversion
GWD_20	GWD	Bella Vista Park	Irrigation - Recreation	0	5.0	GWD provided estimate, potential conversion
GWD_22	GWD	Santa Barbara Airport	Irrigation - Recreation	0	0.5	GWD provided estimate, potential conversion
GWD_23	GWD	Twin Lakes Golf Course	Irrigation - Recreation	0	16.0	GWD provided estimate, LT Infrastructure exp.
GWD_24	GWD	Anisq Oyo Park and Peoples' Park	Irrigation - Recreation	0	3.7	GWD provided estimate, LT Infrastructure exp.
GWD_25	GWD	Trigo-Pasado Park	Irrigation - Recreation	0	0.4	GWD provided estimate, LT Infrastructure exp.
GWD_26	GWD	Evergreen Park	Irrigation - Recreation	0	3.5	GWD provided estimate, LT Infrastructure exp.
GWD_27	GWD	Brandon School	Irrigation - Recreation	0	1.5	GWD provided estimate, LT Infrastructure exp.
GWD_28	GWD	El Rancho School	Irrigation - Recreation	0	2.0	GWD provided estimate, LT Infrastructure exp.
GWD_29	GWD	Gol Pk/greenbelt	Irrigation - Recreation	0	3.5	GWD provided estimate, potential conversion
GWD_30	GWD	Sueno Orchard	Irrigation - Recreation	0	0.5	GWD provided estimate, LT Infrastructure exp.
GWD_31	GWD	Window to the Sea Park	Irrigation - Recreation	0	0.3	GWD provided estimate, LT Infrastructure exp.
GWD_32	GWD	Sea Lookout Park	Irrigation - Recreation	0	1.2	GWD provided estimate, LT Infrastructure exp.
GWD_33	GWD	Estero Park	Irrigation - Recreation	0	1.2	GWD provided estimate, LT Infrastructure exp.
GWD_34	GWD	Pelican Park	Irrigation - Recreation	0	0.5	GWD provided estimate, LT Infrastructure exp.
GWD_35	GWD	Little Acorn Park	Irrigation - Recreation	0	0.7	GWD provided estimate, LT Infrastructure exp.
GWD_36	GWD	Camino Pescadero Park	Irrigation - Recreation	0	0.2	GWD provided estimate, LT Infrastructure exp.
GWD_37	GWD	Walter Capps Park	Irrigation - Recreation	0	0.9	GWD provided estimate, LT Infrastructure exp.
GWD_38	GWD	Children's Park	Irrigation - Recreation	0	1.0	GWD provided estimate, LT Infrastructure exp.
GWD_39	GWD	Sueno Park	Irrigation - Recreation	0	0.5	GWD provided estimate, LT Infrastructure exp.
GWD_40	GWD	Tierra de Fortuna Park	Irrigation - Recreation	0	0.4	GWD provided estimate, LT Infrastructure exp.
GWD_41	GWD	Pardall Gardens	Irrigation - Recreation	0	0.4	GWD provided estimate, LT Infrastructure exp.
GWD_42	GWD	Hollister Business Park	Irrigation - Recreation	0	4.6	GWD provided estimate, LT Infrastructure exp.
GWD_43	GWD	Cabrillo Bus. Park (includes Los Carneros and Hollister Medians)	Irrigation - Recreation	0	3.0	GWD provided estimate, LT Infrastructure exp.
GWD_44	GWD	Coromar Office Buildings	Irrigation - Recreation	0	1.5	GWD provided estimate, LT Infrastructure exp.

Santa Barbara South Coast Regional Reuse Study
Potential Recycled Water Demands

Id	Agency	Customer	Type	Avg. Demand (AFY) Near-Term	Avg. Demand (AFY) Long-Term	Data Source
GWD_45	GWD	Village at Los Carneros Housing Project	Irrigation - Recreation	0	10.0	GWD provided estimate, LT Infrastructure exp.
GWD_46	GWD	Raytheon Offices	Irrigation - Recreation	0	2.6	GWD provided estimate, LT Infrastructure exp.
GWD_47	GWD	Goleta Valley School District	Irrigation - Recreation	0	2.3	GWD provided estimate, LT Infrastructure exp.
			Subtotal	**27**	**99**	
LCMWC_1	LCMWC	La Cumbre Golf and Country Club	Irrigation - Recreation	0	127	2009-11 Water Records, %RW
LCMWC_2	LCMWC	Laguna Blanca School Chase Field	Irrigation - Recreation	0	3	2009-11 Water Records, %RW
			Subtotal	**0**	**130**	
MWD_1	MWD	Lookout Park	Irrigation - Recreation	0	7.5	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
MWD_2	MWD	Manning Park	Irrigation - Recreation	0	30.0	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
MWD_3	MWD	Westmont College	Irrigation - Recreation	0	100.0	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
MWD_4	MWD	Crane County Day School	Irrigation - Recreation	0	20.0	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
MWD_5	MWD	Montecito Union School	Irrigation - Recreation	0	7.5	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
MWD_6	MWD	Cold Spring Elementary School	Irrigation - Recreation	0	10.0	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
MWD_7	MWD	Summerland School	Irrigation - Recreation	0	1.5	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
MWD_10	MWD	Caltrans (Montecito)	Irrigation - Recreation	0	9.0	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
MWD_11	MWD	Caltrans (Summerland)	Irrigation - Recreation	0	5.0	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
MWD_12	MWD	Santa Barbara Cemetery	Irrigation - Recreation	0	139.0	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
MWD_13	MWD	Lemons and Avocados	Agriculture	0	6.3	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
MWD_14	MWD	Agricultural Land	Agriculture	0	260.9	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
MWD_15	MWD	Agricultural Land	Agriculture	0	180.2	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
MWD_16	MWD	Agricultural Land	Agriculture	0	458.6	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
MWD_17	MWD	Agricultural Land	Agriculture	0	56.2	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
MWD_18	MWD	Agricultural Land	Agriculture	0	66.7	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
MWD_19	MWD	Agricultural Land	Agriculture	0	388.4	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
MWD_20	MWD	Agricultural Land	Agriculture	0	39.6	1991 CH2M Hill (Fig 5-1; Tbl 5-6)
			Subtotal	**0**	**1,786**	
SB_59	SB	County of Santa Barbara	Irrigation - Recreation	0	11.2	2009 WSPS, water records
SB_63	SB	City of Santa Barbara	Irrigation - Recreation	0	12.3	2009 WSPS, water records
SB_65	SB	Chase Palm Park (Expansion)	Irrigation - Recreation	0	14.6	2009 WSPS, water records
SB_66	SB	City of Santa Barbara	Irrigation - Recreation	0	10.1	2009 WSPS, water records
SB_67	SB	City of Santa Barbara	Irrigation - Recreation	0	12.3	2009 WSPS, water records
SB_73	SB	Harbor View Inn	Irrigation - Commercial	2.2	2.2	2009 WSPS, water records
SB_75	SB	Housing Authority of S.B.	Irrigation - Residential	0	4.5	2009 WSPS, water records
SB_77	SB	Avocado Grower	Agriculture	0	4.5	2009 WSPS, water records
SB_78	SB	Vista Madera Owners Association	Irrigation - Residential	0	4.5	2009 WSPS, water records

Santa Barbara South Coast Regional Reuse Study
Potential Recycled Water Demands

Id	Agency	Customer	Type	Avg. Demand (AFY) Near-Term	Long-Term	Data Source
SB_80	SB	Ralphs Grocery	Irrigation - Commercial	0	3.4	2009 WSPS, water records
SB_81	SB	Vista del Monte	Irrigation - Residential	0	3.4	2009 WSPS, water records
SB_85	SB	Villa Constance South	Irrigation - Residential	0	3.4	2009 WSPS, water records
SB_86	SB	Stone Creek Owners Assoc. (online in 2013)	Irrigation - Residential	4.5	4.5	2009 WSPS, water records
SB_88	SB	Towbes Group Inc	Irrigation - Residential	6.7	6.7	2009 WSPS, water records
SB_89	SB	Las Positas Meadows HOA	Irrigation - Residential	0.0	5.6	2009 WSPS, water records
SB_90	SB	Franciscan Villas Association	Irrigation - Residential	10.1	10.1	2009 WSPS, water records
SB_93	SB	Avocado Grower	Agriculture	0	4.5	2009 WSPS, water records
SB_94	SB	Reef Court Owners	Irrigation - Recreation	2.3	2.3	2009 WSPS, water records
SB_96	SB	Avocado Grower	Agriculture	0	4.5	2009 WSPS, water records
SB_98	SB	Villa Constance Nort	Irrigation - Residential	0	4.5	2009 WSPS, water records
SB_99	SB	Vista Pacifica Home	Irrigation - Residential	0	4.5	2009 WSPS, water records
SB_101	SB	Irrigation - Residential	Irrigation - Residential	0	3.4	2009 WSPS, water records
SB_102	SB	Avocado Grower	Agriculture	0	4.5	2009 WSPS, water records
SB_104	SB	Vista Del Monte	Irrigation - Residential	0	4.5	2009 WSPS, water records
SB_105	SB	Shifco	Irrigation - Recreation	0	3.4	2009 WSPS, water records
SB_107	SB	Vista Pacifica Home	Irrigation - Recreation	0	3.4	2009 WSPS, water records
SB_109	SB	Santa Barbara Auto Group	Irrigation - Recreation	3.4	3.4	2009 WSPS, water records
SB_116	SB	LAUNDERLAND	Commercial	0	17.9	2009 WSPS, water records
SB_118	SB	MISSION LINEN SUPPLY	Industrial	0	29.1	2009 WSPS, water records
SB_119	SB	S B HAND CAR WASH	Industrial	0	5.6	2009 WSPS, water records
SB_120	SB	ABLITT'S FINE CLEANERS	Industrial	0	4.5	2009 WSPS, water records
SB_121	SB	FIESTA CAR WASH	Industrial	0	3.4	2009 WSPS, water records
SB_122	SB	EDUCATED CAR WASH	Industrial	0	9.0	2009 WSPS, water records
SB_123	SB	DALEE CAR BATH	Industrial	0	4.5	2009 WSPS, water records
SB_124	SB	ST PAUL CLEANERS	Industrial	0	3.4	2009 WSPS, water records
SB_125	SB	MISSION LINEN SUPPLY	Industrial	0	12.3	2009 WSPS, water records
SB_128	SB	Hotel Mar Monte	Irrigation - Commercial	0	0.8	2009 WSPS, water records
SB_129	SB	Santa Barbara Inn	Irrigation - Commercial	0	1.5	2009 WSPS, water records
SB_130	SB	Elise Court Owners	Irrigation - Recreation	1.0	1.0	2009 WSPS, water records
SB_131	SB	Marina Restrooms	Commercial	1.6	1.6	2009 WSPS, water records
SB_133	SB	Las Positas Tennis Courts	Irrigation/Toilets	1.9	1.9	2009 WSPS, water records
SB_136	SB	Sunflower Park	Irrigation - Recreation	0	0.5	2009 WSPS, water records
SB_137	SB	Eastside Neighborhood Park	Irrigation - Recreation	0	3.0	2009 WSPS, water records
SB_138	SB	Franklin Park & School	Irrigation - Recreation	0	11.2	2009 WSPS, water records
SB_139	SB	Clark Estate	Irrigation - Recreation	0	10.0	City Staff

Santa Barbara South Coast Regional Reuse Study
Potential Recycled Water Demands

Id	Agency	Customer	Type	Avg. Demand (AFY) Near-Term	Avg. Demand (AFY) Long-Term	Data Source
SB_140	SB	First Baptist Church	Irrigation - Recreation	4.0	4.0	City Staff
SB_141	SB	Cottage Hospital (Expansion to cooling towers)	Commercial	2.0	3.0	City Staff
SB_142	SB	East Beach	Irrigation - Recreation	0	2.5	City Staff
SB_143	SB	San Roque High School	Irrigation - Recreation	0	7.0	City Staff
SB_144	SB	SB Old Mission	Irrigation - Recreation	0	8.0	City Staff
SB_145	SB	Mission Rose Gardens	Irrigation - Recreation	0	4.5	City Staff
			Subtotal	**40**	**306**	
			Total	**66**	**4,922**	

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Appendix 1-C: Santa Maria Valley Groundwater Assessment, GEI, 2013

Santa Maria Valley

Groundwater Assessment

Santa Barbara County, California

Submitted to:
Salt and Nutrient Planning Workgroup
Santa Barbara County IRWM Plan 2013

Date: October 9, 2013
Project No: 118210

Robert Almy, PG
Project Director

Samuel W. Schaefer, PE
Senior Engineer

GEI Consultants, Inc.

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Figures

Appendices

Abbreviations and Acronyms

CCAMP	Central Coast Ambient Monitoring program
CCRWQCB	Central Coast Regional Water Quality Control Board
CCWA	Central Coast Water Authority
CIMIS	California Irrigation Management Information System
CMP	Cooperative Monitoring Program
IRWM	Integrated Regional Water Management
NPDES	National Pollution Discharge Elimination System
POTW	Publically-Owned Treatment Works
SMVWMA	Santa Maria Valley Water Management Authority
SMVWCD	Santa Maria Valley Water Conservation District
TDS	total dissolved solids
TMA	Twitchell Management Authority
TMDL	total maximum daily load
USBR	United State Bureau of Reclamation
USGS	Unites States Geological Society
WRCB	Water Rescources Control Board
WDRs	Water Discharge Requirements

1 Introduction

This Assessment has been prepared to evaluate sources, transport and fate of “salts” and “nutrients” (Nitrate and other forms of nitrogen) in surface water and groundwater within the Santa Maria Valley. Stakeholders in the Santa Maria Valley are interested in assuring sustainability of water supplies and addressing water quality regulations, specifically the future development of Salt and Nutrient Plans. The goals of this assessment are to 1) identify regulatory requirements, 2) gather data, 3) summarize key issues, and 4) provide recommendations to support future development of Salt and Nutrient Management Plans that are required by regulation for all groundwater basins and sub-basins in California. The assessment is specific to the Santa Maria Valley Groundwater Management Area as defined by The Superior Court (2008) (Figure 1) and is a part of the update to the Santa Barbara County Integrated Regional Water Management (IRWM) Plan 2013 under development by regional interests. Funding has been provided by the California State Department of Water Resources (DWR) as part of a Proposition 84 IRWM Planning Grant to the Santa Barbara County Region. This assessment is intended to support the development of a Salt and Nutrient Management Plan pursuant to State Water Resources Board Policy (Policy 2009-0011).

Over time, salts and nutrients may increase in groundwater basins due to a number of influences. As use and reuse of water has increased in California, understanding these influences and developing strategies to assure sustainable water resources has become more important. Santa Maria Valley water users, through a Salt and Nutrient Planning Working Group (Working Group), have prepared this assessment in order to better understand both existing water quality and the effectiveness of ongoing water resource management efforts. The Group has been responsible for guiding collaboration with local organizations and public agencies, as well as the public. The goals of this assessment are to identify regulatory requirements, gather and evaluate data, summarize key issues, and provide recommendations to support future development of a Salt and Nutrient Management Plan by individual stakeholders within the Santa Maria Valley. This report does not discuss climate change since it is a specific topic addressed in the IRWM Plan update.

This assessment is based on existing hydrologic information and water quality data available through the Working Group and public agencies. Funding is provided through an IRWM Planning Grant for consultant services to assist in development of the report.

The scope of work for this assessment was developed by the Working Group and approved by DWR in conjunction with the grant (Appendix A). This assessment contains several sections:

- Purpose of the Assessment
- Overview of regulatory requirements pertaining to water quality in the Santa Maria Valley
- Working Group collaborative process
- Conceptual model of sources, transport, and fate of salt and nutrient
- Data acquisition, management, and analysis
- Description of the groundwater basin
- Overview of salt and nutrient management in the Santa Maria Valley

In addition to this assessment, the Working Group formulated a process to discuss goals and objectives in a separate Technical Memorandum. This process is based on the review of existing data (Section 2 of this Assessment), the development of a shared understanding of salt and nutrient transport and fate (Section 3), and the conclusions of the Groundwater Assessment Report (Section 6). The Working Group addressed both institutional and quantitative goals and objectives.

1.1 Regulatory Requirements Pertaining to Water Quality in the Santa Maria Valley

Quality of surface and groundwater is generally regulated by two agencies, the State Water Resources Control Board (State Board) and the Central Coast Regional Water Quality Control Board (Central Coast Board). These boards have a number of regulatory programs that pertain to the Santa Maria Valley. They include:

- Water quality planning programs (adoption, review, and amendment of state-wide and basin water quality control plans and policies), including development and adoption of Total Maximum Daily Loads (TMDLs) and implementation plans
- Regulatory programs, including permitting and control of discharges through National Pollutant Discharge Elimination System (NPDES) and Waste Discharge Requirement (WDR) permits, discharge to land (California Code of Regulations Chapter 15), and storm water and storage tank programs
- Monitoring and quality assurance programs
- Nonpoint source management programs, including the “Watershed Management Initiative”
- Funding assistance programs, including grants and loans

1.1.1 Basin Plan and Beneficial Uses

The Central Coast Board relies on its adopted “Water Quality Control Plan for the Central Coast Basin Plan” (Basin Plan) to describe the actions necessary to:

- Achieve water quality objectives
- Establish a time schedule for complying with them
- Describe necessary surveillance and monitoring activities

The nature of actions to be taken to meet water quality objectives include, but are not limited to, issuance of WDRs (non-water body discharges) and NPDES permits (for surface water body discharges) for point discharges, establishment of water-quality based effluent limitations, prohibitions of discharge, and the review and establishment of TMDLs.

The Basin Plan also establishes beneficial uses used to guide development of water quality objectives in each surface water body. Each water body is designated for one or more beneficial uses such as domestic, municipal, agricultural, and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and preservation and enhancement of fish, wildlife, and other aquatic resources. Generally speaking the municipal use and environmental designations carry the strictest water quality standards. Monitoring activities to determine compliance with water quality objectives include discharger self-monitoring required under WDRs and NPDES permits, and monitoring undertaken by the Central Coast Board through its Central Coast Ambient Monitoring Program (CCAMP) program.

1.1.2 Total Maximum Daily Loads

Consistent with Section 303(d) of the Clean Water Act, the State has identified surface water bodies that do not meet water quality standards and considers them "impaired." In order to improve water quality in the impaired surface water bodies in the Santa Maria Valley, the Central Coast Board has implemented the regulatory process of TMDLs. The TMDL process involves determining the quantity of one or more pollutants that can be allowed in each surface water body without exceeding water quality objectives, and allocating responsibility for managing those pollutants. The role of groundwater in developing a TMDL has not been determined by CCRWQCB.

Although the abbreviation stands for Total Maximum Daily Load, the limitations contained in a TMDL may be other than daily load limits. There can also be multiple TMDLs on a particular surface water body, or there can be one TMDL that addresses numerous pollutants. California's Porter-Cologne Water Quality Control Act (Section 13242) requires that any TMDL implementation program be adopted as a Basin Plan amendment. The CCRWQCB has initiated a TMDL regulatory process for Total Dissolved Solids (TDS or "salt") and nutrients in the Santa Maria Valley. In support of the TMDL process, the CCRWQCB is developing a numerical model of elements on the hydrologic system of the Santa Maria Valley that affect sources, transport and fate of TDS in surface and groundwater. The model is intended to guide decisions by the CCRWQCB in its regulatory process. The model was not used in the analysis presented in this report.

1.1.3 Point Source Waste Discharge Requirements

NPDES permits are required by all dischargers—municipal, industrial, and others that discharge pollutants from any point source (such as "end of pipe" systems) into waters of the United States—and are intended to ensure that discharges do not adversely affect the quality and beneficial uses of surface waters. All permit requirements must also comply with the

Central Coast Board Basin Plan and any statewide water quality control plans. Permits include requirements for effluent limitations. Permits for discharges to water bodies that do not yet meet water quality objectives may require effluent limitations consistent with a waste load allocation to ensure that the discharge will allow achievement of applicable water quality objectives. An appropriate monitoring and reporting program is included in all permits.

WDRs are issued under State law pursuant to Section 13263 of the Water Code and apply to dischargers that discharge waste to land or to percolation ponds. The disposal method may be by agricultural or non-agricultural irrigation or to ponds, landfills, or leach fields. Similar to NPDES requirements, all WDRs contain effluent limitations, provisions for maintaining an administrative record, and monitoring and reporting requirements. The City of Guadalupe, the City of Santa Maria and the Laguna County Sanitation District discharge wastewater under separate WDRs.

1.1.4 Nonpoint Source Discharge Requirements

The State Boards Nonpoint Source (NPS) Pollution Control Program is responsible for statewide NPS program management, and for providing administrative and technical support for the program to the State and Regional Boards. Nonpoint source is defined to mean any source of water pollution that does not meet the legal definition of “point source” in CWA 502(14). Typically, nonpoint source pollution is transported by rainfall or runoff and may reach surface water or groundwater. Atmospheric deposition and hydrologic modification of surface characteristics (leading to sediment runoff or increased peak runoff, etc.) are also considered nonpoint sources of pollution. The State has several programs to control nonpoint source pollution. They are discussed below.

1.1.5 Condition Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands: Order No. R3-2012-0011(Agricultural Order)

The Central Coast Board employs a regulatory process called a Conditional Waiver of Waste Discharge Requirements to control discharges from irrigated agricultural lands to protect surface water and groundwater quality. This permit applies to owners and operators of irrigated land used for commercial crop production; it is intended to control pollution from pesticides, nutrients, and sediments. Each grower in the Central Coast Region must submit a Notice of Intent to comply with the Order.

On March 15, 2012, the Central Coast Board adopted an updated Conditional Waiver of Waste Discharge Requirements (Agricultural Order No. RB3-2012-0011). The waiver expands the ongoing monitoring and reporting program and places farms in one of three tiers based on risk to water quality. Specifically, the Order includes water quality monitoring of surface and groundwater as well as implementing nutrient management practices pursuant to a plan developed specifically for each farming operation. A fact sheet outlining the requirements of the Order is contained in Appendix D; at this time and during the writing of this report, full implementation of the Order is pending legal challenges.

1.1.6 Stormwater Regulations

The 1987 amendments to the Clean Water Act added Section 402(p) and established initial regulation of municipal and industrial storm water discharges under the NPDES program. In 1990, EPA established application requirements for storm water permits. The regulations require that storm water associated with industrial activities that discharge either directly to surface waters or indirectly through separate municipal storm sewers must be regulated by an NPDES permit. In California a separate statewide general permit has also been issued for construction activity. Currently the City of Santa Maria and the community of Orcutt are subject to municipal stormwater permits focusing on their storm drain systems, which require six types of pollution control activity: public education, pollution source identification and abatement, water quality monitoring, land use regulations, construction site regulation and control of municipal operations.

The State Board issued a general permit regulating all dischargers where construction activity disturbs five or more acres. The intentions of this permit were to eliminate or reduce non-storm water discharges to storm sewer systems and other waters, and to implement and perform inspections of Best Management Practices (BMPs). State agencies such as CALTRANS, municipal agencies and private construction activities are subject to this permit.

1.1.7 Recycled Water Policy

The State of California encourages recycling of water to increase availability and reliability of existing supplies. In order to address long term water quality issues raised by water reuse, the State Board adopted a Recycled Water Policy in February 2009. The purpose of the policy was to protect long term water quality pursuant to existing laws.

The Recycled Water Policy states that Salt and Nutrient Management Plans need to be completed by 2014 to facilitate basin-wide management of salt and nutrient from all sources in a manner that optimizes recycled water use while ensuring protection of groundwater supply and beneficial uses, agricultural beneficial uses, and human health. The Central Coast Board, through its regulation of discharges, now requires operators of publically owned treatment works (POTW) to develop implementation plans to meet the objectives of the Recycled Water Policy, including preparation of Salt and Nutrient Management Plans. The plans will then be adopted by the Central Coast Board as amendments to the region's Basin Plan. The proposed outline for plans developed by the WRCB is contained in Appendix B.

1.1.8 Groundwater Basin Adjudication

The Santa Maria Groundwater Basin was subject to litigation that was partially settled in a June 30, 2005, Stipulation entered by the Superior Court of the State of California, County of

Santa Clara (Superior Court, 2008). The Stipulation divided the overall Santa Maria Valley Groundwater Basin into three management areas, the largest of which overlies the main Santa Maria Valley (the Santa Maria Valley Management Area, or SMVMA) which is subject to annual reporting by the Twitchell Management Authority. The other two management areas, the Nipomo Mesa Management Area (NMMA) and the Northern Cities Management Area, are addressed in separate annual reports prepared by separate entities. Most water users, including the public purveyors of water, are subject to the Stipulation. Upon final settlement of the adjudication, all water users in the Valley will be subject to the stipulation.

The Stipulation specifies that monitoring will occur to determine groundwater conditions, land and water uses, sources of water supply, and the disposition of all water supplies in the Valley. Annual Reports by the TMA on the SMVMA to the Court summarize the results of the monitoring and include an analysis of the relationship between projected water demand and supply. Some discussion of water quality is included. Currently the SMVMA annual report is prepared by Luhdorff and Scalmanini Engineers.

1.2 Working Group Collaboration Process

The Santa Maria Valley Groundwater study is a new evaluation focusing on salt and nutrient issues that was developed through a collaborative process involving stakeholders within the Santa Maria Valley, as further described below (Appendix C).

1.2.1 IRWM Planning Framework

The development of this report was guided by a Working Group comprising water users, local and state agencies, non-governmental organizations and other interested parties (Appendix C). The Working Group was formed within the framework of the Santa Barbara county IRWM Plan update to focus specifically on salt and nutrient issues in the Santa Maria Valley. The group was open to all interested parties and worked under mutually agreed upon ground rules relating to meeting protocol and decision making. Participation by a diverse group of stakeholders and the public was actively solicited and project development was reported through the County of Santa Barbara IRWM website.

1.2.2 Guided by Local Stakeholder Interests

Local stakeholder in-basin interests provided much of the data used to prepare this report and provided review to assure the report accurately reflects issues related to salt and nutrient planning in the Santa Maria Valley. From the outset, the local stakeholder interests sought a report that could help all users to provide sustainable, local water sources to meet all local needs as well as recognizing the sustainable practices already implemented by stakeholders.

1.2.3 Water Users and Dischargers

Two types of operations are essential to characterizing Santa Maria Valley water quality: 1) production and use by municipal and agriculture interests and 2) water discharge by WWTP operators and agriculture (Figures 1.2a, 1.2b, 1.2c, 1.2d, 1.2e, and 1.2f are a set of six conceptual transport and fate diagrams, which are the same diagrams referred to later in this report in several places). Water user groups are well represented in the Working Group. Water users included urban water suppliers, agricultural water users, and environmental demands. In the Santa Maria Valley, urban water suppliers rely on both groundwater and imported deliveries from the State Water Project (SWP). Agricultural water users rely predominately on groundwater extractions. (Some minor sprinkler irrigation relies on treated WWTP effluent.)

Dischargers include WWTPs, municipal storm drains, and agricultural drainage. As described in subsequent sections, discharges within the Santa Maria Valley have been adequately monitored to allow general characterization.

1.2.4 Collaborative and Non-Regulatory

Like all other elements of the IRWM Planning process, the Working Group is non-regulatory and collaborative. The group structured its meetings, adopted ground rules, hired a technical consultant, and modified the scope of work during the initial stages of the process. The scope of work and structure of the work products were deliberately crafted to avoid the appearance of complying with a particular regulatory process, while developing information each of the individual dischargers may use as a basis for meeting State mandates to prepare a Salt and Nutrient Management Plan.

1.2.5 Regular Meetings Open to the Public

Regular monthly meetings were held in the Santa Maria Valley among Working Group members, the technical consultant, and members of the IRWM Planning team. These meetings were used to share information, review interim work products, and provide direction to the technical consultant.

1.3 Agency Coordination

This report was prepared under the auspices of the Santa Barbara County Integrated Regional Water Management Plan. The IRWM Planning process includes 28 agencies including the following members of the working group that guided preparation of this report:

- Santa Barbara County Water Agency (CWA)
- Twitchell Management Authority (TMA)
- Santa Maria Valley Water Conservation District (SMVWCD)
- City of Santa Maria and City of Guadalupe
- Golden State Water Company (GSWC)

- Laguna County Sanitation District (LCSD)
- Central Coast Regional Water Quality Control Board (CCRWQCB)

These agencies collaborate in a number of areas on an ongoing basis. They each participated as active members of the working group and provided data as well as comments on the direction of the assessment. These agencies will continue to collaborate and provide direction through the IRWM Planning process.

1.4 Purpose of the Groundwater Assessment

This groundwater assessment was conceived and scoped based on water users' interest to assure sustainability of water supplies as well as address concerns about regulatory requirements, specifically future development of Salt and Nutrient Management Plans that are required pursuant to recycled water policy as discussed in Section 1.1.

The goals of this assessment are to identify regulatory requirements, gather data, summarize key issues, and provide recommendations to support future development of Salt and Nutrient Management Plans that are required by regulation for all groundwater basins and sub-basins in California. To reach those goals, this report includes the following:

- Regulatory overview including identification of current beneficial uses
- Description of institutional responsibilities and roles among water users
- Description of transport and fate mechanisms
- Estimate of the salt and nutrient balance in the Santa Maria Valley
- Description of ongoing management activities

The identification of current uses and water quality trends in the assessment are based on existing reports and input from the Working Group focusing on:

- Urban Water Supply
- Agricultural Water Supply
- Habitat support

Excessive salts or nutrients in water may threaten both human health and agricultural viability (Center for Watershed Sciences, 2012). Currently the principal source of supply in the Santa Maria Valley is groundwater. Ongoing monitoring suggests that both salt (TDS) and Nutrients, specifically nitrate (NO_3), are increasing in some areas of the Valley. NO_3 is a component of "salts" and is included in the measurement of TDS. However, due to the nature of its potential effects on human health and environmental resources, NO_3 is generally considered separately from other chemical species comprising TDS.

In the past decades development of supplemental supplies and new management practices have changed the manner in which salts and nutrients are introduced to the local hydrologic system. At the same time, regulatory agencies may seek to limit discharge of excess salt and nutrients from the Valley through regulation of discharges. Since existing monitoring practices may not provide a comprehensive picture of the benefits of existing and future management practices, conflicts may arise between narrow regulatory objectives and implementation of feasible management practices.

This assessment establishes an information base upon which to plan for the sustainability of water resources for all users. It is intended to be a first step in understanding the sources and transport of salts and nutrients within the Santa Maria Valley as well as their fate. This is key to modifying the current monitoring program so that future monitoring may demonstrate how effectively management measures control or reduce salt and nutrient levels in ground- and surface water within the basin.

1.5 Approach of the Groundwater Assessment

In order to put available data in a straightforward framework and evaluate changes in conditions with time, the assessment focuses on typical conditions in three years: 1990, 2000 and 2010. Based on a conceptual model of salt and nutrient sources and movement in the basin the following factors were evaluated:

- Sources and chemical quality of water sources
- Nature, amount, and use of water produced
- Transport of water
- Changes in water quality
- Changes in water and nutrient management

1.5.1 Conceptual Model Discussion

The Working Group based its development of a working conceptual model (included as Figures 1.2a through 1.2f) of Santa Maria Valley hydrology on previous work (such as Gibbs 2012 and Luhdorff and Scalmanini, 2011). The conceptual model shows the basic elements of sources, transport, and fate of salt and nutrient. These essential elements are represented numerically in the evaluation section. The calculation of flow volume and salt and nutrient concentration allows estimates of total transport and balance (salt/nutrient transported into and out of the valley) as discussed in Section 3.

1.5.2 Hydrology

For the purposes of understanding salt and nutrients in the Santa Maria Valley, there are three essential hydrologic factors that control transport and fate. They are:

- **Elements of Recharge:** rainfall, stream flow, importation of state water substituted for pumping, waste water treatment ponds, and deep percolation (return flow) from agriculture and other irrigation.

- **Elements of Discharge:** flow to surface water bodies that discharge into the ocean, groundwater flow to ocean, and in the case of nutrient, transformation to other forms (such as N_2) that have no water quality implications.
- **Sinks:** salt and nutrient accumulation that may occur without deleterious effects.

1.5.3 Inputs-Sources of Salt and Nutrient

The evaluation of salt and nutrient requires data on water quality as well as the volume of water moving into and through the elements of the hydrologic system. For this report, data on sources of salt and nutrient were obtained from water quality sample results posted on the Central Coast Board and USGS websites as well as limited data in other publications (Luhdorff and Scalmanini, 2011). In addition, data were provided by water purveyors including the City of Guadalupe, City of Santa Maria, and Golden State Water Company. Discharge data were obtained from operators of POTWs and the Central Coast Board. Data on nutrient use by agriculture was based on nutrient application guidelines for crops published by the University of California Cooperative Extension Service. These guidelines provide an order of magnitude estimate of nutrient use. Refined estimates could be developed from use of alternative data sources (e.g. Center for Watershed Sciences, 2012), however, professional judgment discussed among the Working Group members indicates a key conclusion of Section 4 (that NO_3 loading has decreased with time) would likely not change.

1.5.4 Transport Mechanism

Transport mechanism refers to the manner and means that salt and nutrient move through the Valley's hydrologic cycle. Salt transport generally follows flow of surface water and groundwater. The transport of nutrients, specifically nitrate (NO_3), is more complex as a result of plant uptake and chemical transformations that occur in soil.

1.5.5 Fate

Generally speaking salt and nutrients are removed from the hydrologic system through surface or subsurface flow or disposal (by Laguna Sanitation District). Specific to nitrogen, natural processes may convert nitrate (NO_3) into N_2 (a gas) or other forms that are less detrimental from a management standpoint. The movement of both salt and nitrates may be attenuated during movement through unsaturated soils above the water table known as the vadose zone. This attenuation may be a factor in understanding the accumulation of salt and nitrate in that zone. The fate of salt is somewhat less complex since the evapotranspiration of water from the root zone by plants does not remove salts. As a result the majority of salt is concentrated by evapotranspiration and remains available for transport by water movement.

Nitrogen, on the other hand, is added to the root zone in any of several forms to support plant growth to meet target yields and extracted with the plant material when it is harvested; keeping track of the fate of nitrogen requires several components: 1) short-term decisions regarding nitrogen management during a crop growing season, 2) annual and multi-year, long-term root zone budgeting for available nutrients, and 3) a basin wide long-term budget to understand the fate of nitrate that leaches past the root zone and into the groundwater basin. The third component, the groundwater basin, is a large-scale system in comparison to the management of each crop growing in a field-scale.

1.5.6 Water and Nutrient Management

Water and nutrient management, practiced by water management agencies (discussed below) and water users, is influenced by changes in annual precipitation, regulations, and pricing. In particular, changes in cost and availability of water and cost of nutrients are considered in this report as a function of time focusing on three points in time, ten years apart, specifically 1990, 2000 and 2010. The operation of Twitchell Reservoir, importation of relatively expensive supplies from the State Water Project, increasing power costs (which increase the cost of pumping and conveying water) and increased fertilizer costs have led to increased management of salt and nutrients.

1.6 Existing Water Management and Institutional Framework

Extraction, use and discharge of water are subject to a complex management and institutional framework. Generally speaking, groundwater extraction is subject to court jurisdiction pursuant to adjudication (Superior Court, 2008; Luhdorff and Scalmanini, 2011). The adjudication provides certainty as to allocation of groundwater and requires ongoing monitoring to be summarized in annual reports (Superior Court, 2008). In addition, the court established the Twitchell Management Authority to oversee preparation of the annual report for the SMVMA and provide for long term maintenance of the Twitchell Reservoir. Data for the annual report is developed by local agencies and the U. S. Geologic Survey (USGS). Water imported to the valley from the State Water Project on behalf of municipal users is managed by the Central Coast Water Authority, a joint exercise of powers agency comprising local agencies including the three municipal system operators in the valley.

Surface water is managed through the operation of Twitchell Reservoir and maintenance of the Santa Maria River levee system. Twitchell Reservoir is operated by the Santa Maria Valley Water Conservation District to provide enhanced groundwater recharge and regulate flood flows in the Cuyama and Santa Maria Rivers. The Sisquoc River, the other main tributary to the Santa Maria River, is unregulated.

1.7 Stakeholder Roles and Responsibilities

A wide range of interests were represented during scoping and preparation of this report. These interests, or stakeholders, formed a working group (Appendix C) to provide the following:

- Guide development of Groundwater Assessment Report
- Provide information, analysis reports and management program overviews
- Accept Groundwater Assessment Report

- Discuss process to Develop Salt/Nutrient Management Plan(s)

The development of this report is part of a broader process to update the Santa Barbara County Integrated Regional Water Management Plan. The Working Group is a subset of the group performing that update and provided regular updates to the IRWM Steering Committee. This assessment will be incorporated into the revised IRWM Plan.

1.8 Organization of This Report

This assessment is based on a scope of work developed by the Working Group and approved by the DWR in conjunction with the grant (Appendix A). This assessment contains several sections:

1 Introduction
2 Existing Monitoring and Uses of Data
3 Description of Valley Hydrology and Hydrogeology
4 Sources, Transport and Fate of Sodium, Chloride and Nitrogen
5 Evaluation of Existing Monitoring
6 Summary and Conclusions

In addition to this assessment, the Working Group will formulate a process to develop goals and objectives as a separate Technical Memorandum. This process will be based on the review of existing data (Section 2 of this assessment) and development of shared understanding of salt and nutrient transport and fate (Section 3) and the conclusions of the Groundwater Assessment Report (Section 6). The working group is expected to address both institutional and quantitative goals and objectives.

Section 2 of this report includes a discussion of the source of existing monitoring programs and uses of data collected. The purpose of each major data acquisition program is described along with a summary of data acquisition, management, and availably. Other data acquisition efforts that contributed to this report are described as well.

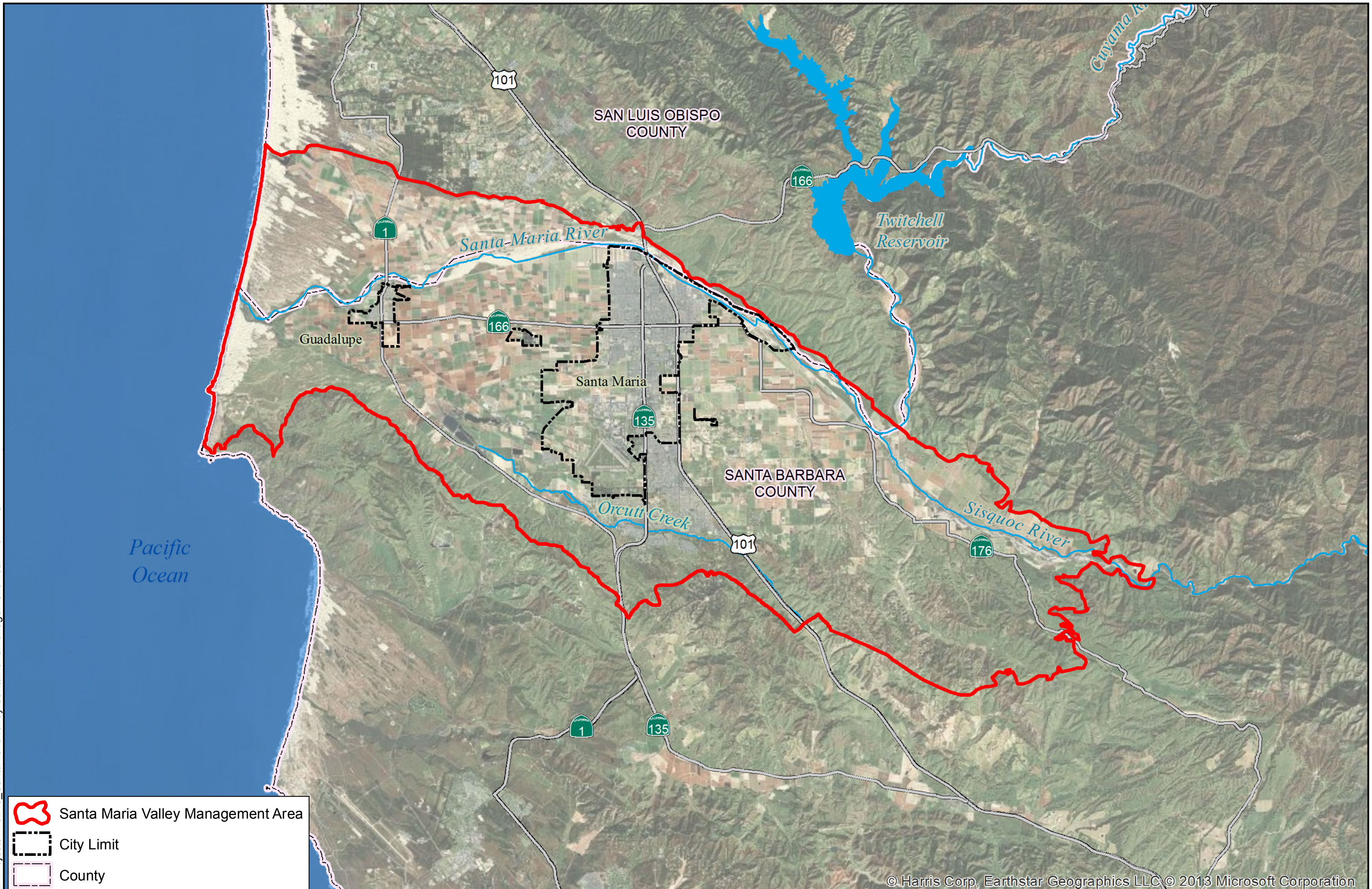
Section 3 of the report includes a description of water resources and use in the valley. In particular, hydrology and hydrogeology of the valley are discussed as they pertain to transport and fate of salt and nutrient. This description of the valley's water resources is based on past studies and reports. The information, including current water management, is structured to support development of a conceptual model of the basin.

Section 4 of the report describes the sources, transport, and fate of TDS, chloride and nitrogen. The working group developed a conceptual model of the basin focusing on sources of salt and nitrogen, and mechanism of transport. Three points in time are discussed (1990, 2000, and 2010) in order to capture changes in management that may be reflected in water quality data. Notable changes in nutrient management practices that may reduce nitrogen loading are discussed along with measures to reduce salt levels in urban water supplies and recycled water. The model was used to organize available data in tables showing estimated inputs and outputs of TDS, Cl, and NO_3 in the years 1990, 2000, and 2010. These tables show the estimated "balance" of these dissolved species within the hydrologic system for each of the three years.

Section 5 of the report evaluates the existing data used to estimate various elements of the conceptual model (groundwater, surface water, wastewater, etc.). Existing monitoring efforts include:

- Measurement of groundwater extraction
- Measurement of the volume of SWP water imported to the valley
- Measurement of discharge from waste water treatment plants and tail water systems
- Measurement of water table fluctuation
- Measurement of surface and subsurface discharge to the ocean
- Measurement of surface water quality
- Measurement of extracted groundwater quality
- Measurement of return flow quality (to groundwater)

Because existing monitoring programs were not developed to document salt and nutrient issues, this report discusses data collection programs in the context of their applicability to the estimates developed in the report. The conclusions and recommendations resulting from the evaluation of monitoring programs are incorporated into the conclusions and recommendation of this report.



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Miles

Salt and Nutrient Planning Workgroup
Santa Barbara County IRWM Plan 2013

Santa Maria Groundwater Management Area

GEI Consultants
Bookman-Edmonston Division

LOCATION OF ASSESSMENT AREA: SANTA MARIA VALLEY GROUNDWATER MANAGEMENT AREA

FEBRUARY 2013

FIGURE 1

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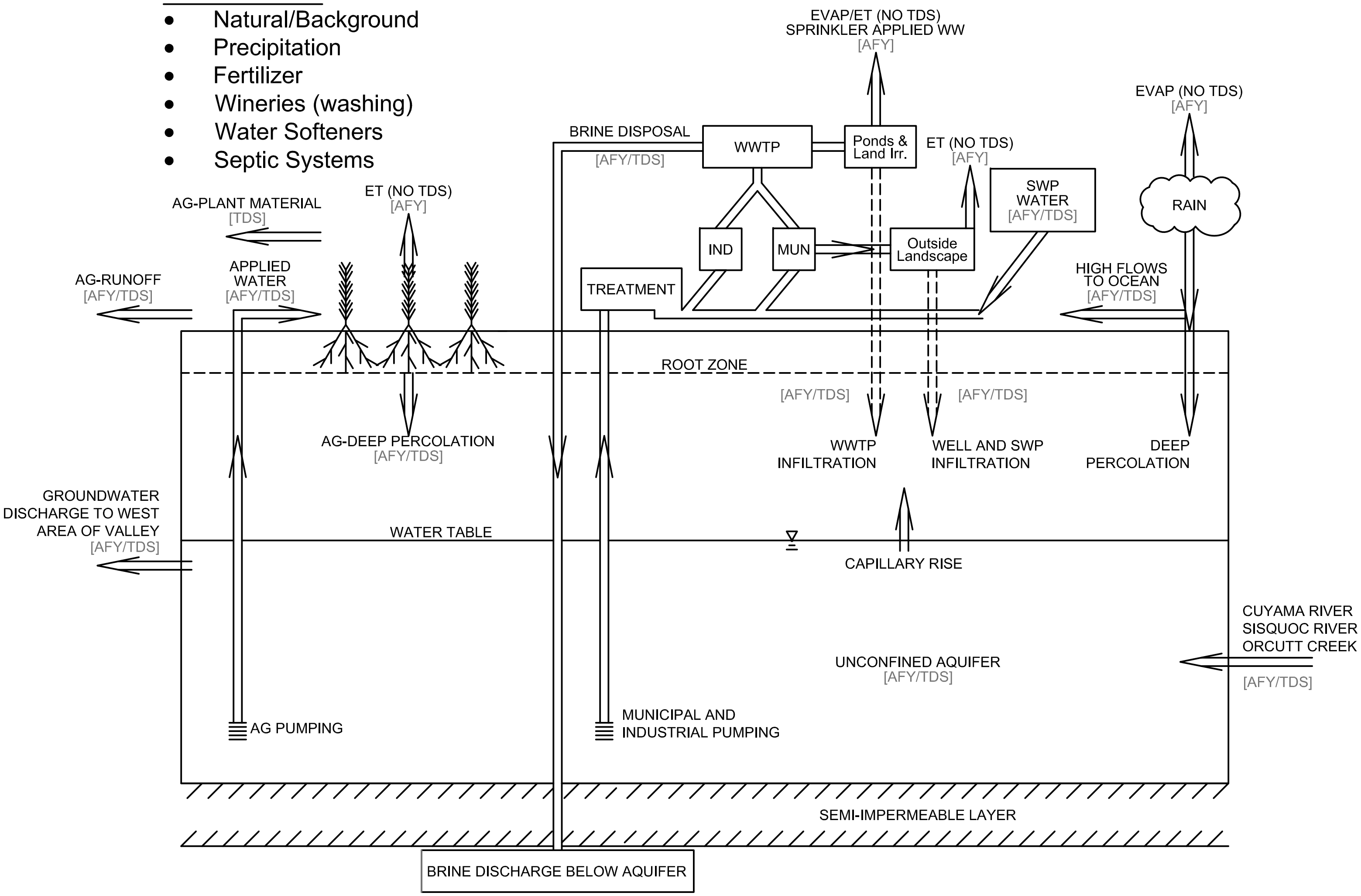
12-Feb-2013

FIGURE 1.2a TDS BALANCE DIAGRAM
EASTERN SANTA MARIA VALLEY
EAST OF BLACK ROAD

Sources of Salt
- Natural/Background
- Precipitation
- Fertilizer
- Wineries (washing)
- Water Softeners
- Septic Systems

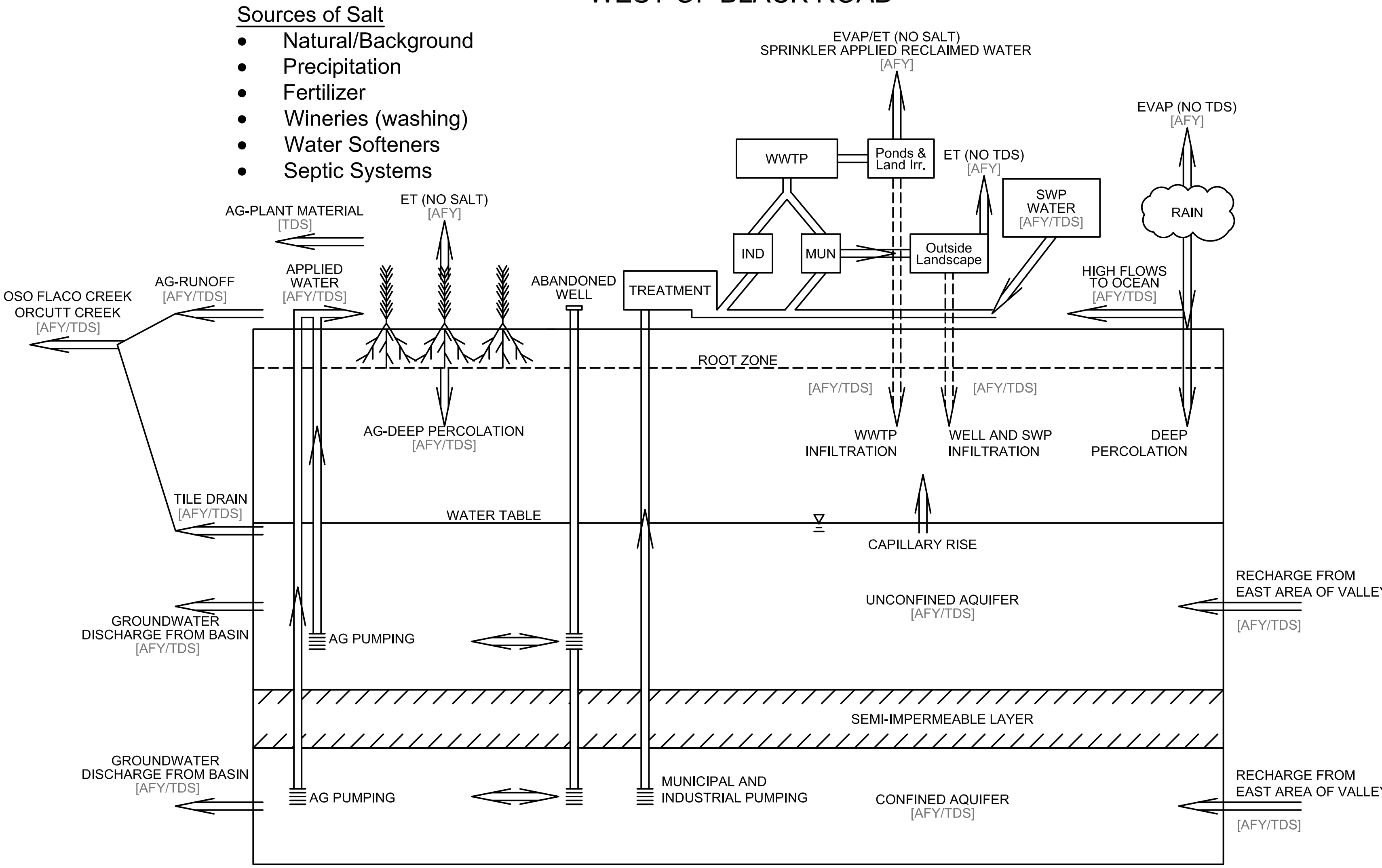


For TDS Balance: TDS In = TDS Out + ΔTDS
Calculated using: Volume x Concentration = Mass

Loading of components in diagram: [AFY/TDS]
- AFY - Volume of water in/out of the system
- TDS - Total Weight of Total Dissolved Solids
- Units are [Acre-feet per year/Pounds]

Salt and Nutrient Planning Workgroup Santa Barbara County IRWM Plan 2013	GEI Consultants Bookman-Edmonston Division	TDS Balance Diagram, Eastern Santa Maria Valley
Santa Maria Groundwater Management Area		February 2013 — Figure 1.2a

FIGURE 1.2b TDS BALANCE DIAGRAM
WESTERN SANTA MARIA VALLEY
WEST OF BLACK ROAD

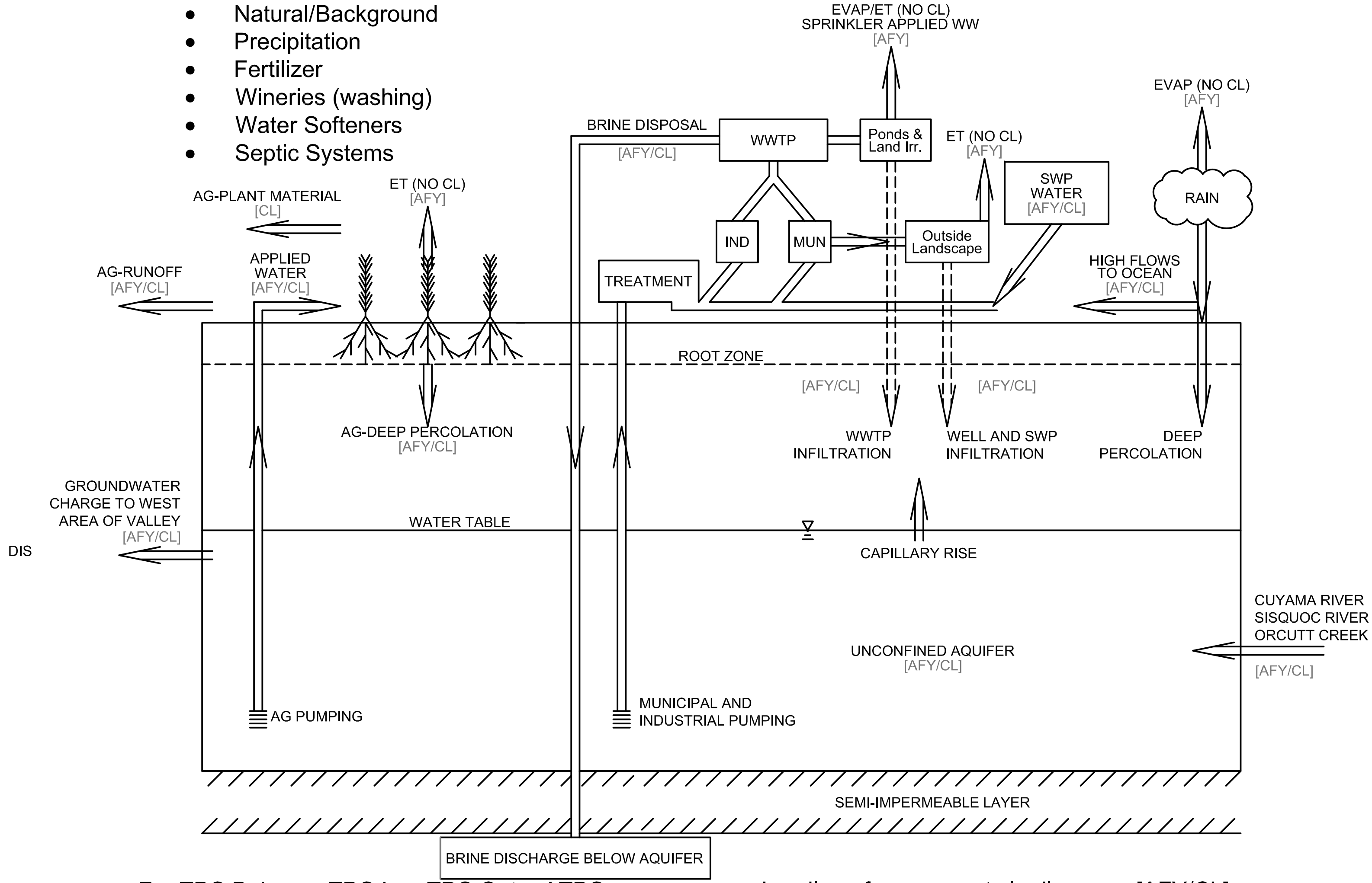


For TDS Balance: TDS In = TDS Out + ΔTDS
Calculated using: Volume x Concentration = Mass

Loading of components in diagram: [AFY/TDS]
- AFY - Volume of water in/out of the system
- TDS - Total Weight of Total Dissolved Solids
- Units are [Acre-feet per year/Pounds]

FIGURE 1.2c CHLORIDE BALANCE DIAGRAM
EASTERN SANTA MARIA VALLEY
EAST OF BLACK ROAD

Sources of Salt
- Natural/Background
- Precipitation
- Fertilizer
- Wineries (washing)
- Water Softeners
- Septic Systems



For TDS Balance: TDS In = TDS Out + ΔTDS
Calculated using: Volume x Concentration = Mass

Loading of components in diagram: [AFY/CL]
- AFY - Volume of water in/out of the system
- CL - Total Weight of Chloride
- Units are [Acre-feet per year/Pounds]

Salt and Nutrient Planning Workgroup
Santa Barbara County IRWM Plan 2013

Santa Maria Groundwater Management Area

GEI Consultants
Bookman-Edmonston Division

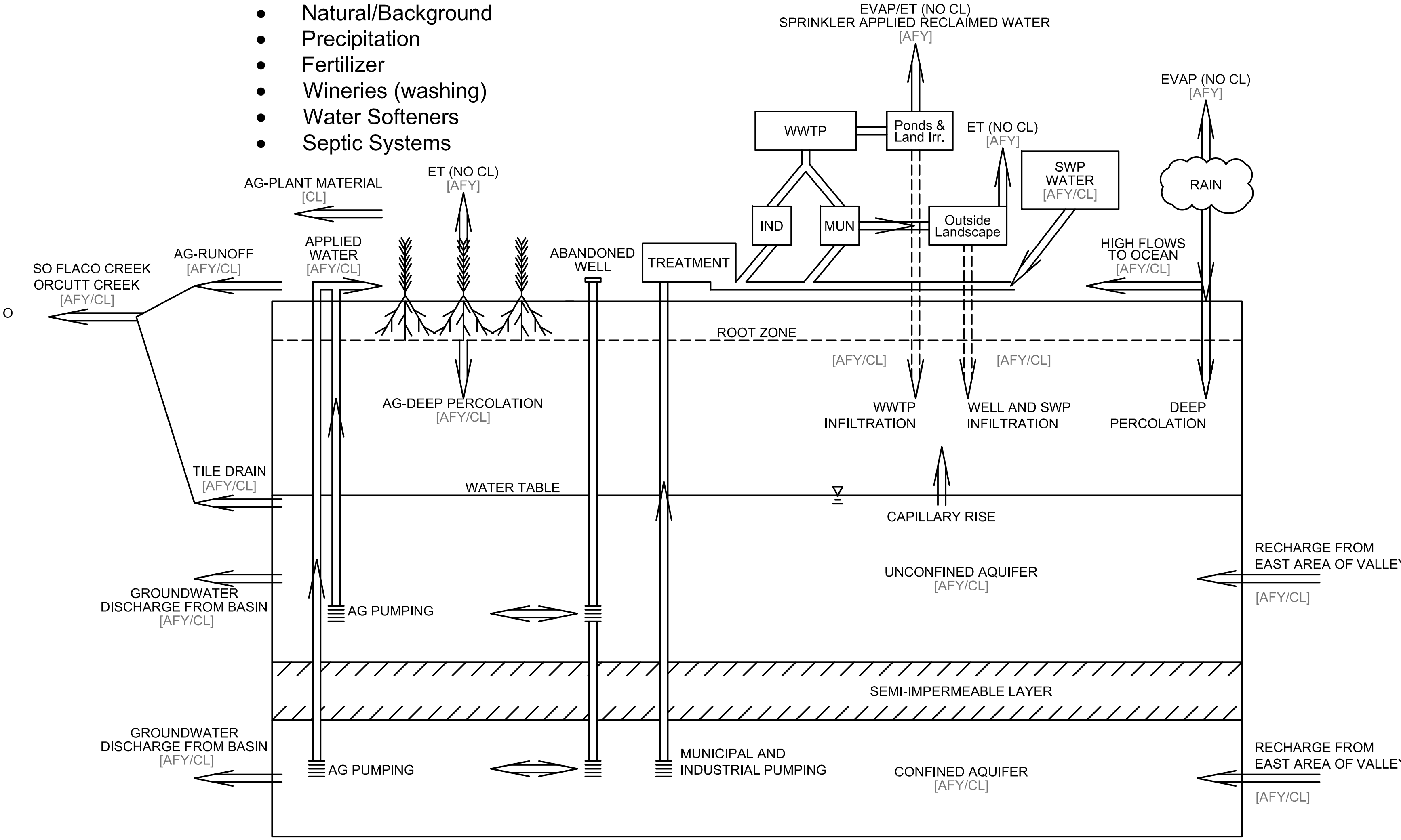
Chloride (Cl-) Balance Diagram, Eastern Santa Maria Valley

February 2013

Figure 1.2c

FIGURE 1.2d CHLORIDE BALANCE DIAGRAM
WESTERN SANTA MARIA VALLEY
WEST OF BLACK ROAD

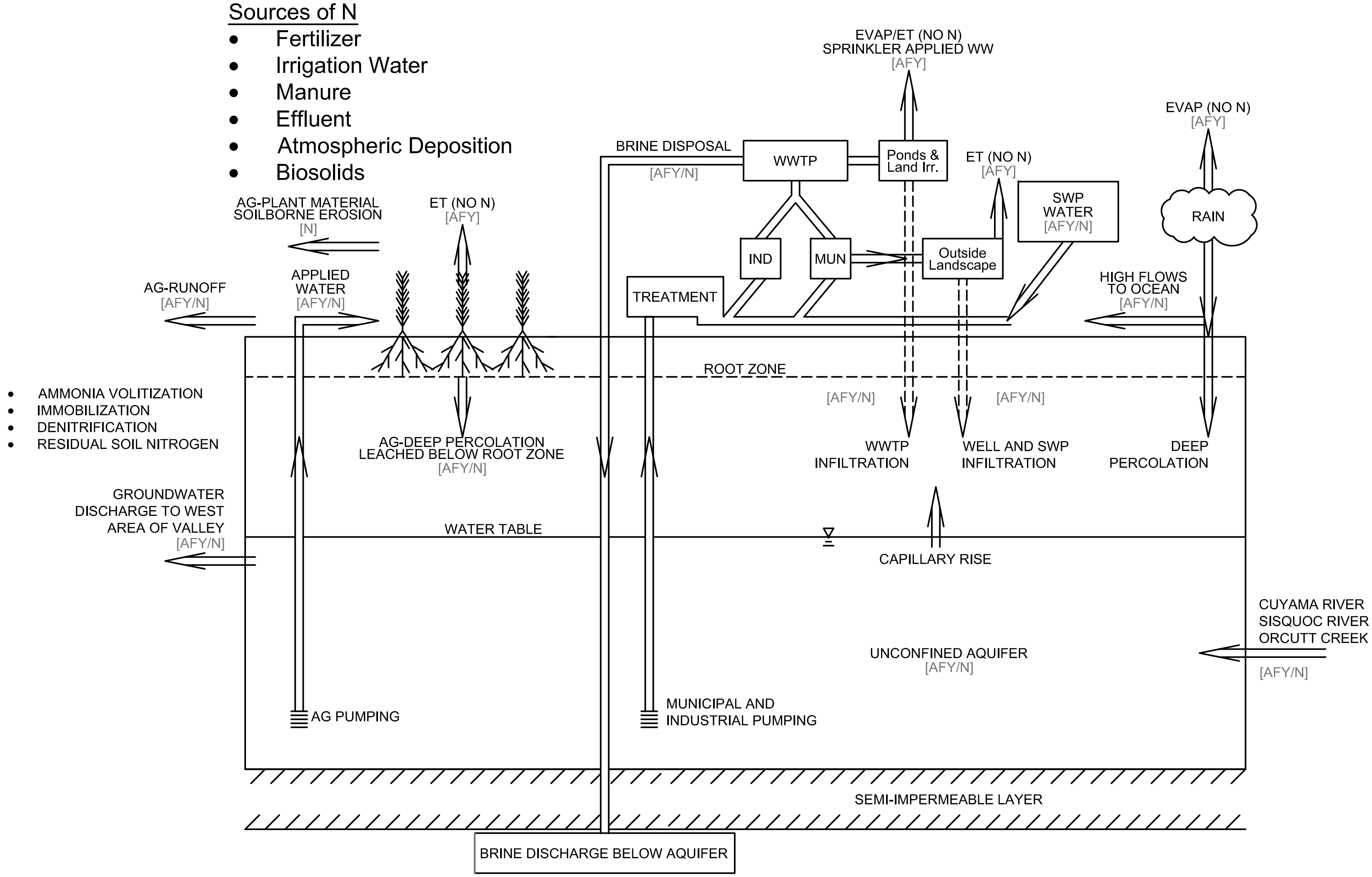
Sources of Salt
- Natural/Background
- Precipitation
- Fertilizer
- Wineries (washing)
- Water Softeners
- Septic Systems



For TDS Balance: TDS In = TDS Out + ΔTDS
Calculated using: Volume x Concentration = Mass

Loading of components in diagram: [AFY/CL]
- AFY - Volume of water in/out of the system
- CL - Total Weight of Chloride
- Units are [Acre-feet per year/Pounds]

FIGURE 1.2e NITRATE/NO3 BALANCE DIAGRAM
EASTERN SANTA MARIA VALLEY
EAST OF BLACK ROAD



For Nitrogen Balance: N In = N Out + ΔN
Calculated using: Volume x Concentration = Mass

Loading of components in diagram: [AFY/N]
- AFY - Volume of water in/out of the system
- N - Total Weight of Nitrogen [NO3-N]
- Units are [Acre-feet per year, Pounds]
- 10 ppm NO3-N ≈ 44.27 mg/L NO3

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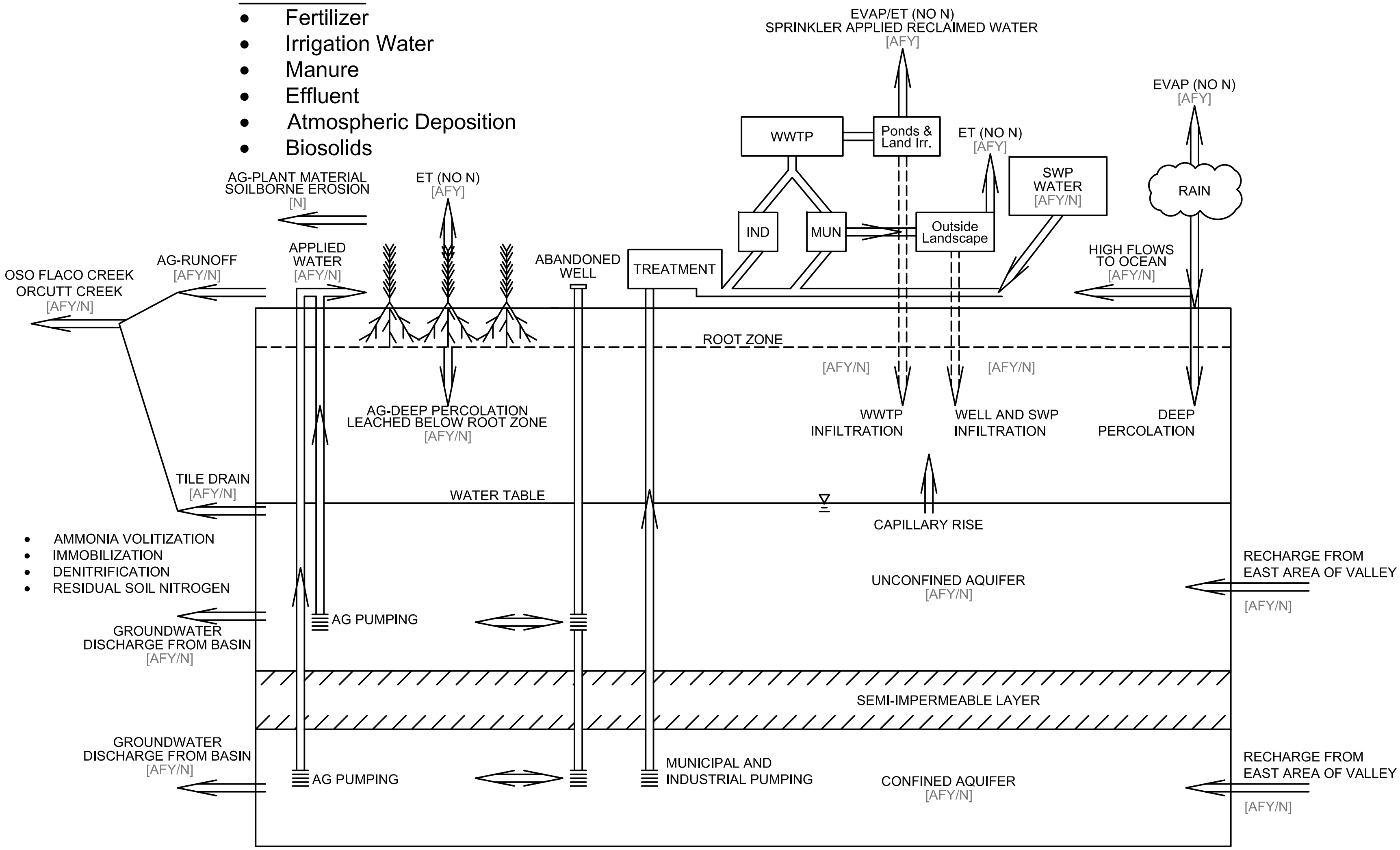
Nitrate (NO_3) Balance Diagram, Eastern Santa Maria Valley

February 2013

Figure 1.2e

FIGURE 1.2f NITRATE/NO3 BALANCE DIAGRAM
WESTERN SANTA MARIA VALLEY
WEST OF BLACK ROAD

Sources of N
- Fertilizer
- Irrigation Water
- Manure
- Effluent
- Atmospheric Deposition
- Biosolids



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Nitrate (NO_3) Balance Diagram, Western Santa Maria Valley

February 2013

Figure 1.2f

2 Existing Monitoring and Uses of Data

Several types of data were utilized for this assessment. When available, firsthand water use information was obtained from city, county, and private agencies; such as the City of Santa Maria, the City of Guadalupe, the Central Coast Water Authority, and Golden State Water Company. The data provided from these agencies often included water quality information including:

- Time series data on water levels, water quality, water use and water discharge.
- Spatial data including crop types and variation in aquifer characteristics, and
- Guidelines for water and fertilizer use and management.

In other cases, data was developed from University of California, Division of Agricultural and Natural Resources and the Natural Resources Conservation Service information relating to general practices in effect during the time period evaluated.

Information was available from a number of sources listed in the bibliography including agency websites, published reports and agency files. Although data acquisition and analysis focused on the years 1990, 2000, and 2010, all data made available was reviewed for relevance and applicability.

2.1 Existing Monitoring Programs and the Current Use of Data

Extensive monitoring of water resources in the Santa Maria Valley has occurred for decades. Measurements of stream flow, groundwater levels and surface- and groundwater quality have been made in support of water resources management. The location and nature of measurements has changed as the perceived need for data collection has changed. This section describes existing water resources monitoring.

2.1.1 Geological Survey Monitoring

Groundwater levels are measured in the spring and a subset of these wells is measured in the fall. Water levels and water quality are measured at multiple completion wells at two locations along the coast to monitor for sea water intrusion. Annual water quality measurements are made in shallow and deep wells indicated in Figures 2.1a and 2.1b. In cooperation with local agencies the United States Geological Survey (USGS) measures stream flow, groundwater elevation and water quality in locations throughout the valley indicated in Figure 2.1c. Continuous stream flow monitoring occurs at two stations, on the Sisquoc River near Garey and the other on the Santa Maria River at the Bonita School Road crossing between the Cities of Santa Maria and Guadalupe. In addition, releases from Twitchell Reservoir are monitored by the U.S. Army Corps of Engineers.

2.1.2 CCRWQCB Monitoring

In 1998 the CCRWQCB established its Central Coast Ambient Monitoring Program (CCAMP) which includes 37 surface water sites in the Santa Maria Valley. Sites in the valley include natural stream flow and agricultural tail water discharges. The CCAMP monitoring is done in sites throughout the Central Coast region on a 5-year cycle. Data are used to identify long-term trends in surface water quality, particularly water bodies that may be affected by point or non-point discharges. The monitoring strategy calls for dividing the Central Coast into five watershed rotation areas and conducting sampling each year in one of the areas. Monitoring sites are placed at the lower ends of tributaries and along the main stem of major rivers. In the Santa Maria Valley the monitoring sites are located on the Santa Maria, Sisquoc and Cuyama Rivers as well as Orcutt Creek, Oso Flaco Creek and the Bradley Ditch. The Santa Maria Valley area was last sampled in 2011.

2.1.3 City of Santa Maria

The City of Santa Maria measures water quality and volume of pumped groundwater from each of their production wells. The purpose of these measurements is to comply with water quality regulations and efficiently manage its resources. Due to elevated levels of nitrate in some of the production wells, the City utilizes a blending program whereby lower-quality water is blended with higher-quality water from other wells, or with treated SWP surface water, to meet potable water quality requirements.

2.1.4 Golden State Water Company

Golden State Water Company, which supplies the unincorporated community of Orcutt and other smaller nearby communities with potable water, also measures water quality and the volume of pumped groundwater from each of their production wells. The water quality of most of GSWCs production wells is generally good. As such, a formal blending program has not been implemented.

2.1.5 City of Guadalupe

The City of Guadalupe has two available groundwater production wells and SWP water with which to meet its urban water demand. Water quality measurements are taken regularly to ensure the pumped groundwater that is blended with treated SWP water meets all state water quality regulations. In 2011 and 2012 the City of Guadalupe blended SWP surface water with one of their groundwater production wells to meet their urban water demands.

2.1.6 Central Coast Water Authority

The Central Coast Water Authority performs water quality tests on SWP water delivered to each SWP contractor. Water quality tests and volume measurements are performed at the point of delivery to each contractor. The water volume data is collected for the obvious reason of ensuring that SWP contractors receive their water allotments.

2.1.7 County of Santa Barbara Public Works Department

The County of Santa Barbara Public Works Department, Water Resources Division operates a number of rainfall gauges throughout the Santa Maria Valley, including two Primary Rainfall Stations; the Santa Maria City and Sisquoc Fire Station gauges. These gauges collect daily, monthly, and yearly rainfall data, as well as rainfall intensity data. These data sets are used to develop historical rainfall graphs, trend graphs, rainfall contour maps, and frequency-duration curves.

2.1.8 Waste Water Treatment Plants

Each of the wastewater treatment plants (Santa Maria WWTP, Guadalupe WWTP, and Laguna County Sanitation District WWTP) monitors the flow volume and water quality of their treated effluent. The city of Santa Maria WWTP discharges at its effluent to infiltration/evaporation ponds. Laguna County Sanitation District and the City of Guadalupe use their effluent for landscape irrigation purposes. Laguna County Sanitation District also provides further treatment (reverse osmosis) to a portion of its waste stream which creates concentrated brine that is discharged to a (brine) well, the discharge of which is located far below the Santa Maria Valley Groundwater Basin (specifically, below the underground source of drinking and irrigation water).

2.1.9 Central Coast Water Quality Preservation, Inc.

Preservation, Inc. is a grower-directed non-profit that manages the Cooperative Monitoring Program (CMP) to fulfill water quality monitoring required in the Ag Waiver. Preservation Inc. is not a regulatory agency and does not enforce regulations. The CMP consists of monthly monitoring of conventional parameters (i.e. nutrients and general chemical/physical parameters) at roughly 50 sites in agricultural watersheds throughout the Central Coast, including 10 sites in the Santa Maria and Oso Flaco watersheds as shown in Figure 2.1d. All sites exhibited water quality impairment (i.e. 303d-listed) prior to selection for the program. Sites are also monitored for aquatic toxicity to invertebrates, fish, and algae in water (four times per year) and to invertebrates in sediment (once per year). Testing for pesticides, herbicides, and other potential toxicants is performed occasionally during special projects.

2.2 Sources, Nature and Applicability of Data to this Assessment

USGS – The USGS collects groundwater samples from various wells in the Santa Maria Valley. As groundwater hydrology is an interpretive science, known points of data are used to interpolate and extrapolate information regarding a given groundwater basin. In general, water level measurements are the principal source of information about the hydrologic stresses acting on an aquifer, and how these stresses affect groundwater recharge, storage, and discharge. Additionally, water quality measurements are used to determine the relative health of the aquifer, and to identify degradation or contamination of the aquifer. The goal of the water level and water quality monitoring is to obtain the groundwater data needed for operating, administering, managing, researching, and planning water resources programs.

The water quality information from the USGS is invaluable to the salt and nutrient analysis. The data provides a snapshot of the composition of water in the basin. When combined with flow and quality data from other sources (surface water, M&I pumping, WWTPs, etc.) a clearer picture of the interaction between the various water sources begins to develop. USGS data is used in developing the SMVMA Annual Reports.

CCAMP – As indicated in the previous section, CCAMP collects stream flow and water quality measurements on tributaries, main-stems, and water-bodies of special concern. Salt and nutrient loading on surface water within the Santa Maria Valley are seasonally dependent, and highly variable. The yearlong monitoring provided by CCAMP captures this variability and allows for a one-year "snapshot" of salt and nutrient levels in surface waters and discharge from certain areas of the groundwater basin.

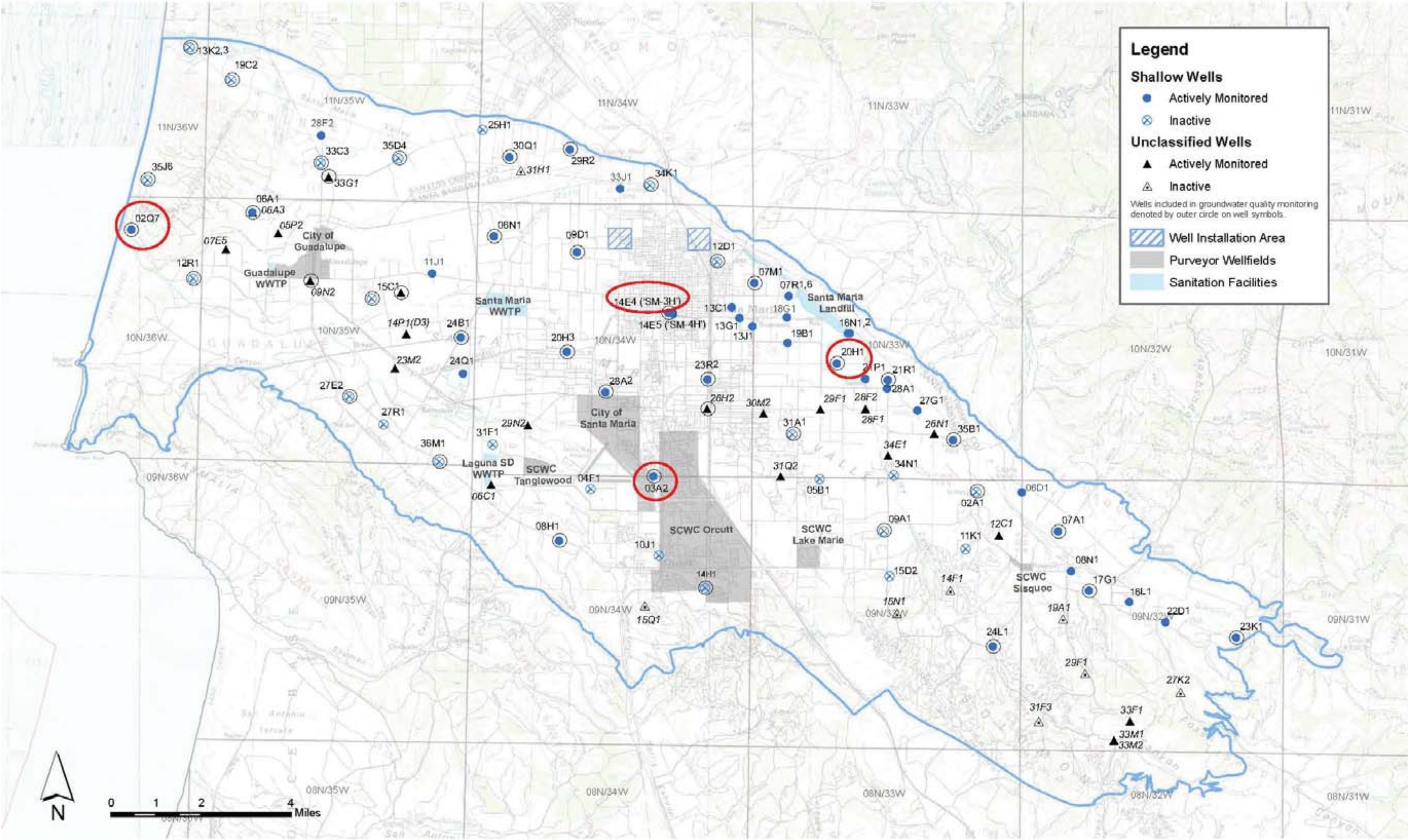
SMVMA Reports – The Santa Maria Valley Management Area Reports compile the volume and water quality data for each purveyor into a single source (for example see Luhdorff and Scalmanini 2012). When water data from the various sources was not provided, the SMVMA Reports were used to supplement water use, water quality and discharge estimates.

Water Purveyors – The water volume and quality data collected by each water purveyor was utilized to develop the water, salt, and nutrient balance estimates in this report.

WWTP Operators – In similar fashion to the water purveyors, the volume and quality data collected by the WWTP operators was used to develop the water, salt, and nutrient balance estimates used in this report.

County Agricultural Commissioner– Crop land use information, and crop water use was provided to estimate the agricultural applied water demand.

Central Coast Water Quality Preservation, Inc. – Surface water sampling has been conducted on behalf of the growers since 2004. The volume and quality data was used to develop the water, salt, and nutrient balance estimates used in this report.



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Santa Maria Groundwater Management Area

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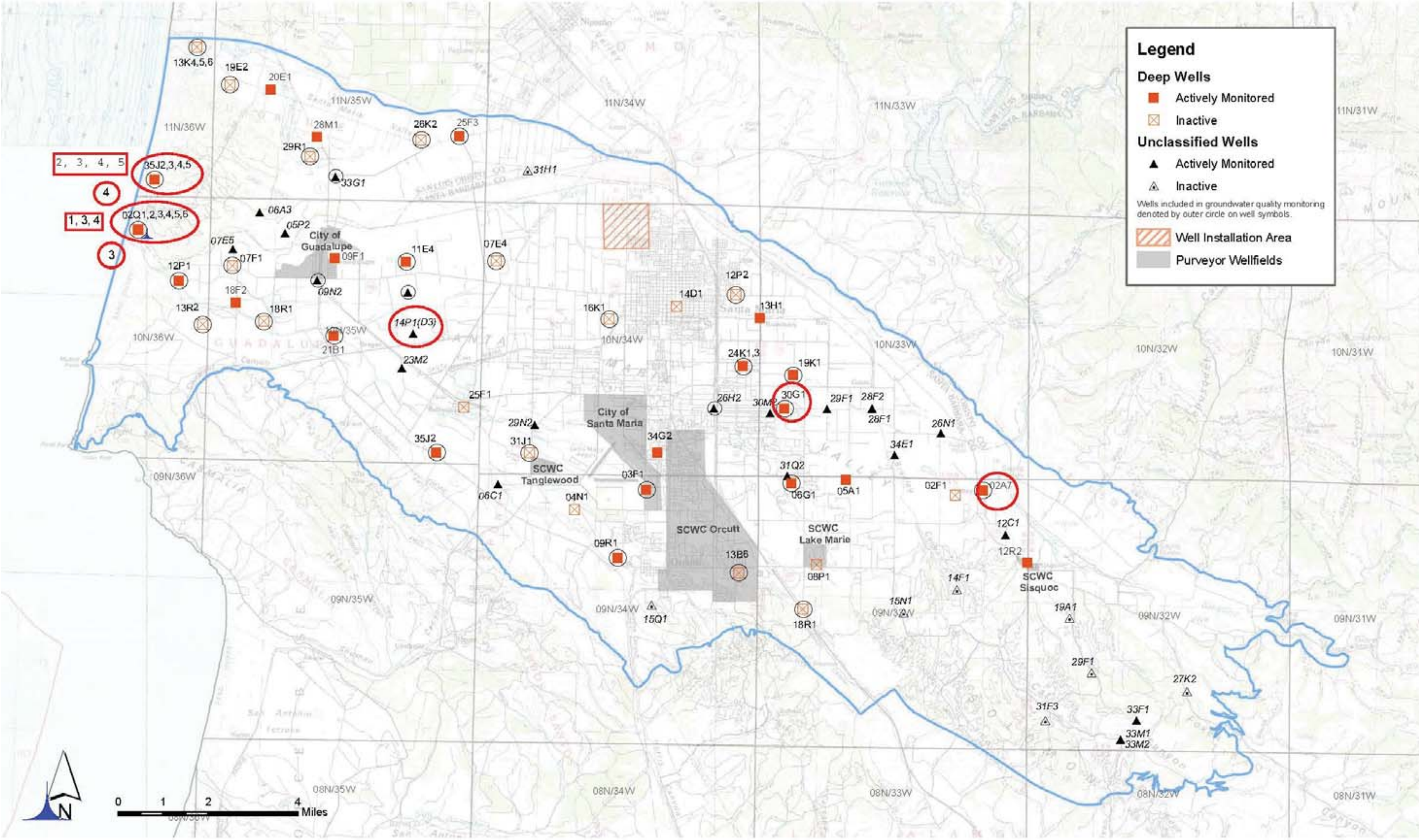
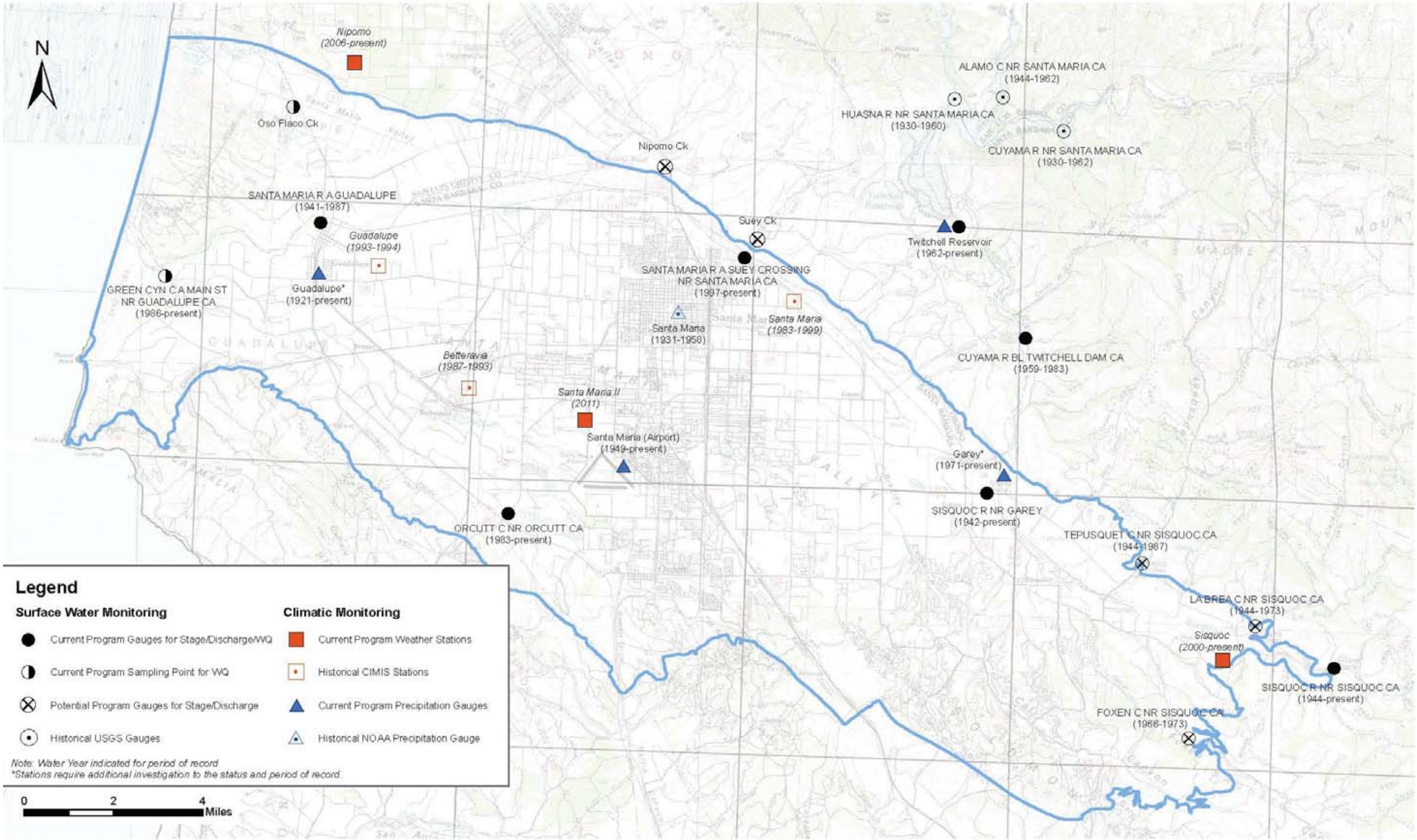
Well Network for Monitoring Shallow Groundwater

February 2013

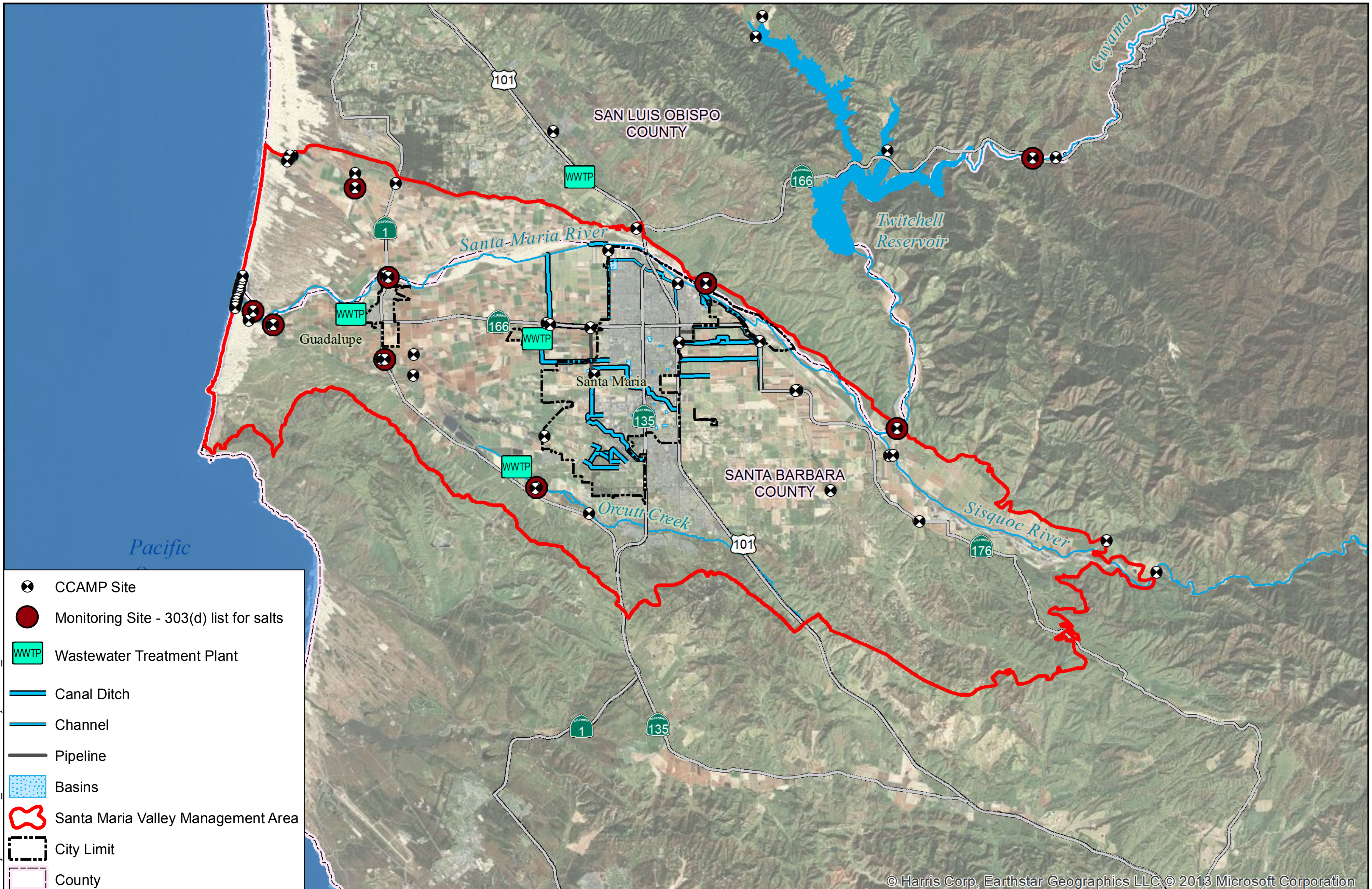
Figure 2.1a



Salt and Nutrient Planning Workgroup Santa Barbara County IRWM Plan 2013	GEI Consultants Bookman-Edmonston Division	Well Network for Monitoring Deep Groundwater	
Santa Maria Groundwater Management Area		February 2013	Figure 2.1b



Salt and Nutrient Planning Workgroup Santa Barbara County IRWM Plan 2013	GEI Consultants Bookman-Edmonston Division	Surface Water and Climatic Monitoring Network
Santa Maria Groundwater Management Area		February 2013 — Figure 2.1c



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CENTRAL COAST AMBIENT MONITORING PROGRAM SAMPLING SITES

FEBRUARY 2013

FIGURE 2.1D

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3 Description of Basin

This section discusses the hydrology, hydrogeology and development of water resources of the Santa Maria Valley as it pertains to transport and fate of TDS, Cl^- and NO_3. The importance of water to the valley's economy has resulted in numerous studies of water resources and ongoing monitoring of water supplies and water quality. The discussion below is a summary; more detailed discussions are provided in the references listed in the Section References, particularly USGS Professional Paper 1000 (Worts, 1951), annual reports prepared by the Twitchell Project Authority (Luhdorff and Scalmanini, 2008, 2009, 2010, 2011 and 2012) and the County's Triennial Groundwater report (Gibbs 2012).

3.1 Past Studies and Sources of Information

This report relies on a wide range of sources of information including but not limited to the major sources mentioned below. Studies developed to describe and evaluate water resources are listed in the references section of this report. Key evaluations of water resources by Lippincott and the United States Bureau of Reclamation described surface hydrology of the Santa Maria River and its tributaries and led to development of the Santa Maria Project (Twitchell Reservoir) to provide flood protection and enhanced groundwater recharge.

Detailed studies by the US Geological Survey have described surface and groundwater resources including elements of recharge and discharge as well as water quality. The US Geological Survey established ground and surface water monitoring which has continued as a cooperative program with the County Water Resources Division and the Santa Maria Valley Water Conservation District. In addition, the Twitchell Management Authority prepares an annual report pursuant to the recent adjudication (Luhdorff and Scalmanini, 2012) and the RWQCB periodically samples water quality at a number of surface water locations (CCAMP). Finally, water purveyors make regular tests of supplies and waste water treatment plant operators make measurements of discharges.

3.2 Geography and Surface Hydrology

Santa Maria Valley is a broad alluvial plain generally considered to include the lower portion of the Sisquoc River and the Santa Maria River. Low hills drained by smaller streams occur along the southern margin. The Valley is bounded by the Solomon hills in the South, the Nipomo Mesa to the north, the Sierra Madre Mountains to the northeast and east and the Pacific Ocean to the west. This assessment focuses on the lower portion of the basin which encompasses approximately 260 square miles including areas of both agriculture and urban and suburban development.

Figure 1 contains rivers, urban areas, and surface water features (including Twitchell Reservoir). Location and depth of monitoring wells, rainfall and stream flow gages, and location of CIMIS stations are found in Section 2 of this report and available from the Annual Report of Hydrological Conditions, Water Requirement, Supplies, and Disposition (Luhdorff and Scalmanini, 2012).

The Santa Maria Valley is traversed by the Santa Maria River along its northern margin and lower reaches of its tributaries, the Sisquoc and Cuyama Rivers, to the east. Although the Santa Maria River and its tributaries are ephemeral, surface flow is responsible for a majority of groundwater recharge. But due to extreme variation in flow, surface water is not used directly (diverted) as a water supply. However, significant recharge does occur during and after storm events thus recharge from the larger tributaries affects groundwater quality.

Twitchell Reservoir was designed to capture intermittent storm runoff in order to provide increased groundwater recharge and flood protection. The reservoir has demonstrated effective management over the lower Cuyama River, but inflow is highly variable. For example inflow reached a peak of 190,000 Acre-feet in 1983 but the reservoir has received little or no inflow for up to three years at a time. Since 1965 (when the reservoir was placed in operation) reservoir storage has exceeded 100,000 AF only 8 times.

Other significant surface water recharge occurs as a result of infiltration of treated waste-water and from surface streams such as the Orcutt/Solomon Creek system and Bradley Ditch. Generally speaking, surface recharge that occurs east of Black Road percolates to the deeper elements of the aquifer system. Treated sewage effluent from the City of Santa Maria is recharged to the groundwater system from percolation ponds in the vicinity of Black road. The majority of this recharge is believed to percolate to the deeper elements of the Aquifer and recharge the lower (confined/semi-confined) zone underlying the western most portion of the valley. Tertiary treated sewage effluent from the Laguna County Sanitation District (serving Orcutt and unincorporated Santa Maria) is used for irrigation. The City of Guadalupe discharges treated water through sprinkler irrigation on an area of grasses to the north and east of the City. Any recharge to the groundwater from the City of Guadalupe discharge is mostly confined to the uppermost aquifer zone in an area west of most groundwater development.

Two surface discharge points that discharge out of the SMMA towards the ocean exist; 1) Orcutt Creek that discharges to SM River prior to the ocean outlet and 2) Oso Flaco Creek [detailed descriptions are found in the CMP 2008 summary report Follow-up Monitoring Report, WQ Results from Upstream Monitoring, 2008]

3.3 Geology, Geologic History and Hydrogeology

The materials underlying the Santa Maria Valley comprise extensive deposits of water bearing alluvium and semi-consolidated sedimentary materials of Plio-Pleistocene to Recent age. These materials have accumulated in a broad asymmetrical syncline or trough formed by downward warping of underlying bedrock. The water-bearing materials are as much as 1,200 feet thick beneath the central portion of the valley and extend beneath the ocean to the west. The older (and deeper) water-bearing materials include the Careaga Sand and overlying Paso Robles Formation. Quaternary age alluvium overlies the Paso Robles Formation. Dune sand and bedrock occur along the margins of the basin but are not widely developed as sources of water. (The occurrence of these materials is described in several reports including Worts, 1951, Gibbs, 2012 and Luhdorff and Scalmanini, 2012).

In general the alluvial materials and the Paso Robles Formation become progressively less coarse grained from east to west (Luhdorff and Scalmanini, 2012). In the westernmost portion of the Valley, the alluvium appears crudely stratified with a confining or semi-confining horizon dividing the aquifer into at least two zones west of the Bonita School Road. Both the upper and lower zones of the aquifer are described as extending to the west beneath the ocean for as much as several miles (Worts, 1951).

The aquifer is unconfined in most of the basin (east of Black Road) and stream flow, rainfall, and return flows all contribute significant recharge. The westernmost portion of the aquifer includes two zones separated by an impermeable (confining) zone. Agricultural return flows and rainfall are the main sources of recharge to the upper (unconfined) zone. The lower zone is confined and receives most of its recharge from where it is unconfined east of Black Road and may receive some recharge from interzonal flow in wells that are completed in both zones. Local water level elevations suggest that both aquifer zones discharge to the Pacific Ocean to the west. No evidence of sea water intrusion has been found in monitoring wells located along the westernmost edge of the basin.

3.4 Development of Water Resources

The majority of water available to the Santa Maria Valley has historically derived from stream flow in the Santa Maria River originating from the Cuyama and Sisquoc rivers. This stream flow is not developed directly as a supply, but rather is the main source of groundwater recharge in the area. Releases from Twitchell Reservoir are used exclusively to augment natural recharge to the groundwater basin. Thus, quality in aquifers underlying much of the Santa Maria Valley has historically reflected the water quality of stream flow in the Cuyama and Sisquoc rivers.

Urban supplies are developed from both groundwater and imported (surface) sources. Typical deliveries of water to urban users are about 23,000 AFY, with a peak historical demand of 25,600 AF in 2007. Agricultural users are supported entirely by wells and water use ranges from 80,000 to 130,000 AFY on roughly 50,000 acres of irrigated crops. In the Santa Maria Valley habitat is supported by surface flows and in some areas shallow groundwater. Water supported habitat includes willows and wetlands along the lower Santa Maria River and Green Canyon and the lagoon at the mouth of the Santa Maria River. No estimates of water needed to support these habitats are available.

Groundwater storage within the basin varies as a function of annual rainfall, and to a lesser extent, importation of State Water Project supplies. Groundwater storage has been estimated to be about 2.5 million AF (MAF) in 1984 and 1.97 MAF in 1991 (Ahlroth, 2002). Substantial fluctuations in water levels are caused by variations in annual rainfall and are documented by the County Water Agency in regular reports (Gibbs 2012).

Until 1996 groundwater was the source of supply for all users in the Valley; in that year urban water users began importing water from the State Water Project. Currently the Santa Maria Valley relies on groundwater to meet all agricultural and some urban needs and with imported water being used extensively in the City of Santa Maria and to some extent in the City of Guadalupe and the community of Orcutt.

Water is imported to the Santa Maria Valley through the Coastal Branch of the State Water Project for municipal use. Municipal supplies are delivered directly to the cities of Santa Maria and Guadalupe and the Tanglewood community serviced by the Golden State Water Company (GSWC, formerly Southern California Water Company). The GSWC serves both groundwater and SWP supplies to the community of Orcutt and its immediate area. GSWC makes its SWP deliveries to the community of Orcutt through interconnections with the City of Santa Maria. (The GSWC provides solely groundwater to the small towns of Sisquoc and Garey.)

3.4.1 Groundwater and Wells

Groundwater development began in the early 1900's and rapidly became the principle source of water for all uses. For decades until the importation of State Water supplies, groundwater was the sole source of supply. Roughly 80 percent or more of the water used in any given year is developed from wells. Wells are generally completed in alluvium or the Paso Robles formation with some being completed in the deeper Careaga Sand.

3.4.2 Twitchell Reservoir

Twitchell Reservoir was constructed as a dual purpose reservoir, built by USBR under contract with SBCWA to provide both flood protection and groundwater recharge. The dam was completed on and put into service in 1966. The reservoir provides no direct deliveries for supply; its releases are controlled to provide infiltration to alluvium in the Santa Maria River.

As discussed by Luhdorff and Scalmanini, inflow and storage in the reservoir vary greatly; this variation results in significant variation in recharge to the groundwater basin (see Figure 2.3-1a and Table 2.3-1 of Luhdorff and Scalmanini, 2011). The average annual recharge is estimated to be 32,000 AFY. The principle area of recharge is dictated by geologic conditions and is in the Santa Maria River from the confluence of the Cuyama and Sisquoc Rivers to Bonita School Road crossing.

Analysis by Luhdorff and Scalmanini suggests that operation of the Reservoir has changed the nature of recharge to the groundwater basin from the Cuyama River. Prior to construction of the reservoir, much of the storm runoff from the Cuyama drainage passed to the ocean immediately during and after high flow events. During operation of the reservoir, storm runoff is captured for later recharge to the groundwater basin. Low flow from the Cuyama River tends to have higher TDS than storm runoff. Thus the reservoir captures higher quality water for recharge and increases the percentage and amount of higher quality water recharging the groundwater basin (Luhdorff and Scalmanini, 2012). Water quality trends in groundwater, particularly in the zones affected by Twitchell recharge, supports their interpretation. The Operation of Twitchell Reservoir has been estimated to provide an average of 32,000 AFY (Luhdorff and Scalmanini, 2012) of recharge to the groundwater basin.

3.5 Agricultural Water Supply and Demand

For the purpose of this report, an agriculture water supply and demand estimate for three ten-year periods 1981-1990, 1991-2000, and 2001-2010 was utilized, as shown in Table 3.5. All agricultural water demand in the Santa Maria Valley Management Area (SMVMA) is supplied by local groundwater, with the exception of some wastewater effluent.

3.5.1 Agriculture Water Requirements

The estimated agricultural water requirement for each time period was based on crop acreage and estimated groundwater pumping to meet crop water requirements found in the 2011 Annual Report of Hydrogeologic Conditions, Water Requirements, Supplies and Disposition, Santa Maria Valley Management Area, (Luhdorff and Scalmanini, 2012). The report contains an estimate for applied water required for crops, groundwater pumping by year, back to 1945. However, the total applied water for each crop type (calculated as crop acres multiplied by applied water per acre) is only shown in Annual Reports since 2008, and not shown for the years prior to 2008. Available data from the Annual Reports included annual acres by crop and total annual pumpage (Table 3.5, below); estimates of annual pumping was available and plotted in Figure 3.1-1c of the Annual Report (Luhdorff and Scalmanini, 2012).

The average water requirements (in terms of groundwater pumping requirements) were used to represent applied water required for the three periods; years 1981-1990, 1991-200, and 2001-2010. Dividing the average pumping by the average acres within each crop allowed for a comparison of unit water use by crop category. Observation of the applied crop water duties in comparison to a 5-year average of crop water duties from the Annual Report combined with professional judgment was used to assign pumping by crop type in each of the three time periods used for this study.

Infiltration of rainfall, an important mechanism, is known to vary significantly in correlation with the wet, normal, and dry years. Thus change to climate may affect the sources and transport of salts and nutrients; however, climate change was not a focus of this study.

Table 3.5. Irrigated Crop Acres, Unit Applied Water, and Calculated Applied Water by Crop Category

The Historical Distribution of Irrigated Acres, Table 3.1-1b of the Annual Report, provided information on the land use changes over time for the crop categories: Rotational Vegetables, Strawberries, Vineyard, Pasture, and Other. Rotational Vegetables consists of lettuce, celery, broccoli, and cauliflower crops. During the three time periods the SMVMA has experienced an increase in truck crop type acreage. Over these time periods, rotational vegetables became the largest crop category, strawberry acreage increased significantly in last decade, vineyard acres remained fairly consistent, and pasture (including alfalfa), field, and orchard acreages have declined.

The following description of the agriculture land use is from Luhdorff and Scalmanini, (2011):

> "In 2010, approximately 50,650 acres in the Santa Maria Valley were irrigated cropland, with the predominant majority (87 percent) in truck crops, specifically Rotational Vegetables (33,850 acres) and Strawberries (10,000 acres). Vineyard comprised the next largest category (4,700 acres), with Grain, Pasture, Nursery, and Orchard in descending order of acreage (990, 320, 215, 20 and 34 acres, respectively). Fallow cropland was estimated to be just over 500 acres. Cropland occupies large portions of the Santa Maria Valley floor, Orcutt Upland, Oso Flaco area, and Sisquoc plain and terraces.
>
> Total irrigated acreage of about 50,650 acres in 2010 is near the upper end of the range over the last 15 years, and within the reported historical range between roughly 34,000 acres in 1945 and 53,000 acres in 1995, as shown in Table 3.1-1b (USGS, Worts, G.F., 1951; California DWR, 1959, 1968, 1977, 1985, and 1995; LSCE, 2000 and 2009). The 2010 irrigated acreage is consistent with those of the last decade, during which total acreages gradually increased from 48,200 acres in 1998. The 2010 cropland locations continue the historical trend of agricultural expansion onto portions of the Orcutt Upland and Sisquoc Valley as urban land use expands into former cropland near the central portions of the Santa Maria Valley and Orcutt Upland."

3.5.2 Agriculture Water Demand – Pumped Groundwater

Agriculture is the dominant local industry within the SMVMA and principle water user. All agricultural applied water relies solely on groundwater pumping. The total acres irrigated has remained relatively constant since 1981 with the annual agricultural water demand varying between wet, normal, and dry precipitation years as much as 50,000 AFY, ranging from below 80,000 AFY to over 130,000 AFY (Luhdorff and Scalmanini, 2011).

Agricultural water demand is indirectly calculated using crop water requirements multiplied by the number of acres of each crop type. For this report, the estimate of annual pumped groundwater to meet total agricultural water requirement for all crops was utilized from the SMVMA Annual Report (Luhdorff and Scalmanini, 2011). Applied crop water requirements

(AW) vary by each crop type and vary substantially for a wet, normal, and dry precipitation year. For the purpose of this assessment, the AW for each of the crop type categories in each of the three periods was estimated based on available information. The estimated annual pumping was averaged for the 10-year periods then divided by the average crop acres by crop categories; a comparison of unit water use for each crop category required some professional judgment in assigning the unit water use in order to match the total average pumping with the sum of each crop category pumping. Unit crop water use is based on Crop ET, Effective Precipitation, and Irrigation System Distribution Uniformity factors.

During the period of 1981 to 2010 the total irrigated area of about 50,000 acres have remained fairly constant with some of the crops acres changing from one crop type to another reflecting growers' crop selection as market conditions change over time. Annual groundwater pumping to meet crop water requirements varies substantially by the type of rainfall that happens in a given growing season. The main reason for this is the effect that effective precipitation has on crop water requirements for wet years versus dry years in this coastal climate. Improvements to irrigation methods over time have increased the distribution uniformity and increased the effectiveness of applied water over the basin; irrigation method improvements are a positive improvement regarding the basin water management and noteworthy in conjunction with the effect of precipitation on agricultural water requirements.

The variation in total crop water requirements (ETc) and AW (ETaw) to meet the crops' annual needs are influenced by the coastal climate. The primary factors that influence this variability between years are the total Evapotranspiration (ETc) and the amount of precipitation utilized by each crop type to meet the ETc, known as the Effective Precipitation (Pe). During the time period of 1981 to 2010, the California Irrigation Management Information System (CIMIS) has improved irrigation scheduling and on-farm irrigation efficiency for applied water has improved as irrigation methods have changed over to micro-irrigation systems. An indication of this improvement is shown in the decrease over time of the annual unit applied water, in AF/A for the basin's crops. The improvements to irrigation methods provide a positive effect in both reduced groundwater pumping and help to reduce water movement past the root zone, therefore, helping to contain nutrients in the active root zone where plants can uptake the available nitrate (NO_3). However reduced movement of water through and past the root zone may cause levels of salts in root zone soils to rise.

3.5.3 Agriculture Return Flow

A description of the agriculture return flow component is contained in Chapter 4 of the Luhdorff and Scalmanini, 2011 and included in this assessment. The annual report provides an estimate of return flow for the basin due to irrigation; however, this estimate accounts for effective precipitation, but, does not include the amount of precipitation that moves through the root zone. Therefore, it is possible a more detailed site-specific assessment of the water quality monitoring by drainage areas is necessary to understand the salt and nutrient characteristics by drainage area.

> "For the range of crops and irrigation systems in the SMVMA, most crops are considered to consumptively use about 80 to 85 percent of the water applied to them, resulting in an estimated 15 to 20 percent of applied water exceeding crop consumption and deep percolating as return flow to the underlying aquifer system (the one exception to the preceding ranges is wine grapes, where 95% of applied water is estimated to be consumptively used, resulting in return flow of only 5% of applied water).
>
> For the full range of crop categories in the SMVMA, return flow rates in 2010 are estimated to range from less than 0.1 af/ac for Vineyard, to about 0.4 af/ac for the predominant Rotational Vegetables in the Valley, to a maximum of about 0.7 af/ac for Pasture. The respective estimated agricultural return flow rates are detailed in Appendix E. When combined with their respective individual crop acreages, it is estimated that just under 17,000 af of applied agricultural irrigation deep percolated to groundwater as return flows in the SMVMA in 2010." (Luhdorff & Scalmanini, 2010)

AW in excess of crop water requirement is considered deep percolation once beyond the crop root depth. Deep percolation either returns to the groundwater source or is intercepted by the subsurface tile drains that collect into a surface drain, or it can also be intercepted directly by the surface drain. In either case, the surface drain eventually discharges through an outlet to a surface drainage. Tile drainage discharges in two main locations west of Black Road: Oso Flaco Creek and Orcutt Creek. Some additional tile drainage flows into the lower Santa Maria River.

Since the Agricultural Waiver program changes occurred in 2004, the Central Coast Water Quality Preservation, Inc. has collected surface water samples from the two main drainages that outlet the SMMA. They have also collected samples from the minor drainages that collect to the main drainages. The characteristics of the two minor drainages as measured during a wet period when the drainage flows were fairly consistent year round are included in the following sections as sample observation of a localized intermittent drainages; the sample data is limited and not intended to be used as a representative of all drainage: [The descriptions in Section 3.5.4 and Section 3.5.5 are from the 2008 Upstream Monitoring Report, provided to the Grower Groups and RWQCB through the efforts of Preservation Inc.]

3.5.4 Orcutt-Solomon Creek at Sand Plant (312ORC)

Flows at core CMP site 312ORC were moderate and fairly consistent during 2008, averaging 7.9 CFS. Flows from each of the two contributing channels (Orcutt-Solomon Creek further upstream – 312ORI, and the north fork Solomon Creek – 312ORN) were lower and comparable, with each appearing to contribute about half of the flows aggregated at 312ORC, with 312ORI slightly higher. All sites in the watershed had measurable flows during all 2008 monitoring events.

Nitrate concentrations at 312ORC and in both of the contributing creek channels (312ORN and 312ORI) were consistently high throughout 2008. At 312ORC, concentrations ranged from 19.0 to 72.6 mg/L as N, with a median of 40.3 mg/L. On the basis of median values, 312ORN contributions were somewhat lower and 312ORI somewhat higher, however 312ORN had a maximum nitrate concentration of 380 mg/L.

Nitrate Loads were around 60 lbs. N/hr on a median basis at 312ORC. Contributing loads from 312ORI were typically a bit higher than those from 312ORN, with some exceptions.

3.5.5 Oso Flaco Creek

Flows were present at measurable levels at all Oso Flaco watershed sites during at least ten of the twelve 2008 monitoring events. Flows were highest at the core CMP site (312OFC), with a median value of 2.14 CFS. Flows were lowest at the Bonita School Rd/Division St intersection (312BSR) and where Oso Flaco Creek crosses Highway 1 (312OSR), with median values of 0.19 and 0.33 CFS respectively.

Nitrate concentrations were very high throughout the Oso Flaco watershed, with average values near or above 30 mg/L as N at all sites. Concentrations were lower during the January winter storm event, with values below 10 mg/L at all sites except for the core CMP site (312OFC), which had a concentration of 11.5 mg/L. The highest concentrations on the watershed in 2008 were at the more upstream sites, 312OSR and 312BSR, which had maximum concentrations of 95.6 and 125.0 mg/L, respectively.

Nitrate Loads were highest at the core CMP site (312OFC), following patterns in flow. Median loads at the upstream monitoring sites were roughly three to six times lower, at 2.5 to 5.2 lbs. N/hr.

3.6 Urban Water Supply and Demand

The three main public water system operators serving urban users currently deliver approximately 17 percent of the water used in the Valley. Development of most groundwater for municipal purposes is from numerous water supply wells located in the vicinity of the Santa Maria Airport and the town of Orcutt. The City of Guadalupe and the communities of Sisquoc and Garey are served by wells within each community. Historic demand in urban areas of Guadalupe, Santa Maria and Orcutt is tied to population water use by the urban suppliers (GEI 2012).

Water supply and water quality concerns led to importation of SWP supplies in the 1990s. Prior to the late 1990s, all municipal and agricultural water requirements in the Santa Maria Valley were met by local pumping. Since the beginning of SWP availability in 1997, deliveries of SWP water have replaced some of the local pumping for municipal supply. In particular, the City of Santa Maria and Golden State Water Company have reduced pumping in the vicinity of the Santa Maria Airport. The reduction since 1997 has been estimated to be 50-percent on an average annual basis.

Santa Maria relies on the SWP for its principle supply while relying on groundwater for backup. Currently the City of Guadalupe relies on a blend of groundwater and SWP supplies. The Golden State Water Company supplies up to 20-percent of its deliveries from the SWP due to limitations in its allocation from that source. Due to their remote location, the small communities of Garey and Sisquoc are supplied by wells. The importation of SWP supplies has improved the quality of water delivered to customers in the Cities of Santa Maria and Guadalupe, and the TDS of treated wastewater recharged to the groundwater basin at their waste water treatment facilities. However, SWP importation does result in importation of salts to the basin.

3.7 Urban Return Flow

Urban return flow is primarily effluent from three publicly owned and operated wastewater treatment plants. A much smaller amount percolates from excess irrigation applied to urban landscaping. The three publically owned WWTPs serve the City of Santa Maria, the City of Guadalupe and the community of Orcutt and unincorporated Santa Maria area. Effluent concentrations of TDS, NO_3 and Cl- as well as contributions to groundwater are shown in Appendix E. The nature and discharge of return for each WWTP is summarized below.

3.7.1 City of Santa Maria WWTP

The City of Santa Maria operates a WWTP located on Black Road west of the City. The City's treated wastewater is percolated to the groundwater pursuant to a Waste Discharge Requirement issued by the CCRWQCB. The volume and quality of the effluent stream are monitored pursuant to that permit and form the basis for estimates used in Appendix E. The importation and use of SWP water and concurrent reduction in regenerative water softener use have lowered the TDS level of the water entering the aquifer from the percolation ponds.

A lesser volume of water, not related to the WWTP, is returned to the groundwater from infiltration of flow from Blosser Channel, Bradley Channel, and Main St. Ditch. During periods of high runoff, these surface drainages flow to the Santa Maria River but during periods of lower flow, most flow seeps into the ground.

3.7.2 City of Guadalupe WWTP

The City of Guadalupe operates a WWTP located at the northwest edge of its incorporation boundary. The City's treated wastewater is spray irrigated to pasture land pursuant to a Waste Discharge Requirement issued by the CCRWQCB. The volume and quality of the effluent stream are monitored pursuant to that permit and form the basis for estimates used in Appendix E. The importation and use of SWP water has lowered the TDS level of the water discharged.

3.7.3 Laguna County Sanitation District (Orcutt) WWTP

The Laguna County Sanitation District operates a WWTP located northwest of the community of Orcutt and surrounding unincorporated Santa Maria which it serves. Tertiary treated wastewater is treated and discharged pursuant to a Waste Discharge Requirement issued by the CCRWQCB. A portion of the effluent stream is treated by reverse osmosis to reduce TDS. The effluent is discharged as recycled water by irrigation and some industrial uses. Brine resulting from the reverse osmosis is injected into a deep disposal well below the aquifer zones and is permitted by the EPA. The volume and quality of each element of the effluent stream are monitored pursuant to that permit and form the basis for estimates used in Appendix E.

3.8 Existing Water Management

Several public agencies are responsible for various aspects of water management in the Santa Maria Valley. However no single agency is responsible for all aspects of water supply or water quality.

3.8.1 Regional

SMVMA - Santa Maria Valley Water Conservation District. SMVWCD was established as a Special District in 1937. The SMVWCD has a contract with SBCWA to pay capital costs and operation of Twitchell Reservoir. The district encompasses an area generally thought to benefit from recharge from Twitchell Reservoir.

TMA – Twitchell Management Authority. The TMA was established pursuant to the settlement of the adjudication and comprises representatives of urban and agricultural interests. The TMA prepares an annual report to court and addresses long term maintenance of Twitchell Reservoir associated with protecting reservoir yield.

CCRWCB - Central Coast Regional Water Quality Control Board. The CCRWQCB is a regulatory agency responsible for oversight of discharges to surface water and implementing water recycling policy.

RCD – Cachuma Resource Conservation District. The RCD provides technical support to growers for improved water and nutrient management.

3.8.2 System Operators

City Santa Maria (water, sewer) – The City of Santa Maria water provides water and sewer service to customers within its service area. The City balances its water resources to fully utilize its State Water supply in the most cost effective manner while meeting both drinking water and wastewater effluent quality requirements.

City of Guadalupe (water, sewer) – The City of Guadalupe serves customers throughout its boundaries and utilizes a single well for urban water demands. Connected to the Coastal Branch, the City receives deliveries of state water and blends with one groundwater well prior to distribution. The City operates a WWTP and discharges its effluent through spray irrigation.

Golden State Water Company (water purveyor) – Golden State Water Company delivers water to urban users in the community of Orcutt. GSWC utilizes a number of groundwater production wells (of varying water quality) and SWP water as their source. As some of the production wells are of marginal quality, GSWC blends water from its various sources to assure drinking water standards are met.

3.9 Management of Salt and Nutrients

Management of salts and nutrients associated with agricultural, urban, and environmental water uses within the Santa Maria Groundwater Basin has evolved over time. The reasons include various social, technical, economical, and environmental factors such as cost of fertilizer and energy as well as regulatory mandates. The following outline shows the agricultural and urban changes in management of salts and nutrients that were identified during preparation of this assessment. Because many practices were implemented incrementally, the management changes are described, in general, as occurring during a sequence of three time periods, 1990, 2000, and 2010.

In the context of implementing policy or regulatory changes in the Santa Maria Valley, it is also important to recognize that significant management practices have already been established within the basin. Therefore, any future regulatory actions need to be taken in a way to maximize the benefit of continued cooperative programs. Otherwise, there is a risk that regulatory actions inhibit management measures intended to improve the salt and nutrient management of the basin. For example, strict limitations of discharges of NO_3 from farmlands may cause increased development of low NO_3 groundwater zones rather than encourage the use of NO_3 containing water as a source of fertilizer.

The Salt and Nitrate management practices that are being implemented over time by agricultural and urban water users within the Santa Maria Valley relate to several concepts of salt and nutrient management including; 1) reducing deep percolation past the root zone, 2) utilizing a higher percentage of the nitrates applied in the root zone, 3) introduction of higher quality water sources, and 4) increased removal of salt and nutrient through water treatment or use techniques.

In many instances economics were a main driver of management practices for agricultural and urban interests. In other situations regulatory pressures strongly influenced urban interests, and in recent times, agricultural interests. Because urban and agricultural uses rely on a common groundwater resource and a shared economic dependence on this resource, several management practices have been instituted as joint efforts among various stakeholders. As a result, some practices are listed below are not identified with a particular water user group.

Prior to 1990, Management Practices that notably changed included:

- All municipal needs met by local groundwater, however, in the 1960s both urban and agriculture water users invested in Twitchell Reservoir, the operations of which increased the recharge water.
- Agricultural irrigation mainly used furrow irrigation method; sprinklers were used for soil pre-irrigation and preparing the field for planting; once a crop germinated, sprinklers were removed
- Dairies were operating in the area, which produced a source of animal waste (a source of salts and nitrogen)
- A large poultry farm operated in the area, which produced a source of animal waste (a source of salts and nitrogen)
- Main crops grown were potatoes, sugar beets, and some vegetables

During the 1990's, Management Practices that notably changed included:

- Dairies and feed lots stopped operations in the area during this decade; thus decreasing sources of animal waste (a source of salts and nitrogen)
- Vegetables were well established by this time in the area; acres increased from over 35,000 acres in 1990 to around 38,000 acres in 2000 (L&S 2010 Annual Report)
- Strawberry acreage started in the area, which increased to around 3,000 acres planted by 2000
- Drip irrigation technology and field application of drip irrigation methods advanced
- Municipal users approved importation of State Water Project water to offset sole reliance on groundwater for urban uses. (Significant deliveries began in 1997.)

During the 2000's, Management Practices that notably changed included:

- The Municipal water users received delivery of State Water Project water which offset groundwater pumping and imported lower TDS and nutrient supply
- The poultry farm in the area ended operation; thus, decreasing a source of animal waste
- Crop acres were predominately strawberries and vegetable row crops; strawberries increased to about 10,000 acres by 2010, while vegetables decreased slightly to 34,000 acres
- Cost of fertilizers fluctuated in price 20 to 30 percent which increased uncertainty, which encouraged more conservative fertilizer practices, including development of new management techniques
- Split application, or methods for improving the timing of fertilizer applications with a crop needs became common practice
- Slow release fertilizers introduced which improve nutrient management

- Use of transplant seedlings lowered the number of days between planting and harvest and reduced water and nutrient use on a per-crop basis
- Drip irrigation systems were more widely installed, resulting in better distribution uniformity and fertilizer application
- Sprinkler irrigation method remains necessary during the early stages of crops for salt management in the root zone
- Agricultural Waiver regulations adopted in 2004 required additional water quality monitoring
- Municipal disposal of brine collected from urban water users

Since 2010, Management Practices that notably changed include:

- Municipal use of higher nitrate production wells for a portion of urban landscape irrigation
- Cost of fertilizers increased 2 to 3 times in comparison to prices prior to 1990 (based on USDA information)
- Fertilizer application methods continue to improve as costs of fertilizer rises and growers implement improved practices, such as, transplanting seedlings to establish a crop and use of techniques to control release of NO_3 from fertilizer materials
- Slow release fertilizers widely utilized
- Agricultural Waiver adopted in 2012 requires additional management practices through development of a farm plan with sections on irrigation and nutrient management for Tier 1, Tier 2, and Tier 3 farms; for Tier 3 farms only, the farm plan must include a developed on-farm irrigation and nutrient plan
- City of Guadalupe is blending imported SWP water with well water to deliver to urban water users
- Laguna County Sanitation District implemented an ordinance that prohibits the use of salt load regenerating water softeners in construction after January 1, 2012.

4 Sources, Transport and Fate of Water, TDS, Sodium, Chloride and Nitrogen (Conceptual Model)

In order to understand and quantify the sources of transport and fate of salt and nutrient in the Santa Maria Valley, the Working Group developed a working conceptual model (Figures 1.2a through 1.2f) of Santa Maria Valley hydrology based on previous work (such as Gibbs 2012 and Luhdorff and Scalmanini, 2011). The conceptual model shows the basic elements of sources, transport, and fate of salt and nutrients. These essential elements are represented numerically in the evaluation section. The calculation of flow volume and salt and nutrient concentration allows estimates of total transport and balance (salt/nutrient transported into and out of the valley) as discussed below.

For the purposes of this report, three water quality factors are considered: total dissolved Solids (TDS), Chloride (Cl^-) and Nitrate (NO_3). Each factor was selected based on availability of data, and potential limitations increasing levels place on use of water resource in the valley.

4.1 Relationship between hydrology and transport of salt and nutrient

Since both Salts and Nutrients are soluble in water, elements of surface and groundwater flow comprise the transport medium and are responsible for their distribution. The materials through which groundwater moves may attenuate the flow of certain dissolved constituents through adsorption on geologic media.

The quantity and quality of sources dictate the volume of salts and nutrients introduced into the valley; other factors increase/concentrate salts and nutrients. Water entering the valley by natural flow or due to importation (SWP) carries dissolved solids and nitrates. The salts and nutrients may be concentrated or diluted by various mechanisms during use and transport of surface and groundwater. Those factors include evapotranspiration, leaching or adsorption in the vadose zone etc.

This assessment focuses on specific chemical species that have been identified as important to water users in the Valley. Although many chemical species may be of concern in a particular area, water users in the Valley have identified TDS (as an indicator of salt), Chloride (Cl^-) and Nitrate (NO_3) as the constituents of concern for the following reason:

- TDS: may limit crops and is a drinking water standard
- Cl^-: may affect soil characteristics to reduce crop yield

- NO_3: has been identified as a potential health threat, the State Department of Public Health has established a drinking water standard of 45 parts per million as nitrate.

Although conditions may change in the future, the trends of these constituents are highest priority to the working Group and are incorporated into the conceptual model. The conceptual model was developed to provide a simplified description of hydrogeology, flow mechanisms and sources of TDS, Cl^- and NO_3 in the Valley. The model was a basis for estimating the balance between inputs and discharge of salts and nutrients in the basin.

4.2 Source, Transport, Fate Cycle Conceptual Model

The Working Group developed a conceptual model as a basis for a simplified calculation of source, transport and fate of TDS, chloride, and nitrate. The conceptual model was represented in diagrams showing sources, flow, discharge and potential areas of accumulation of TDS, Chloride and NO_3. Due to differences in subsurface conditions, the western and eastern portions of the valley were represented in separate diagrams; resulting in a total of six diagrams (two each for TDS, Cl^- and NO_3) see figures 1.2a through 1.2f. The diagrams were kept generic so as to be able to encompass changes in management practices discussed in Section 3.

There are numerous elements of the Conceptual Model, but these elements generally fall in to one of three “systems”: the agricultural extraction and return flow “system”, the urban supply and return flow “system” and the remaining element of the model representing the surface and groundwater hydrology. The elements of the conceptual model are discussed in these three categories below.

Some features of the conceptual model (such as ET and plant root zone) were placed in the agricultural system for convenience. Both the agricultural and urban systems share elements with the groundwater system; however the specific operations of each have differing impacts on the basin. There are also elements of the groundwater system that occur independent of the agricultural and urban systems.

In addition, a Source, Transport, and Fate Cycle of nitrate as “N” (NO_3–N) for the basin and root zone was developed since it requires two types of accounting or budgets to understand and manage: a root-zone budget to determine Nitrate efficiency use, and a groundwater basin balance to estimate whether accumulation of N in the form of NO_3 (nitrate) is taking place. Nitrogen is added to the soil root zone in various forms of pounds of N expressed as equivalent NO_3-N. Nitrate, NO_3, is the form of Nitrogen available and used by plants as uptake that leads to Nitrogen removal at harvest. Nitrate, $NO_{3,}$ is also the form of Nitrogen that may leach to groundwater or may or may not get reapplied to the root zone or discharged to drain outlet, possibly outside of the basin boundary and eventually reaching the ocean. For the purpose of calculating the estimated amount of N, the terms in the mass balance equations are expressed as pounds of N as NO_3-N. The conceptual diagram for nitrogen in the root zone is shown in Figure 4.2.

TESTING

- Soil test at start of season
- Quick Nitrate (NO3-N) soil test during growing season
- Soil test prior to side dressing
- Plant tissue sampling

APPLICATION METHODS

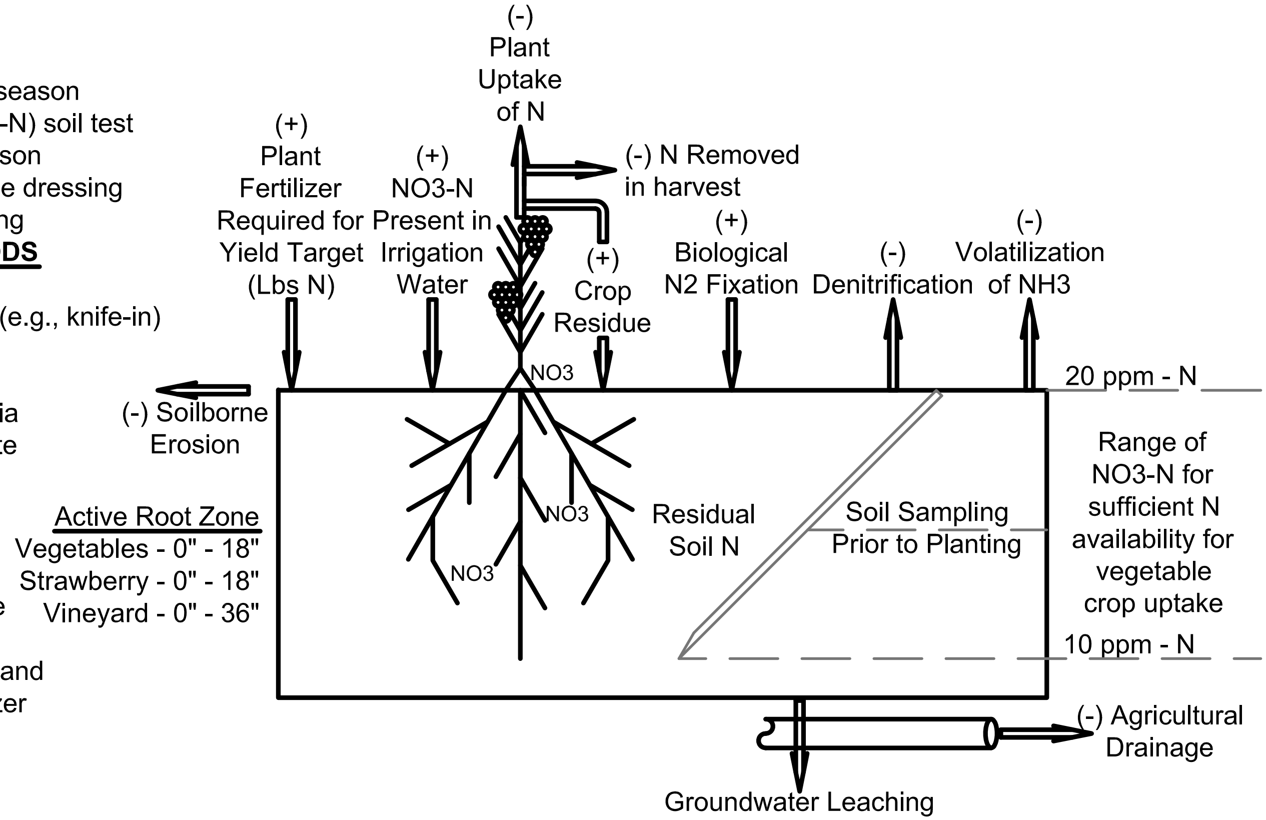
- Broadcast fertilizer
- Precision insertion (e.g., knife-in)
- Fertigation

TYPE OF FERTILIZER

- Anhydrous ammonia
- Ammonium sulphate
- Urea
- Ammonium nitrate
- Calcium nitrate
- Sodium nitrate
- Calcium cyanamide

TIMING/METHOD

- As needed/on-demand
- Slow release fertilizer



NOTES:

- **Soils with a modest level of N (≥10ppm) can support immediate needs of vegetable crop uptake.**
- **Soils may need higher level of 20ppm N to maintain maximum growth rates for several weeks or longer.**
- **10ppm NO3-N ≈ 45 mg/L of NO3**
- **1ppm of NO3-N ≈ 2lb/Ac in 0"- 8" Active Root Zone**
- **Pounds of N/Acre = 0.23 x ppm NO3-N in irrigation water x inches of water.**
- **Pounds of N/Acre = 0.051 x ppm NO3 x inches of water.**

NITROGEN BALANCE EQUATION:

N*Groundwater* = **N***Fertilizer* + **N***Applied Water* - **N***Harvest* + **N***Fixation* - **N***Denit/Volat* - **N***Drainage* - **N***Erosion*

N*Harvest* = **N***Uptake* - **N***Residue*

Salt and Nutrient Planning Workgroup Santa Barbara County IRWM Plan 2013	GEI Consultants Bookman-Edmonston Division	Nitrogen in Rootzone Balance
Santa Maria Groundwater Management Area		February, 2013 — Fig. 4-2

The components shown in the "nitrate in rootzone" balance can be used in a mass balance equation to estimate nitrogen loading to the groundwater based on the following equation:

$N_{Groundwater} = N_{Fertilizer} + N_{AW} – N_{Harvest} + N_{Fixation} – N_{Denit/Volat} – N_{Drainage} - N_{Erosion}$

- **$N_{Groundwater}$ –** Pounds of N leached below the root zone
- **$N_{Fertilizer}$ –** Pounds of N added to meet target yield
- **N_{AW}** – Pounds of N added based on source water concentration
- **$N_{Harvest}$** – Pounds of N removed at harvest, a component of crop uptake
- **$N_{Crop\ uptake} = N_{Harvest} + N_{Residue}$**
- **$N_{Residue}$** – Pounds of N returned or added to root zone as crop residue from crop uptake
- **$N_{Fixation}$** – Pounds of N added to the root zone
- **$N_{Denit/Volat}$** – Pounds of N removed from the root zone
- **$N_{Drainage}$** - Pounds of N removed by drainage to outside of groundwater boundary
- **$N_{Erosion}$** - Pounds of N transported by soil erosion outside groundwater boundary

Two important factors that affect nitrogen loading and movement to the groundwater include: the amount of nitrate in the root zone and the crops' applied water. Management of N added as fertilizer and the efficiency of the type of N, and the amount of and timing of water applied for irrigation are the factors that have effected improvements over time. A factor that is not easily controlled by the grower's management is the timing of rainfall, which can transport the available nitrate in the root zone. It is important to recognize the root zone balance is an estimate of potential to transport NO_3 to the groundwater since it can only be transported to the groundwater when leaching of water occurs below a root zone and the leaching path connects it to the groundwater.

From this evaluation, estimating the pounds of N loading to groundwater was based on available UCCE information. In general logic, if the amount of NO_3 contained in the soil profile and the source water applied for irrigation are accounted for, then the $N_{Fertilizer}$ applied to meet the crop yield target can be more effectively managed to reduce the potential loading to the groundwater.

The Agricultural System, as its name suggests, consists of the elements of the Conceptual Model related to agricultural production in the Santa Maria Valley. Groundwater pumping for the purpose of crop irrigation makes up the most significant portion of salt and nutrient movement out of the aquifer. Likewise, deep percolation of applied water makes up a significant portion of salt and nutrient movement back into the groundwater basin. The elements of the Conceptual Model, as they relate to the Agricultural System are as follows:

- **Agricultural Deep Percolation –** The drainage of agricultural applied water which moves below the effective depth of the root zone and is not captured in tile drains or as tailwater, but is stored in subsurface strata. Deep percolation of agricultural water carries salts and nutrients that have leached out of the root zone, into the groundwater basin. There are indications that microbial activity plays a role in GW leaching.

- **ET –** Evapotranspiration is the combined loss of water from a given area by evaporation from the land and transpiration from plants.
- **Ag Plant Material –** Some of the salts, nutrients, and water present in the crops are removed from the groundwater basin once those crops are harvested. However, plant material remaining after harvest is worked back into the ground and may become available to the next crop or may be leached below the root zone.
- **Ag Pumping –** Groundwater pumping for agricultural purposes occurs from both the confined and unconfined aquifers. Groundwater is the sole source of applied water for agriculture users in the Santa Maria Groundwater Basin.
- **Ag Runoff and Tailwater –** Excess water applied for agricultural uses may result in surface runoff from agricultural lands, or may be captured below the root zone in tile drains, or is leached as deep percolation.
- **Root Zone –** The root zone depth is the zone in which water and nutrients can be utilized by the crop, varies from crop type to crop type.
- **Applied Water –** Applied water for agricultural uses is the amount of water pumped from the groundwater basin for agricultural uses. The applied water volume takes into account the evapotranspiration rate for the specific crop in the climate of the area, irrigation efficiency, and crop-specific water requirements that may include salt leaching.

The Urban System consists of elements of the Conceptual Model related to municipal and industrial water production and water importation into the Santa Maria Valley. While the urban water use is significantly less than the agricultural water use, elements of the Urban System still have an impact on the groundwater basin.

- **Brine Disposal –** Effluent from a wastewater treatment plant that has been processed with reverse osmosis, or other salt-removal equipment, results in two wastewater streams; a highly concentrated solution of salts and other dissolved solids; and high quality recycled water. While the high quality recycled water may be infiltrated into the groundwater basin, or used for irrigation, the highly concentrated brine must be properly disposed of. In the case of Laguna County Sanitation District, the brine is injected into a deep well below the underground source of drinking water (USDW) aquifer, which is protected by a packer between the tubing and casing, a cemented exterior casing, and injection below the Sisquoc confining layer.
- **Deep Percolation, Municipal/Industrial –** The drainage of municipal/industrial water that is not evaporated or utilized by landscaping, may move downward by gravity below the maximum effective depth of the root zone toward storage in subsurface strata. Deep percolation of municipal/industrial water may carry contaminants into the groundwater basin.
- **Municipal and Industrial Pumping –** Groundwater pumping occurs from both the confined and unconfined aquifers. Groundwater, in conjunction with imported SWP water, provides the municipalities and agencies with potable water for their urban users.

- **SWP –** Water within the Santa Maria Valley groundwater basin received from the State Water Project, originating outside the basin that adds to recharge of the basin.
- **Well and SWP Infiltration –** Infiltration of groundwater and State Water from over-application of landscape irrigation.
- **WWTP Infiltration –** Effluent from a wastewater treatment plant treated to appropriate level can be used for landscape irrigation, as well as agricultural, industrial, and other beneficial uses. Effluent may also be placed in ponds to evaporate and/or percolate into the groundwater basin.

The Groundwater elements of the Conceptual Model relate to the movement of groundwater into, out of, and within the groundwater basin that aren't directly related to the Agricultural and Urban extraction and recharge.

- **Abandoned Well –** There are a number of abandoned wells in the Santa Maria Valley which once drew from either the confined or unconfined aquifer, or both. Groundwater from the deeper confined aquifer is generally of better quality than groundwater from the shallower unconfined aquifer. Abandoned wells that once drew from both aquifers that have not been properly destroyed allow for the movement of groundwater from one aquifer to another, which results in the degradation of the water quality of the confined aquifer; .improperly constructed or maintained well heads may allow contaminants to enter groundwater.
- **Groundwater Discharge to Ocean –**The Santa Maria Valley groundwater basin gradient is generally sloped toward the ocean. Infiltration from rivers, rainwater, and other activities maintains sufficient gradient that some groundwater flows out into the ocean. Once groundwater is discharged to the ocean, it cannot be recovered.
- **High Flows to Ocean –** In high-flow years when the Santa Maria River, Sisquoc River, and Cuyama River are transporting more water than can be used or infiltrated into the groundwater basin, surface water is discharged to the ocean. Once surface water is discharged to the ocean, it cannot be recovered.
- **Recharge from East Area of Valley –** Groundwater from the unconfined aquifer in the East Area of the Santa Maria Valley flows west due to the gradient of the groundwater basin. As it moves west, a horizontal layer of semi-impermeable soil divides the aquifer into unconfined (upper) and confined (lower) portions. The flow remaining above the layer continues to move through the unconfined aquifer in the west area of the valley, while a portion of the groundwater moves below the semi-impermeable layer and recharges the confined aquifer.
- **Recharge from Cuyama River –** Releases from Twitchell Reservoir are designed to more effectively recharge the groundwater basin by infiltration through the riverbed.
- **Recharge from Orcutt Creek –** A portion of the surface water that flows down Orcutt Creek recharges the groundwater basin by infiltration through the riverbed.
- **Recharge from Sisquoc River –** A portion of the surface water that flows down the Sisquoc River recharges the groundwater basin by infiltration through the riverbed.

- **Semi-Impermeable Layer –** A layer of impermeable or semi-impermeable material that separates the shallow unconfined aquifer from the deep confined aquifer.
- **Unconfined Aquifer –** A condition in which the water in an aquifer forms a free surface under atmospheric pressure.
- **Water Table –** The upper surface of the zone of saturation on which the water pressure in the porous medium equals atmospheric pressure.

Due the nature of data available for this analysis, estimates of basin balance and accumulation of TDS, NO_3 and Cl^- contain significant uncertainty. Recommendations for changes in various monitoring efforts to reduce this uncertainty are provided in Section 5.

4.2.1 Basin Balance Estimates

Existing data were obtained and applied to elements of the conceptual model to estimate the volume of TDS, Cl^- and NO_3 entering, moving through and leaving the basin. The analysis was based on a simple accounting balance approach and represents an "order of magnitude" calculation of the "balance" of TDS and NO_3 in the Valley for the years of 2010, 2000, and 1990 and is shown in Tables 4.2-1 through 4.2-6 (see also Appendix E).

This analysis shows evidence that the degree of loading of TDS and NO_3 to the Valley is decreasing with time. This trend would be expected given the management activities discussed in Section 4. In addition, the loading of TDS to groundwater in the basin may have decreased to a level where groundwater quality is stable as reflected in monitoring results in some areas (Figure 4.2.1). This analysis focuses on general trends thus does not include consideration of rare and catastrophic events such as large wildfires that may introduce

The amount of Nitrate loading has decreased substantially, but water quality samples in some areas continue to show elevated levels of NO_3 even with the substantial management techniques in place. This is consistent with the loading estimates for 2010 which suggest levels of NO_3 entering the Valley hydrologic system continue to exceed the amounts discharged. Since there is a great level of uncertainty in the balance estimates, more research may be useful to understand Nitrogen losses from the various elements that store and transport NO_3 within the system. That additional research is beyond the scope of this report and the regulatory processes discussed in Section 1.

4.2.2 Evidence in Support of Transport Model

Coastal monitoring wells are the most down-gradient measurements of water quality in the basin. Although originally installed to monitor for potential sea water intrusion, regular measurements of water quality in these well show several important features. First, while shallow groundwater has experienced increasing specific conductance (an indication of TDS concentrations) over the last 30 years, the intermediate and deep zones do not show a similar trend (Luhdorff and Scalmanini, 2011), particularly in the southern installation of wells. Water in the intermediate and lowermost zones indicates lower specific conductance and less increase over time. These data presented in the Annual Report support the interpretation by Luhdorff and Scalmanini that increased recharge of stormwater to the basin from Twitchell Reservoir has generally stabilized water quality in the zone influenced by recharge from the Santa Maria River east of Bonita School Road crossing. Shallow groundwater west of Bonita School Road is more influenced by returnflow than recharge from the river and in that area the shallow groundwater has experienced increasing Specific Conductance (or TDS).

Two lines of evidence suggest the mechanism by which Nitrate is transported in the groundwater basin: water quality trends in coastal wells and the difference in water quality between shallow and deeper zones east of the Bonita School road. Luhdorff and Scalmanini observes that nitrate in coastal wells in shallow and intermediate zones in the northerly monitoring well cluster began increasing in the 1980s while Nitrate levels in deep zones has remained low. Nitrate levels in shallow groundwater throughout the valley have increased while deeper zones remain relatively low. This trend is shown in monitoring wells and in the isolation tests performed by the City of Santa Maria on their well # 9 (e-mail correspondence, City of Santa Maria).

These data are consistent with the conceptual model which describes downward movement of TDS and NO_3 during periods of above average rainfall. A higher concentration of TDS and NO_3 is not expected to migrate rapidly through the saturated zone to the deep zone, but rather migrate to the west along the regional groundwater gradient toward the coast.

The shallowest zones west of Bonita School Road may be intercepted by drains or discharge naturally to surface water bodies. This is consistent with the higher levels of TDS and NO_3 measured in surface water in this area.

Table 4.2-1. Estimated Annual Chloride and TDS Load Balance, Santa Maria Valley, 1990

Agency/Location	Source of Water	In		Out		Balance	
		Chloride	TDS	Chloride	TDS	Chloride	TDS
	Imported/SWP, Wells	Lb	Lb	Lb	Lb	Lb	Lb
City of Santa Maria - SWP Outside Landscape Infiltration	SWP	-	-			-	-
City of Santa Maria - WWTP Infiltration	SWP/Wells	-	-			-	-
City of Santa Maria - Municipal and Industrial Pumping	Wells			-	27,868,000	-	(27,868,000)
City of Santa Maria - Well Outside Landscape Infiltration	Wells	-	5,574,000			-	5,574,000
City of Guadalupe - WWTP Infiltration	Wells	-	-			-	-
City of Guadalupe - Municipal and Industrial Pumping	Wells			-	-	-	-
City of Guadalupe - Well Outside Landscape Infiltration	Wells	-	-			-	-
Golden State Water Co. - SWP Outside Landscape Infiltration	SWP	-	-			-	-
Golden State Water Co. - Municipal and Industrial Pumping	Wells			485,000	8,283,000	(485,000)	(8,283,000)
Golden State Water Co. - Well Outside Landscape Infiltration	Wells	10,000	167,000			10,000	167,000
Laguna Sanitation District - WWTP Infiltration	SWP/Wells	2,173,000	7,304,000			2,173,000	7,304,000
Laguna Sanitation District - Brine Disposal				-	-	-	-
Agriculture - Pumped	Wells			23,228,000	309,600,000	(23,228,000)	(309,600,000)
Agriculture - Deep Percolation (74.5%)	Wells	17,305,000	230,652,000			17,305,000	230,652,000
Santa Maria River	N/A					-	-
Cuyama River	N/A	5,656,000	104,423,000	-	-	5,656,000	104,423,000
Sisquoc River	N/A	870,000	43,510,000	680,000	33,992,000	190,000	9,518,000
Orcutt Creek	N/A	-	1,135,000	-	8,170,000	-	(7,035,000)
Oso Flaco Creek	N/A			-	11,435,000	-	(11,435,000)
Groundwater Discharge From Basin	N/A			3,052,000	29,212,000	(3,052,000)	(29,212,000)
High flows directly to Ocean	N/A	-	-	-	-	-	-
	Totals	**26,014,000**	**392,765,000**	**27,445,000**	**428,560,000**	**(1,431,000)**	**(35,795,000)**

Notes:

Estimated - 25% of the Agriculture-Pumped water and associated salts, are lost to surface runoff.

Estimated - 0.5% of the Agriculture-Pumped water and associated salts, are lost to crop harvest.

Estimated - 74.5% of the Agriculture-Pumped water and assiciated salts are assumed to return to the basin as Agriculture-Deep Percolation.

Positive values in the Balance columns indicate a general inflow of chloride/TDS into the basin.

Negative values (values in parentheses) in the Balance columns indicate a general removal of chloride/TDS from the basin.

Values in this table are based on those presented in Appendix E. These values have been rounded to reflect a reasonable level of certainty of the source information.

Table 4.2-2. Estimated Annual Nitrate Load Balance, Santa Maria Valley, 1990

Agency/Location	Source of Water	In	Out	Balance	Balance NO3-N
		Nitrate	Nitrate	Nitrate	Equivalent
	Imported/SWP, Wells	Lb	Lb	Lb	Lb
City of Santa Maria - SWP Outside Landscape Infiltration	SWP	-		-	-
City of Santa Maria - WWTP Infiltration	SWP/Wells	-		-	-
City of Santa Maria - Municipal and Industrial Pumping	Wells		114,800	(114,800)	(25,900)
City of Santa Maria - Well Outside Landscape Infiltration	Wells	23,000		23,000	5,200
City of Guadalupe - WWTP Infiltration	Wells	-		-	-
City of Guadalupe - Municipal and Industrial Pumping	Wells		-	-	-
City of Guadalupe - Well Outside Landscape Infiltration	Wells	-		-	-
Golden State Water Co. - SWP Outside Landscape Infiltration	SWP	-		-	-
Golden State Water Co. - Municipal and Industrial Pumping	Wells		92,900	(92,900)	(21,000)
Golden State Water Co. - Well Outside Landscape Infiltration	Wells	1,900		1,900	400
Laguna Sanitation District - WWTP Infiltration	SWP/Wells	138,700		138,700	31,300
Laguna Sanitation District - Brine Disposal			-	-	-
Agriculture - Pumped	Wells		1,381,200	(1,381,200)	(311,800)
Agriculture - Deep Percolation	Wells	19,225,800		19,225,800	4,339,900
Santa Maria River	N/A			-	-
Cuyama River	N/A	2,200	-	2,200	500
Sisquoc River	N/A	23,800	18,600	5,200	1,200
Orcutt Creek	N/A	20,200	145,100	(124,900)	(28,200)
Oso Flaco Creek	N/A	-	306,900	(306,900)	(69,300)
Groundwater Discharge From Basin	N/A		417,400	(417,400)	(94,200)
High flows directly to Ocean	N/A	-	-	-	-
	Totals	**19,435,600**	**2,476,900**	**16,958,700**	**3,828,000**

Notes:

Positive values in the Balance columns indicate a general inflow of nitrate into the basin
Negative values (values in parentheses) in the Balance columns indicate a general removal of nitrate from the basin.
Values in this table are based on those presented in Appendix E. These values have been rounded to reflect a reasonable level of certainty.

4.2-3. Estimated Annual Chloride and TDS Load Balance, Santa Maria Valley, 2000

Agency/Location	Source of Water	In		Out		Balance	
		Chloride	TDS	Chloride	TDS	Chloride	TDS
	Imported/SWP, Wells	Lb	Lb	Lb	Lb	Lb	Lb
City of Santa Maria - SWP Outside Landscape Infiltration	SWP	13,000	2,052,000			13,000	2,052,000
City of Santa Maria - WWTP Infiltration	SWP/Wells	124,000	508,000			124,000	508,000
City of Santa Maria - Municipal and Industrial Pumping	Wells			42,000	1,031,000	(42,000)	(1,031,000)
City of Santa Maria - Well Outside Landscape Infiltration	Wells	8,000	206,000			8,000	206,000
City of Guadalupe - WWTP Infiltration	Wells	19,000	744,000			19,000	744,000
City of Guadalupe - Municipal and Industrial Pumping	Wells			28,000	949,000	(28,000)	(949,000)
City of Guadalupe - Well Outside Landscape Infiltration	Wells	6,000	229,000			6,000	229,000
Golden State Water Co. - SWP Outside Landscape Infiltration	SWP	167,000	2,551,000			167,000	2,551,000
Golden State Water Co. - Municipal and Industrial Pumping	Wells			973,000	14,330,000	(973,000)	(14,330,000)
Golden State Water Co. - Well Outside Landscape Infiltration	Wells	20,000	288,000			20,000	288,000
Laguna Sanitation District - WWTP Infiltration	SWP/Wells	2,261,000	8,306,000			2,261,000	8,306,000
Laguna Sanitation District - Brine Disposal				-	-	-	-
Agriculture - Pumped	Wells			21,161,000	271,079,000	(21,161,000)	(271,079,000)
Agriculture - Deep Percolation (74.5%)	Wells	15,765,000	201,954,000			15,765,000	201,954,000
Santa Maria River	N/A					-	-
Cuyama River	N/A	4,786,000	95,721,000	-	-	4,786,000	95,721,000
Sisquoc River	N/A	1,160,000	44,960,000	906,000	35,125,000	254,000	9,835,000
Orcutt Creek	N/A	-	1,167,000	-	8,402,000	-	(7,235,000)
Oso Flaco Creek	N/A			-	11,435,000	-	(11,435,000)
Groundwater Discharge From Basin	N/A			3,052,000	29,212,000	(3,052,000)	(29,212,000)
High flows directly to Ocean	N/A	-	-	-	-	-	-
	Totals	**24,329,000**	**358,686,000**	**26,162,000**	**371,563,000**	**(1,833,000)**	**(12,877,000)**

Notes:

Estimated - 25% of the Agriculture-Pumped water and associated salts, are lost to surface runoff.

Estimated - 0.5% of the Agriculture-Pumped water and associated salts, are lost to crop harvest.

Estimated - 74.5% of the Agriculture-Pumped water and assiciated salts are assumed to return to the basin as Agriculture-Deep Percolation.

Positive values in the Balance columns indicate a general inflow of chloride/TDS into the basin.

Negative values (values in parentheses) in the Balance columns indicate a general removal of chloride/TDS from the basin.

Values in this table are based on those presented in Appendix E. These values have been rounded to reflect a reasonable level of certainty of the source information.

4.2-4. Estimated Annual Nitrate Load Balance, Santa Maria Valley, 2000

Agency/Location	Source of Water	In	Out	Balance	Balance NO3-N
		Nitrate	Nitrate	Nitrate	Equivalent
	Imported/SWP, Wells	Lb	Lb	Lb	Lb
City of Santa Maria - SWP Outside Landscape Infiltration	SWP	21,300	-	21,300	4,800
City of Santa Maria - WWTP Infiltration	SWP/Wells	-	-	-	-
City of Santa Maria - Municipal and Industrial Pumping	Wells		16,500	(16,500)	(3,700)
City of Santa Maria - Well Outside Landscape Infiltration	Wells	3,300		3,300	700
City of Guadalupe - WWTP Infiltration	Wells	2,200	-	2,200	500
City of Guadalupe - Municipal and Industrial Pumping	Wells		3,000	(3,000)	(680)
City of Guadalupe - Well Outside Landscape Infiltration	Wells	700		700	160
Golden State Water Co. - SWP Outside Landscape Infiltration	SWP	44,500	-	44,500	10,000
Golden State Water Co. - Municipal and Industrial Pumping	Wells		12,900	(12,900)	(2,900)
Golden State Water Co. - Well Outside Landscape Infiltration	Wells	4,800		4,800	1,100
Laguna Sanitation District - WWTP Infiltration	SWP/Wells	191,700		191,700	43,300
Laguna Sanitation District - Brine Disposal			-	-	-
Agriculture - Pumped	Wells		5,045,600	(5,045,600)	(1,139,000)
Agriculture - Deep Percolation	Wells	18,036,600		18,036,600	4,071,500
Santa Maria River	N/A			-	-
Cuyama River	N/A	77,000	-	77,000	17,400
Sisquoc River	N/A	51,400	40,100	11,300	2,600
Orcutt Creek	N/A	81,000	583,100	(502,100)	(113,300)
Oso Flaco Creek	N/A	-	306,900	(306,900)	(69,300)
Groundwater Discharge From Basin	N/A		417,400	(417,400)	(94,200)
High flows directly to Ocean	N/A	-	-	-	-
	Totals	**18,514,500**	**6,425,500**	**12,089,000**	**2,729,000**

Notes:

Positive values in the Balance columns indicate a general inflow of nitrate into the basin
Negative values (values in parentheses) in the Balance columns indicate a general removal of nitrate from the basin.
Values in this table are based on those presented in Appendix E. These values have been rounded to reflect a reasonable level of certainty.

Table 4.2-5. Estimated Annual Chloride and TDS Load Balance, Santa Maria Valley, 2010

Agency/Location	Source of Water	In		Out		Balance	
		Chloride	TDS	Chloride	TDS	Chloride	TDS
	Imported/SWP, Wells	Lb	Lb	Lb	Lb	Lb	Lb
City of Santa Maria - SWP Outside Landscape Infiltration	SWP	11,000	1,732,000			11,000	1,732,000
City of Santa Maria - WWTP Infiltration	SWP/Wells	3,856,000	17,671,000			3,856,000	17,671,000
City of Santa Maria - Municipal and Industrial Pumping	Wells			382,000	7,171,000	(382,000)	(7,171,000)
City of Santa Maria - Well Outside Landscape Infiltration	Wells	76,000	1,434,000			76,000	1,434,000
City of Guadalupe - WWTP Infiltration	Wells	168,000	1,606,000			168,000	1,606,000
City of Guadalupe - Municipal and Industrial Pumping	Wells			45,000	1,532,000	(45,000)	(1,532,000)
City of Guadalupe - Well Outside Landscape Infiltration	Wells	9,000	306,000			9,000	306,000
Golden State Water Co. - SWP Outside Landscape Infiltration	SWP	300	42,000			300	42,000
Golden State Water Co. - Municipal and Industrial Pumping	Wells			751,000	13,003,000	(751,000)	(13,003,000)
Golden State Water Co. - Well Outside Landscape Infiltration	Wells	15,000	262,000			15,000	262,000
Laguna Sanitation District - WWTP Infiltration	SWP/Wells	1,085,000	4,493,000			1,085,000	4,493,000
Laguna Sanitation District - Brine Disposal				993,000	2,244,000	(993,000)	(2,244,000)
Agriculture - Pumped	Wells			23,238,000	279,780,000	(23,238,000)	(279,780,000)
Agriculture - Deep Percolation	Wells	17,312,000	208,436,000			17,312,000	208,436,000
Santa Maria River	N/A					-	-
Cuyama River	N/A	4,786,000	95,721,000	-	-	4,786,000	95,721,000
Sisquoc River	N/A	1,160,000	44,960,000	906,000	35,125,000	254,000	9,835,000
Orcutt Creek	N/A	-	1,167,000	-	8,402,000	-	(7,235,000)
Oso Flaco Creek	N/A			-	11,435,000	-	(11,435,000)
Groundwater Discharge From Basin	N/A			3,531,000	29,562,000	(3,531,000)	(29,562,000)
High flows directly to Ocean	N/A	-	-	1,893,000	26,655,000	(1,893,000)	(26,655,000)
	Totals	**28,478,300**	**377,830,000**	**31,739,000**	**414,909,000**	**(3,260,700)**	**(37,079,000)**

Notes:

Estimated - 25% of the Agriculture-Pumped water and associated salts, are lost to surface runoff.

Estimated - 0.5% of the Agriculture-Pumped water and associated salts, are lost to crop harvest.

Estimated - 74.5% of the Agriculture-Pumped water and assiciated salts are assumed to return to the basin as Agriculture-Deep Percolation.

Positive values in the Balance columns indicate a general inflow of Chloride/TDS into the basin.

Negative values (values in parentheses) in the Balance columns indicate a general removal of Chloride/TDS from the basin.

High flows directly to Ocean include flow from Blosser Creek, Bradley Channel, Greene Valley Creek, and Main Street Canal.

Values in this table are based on those presented in Appendix E. These values have been rounded to reflect a reasonable level of certainty of the source information.

Table 4.2-6. Estimated Annual Nitrate Load Balance, Santa Maria Valley, 2010

Agency/Location	Source of Water	In	Out	Balance	Balance NO3-N
	Source of Water	Nitrate	Nitrate	Nitrate	Equivalent
	Imported/SWP, Wells	Lb	Lb	Lb	Lb
City of Santa Maria - SWP Outside Landscape Infiltration	SWP	18,000	-	18,000	4,100
City of Santa Maria - WWTP Infiltration	SWP/Wells	406,200	-	406,200	91,700
City of Santa Maria - Municipal and Industrial Pumping	Wells		224,600	(224,600)	(50,700)
City of Santa Maria - Well Outside Landscape Infiltration	Wells	44,900		44,900	10,100
City of Guadalupe - WWTP Infiltration	Wells	44,100	-	44,100	10,000
City of Guadalupe - Municipal and Industrial Pumping	Wells		4,800	(4,800)	(1,100)
City of Guadalupe - Well Outside Landscape Infiltration	Wells	1,000		1,000	230
Golden State Water Co. - SWP Outside Landscape Infiltration	SWP	100	-	100	20
Golden State Water Co. - Municipal and Industrial Pumping	Wells		14,600	(14,600)	(3,300)
Golden State Water Co. - Well Outside Landscape Infiltration	Wells	5,000		5,000	1,100
Laguna Sanitation District - WWTP Infiltration	SWP/Wells	178,700		178,700	40,300
Laguna Sanitation District - Brine Disposal			79,700	(79,700)	(18,000)
Agriculture - Pumped	Wells		7,693,000	(7,693,000)	(1,736,600)
Agriculture - Deep Percolation	Wells	14,537,000		14,537,000	3,281,500
Santa Maria River	N/A			-	-
Cuyama River	N/A	77,000	-	77,000	17,400
Sisquoc River	N/A	51,400	40,100	11,300	2,600
Orcutt Creek	N/A	81,000	583,100	(502,100)	(113,300)
Oso Flaco Creek	N/A	-	306,900	(306,900)	(69,300)
Groundwater Discharge From Basin	N/A		794,500	(794,500)	(179,300)
High flows directly to Ocean	N/A	-	646,100	(646,100)	(145,800)
	Totals	**15,444,400**	**10,387,400**	**5,057,000**	**1,142,000**

Notes:

Estimated - 25% of the Agriculture-Pumped water and associated salts, are lost to surface runoff.

Estimated - 0.5% of the Agriculture-Pumped water and associated salts, are lost to crop harvest.

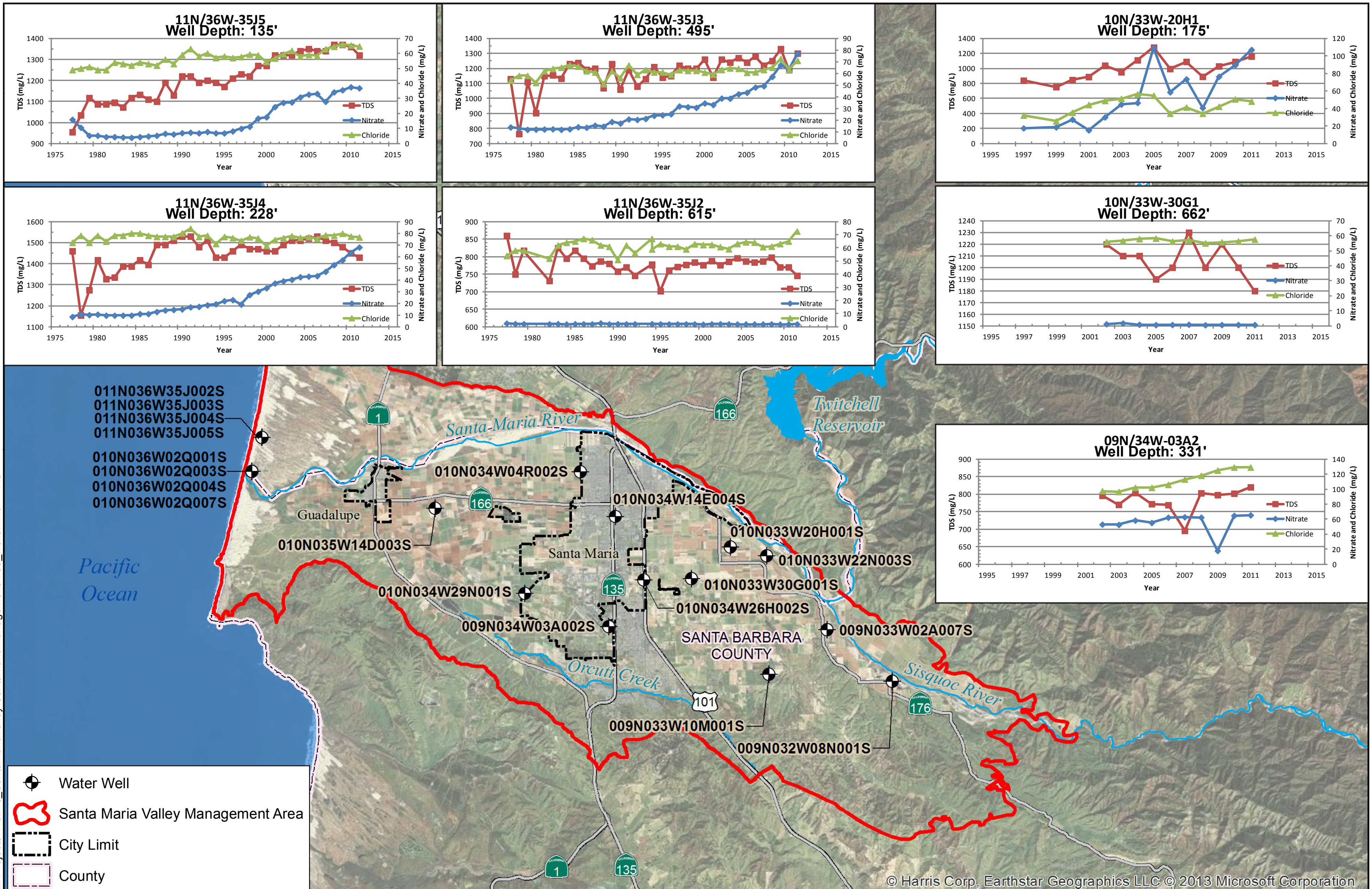
Estimated - 74.5% of the Agriculture-Pumped water and assiciated salts are assumed to return to the basin as Agriculture-Deep Percolation.

Positive values in the Balance columns indicate a general inflow of nitrate into the basin

Negative values (values in parentheses) in the Balance columns indicate a general removal of nitrate from the basin.

High flows directly to Ocean include flow from Blosser Creek, Bradley Channel, Greene Valley Creek, and Main Street Canal.

Values in this table are based on those presented in Appendix E. These values have been rounded to reflect a reasonable level of certainty.



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Salt and Nutrient Planning Workgroup
Santa Barbara County IRWM Plan 2013

Santa Maria Groundwater Management Area

GEI Consultants
Bookman-Edmonston Division

TDS, CHLORIDE AND NITRATE CONCENTRATIONS WITHIN SANTA MARIA VALLEY ASSESSMENT AREA

FEBRUARY 2013

FIGURE 4.2.1

5 Evaluation of Existing Monitoring

A significant amount of the data used in this report has been extracted from the annual reports prepared for the TMA which rely on both existing monitoring programs and other data collected from water and wastewater system operators. In addition, the USGS, CCWQP and CCRWQCB collect stream flow and water quality data. This section discusses the data and its utility for this report.

5.1 Existing monitoring programs

Existing monitoring programs and the data collected in the Santa Maria Valley (Valley) are described in Section 2 of this report. This section evaluates the applicability of the existing monitoring to the salt and nutrient transport and fate analysis in Section 3 and identifies gaps in the data that have constrained the evaluation of past and present salt and nutrient management measures. While each monitoring program reviewed was set up to meet certain objectives, none of the programs were established to support this specific evaluation. This discussion does not evaluate data collection programs themselves or whether the data collected meets other objectives.

Existing data collection provides information on:

- Salt and nutrient inputs
- Climate conditions
- Surface flow (volume and quality)
- Water table gradient and fluctuation
- Ground water quality in the saturated zone,
- Water quality variation of drainage and other shallow groundwater discharges

The existing monitoring provides measurement of salts (TDS), Chloride Cl^- and Nitrogen (NO_3) at certain locations on a regular basis; however, measurements of TDS, Cl^- and NO_3 in other areas within in the Valley are not adequate to define all parameters represented in Figures 1.2a to 1.2f. As a result the current monitoring programs provided a sufficient basis for only a very general estimate of loading, transport and discharge as related to each parameter in the diagram.

As discussed in this section, data available for salt and nutrient assessment is of variable quality. In general public agency data collection is of good to excellent quality for the periods collected. Water production and discharge information from water purveyors and water treatment plants is detailed and complete for the period evaluated. Stream flow data is not consistently available due to a number of factors including cost and practicality. Private well production and nutrient use data were not available and were estimated from published cropping and best practices information.

5.1.1 Measurement of Recharge and Sources of TDS, Cl^- and NO_3

Recharge to the basin both replenishes water supplies and introduces TDS, Cl^- and NO_3 into the hydraulic system. Recharge to the hydrologic system occurs from three sources:

- Rainfall
- Surface recharge (from streams flowing into the valley)
- Imported water

In addition, TDS, Cl^- and NO_3 are added as water softener discharge and as a result of fertilizer use. TDS, Cl^- and NO_3 are concentrated as water is used for urban, industrial and agricultural purposes.

Rainfall has been measured at two locations in the valley since 1900. Rainfall records are on file with the Santa Barbara County Flood Control and Water Conservation District (SBCFCD) and have been evaluated by that agency as a basis for drainage facility designs. Rainfall records are complete and provide daily measurements.

Surface water flows are derived from runoff and flow into the valley from surrounding watersheds including the Cuyama and Sisquoc rivers. The movement of water through the Valley hydrologic system is currently measured by stream gages in four locations. These are important measurements as there is significant variation in rainfall, which causes extreme ranges of stream flow. Surface flow measurements are used to describe elements of surface hydrology in Luhdorff and Scalmanini, 2012. In addition, two gages on the Santa Maria River and gages on five tributary streams are no longer operated, but past records provides insight regarding stream flow during non-measurement periods. This data was also used to predict runoff from drainages with no gage data but similar land uses.

Data from gaging has been used to estimate the recharge form certain streams. Stream gage information has been collected by the USGS, the SBCFCD and through occasional estimates by RWQCB and Central Coast Water Quality Preservation, Inc. (CCWQP). Stream gage data collected on the Cuyama River (as releases from Twitchell Reservoir), Sisquoc River, and Santa Maria River provide the basis for estimating the volume of recharge from unregulated flow and from releases from Twitchell Reservoir. These data have been collected for many years and are reliable. Gaging is the basis for estimates of annual recharge from surface flow. However, water quality data for these sources of recharge has been collected intermittently. Data collected indicates a range of TDS, Cl^- and NO_3 depending on season and level of flow. Data used in the analysis relied on averages of reported water quality and applied to annual flow.

Water quality data on smaller streams flowing in the Valley is contained in studies by the USGS and has been collected by CCWQP and RWQCB. No systematic measurements of flow in smaller streams are available, but the SBCFCD has measured depth of flow in discharge from the Green Canyon Watershed since 2006. From this limited data, rough estimates of annual flow were made. This data relates to discharge since recharge in smaller watersheds is generally due to direct infiltration of precipitation.

In the most northwesterly portion of the valley, several locations along Oso Flaco Creek and Orcutt-Solomon Creek are monitored for water quality monthly by the CCWQP. Flow velocity is estimated when water quality samples are collected, but the stream channel conditions are not generally conducive to accurate calculations of flow volume. In addition, this flow is generally discharged from shallow groundwater and does not contribute to recharge by surface streams.

5.1.2 Groundwater measurements and movement of TDS, Cl^- and NO_3

Groundwater levels and water quality are measured regularly at a number of points throughout the Valley (Luhdorff and Scalmanini, 2012). As many as 149 potential monitoring wells exist in the Valley; water quality information is currently measured in 14 wells. Existing groundwater monitoring wells that are included in the Annual Report for the Santa Maria Basin (Luhdorff and Scalmanini, 2012) are separated into two well networks; wells to monitor shallow groundwater and wells to monitor deep groundwater. Figures showing the shallow and deep well networks are included in Section 2 as Figures 2a and 2b (figures 2a and 2b in this assessment are the same as Figures 2a and 2b of the Annual Report prepared by Luhdorff and Scalmanini, 2012). At this time, four shallow wells and 10 deep wells are actively monitored for water quality.

With the exception of wells along the coast that were installed to monitor potential sea water intrusion and wells for water quality monitoring at the land fill and WWTPs, the other wells for which data were available were not constructed specifically for data collection. These wells serve other purposes such as agricultural and municipal production. However, water level, production, and water quality measurement data from municipal supply wells has been detailed enabling the calculation of the amount of TDS, Cl^- and NO_3 produced for urban use.

The data collected from irrigation production wells can be used only for estimates of water quality due to lack of available pumping records and only intermittent water quality testing. In addition, these wells typically are not equipped to allow sampling of individual aquifer zones. In the analysis reported in Section 3, values of water quality were averaged from wells of known depth and used with estimates of applied water as a basis for calculating volumes of TDS, Cl^- and NO_3 removed from the groundwater by agricultural pumping. Applied water was estimated from published crop data and surveys of land use which identify crop types and acreages. Applied water estimates were used to develop volumes of water pumped for agricultural use.

Spot measurements of agricultural drain flows made during water quality sampling by CCWQP and the CCRWQCB were used to estimate volumes of TDS, Cl^- and NO_3 discharged from shallow groundwater. Variation in water table elevation during wet periods will cause changes in drainage volume and subsurface transport so that salt and nutrients are discharged from shallow groundwater into surface drainages at varying rates. Since this flow is discharged from shallow groundwater, it was considered to contribute to recharge by surface streams.

Existing drain and surface water flow measurements and water quality measurements provide an estimate of load discharging out of the groundwater basin. However, these measurements do not extend throughout the 10-year analysis periods and therefore do not capture changes that may have occurred due to changes in management practices.

5.1.3 Measurements of TDS, Cl^- and NO_3 Discharge

Discharge of water from the basin is an essential mechanism for removing salt and nutrient from the basin. Discharge of water occurs through four basic mechanisms:

- Subsurface discharge through aquifer zones that extend beneath the ocean
- Surface flow from collection systems that receive agricultural drain water and surface runoff
- Natural surface flow (including runoff from urban and agricultural lands) in streams and the Santa Maria River
- Discharge through the Laguna County Sanitation District deep injection well.

Subsurface discharge to the ocean has been estimated from well data by the USGS and California Department of Water Resources (DWR) and is based on a groundwater gradient and a hypothetical cross-section of the Santa Maria Groundwater basin aquifer at the shoreline through the USGS coastal wells (Miller and Evanson 1966; DWR 2002). The accuracy of these estimates is constrained by a limited understanding of hydraulic characteristics of subsurface materials used in calculation of subsurface discharge. Water quality samples from these wells at various depths allow estimation of transport of TDS, Cl^-, and NO_3 from the groundwater basin as underflow and discharge to the ocean.

Surface flow from discharge of agricultural drains is discussed in the previous section. Other shallow discharges in the Valley vary as a function of rainfall and location. Estimates used in the analysis are based on occasional measurements of surface flow made during water quality sampling. Therefore, the variation of flow is not well documented. Since 2005, some monthly sampling of drainages has occurred through the Cooperative Management Program operated by CCWQP. Measurements made in high flow conditions provide some support for estimates of wet condition discharge. Flow and water quality measurements were combined to estimate average annual discharge of water as well as TDS, Cl^- and NO_3 from the drains. Discharge from drains was assumed to be transported from the basin.

In addition to the flow measurements made by CCWQP, stage measurements made in Green Canyon by the SBCFCD were converted into flow measurements using standard formulas for concrete structures of similar profile. This flow was prorated for two other, similar, watersheds (Bradley and Blosser drainages). Flows over 1 cfs in each drainage were considered to flow from the basin transporting TDS, Cl^- and NO_3. Volume of flow over 1 cfs and average water quality was used to estimate the volume of TDS, Cl^- and NO_3 discharged by this mechanism.

Surface flow is actively measured at Twitchell Reservoir (as reservoir releases) and four other stream gages in the basin by the USGS and FCD; two inactive gages are planned to be reestablished. Measurements in locations with good control are within typical accuracy for surface flow measurements. Other locations, such as the lower Santa Maria River have poorly defined channel geometry and thus flow is not presently gaged.

Discharge to the lower Cuyama River from Twitchell Reservoir is measured by the operator, the SMVWCD. During periods when releases are made, virtually all flow in the lower Cuyama River is from the reservoir. Measurement of releases has been standard operating procedure since the Reservoir was completed in 1958. Water quality measurements from reservoir discharges of Cuyama River flow have been taken only in the last few years. The available data were combined with measurements of releases for groundwater recharge to estimate TDS, Cl^- and NO_3 loading to the ground water basin.

Discharge of brine to the deep injection well by the LCSD is measured as a condition of operation of the WWTP. The data from those measurements are complete and provide an accurate measure of salt discharged from the basin through deep injection since 2003.

TDS, Cl^- and NO_3 in the groundwater are measured by several interests including public water suppliers and the USGS. The data summarized as part of the Annual Report (Luhdorff and Scalmanini, 2012); TDS and NO_3 measurements are reported from 10 deep wells and 4 shallow wells. Samples at each sample point are from a single zone; no data are available to show vertical variation.

No unsaturated (vadose) zone measurements are reported in the Annual Report. Estimates of TDS, Cl^- and NO_3 in the vadose zone were utilized in the evaluation discussed in Section 3.

5.2 Applicability of Existing Data

This section discusses the adequacy of existing data as a basis to estimate the salt and nutrient balance in the Santa Maria Valley discussed in Section 3.

Volume measurements for sources

- Imported water (SWP supplies) is directly monitored and high-quality volumetric and water quality data collected, which allows for the accurate characterization of salt and nutrient inflow.

- Urban groundwater extractions for municipal use are directly monitored and high-quality volumetric and water quality data collected, which allows for the characterization of the salt and nutrient value in water extracted for municipal use.
- For agricultural groundwater extractions, only indirect estimates of volume, and no direct data on water quality, are available. A limited number of USGS sampling points were used to estimate quality of water produced for agricultural uses, but information on the zones developed was limited. Use of estimates and uncertain data introduces significant uncertainty into the analysis.
- Vadose zone conditions between the root zone and the top of the water table were not considered in the evaluation.
- The analysis in Section 3 was based on static conditions; no estimates of attenuation during transport were developed.

Water Quality Measurements for Sources

- Rainfall: No water quality measurements are presently made of precipitation. Generally speaking NO_3 and TDS levels of precipitation are low and may be considered negligible compared to other sources. Therefore, the lack of water quality measurement for rainfall does not significantly affect the analysis.
- Stream Flow: Most stream infiltration occurs during high flows in the Sisquoc River or releases from Twitchell Reservoir. Water quality samples are taken from lower Cuyama River twice a year (when flowing); few water quality measurements are taken of other stream flows on a regular basis. Thus, the existing data are not sufficient to fully characterize water quality of stream flow as a source of ground water recharge. Thus the stream flow infiltration estimates reflected in the analysis introduced uncertainty in sources of TDS and NO_3 from surface flow.
- Groundwater Extractions: Complete high-quality water quality data extracted for municipal use allows characterization of salt and nutrient in water extracted. No direct data on quality of water extracted in agricultural areas is readily available except at a limited number of USGS sampling points which introduces significant uncertainty in estimating the volume of TDS, Cl^- and NO_3 in groundwater being pumped and applied for irrigation purposes. Since agricultural pumping is the largest source of extraction and water use in the valley, the uncertainty in the water quality information is directly reflected in uncertainty in the overall estimates in the analysis.
- Imported Water (SWP supplies): Complete, high-quality water quality data allows characterization of salt and nutrient imported through SWP deliveries.

Transport Mechanism

- Groundwater Movement: The volumes of TDS, Cl^- and NO_3 in transport within aquifers were not used in the analysis and no estimates were developed. Information on thickness and gradient is available in previous reports at a regional scale. However, no data are available with which to characterize changes in TDS, Cl- and NO_3 at depth and therefore data are not adequate for detailed estimates needed to calculate amount of salt and nutrient being transported within the groundwater basin. Since volumes in transport were not a factor in the analysis, any lack of information did not significantly affect the analysis..

Sinks and Fates

- Discharge to Deep Wells: The discharge of brine to a deep injection well by LCSD is well documented through reports to permitting agencies. Thus estimates of discharge of TDS through brine discharge used in the analysis are considered reliable.
- Subsurface Groundwater Flow: The migration of groundwater beneath the coastal area may be estimated by local gradient calculations and the volume of salt and nutrient transported from the basin may be estimated based on water quality measurements from the coastal piezometers. Seasonal variation in water quality in the piezometers appears adequately documented through biannual measurements. However, variation along the shoreline is not well documented given there are only two piezometer clusters and there appears to be variation in nutrient level measured at the two locations.
- Surface Discharge from Field Drains: Some monthly measurements, conducted by CCWQP through the Cooperative Monitoring Program, may represent a composite sample of surface discharge of field drainage and subsurface drainage collected by surface drains.

Assimilative Capacity

- No estimates of assimilative capacity were made as part of the analysis in Section 3.

5.3 Gaps Analysis and Uncertainties

In this section, the existing monitoring system is evaluated, focusing on its ability to define sources, fate and changes of salts and nutrients in the analysis of the hydrologic system discussed in Section 3. Several important points underlie this gaps analysis. Previous sections have described a westward groundwater gradient and significant subsurface discharge to the ocean. Groundwater flow rates have been estimated by the USGS to be less than a few hundred feet per year. In addition, this report (Section 3, Figure 3-2) and others (Luhdorff and Scalmanini, 2012) note increases in NO_3 in monitoring wells in several areas of the Valley, particularly the western portions.

Other sections of this report outline changes in management techniques that reduce loading of nutrients to the basin. However, the existing monitoring shown in Figure 3-2 indicates continued increase or no reduction in NO_3 in all groundwater measured within the study area. This suggests that benefits from reduced NO_3 loading require many years to manifest themselves at existing measurement points.

5.3.1 Well Location, Construction and Hydrogeologic Characteristics

Vertical and horizontal locational information of all monitoring wells is good. Well head location and elevation of all monitoring wells has been established by GPS and/or surveying. However, 29 of the monitoring wells are "unclassified" as to depth of production zone. They are therefore not assigned to the shallow or deep monitoring well network due to inadequate documentation of production zones or vertical extent of filter pack material. In addition, some wells sampled may be completed in both confined and unconfined horizons. Because the water level elevation in confined and unconfined zones may be at different levels, water level data from multiple completion wells is not easily interpreted and water quality data from the well cannot be ascribed to a particular level in the aquifer system.

The location of existing monitoring wells provides uneven and sparse coverage of key areas in the eastern basin. In particular, effects of NO_3 in that area is not well documented. In addition, recharge along the Santa Maria River is not well documented.

Documentation of geologic materials encountered during well construction is inconsistent. The records of the coastal piezometers detail variation in geologic materials and the relationship to screened intervals. In most other wells used for monitoring, little or no reliable information on subsurface materials is available.

5.3.2 Areal Distribution of Ground Water Measurements

The areal distribution of groundwater measurements was sufficient to generally define the regional water table and surface gradients. However, existing measurements were not adequate to define the vertical and horizontal distribution of salt and nutrients within the basin. Currently, water level elevation is measured in 91 wells on an annual or semiannual basis while in a subset of those wells, 26 wells, water levels are made quarterly or semi-annually. Spring measurements are in March or April (before the irrigation season). Additional measurements are made in the fall, after the end of the most intense irrigation season. Some wells, such as those in or near the municipal well fields, are measured more frequently.

Of the 149 potential water level monitoring wells in the basin, 79 wells could be locations for monitoring water quality (37 shallow, 38 deep, and four unclassified). Water quality information was available from 14 wells, four of which are reported as shallow wells.

The location of existing monitoring wells provides uneven and sparse coverage of key areas in the eastern basin. In particular, lack of monitoring wells means that ground water quality in that area is not well documented.

A significant number of unused wells in the western portion of the Valley may be completed in both the upper and lower zones of the aquifer. These wells may allow flow between the upper and lower aquifer zones. The effect of these wells on water level and migration of NO_3 is not understood. Although data from shallow or deep wells was assumed to represent only the designated level, this distinction may or may not be important throughout westernmost portions of the Valley.

5.3.3 Characteristics of Subsurface Discharge to the Ocean

Variation of the horizontal extent and permeability of the zone discharging to the ocean is not well defined. Simplifying assumptions underlie the indirect methods used to estimate rate of discharge. In addition, horizontal variation of nutrient and salt levels along the shoreline is documented but not well defined. Only two piezometer clusters are monitored and there appears to be vertical variation in nutrient level at each location and variation between the two locations. The Annual Report (Luhdorff and Scalmanini, 2012), points out that the deep aquifer zone at the northerly monitoring well has shown gradually increasing levels of nitrate up to the present. In contrast, in all aquifer zones near the southerly monitoring well set, the groundwater has consistently shown very low concentrations of nitrates through the present. These variations suggest uncertainty in estimates of discharge of TDS, Cl^- and NO_3 from the basin through the discharge path to the ocean developed in the analysis in Section 3.

5.3.4 Vertical Stratification of TDS and NO_3 in the Subsurface

Wells currently sampled for water quality are characterized as “deep,” “shallow” or “unknown.” However, these wells are spaced a considerable distance apart, thus only a coarse characterization of vertical groundwater quality, in the most general sense, is possible at the present time. Information is not readily available in the agricultural areas to characterize vertical variation of water quality within the aquifer zones developed as water sources. However, preliminary data provided from the City of Santa Maria suggests that in some areas NO_3 levels in ground-water may be significantly higher in the upper levels of the aquifer compared to lower zones. If this is the case, wells may be constructed and operated to take advantage of high or low NO_3 levels to meet water user preferences and needs.

5.3.5 Surface Water Measurements

Measurement of flow and water quality in surface streams in the Santa Maria Valley is a challenge due to the extremes of rainfall and streambed characteristics. The costs associated with surmounting these challenges and installing effective monitoring have resulted in-stream monitoring focused on the needs of the entity performing the monitoring. Specific challenges in surface water monitoring include:

1. Variation in surface flow due to seasonal/annual variation in rainfall
2. Variation in flow along stream courses due to infiltration
3. Lack of gaging station control (cross section)
4. Gages in need of being reestablished
5. Interpretation of surface drainage sampling to represent groundwater discharge.

Both substantial uncertainties and significant gaps exist in flow and water quality measurements used in the analysis in Section 3. As a result, the analysis and any conclusions drawn from it should be regarded as general in nature.

5.4 Conclusions

5.4.1 Salt and Nutrient Input Data

Inputs are sources of salt and nutrient that contribute to the hydrologic system including rainfall, recharge from Twitchell Reservoir, importation of water from the SWP, and applied fertilizer. The inputs include infiltration from other surface streams and applied irrigation water.

1. Inflow of water to the basin from sources including rainfall, Twitchell Reservoir releases and SWP deliveries is well documented for the analysis period. The data available for calculation of inputs to the conceptual model balance estimates are well defined and detailed.
2. Salt (TDS) loading data for imported SWP water and infiltration of treated sewage effluent is well documented for the analysis period. (This includes sources such as water softeners.) The data available for calculation of inputs to the conceptual model balance estimates are well defined and detailed.
3. Nitrogen (NO_3) loading data for imported SWP water and infiltration of treated sewage effluent is well documented for the analysis period. The data available for calculation of inputs to the conceptual model balance estimates are well defined and detailed.
4. Water quality data from Twitchell Reservoir releases is sparse for the analysis period. TDS and NO_3 data available for calculation of inputs from Twitchell Reservoir to the conceptual model balance estimates lack precision.
5. Streamflow and infiltration data from natural streamflow has been collected intermittently at several sites for the analysis period and generally lacks precision due to the physical characteristics of the measuring points and lack of continuity. TDS and NO_3 data available for calculation of inputs to the conceptual model balance estimates lack precision.
6. Water quality data from natural stream flow has been collected intermittently at several sites for the analysis period and generally lacks precision due to lack of time series data. TDS and NO_3 data available for calculation of inputs to the conceptual model balance estimates lack precision.
7. Irrigation production data for the analysis period were obtained from the Annual Report Luhdorff and Scalmanini (2012). The data were based on cropping information and not actual pumping or electrical use records. These estimates have some basis but there has been no evaluation of their precision.
8. Water quality data for water used for irrigation was not available for the analysis period; water quality was estimated from groundwater quality measurements made at existing monitoring wells. Source zones (aquifer zones sampled) for approximately

30% of the wells are not known. The correspondence between agricultural production zones and the zones represented by monitoring wells is not well documented. TDS and Nitrogen (NO_3) data available for calculation of irrigation water inputs to the conceptual model balance estimates lack precision.

9. Nitrogen application for the analysis period is estimated from NRCS and UCCE guidance materials and anecdotal evidence regarding management practices; no direct data on fertilizer use is available for this analysis. Transformation of the various forms of N to NO_3 was estimated based on academic research. Nitrogen (NO_3) data available for calculation of applied fertilizer inputs to the conceptual model balance estimates lack precision.

5.4.2 Salt and Nutrient Output Data

Outputs are elements of the hydrologic system and other mechanisms that remove salt and nutrient from the Santa Maria Valley. They include stream flow to the ocean, groundwater flow (underflow) to the west beneath the coast, crop material removed at harvest.

10. Streamflow and discharge to streams has been collected intermittently at several sites and generally lacks precision due to the physical characteristics of the measuring points. TDS and Nitrogen (NO_3) data available for calculation of values used in the conceptual model balance estimates lack precision.
11. Subsurface discharge of water is estimated from gradient data developed from 6 deep wells and 3 shallow wells in the western portion of the valley. Other data (permeability and depth of the aquifer) are based on two piezometer clusters near the ocean spaced 1.5 miles apart. Estimates of subsurface discharge have some basis but there has been no evaluation of their accuracy.
12. Subsurface discharge of TDS, Cl^- and NO_3 are estimated from water quality data collected intermittently at two piezometer clusters near the ocean spaced 1.5 miles apart. Estimates of subsurface water quality have some basis. Volume of discharge of TDS, Cl^- and Nitrogen (NO_3) data available as inputs to the conceptual model balance estimates have some basis but there has been no evaluation of their accuracy.
13. TDS, Cl^- and NO_3 in plant material removed at harvest are estimated from agricultural land use, simplifying assumptions for each crop type, NRCS and UCCE guidance materials, and anecdotal evidence regarding soil management practices; no direct data on TDS, Cl^- and NO_3 in plant material removed at harvest was readily available for this analysis.

5.5 Monitoring Recommendations

As discussed in Section 2 of this report, several entities monitor one or more of the following: surface flow, groundwater levels and water quality. These entities include the USGS, the RWQCB, the County of Santa Barbara, Twitchell Management Authority (TMA), and other parties (such as CCWQP). In accordance with the terms of the Settlement

Agreement and Order, the TMA manages a hydrologic monitoring program in the Santa Maria Valley. The original monitoring program has been recently expanded to include a CIMIS station (detailed climate conditions) at the Santa Maria Airport, biannual water quality measurements in the Cuyama River and expanded water level measurement in existing monitoring wells. Additional monitoring will be considered by the Twitchell Management Authority as part of development of their annual budget. This additional data collection is focused on the ongoing requirements of the Court and may or may not pertain to salt and nutrient management.

Recommendation 1: Continue to collect data under existing and newly expanded monitoring programs so that groundwater basin water quality and levels conditions can be reassessed in the future.

Recommendation 2: Periodic samples should be taken to document water quality of Twitchell Reservoir releases. The water quality benefits of releases from Twitchell Reservoir for groundwater recharge are not well documented. These releases appear to improve water quality in areas between the confluence of the Sisquoc and Cuyama Rivers and the Bonita School Road crossing west of the City of Santa Maria. This data will be used along with ground water monitoring to confirm the benefits.

Recommendation 3: Install transducers on northern perimeter wells. Groundwater movement at the boundaries of the study area is a key component to understanding the transport of salts and nutrients and the volume of water in the basin. Transducers provide regular level data to better understand seasonal trends.

Recommendation 4: An additional monitoring well is recommended to be installed in the northern portion of the City of Santa Maria in order to have a more comprehensive understanding of water level and quality in the northern portion of the aquifer Depending on the water quality and geologic materials encountered during drilling, consideration should be given to installation of piezometers rather that completion of the well at a single level.

Recommendation 5: The Green Canyon watershed gage should be rated (for depth vs. flow) and storm water samples collected. Information gathered should be used to evaluate the utility of using the watershed as a basis for estimating salt and nutrient movement from tributary watersheds.

Implementation of these recommendations and any other monitoring should be based on a clear understanding of the purpose and utility of data collected. Data collected should rely on proven and cost effective techniques and applied in defensible and meaningful ways.

6 Summary and Conclusions

This report addresses Total Dissolved Solids (TDS), Chloride (Cl^-) and Nitrate (NO_3) as indicators of salt and nutrient conditions in the Santa Maria Valley. The evaluation focused on conceptual model "snapshots" of 1990, 2000 and 2010 and was based on available information. The main conclusions are listed below.

6.1 Monitoring

- Available existing data provides basis for coarse estimates TDS, Cl^- and NO_3 balance in the Santa Maria Valley area.
- Current monitoring was established to address water management issues and water quality issues in relation to beneficial uses in the basin.
- Existing monitoring characterizes quantity and quality of imported (SWP) supplies and discharged waste water treatment throughout the analysis period.
- Monitoring of the smaller steams and agricultural drains improved during the analysis period.
- The available data are not temporally and spatially sufficient to document effectiveness of past and ongoing salt and nutrient management.
- Salt and nutrients discharged to the basin surface and groundwater by agricultural uses may be better understood in the future by monitoring under the proposed Ag Waiver.

6.2 Sources, Transport and Fate of Salt and Nutrient

- TDS and Cl^- sources include surface water, imported (SWP) water, water softeners, and naturally occurring geologic contributions
- NO_3 sources include municipal waste streams and fertilizer use (for both agriculture and landscaping)
- Significant reduction in NO_3 loading has occurred in the past 20 years due to improved nutrient management.
- Salt and Cl^- loading appears to have decreased in since 2000
- Salts and nutrients are transported by both surface- and groundwater.
- Salts and nutrients are transported from the valley by both surface and subsurface flow.

6.3 Water Quality Trends

- TDS and Cl^- have increased only modestly in monitoring wells along the coast.

- NO_3 levels have increased substantially in shallow wells, particularly in the western portion of the Valley.
- NO_3 levels began increasing in coastal monitoring wells in the mid to late 1980's, suggesting slow response to fertilizer use that has occurred for decades.
- Water quality trends in monitoring wells at the coast do not yet reflect reductions in NO_3 loading that appear to have begun in the 1990's.

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Appendix A

Scope of Work

03/02/2012

Scope of Work

Various water uses within the Santa Maria Valley have an interest in groundwater quality. These interests have formed a Working Group to guide development of a ground water assessment report to support a Salt Nutrient Plan. The Working Group may form a technical advisory committee (TAC). A consultant will assist in development of the report. In addition, the group will be responsible for guiding collaboration with local organizations and public agencies, as well as the public. The report will be based on existing hydrologic information and water quality data available through the working group and public agencies. A budget of $130,000 has been established for consultant services to assist in the work.

Task 1 Establish Collaborative Process

Task 1.1 Develop a Collaborative Process for Discussion

The outcome of this task will be the establishment of a Working Group for guiding the development of the ground water assessment. The working Group will be within the framework on the Santa Barbara County Integrated Regional Water Management Planning process. The consultant will maintain the contact list for working group, the technical committee, and other stakeholders in the watershed and will coordinate all workshops and distribution of meeting notifications and deliverables. If the Working Group establishes sub-groups or a TAC (based on working knowledge and expertise) to focus on specific issues, the consultant will work with that sub-group or TAC within this scope of work.

The Consultant will attend all Working Group meetings and will facilitate communication between the Working Group, the technical advisory committee, and the Consultant.

Task 1.2 Conduct Salt/Nutrient Meetings for Working Group

Under this task, two initial working group meetings will be conducted. The goal of the meetings will be to discuss the following:

- Organization and Function of the Working Group
- Defining and gaining consensus on the water quality problems and issues to be addressed
- Goals of the Groundwater Assessment Report
- Approach and the process for the development Groundwater Assessment Report
- Agency Coordination
- Data needs and data sources (including TMA, CCRWQCB, USGS, DHS)
- Access to data sources

- Process to assure consistency with emerging Regional Water Quality Control Board (RWQCB) guidelines
- Elements of the Groundwater Assessment
- Finalize the Scope of Work to develop the Groundwater Assessment Report

Deliverables:
One working group meeting covering: the purpose of the assessment, the process, and stakeholders roles and responsibilities. Written deliverables include a written summary of the Working Group meeting, final Scope of Work and a draft Word document covering the Introduction section of the Groundwater Assessment Report and a working outline of the report, due one month after the working group meeting required under this task.

Task 2 Gather Data and Develop Data Management Tool

Data regarding the occurrence, use, and quality of local water supplies are extensive. For example, recent efforts by the Twitchell Management Authority (TMA) have resulted in collection of relevant water supply information throughout the basin and development of a spatially oriented database management system (geographic information system or GIS). This Scope of Work assumes the specially oriented data base developed by TMA will be made available as a platform for evaluating ground water hydrology as adding water quality data. In addition, the Central Coast Regional Water Quality Control Board (CCRWQCB) has developed monitoring data and conceptual elements of dissolved solids transport within the basin. Development of the Groundwater Assessment Report will rely on these and other readily available existing data. The following sub-tasks will be conducted under this task:

Task 2.1 Conceptual Model Discussion

Under this task, one working group meeting will be conducted. The goal of the working group meeting is to discuss the following:

- Consensus by the stakeholders on the identity of inputs (sources) and outputs (transport and fate) of water, sodium, chloride, and nitrogen to the groundwater basin on a global (basin wide) basis.

Task 2.2 Review/summarize RWQCB Regulations

A review existing regulations and summary of past and ongoing evaluations of salt and nutrient sources and transport by CCRWQCB will be prepared.

Task 2.3 Identify Constituents and other Data Needs

For purposes of this scope, three constituents (sodium, chloride, and nitrate) will be considered. Data necessary to describe inputs and outputs will be identified.

Task 2.4 Gather Data

Consolidate data from sources identified in Task 1.2 `and identify data needs for analysis identified in Tasks 1.2 and 2.1. Data needed to fill gaps will be identified and requests for additional data made of potential sources. Where available, complete chemical data plotted in Stiff diagrams or trilinear plots or will be reviewed to identify long term changes in water chemistry.

Task 2.5 Data Management Protocol and Develop GIS Themes

Data from Tasks 2.3 and 2.4 will be compared to the data base used by TMA for development of Annual Reports for potential incorporation into existing GIS "themes" or layers for the groundwater basin. Base GIS map layers, templates and themes will be provided by TMA. The use of an existing GIS framework for its utility as a basis for development of the Ground Water Assessment Report will be explored. Example data maps and visualizations produced from other studies will be reviewed with cooperation of the work group. As appropriate, the GIS will be augmented with additional themes (information layers) of readily available and appropriately formatted data provided by TMA. The resulting body of information will be evaluated in Task 2.6 and later in conjunction with Task 3, to identify any gaps in gathered data that would be necessary to complete the Groundwater Assessment Report.

Task 2.6 Summarize and Evaluate Data, and Identify Gaps (in conjunction with Task 3)

The gathered data and information will be summarized in a draft section of the Assessment Report addressing data and data management. This will be an inventory and presentation of the existing and known data and data sources presenting where data is or has been collected (spatial) and when and for what periods the data is available (temporal). The documentation of publicly available data is an important step. The study will use all data made available to provide the basis for subsequent analysis. The inventory of available data will be circulated to the Work Group and ensure all the data is used for purposes of the study. The draft section will be further refined in conjunction with Task 3, in which any needs for additional data in support of development of the Groundwater Assessment Report will be outlined.

Deliverable: A draft Word document covering the current monitoring and data collection section of the Groundwater Assessment Report, due one month after the working group meeting required under this task.

Task 3 Assess Elements of the Ground Water Basin

Extensive evaluation of the Santa Maria groundwater basin has occurred by both public agencies and private interests. Elements of the groundwater basin will be assessed based on those previous evaluations made available through the working group and public agencies.

Task 3.1 Describe Basin Characteristics

Data gathered in the previous task will be used to describe the basin characteristics. The characterization will include the following:

- Climate
- Geology
- Hydrogeology/hydrology (e.g., flow characteristics, aquifer characteristics)
- Existing/background groundwater and surface water quality and quantity conditions
- Land cover and land use evaluation/mapping
- Beneficial uses
- Recharge areas
- Range of groundwater storage conditions.

The characterization will rely on existing information readily available from sources identified by the Working Group and public agencies.

Task 3.2 Describe Current Management

This task will include the following components:

- Facility locations (including NPDES permitted discharges)
- An initial overview of the irrigation, stormwater control, and other land use practices in the watershed.
    - This task may be expanded in the next phases of the Plan. Information presented in the Santa Maria Groundwater Basin Report (2008 SMVMA Annual Report) will be used for developing a preliminary assessment of the watershed.

Task 3.3 Conduct Preliminary Basin Analysis

The Santa Maria Groundwater Basin has been subject to extensive evaluation by various interests for water supply and water quality management. Based on this previous work and available data, an assessment of the basin and its hydrologic function will be developed. The following tasks will be accomplished:

- Preliminary water balance based on TMA evaluations
- Identification of sources of sodium, chloride, and nitrate
- Storage/available storage volume
    - Changes/range in recharge
    - Minimum and maximum storage

- Change in losses (migration from the basin)

The groundwater assessment will address the following:

- Development of a shared understanding of the local hydrologic conditions including the mechanisms for salt/nutrient transport.
- Testing of adequacy of existing data to support a complete description of the local hydrologic system
- Identification of gaps in existing information that inhibit understanding of basin functioning for salt and nutrient transport and assimilation.
- An informational foundation for eventual numeric modeling of alternative management strategies.

The ground water assessment will be developed in stages and will be subject to public review. Two meetings will be conducted to review the water and sodium, chloride, and nitrate balance. The results of the Task 3 evaluation will be incorporated into the Groundwater Assessment Report

The monitoring section of the groundwater assessment report prepared under Task 2 will be updated to identify data gaps and needs identified during the evaluation process from this task.

Task 3.4 Review by Working Group (and TAC)

The Working Group will be provided with 4 weeks to review the draft descriptions of Elements of the Ground Water Basin and its management. Based on the review of the working Group, the draft Elements will be revised for inclusion in the Groundwater Assessment Report prepared in Task 4.

Task 3.5 Update data gaps and needs

Data available for preparation of the draft Elements of the groundwater Assessment Report will be reviewed for relevance and to the extent that data gaps are identified, a discussion of data needs and potential methods to meet those needs will be prepared as a revised monitoring section of the groundwater assessment report prepared under Task 2.

Deliverables:
Results of these tasks will be discussed in one working group meeting scheduled at least three weeks after the draft Elements are available to the working Group. The documents will be provided as Word documents covering the basin characteristics, groundwater inventory, basin water quality and basin evaluation portions of the Assessment Report. In addition, a revised Monitoring Section summarizing data gaps and ways to address the data needs will be prepared.

Task 4 Develop Groundwater Assessment Report

Task 4.1 Develop Groundwater Assessment Report

Based on the results of Tasks 2 through 3, a report will be prepared to summarize the characteristics of the basin, including salt/nutrient inputs and outputs (sources, transport and fate), present the draft goals and objectives, make recommendations to augment ongoing monitoring, and outline the next steps for development and implementation of a Salt Nutrient Plan. The draft report will be sent for stakeholder review. One meeting will be held to review the draft report. Comments from the committees and stakeholder will be addressed, and the report will be revised.

Deliverable:
One meeting will be conducted on the draft Groundwater Assessment Report. A revised report will be prepared based on input from the stakeholders. The revised report will be submitted in a Word file format. The working Group will be provided one set of conformed and non-conflicting comments. Changes to the draft report will be made based on agreed upon responses to comments to produce the final Groundwater Assessment Report.

Task 5 Develop a Technical Memorandum with Potential Goals and Objectives

The Working Group will formulate a process to develop goals and objectives as a separate Technical Memorandum to the Working Group. This process will be based on the review of existing data (Task 2) and development of shared understanding of salt and nutrient transport and fate (Task 3) and the conclusions of the Groundwater Assessment Report (Task 4). It is expected that the working group will address both institutional and quantitative goals and objectives. Examples of issues the working group may choose to address are listed in Tasks 3.1, 3.2 and 3.3.

Task 5.1 Develop Institutional Goals and Local Objectives

The overall goal of this task is to develop institutional goals and local objectives for a Salt Nutrient Plan based on input from the local stakeholders. Topics to be addressed in this task may include:

- Institutional controls and decision making
- Management practices
- Water quality monitoring

Task 5.2 Develop Quantitative Goals and Local Objectives

The purpose of this task is to facilitate discussions among local agencies to develop broad goals and quantitative local objectives for the Technical Memorandum. The local objectives are established to support the region in measuring and tracking progress towards meeting the broader goals. Topics that may be considered for this task include:

- Means of addressing local objectives for water quality
- Groundwater elevation limits
- Groundwater storage objectives (use, volume)
- Control of sub-surface discharge to the ocean
- Limitations on banked water withdrawal rate and storage

Deliverable:
One meeting with the working group to review conclusions of the groundwater basin assessment focusing on whether it is getting better or worse in terms of individual constituents. At that meeting the working group will finalize the draft goals and objectives to be incorporated into the Task 5 Technical Memorandum

Task 6 Project Management

Monthly progress reports and invoices will be prepared. In addition, up to four phone calls will be held with the IRWM Steering Committee to review progress and provide input and coordination for the project.

Appendix B

Suggested Elements of a Salt and Nutrient Management Plan

DRAFT
SALT/NUTRIENT MANAGEMENT PLANS
— SUGGESTED ELEMENTS —

I. BACKGROUND

• Purpose
  • Protection of Beneficial Use
  • Sustainability of Water Resources
  • Problem Statement
• Salt/Nutrient Management Objectives
• Regulatory Framework
• Groundwater Beneficial Uses
• ***Stakeholder Roles and Responsibilities***
• Process to Develop Salt/Nutrient Management Plan

II. GROUNDWATER BASIN CHARATERISTICS
1. GROUNDWATER BASIN OVERVIEW
• Physiographic Description • Groundwater Basin and/or Sub-Basin Boundaries • Watershed Boundaries • Geology • Hydrogeology/Hydrology • Aquifers • Recharge Areas • Hydrologic Areas Tributary to the Groundwater Basin • Climate • Land Cover and Land Use • Water Sources
2. GROUNDWATER INVENTORY

• Groundwater Levels
  • Historical, Existing, Regional Changes
• Groundwater Storage
  • Historical, Existing, Changes
• Groundwater Production
  • Historical, Existing, Spatial and Temporal Changes, Safe Yield
• Groundwater Mixing and Movement
  • Subsurface Inflow/Outflow
  • Horizontal and Vertical Movement and Mixing

3. ***BASIN WATER QUALITY***

• ***Groundwater Quality***
  • Background, Historical, Existing
  • Water Quality Objectives
• Surface Water Quality
• Delivered Water Quality
• Imported Water Quality
• Recycled Water Quality

Bold = Required by the Recycled Water Policy

III. BASIN EVALUATION
1. WATER BALANCE
• Conceptual Model • Basin Inflow/Outflow • Groundwater, Surface Water, Imported Water, Water Transfers, Recycled Water Irrigation, Waste Water Discharges, Agricultural Runoff, Stormwater Runoff (Urban, Agriculture, Open Space), Precipitation • Infiltration, Evaporation, Evapotranspiration, Recharge, Surface Water and Groundwater Connectivity
2. ***SALT AND NUTRIENT BALANCE***
• Conceptual Model • ***Salt and Nutrient Source Identification*** • ***Salt and Nutrient Loading Estimates***   • Historical, Existing, Projected • Import/Export • ***Basin/Sub-Basin Assimilative Capacity for Salt and Nutrients*** • ***Fate and Transport of Salt and Nutrients***
3. ***CONSTITUENTS OF EMERGING CONCERNS (CECs)****
* - Requirements for monitoring CECs will be determined following State Water Board review of the CEC Advisory Panel's report due in June 2010. • Constituents • CEC Source Identification
4. PROJECTED WATER QUALITY
IV. SALT AND NUTRIENT MANAGEMENT STRATEGIES

• Load Reduction Goals
• Future Land Development and Use
• Salt/Nutrient Management Options
• Salt/Nutrient Management Strategies and Modeling
    • Management Strategy Model Results
    • Feasibility
    • Cost

V. BASIN MANAGEMENT PLAN ELEMENTS
1. GROUNDWATER MANAGEMENT GOALS
• Groundwater Management Goals • ***Recycled Water and Stormwater Use/Recharge Goals and Objectives***
2. ***BASIN MONITORING PROGRAMS***
• ***Identify Responsible Stakeholder(s) Implementing the Monitoring*** • Monitoring Program Goals • Sampling Locations • ***Water Quality Parameters*** • ***Sampling Frequency*** • Quality Assurance/Quality Control • Database Management

Bold = Required by the Recycled Water Policy

- Data Analysis and Reporting
- Groundwater Level Monitoring
- ***Basin Water Quality Monitoring***
- ***Groundwater Quality Monitoring***
  - ***Areas of Surface Water and Groundwater Connectivity***
  - ***Areas of Large Recycled Water Projects***
  - ***Recycled Water Recharge Areas***
- Surface Water Quality Monitoring
- Stormwater Monitoring
- Wastewater Discharge Monitoring
- Recycled Water Quality Monitoring
- Salt and Nutrient Source Loading Monitoring
- Other Constituents of Concern
- Water Balance Monitoring
  - Climatological Monitoring
  - Surface Water Flow Monitoring
  - Groundwater Production Monitoring

3. SALT AND NUTRIENT LOAD ALLOCATIONS

VI. ***CEQA ANALYSIS***

VII. ***ANTIDEGRADATION ANALYSIS***

VIII. PLAN IMPLEMENTATION

1. ***SALT AND NUTRIENT MANAGEMENT PROGRAM***

- Organizational Structure
- ***Stakeholder Responsibilities***
- ***Implementation Measures to Manage Salt and Nutrient Loading***
- Salt/Nutrient Management
  - Water Supply Quality
  - Regulations of Salt/Nutrients
  - Load Allocations
  - Salt and Nutrient Source Control
  - CEC Source Control
  - Site Specific Requirements
- Groundwater Resource Protection
- Additional Studies

2. PERIODIC REVIEW OF SALT/NUTRIENT MANAGEMENT PLAN

- Adaptive Management Plan
- Performance Measures
- Performance Evaluation

3. COST ANALYSIS

- CWC § 13141, "…prior to implementation of any agricultural water quality control program, an estimate of the total cost of such a program, together with an identification of potential sources of funding, shall be indicated in any regional water quality control plan."

4. IMPLEMENTATION SCHEDULE

Bold = Required by the Recycled Water Policy

5. PUBLIC HEARING AND ADOPTION

Bold = Required by the Recycled Water Policy

Appendix C

Salt and Nutrient Planning Working Group

Appendix C: Santa Barbara IRWM Plan 2013
Salt and Nutrient Planning Workgroup Planning Participants

#	Name	Agency/Organization
1	Bruce Wales	SYRWCD
2	Martin Wilder	County of SB - Laguna County Sanitation District
3	Julie Fallon	Cachuma Resource Conservation District
4	Claire Wineman	V.P, Grower-Shipper Association of SB & SCO Cos.
5	Richard Quant	Grower-Shipper Association of SB & SCO Cos.
6	Steve Kahn	City of Santa Maria
7	Lisa Long	City of Santa Maria
8	Ellen Pritchett	City of Santa Maria
9	Michael LeBrun	Nipomo CSD
10	Patrick Vowell	Golden State Water Company
11	Kenneth Petersen	Golden State Water Company
12	Kevin Peterson	RCD - Santa Barbara
13	Dennis Delzeit	City of Guadalupe, Contract Engineer
14	Shannon Sweeney	City of Santa Maria
15	Randy Sharer	Stakeholder/TMA (stipulated property owners rep)
16	Peter Meertens	RWQCB, Central Coast
17	Brad Newton	Consultant (Nipomo CSD)(SLO side)
18	Tom Gibbons	Santa Maria Valley WCD
19	Kevin Merrill	Santa Barbara County Farm Bureau (Mesa Vineyard Management)
20	Mike Weil	DWR Regional Service Rep
21	Ann Coats	Cachuma Resource Conservation District
22	Kathy Caldwell	RMC Water and Environment
23	Jane Gray	Dudek
24	Bret Stewart	County Water Agency
25	Matt Naftaly	County Water Agency
26	Rob Almy	GEI
27	Sam Schaefer	GEI
28	Aaron McWilliams	GEI

Appendix D

Fact sheet for Order R3-2012-0011 ("2012 Ag Order")

Fact Sheet

Frequently Asked Questions:

What is the Agricultural Order?

- The Agricultural Order (Order) is a Conditional Waiver of Waste Discharge Requirements for discharges from irrigated lands in the Central Coast Region. The Order number is R3-2012-0011.
- The Order is authorized by the California Porter-Cologne Water Quality Control Act and was adopted by the Central Coast Water Board on March 15, 2012. The Order is in effect for five-years unless modified by the Central Coast Water Board before it expires on March 15, 2017.
- The Order replaces a previous order which had been in effect since 2004.

Who is regulated by the Order?

- Similar to the previous order, the Order regulates both landowners and operators of irrigated lands where water is applied for producing commercial crops, from which runoff could affect water quality. Examples are land planted to row, vineyard, field and tree crops, commercial nurseries, nursery stock production, and some greenhouse operations.

How are growers regulated by the Order?

- Growers must enroll in the Order and pay fees. The fees are based on acres of irrigated agriculture.
- The Order is effective immediately but some conditions have completion or reporting dates months or years into the future.
- Growers are categorized in tiers, based on the risk their farm poses to ground and surface water. They must implement the conditions in the Order, according to the tier that applies to their farm. The conditions in the Order are listed after the words, “It is hereby ordered that:” on page 13 of the Order.
- Growers must implement the monitoring and reporting requirements in the Monitoring and Reporting Program, according to the tier that applies to their farm.
- Growers may indicate that their information is proprietary so the Water Board does not release that information to the public. The Water Code and other laws protect trade secrets from public disclosure.
- The Order scales the requirements based on threat to water quality, placing farms in one of three tiers. Farms that are lower threat are in either Tier 1 or Tier 2 (approximately 97% of all farms in the region) and have fewer requirements.

- Farms that are the highest risk to water quality and drinking water sources are in Tier 3, (approximately 3% of all farms) and have more requirements.
- The Order gives growers flexibility in choosing how to comply, and provides many alternatives to meet requirements. It encourages and provides incentives for cooperative water quality improvement efforts to reduce costs and maximize effectiveness.
- Growers who do not comply with the requirements of the Order may be subject to enforcement, consistent with the State's Enforcement Policy. The Water Board will use progressive enforcement, ranging from notices of violations or requests for information to financial penalties, as appropriate. Growers who meet reporting deadlines and implement management practices that reduce pollution loading will generally be in compliance.
- Summaries of requirements for each tier are included at the end of this Fact Sheet: Tier 1 (p.3), Tier 2 (p.4-5), and Tier 3 (p.6-8).

How does a grower enroll in the Order?

- Growers must enroll in the Order by submitting an electronic-Notice of Intent (eNOI), unless they have already done so. The eNOI and instructions are available on the Water Board's website at: http://www.waterboards.ca.gov/centralcoast/water_issues/programs/ag_waivers/noi_submittal.shtml

How does a grower know what tier their farm is in?

- Water Board staff have updated the eNOI so enrolled growers can see which tier their farms/ranches are in when they access their eNOI information on the Water Board's GeoTracker website using their username and password.
- **By May 15, 2012,** Water Board staff will notify enrolled growers of their tier by mail.

How can a grower and other stakeholders learn about the Order?

- **By May 15, 2012,** Water Board staff will distribute written information to growers, including a copy of the Order, a list of requirements for each tier, a five-year compliance calendar, a list of Water Board contacts, and a list of resources available to growers.
- **In May – July 2012,** Water Board staff will conduct workshops to inform growers of the new requirements.
- More detailed information about the requirements is available at: http://www.waterboards.ca.gov/centralcoast/water_issues/programs/ag_waivers/index.shtml
- For questions or to reach Water Board staff directly, individuals can contact the Water Board office at (805) 549-3147.

What do Tier 1 growers have to do to comply with the Order?

- **By May 15, 2012,** all Tier 1 growers that irrigate land to produce commercial crops must enroll in the Order by submitting an eNOI.
- **By October 1, 2012,** all Tier 1 growers that apply fertilizers, pesticides, fumigants or other chemicals through an irrigation system must have back flow prevention devices.
- **By October 1, 2012,** all Tier 1 growers must develop, implement and keep up to date a Farm Water Quality Management Plan (Farm Plan) that includes management practices, treatment or control measures related to irrigation efficiency, pesticide management, salinity management, nutrient management, sediment and erosion control and aquatic habitat protection.
- All Tier 1 growers must implement management practices to treat or control discharges and protect water quality.
- All Tier 1 growers must minimize bare dirt and prevent erosion.
- All Tier 1 growers must protect existing aquatic habitat next to their farms.
- Monitoring and Reporting-
  - **By September 15, 2012,** all Tier 1 growers must monitor the creeks and estuaries that may receive farm runoff. Growers can choose to participate in the existing Cooperative Monitoring Program (CMP) implemented by Central Coast Water Quality Preservation, Inc., or they can choose to monitor individually. Samples must be collected and analyzed for sediment and nutrients monthly, and pesticides, toxicity and metals quarterly. Results must be reported by January 1, 2013.
  - **By March 15, 2013,** all Tier 1 growers must sample the groundwater from the primary irrigation well and any drinking water well on their farm twice (in Sept/Oct 2012 and March 2013). Groundwater samples must be analyzed for nitrate and general minerals. Growers can also comply by submitting existing groundwater data and can also work with neighboring growers on cooperative groundwater monitoring. Results must be reported by October 1, 2013.
- Tier 1 Growers must comply with the above and all other Tier 1 conditions in the Order (pages 13-27) and the Tier 1 Monitoring and Reporting Program R3-2012-0011-01.
  - The Order is available on the Water Board's website at http://www.waterboards.ca.gov/centralcoast/water_issues/programs/ag_waivers/docs/ag_order/final_agorder_atta_032612.pdf
  - The Tier 1 Monitoring and Reporting Program R3-2012-0011-01 is available on the Water Board's website at http://www.waterboards.ca.gov/centralcoast/water_issues/programs/ag_waivers/docs/ag_order/final_mrp_tier1_032612.pdf

What do Tier 2 growers have to do to comply with the Order?

- **By May 15, 2012,** all Tier 2 growers that irrigate land to produce commercial crops must enroll in the Order by submitting an eNOI.
- **By October 1, 2012,** all Tier 2 growers that apply fertilizers, pesticides, fumigants or other chemicals through an irrigation system must have back flow prevention devices.
- **By October 1, 2012,** all Tier 2 growers must develop, implement and keep up to date a Farm Water Quality Management Plan (Farm Plan) that includes management practices, treatment or control measures related to irrigation efficiency, pesticide management, salinity management, nutrient management, sediment and erosion control and aquatic habitat protection.
- All Tier 2 growers must implement management practices to treat or control discharges and protect water quality.
- All Tier 2 growers must minimize bare dirt and prevent erosion.
- All Tier 2 growers must protect existing aquatic habitat next to their farms.
- **By October 1, 2012,** all Tier 2 growers must calculate their risk of loading nitrate to groundwater from their farm (using specified methodology).
- **By October 1, 2012,** Tier 2 growers must take photos to document the existing condition of adjacent streams or wetlands, if those waters are impaired by sediment, turbidity or temperature (a list is in the Order on page 33).
- **By October 1, 2014,** Tier 2 growers must record and report total nitrogen applied, if the farm/ranch has a high nitrate loading risk.
- Monitoring and Reporting-
    - **By September 15, 2012,** all Tier 2 growers must monitor the creeks and estuaries that may receive farm runoff. Growers can choose to participate in the existing Cooperative Monitoring Program (CMP) implemented by Central Coast Water Quality Preservation, Inc., or they can choose to monitor individually. Samples must be collected and analyzed for sediment and nutrients monthly, and pesticides, toxicity and metals quarterly. Results must be reported by January 1, 2013.
    - **By October 1, 2012,** and annually thereafter, all Tier 2 growers must submit annual compliance information, such as verification of Farm Plan, information about discharge, identification of completed farm water quality management practices and nitrate loading risk. All information must be submitted electronically through an on-line annual compliance form, similar to the eNOI.
    - **By March 15, 2013,** all Tier 2 growers must sample the groundwater from the primary irrigation well and any drinking water well on their farm twice (in Sept/Oct 2012 and March 2013). Groundwater samples must be analyzed for nitrate and

general minerals. Growers can also comply by submitting existing groundwater data and can also work with neighboring growers on cooperative groundwater monitoring. Results must be reported by October 1, 2013.

- Tier 2 Growers must comply with the above and all other Tier 2 conditions in the Order (pages 13-28) and the Tier 2 Monitoring and Reporting Program R3-2012-0011-02.
  - The Order is available on the Water Board's website at http://www.waterboards.ca.gov/centralcoast/water_issues/programs/ag_waivers/docs/ag_order/final_agorder_atta_032612.pdf
  - The Tier 2 Monitoring and Reporting Program R3-2012-0011-02 is available on the Water Board's website at http://www.waterboards.ca.gov/centralcoast/water_issues/programs/ag_waivers/docs/ag_order/final_mrp_tier2_032912.pdf

What do Tier 3 growers have to do to comply with the Order?

- **By May 15, 2012,** all Tier 3 growers that irrigate land to produce commercial crops must enroll in the Order by submitting an eNOI.
- **By October 1, 2012,** all Tier 3 growers that apply fertilizers, pesticides, fumigants or other chemicals through an irrigation system must have back flow prevention devices.
- **By October 1, 2012,** all Tier 3 growers must develop, implement and keep up to date a Farm Water Quality Management Plan (Farm Plan) that includes management practices, treatment or control measures related to irrigation efficiency, pesticide management, salinity management, nutrient management, sediment and erosion control and aquatic habitat protection.
- All Tier 3 growers must implement management practices to treat or control discharges and protect water quality.
- All Tier 3 growers must minimize bare dirt and prevent erosion.
- All Tier 3 growers must protect existing aquatic habitat next to their farms.
- **By October 1, 2012,** all Tier 3 growers must calculate their risk of loading nitrate to groundwater from their farm (using specified methodology).
- **By October 1, 2012,** Tier 3 growers must take photos to document the existing condition of adjacent streams or wetlands, if those waters are impaired by sediment, turbidity or temperature (a list is in the Order on page 33).
- **By October 1, 2014,** Tier 3 growers must record and report total nitrogen applied, if the farm/ranch has a high nitrate loading risk.
- Irrigation and Nutrient Management
    - Tier 3 farms must prepare an Irrigation and Nutrient Management Plan if the farm/ranch has a high nitrate loading risk.
    - The purpose of the Irrigation and Nutrient Management Plan is to protect groundwater and surface water, especially drinking water sources, from nitrate contamination, by preventing the excessive application of water and nutrients.
    - The Irrigation and Nutrient Management Plan includes nutrient budgeting information such as crop nitrogen uptake values, amount of nitrogen applied, nutrient balance ratio, and an estimate of nitrate loading to groundwater and reductions achieved.
    - The Order includes nutrient balance ratio milestones as indicators of pollution reduction. The ratio compares the amount of nitrogen applied to the amount of nitrogen needed to produce a crop. The Order does not require 100 percent crop efficiency. Existing data demonstrate that, in many cases, growers are already achieving the milestones.

- Water Quality Buffer Plan
    - Tier 3 growers must prepare a Water Quality Buffer Plan if the farm/ranch is adjacent to a creek or wetland impaired by sediment, turbidity or temperature (a list is in the Order on page 33).
    - The purpose of the Water Quality Buffer Plan is to protect adjacent streams from erosion and sediment loading or other waste discharges. Growers can prepare an alternative plan if it is similarly protective.
- Monitoring and Reporting-
    - **By September 15, 2012,** all Tier 3 growers must monitor the creeks and estuaries that may receive farm runoff. Growers can choose to participate in the existing Cooperative Monitoring Program (CMP) implemented by Central Coast Water Quality Preservation, Inc., or they can choose to monitor individually. Samples must be collected and analyzed for sediment and nutrients monthly, and pesticides, toxicity and metals quarterly. Results must be reported by January 1, 2013.
    - **By October 1, 2012,** and annually thereafter, all Tier 3 growers must submit annual compliance information, such as verification of Farm Plan, information about discharge, identification of completed farm water quality management practices and nitrate loading risk. All information must be submitted electronically through an on-line annual compliance form, similar to the eNOI.
    - **By March 15, 2013,** all Tier 3 growers must sample the groundwater from the primary irrigation well and any drinking water well on their farm twice in the first year of the Order (in Sept/Oct 2012 and March 2013), and once annually thereafter. Groundwater samples must be analyzed for nitrate and general minerals. Growers can also comply by submitting existing groundwater data and can also work with neighboring growers on cooperative groundwater monitoring. First year results must be reported by October 1, 2013.
    - **By October 1, 2013,** all Tier 3 growers must start individual surface water discharge monitoring. Results must be reported by March 15, 2014, October 1, 2014, and annually thereafter.
    - **By October 1, 2015,** Tier 3 growers whose farm/ranch has a high nitrate loading risk must submit elements of their Irrigation and Nutrient Management Plan and report on progress towards meeting specified nutrient balance ratio targets.
    - **By October 1, 2016,** these same high nitrate risk Tier 3 growers must submit their Irrigation and Nutrient Management Plan Effectiveness Report.

  - **By October 1, 2016,** Tier 3 growers whose farm/ranch is adjacent to a creek or wetland impaired by sediment, turbidity or temperature (a list is in the Order on page 33) must submit their Water Quality Buffer Plan.

- Tier 3 growers must comply with the above and all other Tier 3 conditions in the Order (pages 13-32) and the Tier 3 Monitoring and Reporting Program R3-2012-0011-03.
  - The Order is available on the Water Board's website at http://www.waterboards.ca.gov/centralcoast/water_issues/programs/ag_waivers/docs/ag_order/final_agorder_atta_032612.pdf
  - The Tier 3 Monitoring and Reporting Program R3-2012-0011-03 is available on the Water Board's website at http://www.waterboards.ca.gov/centralcoast/water_issues/programs/ag_waivers/docs/ag_order/final_mrp_tier3_032912.pdf

Appendix E

Preliminary TDS, Cl^-, and NO_3 Balance Calculations

Salt and Nutrient Loading from Source Water, Santa Maria Valley, 2010

Santa Maria Source Water Salt/Nutrient Loading

Source	Flow	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	AF	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Well 9S	0.0	0.0	64	77.7	1000	-	-	-
Well 10S	26.0	8.5	56	52.6	720	3,959	3,715	50,906
Well 11S	1085.0	353.5	30	4.9	730	88,515	14,384	2,153,869
Well 12S	801.0	261.0	52	18.3	860	113,267	39,770	1,873,259
Well 13S	565.0	184.1	48	37.4	935	73,749	57,450	1,436,570
Well 14S	609.0	198.4	62	66.0	1000	102,678	109,257	1,656,091
State Water	10279.0	3349.4	1.98	0.64	310	55,319	18,018	8,662,478
Total	**13365.0**	**4355.0**				**437,487**	**242,595**	**15,833,173**

Source of Data

Well flow data obtained from the City of Santa Maria (TMA Data 2010_LS)

Well chloride conc. obtained from the City of Santa Maria (TMA Data 2011)

Well 11S Cl conc. is a historical average

Well nitrate conc. was obtained from the City of Santa Maria (TMA Data 2010_LS)

Well TDS conc. was obtained from the City of Santa Maria (TMA Data 2011)

Well 11S TDS conc. is a historical average

State Water flow and conc. obtained from CCWA (Process Control Benchsheets)

Cl, N, and TDS conc. are weighted averages.

Subsequent Use of Data

Well data represent salt and nutrient removed from the basin ("Out" in Balance).

State Water data represent salt and nutrient brought in to the basin ("In" in Balance).

Salt and Nutrient Loading from Source Water,
Santa Maria Valley, 2010

Golden State Water Company - Orcutt System Source Water Salt/Nutrient Loading

Source	Flow	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	AF	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Kenneth #1	1398.3	455.6	38	17	650	144,494	64,642	2,471,613
Mira Flores #1	252.9	82.4	98	53.67	810	67,397	36,910	557,058
Mira Flores #2	680.8	221.8	27	5.9	640	49,986	10,923	1,184,858
Mira Flores #4	750.8	244.6	38	8.7	620	77,584	17,763	1,265,851
Mira Flores #5	370.5	120.7	31	5.2	660	31,233	5,239	664,965
Mira Flores #6	360.4	117.4	38	4.3	1100	37,242	4,214	1,078,063
Mira Flores #7	840.7	273.9	35	9.8	610	80,016	22,404	1,394,561
Oak Plant #1	700.7	228.3	22	3.7	650	41,920	7,050	1,238,546
Orcutt #1	389.8	127.0	76	14	510	80,561	14,840	540,603
Woodmere #1	650.6	212.0	36	20	650	63,692	35,384	1,149,990
Woodmere #2	811.5	264.4	35	14	660	77,237	30,895	1,456,462
State Water	248.0	80.8	1.95	0.63	308	1,318	427	207,739
Total	**7455.0**	**2429.2**				**752,680**	**250,693**	**13,210,312**

Source of Data

Well flow data obtained from GSWC (Orcutt System_2010 Monthly Groundwater)

Well chloride conc. obtained from GSWC (Orcutt_WQ_Data)

Results taken from latest year for which data was available - 2008

Well nitrate conc. obtained from GSWC (Orcutt_WQ_Data)

Mira Flores Well #1 concentration is the 2010 average

Well TDS conc. was obtained from GSWC (Orcutt_WQ_Data)

Results taken from latest year for which data was available - 2008

State Water flow and conc. obtained from CCWA (Process Control Benchsheets)

Cl, N, and TDS concentrations are weighted averages.

Subsequent Use of Data

Well data represent salt and nutrient removed from the basin ("Out" in Balance).

State Water data represent salt and nutrient brought in to the basin ("In" in Balance).

Salt and Nutrient Loading from Source Water,
Santa Maria Valley, 2010

Guadalupe Source Water Salt/Nutrient Loading

Source	Flow	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	AF	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Obispo Well	880.5	286.9	19	2	640	45,496	4,789	1,532,483
State Water	0.0	0.0	N/A	N/A	N/A	-	-	-
Total	**880.5**	**286.9**				**45,496**	**4,789**	**1,532,483**

Source of Data

Well flow data from the City of Guadalupe (2010 Guadalupe - Water Production)

Well chloride conc. obtained from the City of Guadalupe (Lab Results - 2011)

Well nitrate conc. obtained from the City of Guadalupe (Lab Results - 2010)

Well TDS conc. obtained from the City of Guadalupe (Lab Results - 2011)

The City of Guadalupe received no State Water in 2010.

Subsequent Use of Data

Well data represent salt and nutrient removed from the basin ("Out" in Balance).

Salt and Nutrient Loading from Source Water, Santa Maria Valley, 2010

Agriculture - Source Water Salt/Nutrient Loading and N Balance

Source	Flow	Flow	Ave. Concentration Chloride	Nitrate	TDS	Pumped Chloride	Nitrate	TDS	Nitrate Balance Irrigated Acres	Applied Nitrogen lb/A	Root Zone Efficiency	Returned Chloride	Nitrate	TDS
	AF	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb				Lb	Lb	Lb
Rotational Vegetables	86002	28024	82.81	30	997	19,366,811	7,016,113	233,168,830	36597	205	0.55	19,366,811	12,286,932	233,168,830
Strawberries	9495	3094	82.81	20	997	2,138,181	516,407	25,742,867	6782	174	0.55	2,138,181	2,152,912	25,742,867
Vineyard	5129	1671	82.81	7.66	997	1,155,001	106,839	13,905,757	4662	40	0.95	1,155,001	36,230	13,905,757
Total Pasture	1803	588	82.81	7.66	997	406,018	37,557	4,888,298	515	15	0.85	406,018	345	4,888,298
Field	0	0	82.81	7.66	997	-	-	-	0	-	-	-	-	-
Grain	225	73	82.81	7.66	997	50,668	4,687	610,021	750	90	0.85	50,668	44,256	610,021
Nursery	460	150	82.81	7.66	997	103,588	9,582	1,247,153	228	100	0.85	103,588	13,929	1,247,153
Total Orchard	80	26	82.81	7.66	997	18,015	1,666	216,896	30	100	0.85	18,015	2,243	216,896
Total	103194	33626				23,238,282	7,692,851	279,779,822				23,238,282	14,536,848	279,779,822

Source of Data

Groundwater Chloride, Nitrate, and TDS conc. obtained from Ludhorf & Scalmanini (SMVMA_HistGWQ_LSCE)

Wells Used for determining average groundwater concentration:		
009N034W03A002S	009N033W10M001S	010N036W02Q004S
010N033W20H001S	010N034W14E004S	010N036W02Q007S
010N034W04R002S	010N034W29N001S	011N036W35J002S
010N035W14D003S	010N033W30G001S	011N036W35J003S
009N033W02A007S	010N036W02Q001S	011N036W35J004S
010N033W22N003S	010N036W02Q003S	011N036W35J005S

The average concentrations of Cl, Nitrate, and TDS used in the table above were calculated based on the 18 wells (listed to the left) that were sampled in 2010.

Subsequent Use of Data

The "Pumped" values represent salt and nutrient removed from the basin ("Out" in Balance).

The "Returned" values represent salt and nutrient that are reintroduced to the basin ("In" in Balance).

Nitrate concentration of irrigation source water is increased for Rotational Vegetables and Stawberries (in comparison to previous two decades) which reduces applied nitrogen in recognition of improved management; the inclusion of the management practices is based on grower information obatained at stakeholder meetings.

Root Zone Efficiency increased by 5-percent in each crop category in comparison to previous decade to represent improved nutrient and water mangement practices; root zone efficiency for N is related to applied water distribution uniformity for Vineyard, Pasture, Field, Grain, Nursery, and Orchard categories.

Salt and Nutrient Loading from Wastewater, Santa Maria Valley, 2010

Laguna Sanitation District WWTP - Effluent Salt/Nutrient Loading*

Month	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Jan	58.28	140	31.4	615	68,092	15,286	299,117
Feb	53.20	180	31.4	752	79,916	13,954	333,869
Mar	66.03	167	31.4	733	92,025	17,319	403,917
Apr	63.30	163	17.7	759	86,107	9,354	400,952
May	65.41	233	17.7	750	127,188	9,666	409,404
Jun	62.70	184	17.7	714	96,279	9,265	373,605
Jul	64.17	150	14.2	591	80,329	7,586	316,495
Aug	65.10	150	14.2	676	81,493	7,696	367,261
Sep	63.00	160	14.2	762	84,122	7,448	400,629
Oct	65.10	190	48.7	675	103,224	26,454	366,718
Nov	63.60	150	48.7	724	79,615	25,845	384,276
Dec	70.99	180	48.7	737	106,639	28,848	436,628
Total	760.88				1,085,028	178,719	4,492,873

*Reflects use of reverse osmosis and injection well to reduce TDS and Cl in LCSD effluent.

Source of Data

WWTP Flow and WQ data obtained from LCSD (LCSD Annual POTW Report - 2010)

Nitrate conc. based on quarterly sampling.

Subsequent Use of Data

WWTP data represents salt/nutrient reintroduced to the basin ("In" in Balance)

Salt and Nutrient Loading from Wastewater,
Santa Maria Valley, 2010

Laguna Sanitation District Brine Injection Program - Brine Salt/Nutrient Loading

Month	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Jan	2.33	4900	220.0	22460	95,254	4,277	436,613
Feb	2.05	4900	220.0	10105	83,981	3,771	173,189
Mar	2.19	4900	220.0	11235	89,623	4,024	205,492
Apr	2.19	4280	247.0	10210	78,386	4,524	186,990
May	2.26	4280	247.0	7086	80,668	4,655	133,555
Jun	2.24	4280	247.0	11735	79,836	4,607	218,896
Jul	2.78	2400	810.0	6580	55,684	18,793	152,667
Aug	2.72	2400	810.0	4141	54,533	18,405	94,092
Sep	2.37	2400	810.0	1702	47,519	16,038	33,699
Oct	2.31	5800	11.0	14850	111,695	212	285,977
Nov	2.29	5800	11.0	8510	111,043	211	162,927
Dec	2.16	5800	11.0	8895	104,577	198	160,381
Total	27.901				992,798	79,714	2,244,480

Source of Data

Brine Injection flow and WQ data obtained from LCSD's 2010 EPA Brine Discharge Permit

Cl, Nitrate, and TDS conc. values based on qtrly sampling, unless more detailed data available
August TDS conc. not recorded; Value based on average between Jul/Sep

Subsequent Use of Data

Brine Injection Program data represents salt/nutrient removed from the basin ("Out" in Balance)

Salt and Nutrient Loading from Wastewater,
Santa Maria Valley, 2010

Santa Maria WWTP - Effluent Salt/Nutrient Loading

Month	Flow AF	Flow MG	Chloride mg/L	Nitrate mg/L	TDS mg/L	Chloride Lb	Nitrate Lb	TDS Lb
Jan	652	212	169	33.2	783	299,641	58,864	1,388,277
Feb	564	184	175	33.2	747	268,401	50,919	1,145,688
Mar	629	205	185.5	33.2	802	317,294	56,788	1,371,803
Apr	616	201	196	8.0	857	328,325	13,347	1,435,583
May	641	209	193	8.0	857	336,420	13,889	1,493,845
Jun	637	208	183	8.0	857	316,999	13,802	1,484,523
Jul	677	221	164	26.6	857	301,925	48,897	1,577,743
Aug	728	237	167	26.6	857	330,609	52,580	1,696,598
Sep	715	233	190	26.6	857	369,425	51,641	1,666,302
Oct	724	236	212	8.4	815	417,389	16,559	1,604,586
Nov	621	202	164	8.4	815	276,951	14,203	1,376,309
Dec	645	210	167	8.4	815	292,916	14,752	1,429,500
Total	7849	2558	[redacted]			3,856,294	406,242	17,670,758

Source of Data

WWTP Flow data obtained from the City of Santa Maria (CSM WWTP Flows)

Chloride conc. obtained from the City of Santa Maria (WWTP Salt Data to GEI)

March conc. is an average between February and April

Nitrate conc. obtained from the City of Santa Maria (WWTP Nitrogen data to GEI)

Jan-2011 conc. used for Jan, Feb, Mar 2010

Based on Qtly. Sampling.

TDS conc. obtained from the City of Santa Maria (WWTP Salt Data to GEI)

March conc. is an average between February and April

Based on qtrly sampling, unless more detailed data available

Subsequent Use of Data

WWTP effluent data represents salt/nutrient reintroduced to the basin ("In" in Balance)

Salt and Nutrient Loading from Wastewater, Santa Maria Valley, 2010

Guadalupe WWTP - Effluent Salt/Nutrient Loading

Month	Flow	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	AF	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Jan	-	18.693	93.5	24.5	893	14,586	3,822	139,309
Feb	-	15.548	93.5	24.5	893	12,132	3,179	115,871
Mar	-	17.516	93.5	24.5	893	13,668	3,581	130,537
Apr	-	17.579	93.5	24.5	893	13,717	3,594	131,006
May	-	17.986	93.5	24.5	893	14,034	3,677	134,040
Jun	-	17.696	93.5	24.5	893	13,808	3,618	131,878
Jul	-	18.544	93.5	24.5	893	14,470	3,792	138,198
Aug	-	18.772	93.5	24.5	893	14,648	3,838	139,897
Sep	-	18.640	93.5	24.5	893	14,545	3,811	138,914
Oct	-	19.982	93.5	24.5	893	15,592	4,086	148,915
Nov	-	17.608	93.5	24.5	893	13,739	3,600	131,223
Dec	-	16.954	93.5	24.5	893	13,229	3,466	126,349
Total	572.35	186.501				168,168	44,065	1,606,135

Source of Data

WWTP effluent data obtained from the City of Guadalupe

Chloride, Nitrate, and TDS conc. based on semi-annual monitoring and is calculated as the average of the April and October measurements.

Subsequent Use of Data

WWTP effluent data represents salt/nutrient reintroduced to the basin ("In" in Balance)

Salt and Nutrient Loading from Wastewater,
Santa Maria Valley, 2010

Groundwater Movement - Salt/Nutrient Loading

Well	Flow	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	AFY	MG/Yr	mg/L	mg/L	mg/L	Lb/Yr	Lb/Yr	Lb/Yr
10N36W02Q007S	7000	2281	509	0.08	1380	3,402,600	783,217	25,602,779
11N36W35J003S			63.3	63.6	1190			
11N36W35J004S			77.3	63.3	1450			
11N36W35J005S			65.4	37.6	1360			
10N36W02Q001S	2000	652	22.9	2.07	702	127,991	11,313	3,959,389
10N36W02Q003S			21.6	2.17	712			
11N36W35J002S			26.1	2	770			
Total	9000	2933				3,530,591	794,529	29,562,168

Source of Data

Total average annual groundwater flow obtained from Luhdorff & Scalmanini

Groundwater flow from deep and shallow aquifers was estimated.

Water Quality data obtained from Historical TDS and N - Graphs See fig 4.2

WQ info from Wells 10/36 2Q1 and 2Q3, and 11/36 35J1 were used to represent the deep aquifer. No WQ info for 10/36 2Q2.

WQ info from Wells 10/36 2Q7 and 11/36 35J3, 35J4, and 35J5 were used to represent the shallow aquifer. No depth info for 10/36 2Q4.

The average Cl, Nitrate, and TDS conc. were calculated individually for the deep aquifer and shallow aquifer based on the representative wells.

Subsequent Use of Data

This table represents the movement of groundwater out of the basin, thus the data represents salt/nutrient removed from the basin ("Out" in Balance)

Salt and Nutrient Loading from Wastewater, Santa Maria Valley, 2010

Surface Water Discharge to Groundwater basin/Ocean

Water Body	Flow	Flow	Ave. Concentration			Total			To Ocean				To Groundwater			
			Chloride	Nitrate	TDS	Chloride	Nitrate	TDS	Flow	Chloride	Nitrate	TDS	Flow	Chloride	Nitrate	TDS
	AFY	MG/Yr	mg/L	mg/L	mg/L	Lb/Yr	Lb/Yr	Lb/Yr	MG/Yr	Lb/Yr	Lb/Yr	Lb/Yr	MG/Yr	Lb/Yr	Lb/Yr	Lb/Yr
Cuyama River	32000	10427	55	0.8853	1100	4,786,074	77,041	95,721,490	0	-	-	-	10427	4,786,074	77,041	95,721,490
Sisquoc River	38000	12382	20	0.8853	775	2,066,714	91,486	80,085,167	5431	906,453	40,125	35,125,073	6951	1,160,260	51,361	44,960,094
Orcutt Creek	1700	554		143.64	2070	-	664,056	9,569,430	486	-	583,073	8,402,426	68	-	80,982	1,167,004
Santa Maria River Total	39700	23364	[redacted]			6,852,788	832,583	185,376,086	5917	906,453	623,199	43,527,499	17446	5,946,335	209,384	141,848,587
Oso Flaco Creek	2900	945		38.91	1450	-	306,850	11,434,911	945	-	306,860	11,435,284	0	-	-	-
Blosser Creek	820	267	48	6	725	107,034	13,379	1,616,660	267	107,034	13,379	1,616,660	0	-	-	-
Bradley Channel	3440	1121	47	32	1200	439,666	299,347	11,225,520	1121	439,666	299,347	11,225,520	0	-	-	-
Greene Valley Creek	1260	411	225	58	1960	770,939	198,731	6,715,733	411	770,939	198,731	6,715,733	0	-	-	-
Main Street Canal	2250	733	94	22	1160	575,145	134,608	7,097,531	733	575,145	134,608	7,097,531	0	-	-	-

Source of Data

Flow data for each of the water bodies is the average annual flow, based on Luhdorff & Scalmanini and the CCAMP website

Cuyama River is a losing river; meaning that flows do not discharge to the ocean except in high-flow situations

Cuyama River Nitrate and TDS data obtained from CCAMP (Website; Data from 2007)

Cuyama River Cl obtained from Luhdorff & Scalmanini (Cl conc. not available from CCAMP)

Sisquoc River Nirtate and TDS data obtained from CCAMP (Website; Data from 2007)

Sisquoc River Cl obtained from Luhdorff & Scalmanini (Cl conc. not available from CCAMP)

Orcutt Creek Nitrate and TDS data obtained from CCAMP (Website; Data from 2007)

Orcutt Creek Cl data not available from CCAMP or Luhdorff & Scalmanini

Oso Flaco Creek Nitrate and TDS data obtained from CCAMP (Website; Data from 2007)

Oso Flaco Creek Cl data not available from CCAMP or Luhdorff & Scalmanini

Blosser Creek Flow, Cl, Nitrate, and TDS data obtained from CCAMP (Data Request)

Data from CCAMP used to develop Average Flow and Average CL, Nitrate, and TDS concentrations. Average values shown above

Bradley Channel Flow, Cl, Nitrate and TDS data obtained from CCAMP (Data Request)

Data from CCAMP used to develop Average Flow and Average CL, Nitrate, and TDS concentrations. Average values shown above

Greene Valley Creek Flow, Cl, Nitrate and TDS data obtained from CCAMP (Data Request)

Data from CCAMP used to develop Average Flow and Average CL, Nitrate, and TDS concentrations. Average values shown above

Main Street Canal Flow, Cl, Nitrate and TDS data obtained from CCAMP (Data Request)

Data from CCAMP used to develop Average Flow and Average CL, Nitrate, and TDS concentrations. Average values shown above

Subsequent Use of Data

The "To Ocean" values represent salt and nutrient removed from the basin ("Out" in Balance).

The "To Groundwater" values represent salt and nutrient that are brought into the basin ("In" in Balance).

Table 4.2-5. Estimated Annual Chloride and TDS Load Balance, Santa Maria Valley, 2010

Agency/Location	Source of Water	In		Out		Balance	
		Chloride	TDS	Chloride	TDS	Chloride	TDS
	Imported/SWP, Wells	Lb	Lb	Lb	Lb	Lb	Lb
City of Santa Maria - SWP Outside Landscape Infiltration	SWP	11,000	1,732,000			11,000	1,732,000
City of Santa Maria - WWTP Infiltration	SWP/Wells	3,856,000	17,671,000			3,856,000	17,671,000
City of Santa Maria - Municipal and Industrial Pumping	Wells			382,000	7,171,000	(382,000)	(7,171,000)
City of Santa Maria - Well Outside Landscape Infiltration	Wells	76,000	1,434,000			76,000	1,434,000
City of Guadalupe - WWTP Infiltration	Wells	168,000	1,606,000			168,000	1,606,000
City of Guadalupe - Municipal and Industrial Pumping	Wells			45,000	1,532,000	(45,000)	(1,532,000)
City of Guadalupe - Well Outside Landscape Infiltration	Wells	9,000	306,000			9,000	306,000
Golden State Water Co. - SWP Outside Landscape Infiltration	SWP	300	42,000			300	42,000
Golden State Water Co. - Municipal and Industrial Pumping	Wells			751,000	13,003,000	(751,000)	(13,003,000)
Golden State Water Co. - Well Outside Landscape Infiltration	Wells	15,000	262,000			15,000	262,000
Laguna Sanitation District - WWTP Infiltration	SWP/Wells	1,085,000	4,493,000			1,085,000	4,493,000
Laguna Sanitation District - Brine Disposal				993,000	2,244,000	(993,000)	(2,244,000)
Agriculture - Pumped	Wells			23,238,000	279,780,000	(23,238,000)	(279,780,000)
Agriculture - Deep Percolation	Wells	17,312,000	208,436,000			17,312,000	208,436,000
Santa Maria River	N/A					-	-
Cuyama River	N/A	4,786,000	95,721,000	-	-	4,786,000	95,721,000
Sisquoc River	N/A	1,160,000	44,960,000	906,000	35,125,000	254,000	9,835,000
Orcutt Creek	N/A	-	1,167,000	-	8,402,000	-	(7,235,000)
Oso Flaco Creek	N/A			-	11,435,000	-	(11,435,000)
Groundwater Discharge From Basin	N/A			3,531,000	29,562,000	(3,531,000)	(29,562,000)
High flows directly to Ocean	N/A	-	-	1,893,000	26,655,000	(1,893,000)	(26,655,000)
	Totals	**28,478,300**	**377,830,000**	**31,739,000**	**414,909,000**	**(3,260,700)**	**(37,079,000)**

Notes:

Estimated - 25% of the Agriculture-Pumped water and associated salts, are lost to surface runoff.

Estimated - 0.5% of the Agriculture-Pumped water and associated salts, are lost to crop harvest.

Estimated - 74.5% of the Agriculture-Pumped water and assiciated salts are assumed to return to the basin as Agriculture-Deep Percolation.

Positive values in the Balance columns indicate a general inflow of Chloride/TDS into the basin.

Negative values (values in parentheses) in the Balance columns indicate a general removal of Chloride/TDS from the basin.

High flows directly to Ocean include flow from Blosser Creek, Bradley Channel, Greene Valley Creek, and Main Street Canal.

Values in this table are based on those presented in Appendix E. These values have been rounded to reflect a reasonable level of certainty of the source information.

Table 4.2-6. Estimated Annual Nitrate Load Balance, Santa Maria Valley, 2010

Agency/Location	Source of Water	In	Out	Balance	Balance NO3-N
		Nitrate	Nitrate	Nitrate	Equivalent
	Imported/SWP, Wells	Lb	Lb	Lb	Lb
City of Santa Maria - SWP Outside Landscape Infiltration	SWP	18,000	-	18,000	4,100
City of Santa Maria - WWTP Infiltration	SWP/Wells	406,200	-	406,200	91,700
City of Santa Maria - Municipal and Industrial Pumping	Wells		224,600	(224,600)	(50,700)
City of Santa Maria - Well Outside Landscape Infiltration	Wells	44,900		44,900	10,100
City of Guadalupe - WWTP Infiltration	Wells	44,100	-	44,100	10,000
City of Guadalupe - Municipal and Industrial Pumping	Wells		4,800	(4,800)	(1,100)
City of Guadalupe - Well Outside Landscape Infiltration	Wells	1,000		1,000	230
Golden State Water Co. - SWP Outside Landscape Infiltration	SWP	100	-	100	20
Golden State Water Co. - Municipal and Industrial Pumping	Wells		14,600	(14,600)	(3,300)
Golden State Water Co. - Well Outside Landscape Infiltration	Wells	5,000		5,000	1,100
Laguna Sanitation District - WWTP Infiltration	SWP/Wells	178,700		178,700	40,300
Laguna Sanitation District - Brine Disposal			79,700	(79,700)	(18,000)
Agriculture - Pumped	Wells		7,693,000	(7,693,000)	(1,736,600)
Agriculture - Deep Percolation	Wells	14,537,000		14,537,000	3,281,500
Santa Maria River	N/A			-	-
Cuyama River	N/A	77,000	-	77,000	17,400
Sisquoc River	N/A	51,400	40,100	11,300	2,600
Orcutt Creek	N/A	81,000	583,100	(502,100)	(113,300)
Oso Flaco Creek	N/A	-	306,900	(306,900)	(69,300)
Groundwater Discharge From Basin	N/A		794,500	(794,500)	(179,300)
High flows directly to Ocean	N/A	-	646,100	(646,100)	(145,800)
	Totals	**15,444,400**	**10,387,400**	**5,057,000**	**1,142,000**

Notes:

Estimated - 25% of the Agriculture-Pumped water and associated salts, are lost to surface runoff.

Estimated - 0.5% of the Agriculture-Pumped water and associated salts, are lost to crop harvest.

Estimated - 74.5% of the Agriculture-Pumped water and assiciated salts are assumed to return to the basin as Agriculture-Deep Percolation.

Positive values in the Balance columns indicate a general inflow of nitrate into the basin

Negative values (values in parentheses) in the Balance columns indicate a general removal of nitrate from the basin.

High flows directly to Ocean include flow from Blosser Creek, Bradley Channel, Greene Valley Creek, and Main Street Canal.

Values in this table are based on those presented in Appendix E. These values have been rounded to reflect a reasonable level of certainty.

Salt and Nutrient Loading from Source Water, Santa Maria Valley, 2000

Santa Maria Source Water Salt/Nutrient Loading

Source	Flow	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	AF	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Well 5S*	0.14	0.05	51	19.7	600	20	8	235
Well 7S*	0.02	0.01	42	30.1	710	2	1	30
Well 8S	0.13	0.04	62	42.0	1100	22	15	395
Well 9S	53.99	17.59	55	42.2	1000	8,075	6,195	146,812
Well 10S	109.16	35.57	42	18.6	840	12,467	5,521	249,344
Well 11S*	0.03	0.01	31	3.3	720	3	0	60
Well 12S	61.46	20.03	29	9.4	680	4,847	1,571	113,656
Well 13S	6.32	2.06	21	4.5	640	361	77	10,997
Well 14S	317.63	103.50	19	3.6	590	16,411	3,109	509,612
State Water	12174.0	3966.9	1.98	0.64	310	65,518	21,340	10,259,462
Total		**4145.7**				**107,681**	**37,815**	**11,289,943**

Source of Data

Well flow data obtained from the City of Santa Maria (TMA Data 2010_LS)

Well chloride conc. obtained from the City of Santa Maria (TMA Data 2008)

2001 measurements used unless otherwise indicated

*2002 measurements used

Well nitrate conc. was obtained from the City of Santa Maria (CCR Nitrate)

Well TDS conc. was obtained from the City of Santa Maria (TMA Data 2008)

2001 measurements used unless otherwise indicated

*2002 measurements used

State Water flow data obtained from Luhdorff & Scalmanini

State Water conc. based on 2010 State Water conc.

Subsequent Use of Data

Well data represent salt and nutrient removed from the basin ("Out" in Balance).

State Water data represent salt and nutrient brought in to the basin ("In" in Balance).

Salt and Nutrient Loading from Source Water, Santa Maria Valley, 2000

Golden State Water Company - Orcutt System Source Water Salt/Nutrient Loading

Source	Flow	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	AF	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Crescent #1	1169.9	381.2	43.6	5.6	566	138,712	17,816	1,800,705
Kenneth #1	1059.3	345.2	30.1	9.75	579	86,709	28,087	1,667,925
Mira Flores #1	1216.4	396.4	89.1	33.43	701	294,728	110,581	2,318,794
Mira Flores #2	491.7	160.2	25	5.08	574	33,425	6,792	767,431
Mira Flores #3	700.3	228.2	36.3	8.14	593	69,128	15,501	1,129,280
Mira Flores #4	188.7	61.5	27.2	5.56	577	13,955	2,853	296,034
Mira Flores #5	998.3	325.3	31	4.9	580	84,155	13,302	1,574,521
Mira Flores #6	503.4	164.0	68.6	4.6	658	93,916	6,298	900,827
Mira Flores #7	-					-	-	-
Oak Plant #1	438.8	143.0	18.7	2.81	578	22,315	3,353	689,726
Orcutt #1	313.9	102.3	18.5	2.76	589	15,791	2,356	502,750
Sunrise #1	35.8	11.7	36.3	8.14	593	3,537	793	57,780
Woodmere #1	187.1	61.0	21.5	8.2	553	10,941	4,173	281,425
Woodmere #2	1506.3	490.8	25.9	6.87	572	106,094	28,142	2,343,085
State Water	268.0	87.3	1.95	0.63	308	1,424	462	224,492
Total	**7908.1**	**2576.9**				**836,119**	**222,692**	**12,754,070**

Source of Data

Well flow data obtained from GSWC (Orcutt_Monthly Groundwater 1990-2010)

Well chloride conc. obtained from GSWC (Orcutt_WQ_Data)

Results taken from latest year for which data was available - 1999

Well nitrate conc. obtained from GSWC (Orcut_WQ_Data)

Results taken from latest year for which data was available - 1999

Well TDS conc. was obtained from GSWC (Orcutt_WQ_Data)

Results taken from latest year for which data was available - 1999

State Water flow data obtained from Luhdorff & Scalmanini

State Water conc. based on 2010 State Water conc.

Subsequent Use of Data

Well data represent salt and nutrient removed from the basin ("Out" in Balance).

State Water data represent salt and nutrient brought in to the basin ("In" in Balance).

Salt and Nutrient Loading from Source Water,
Santa Maria Valley, 2000

Guadalupe Source Water Salt/Nutrient Loading

Source	Flow	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	AF	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Obispo Well	545.0	177.6	19	2	640	28,159	2,964	948,513
State Water	233.0	75.9	1.97	0.64	308.97	1,246	405	195,766
Total	**778.0**	**253.5**				**29,405**	**3,369**	**1,144,279**

Source of Data

Well flow data from Luhdorff & Scalmanini

Well chloride conc. based on 2010 chloride conc.

Well nitrate conc. based on 2010 nitrate conc.

Well TDS conc. based on 2010 TDS conc.

State Water flow data obtained from Luhdorff & Scalmanini

State Water conc. based on average of SM and GSWC 2000 State Water conc.

Subsequent Use of Data

Well data represent salt and nutrient removed from the basin ("Out" in Balance).

State Water data represent salt and nutrient brought in to the basin ("In" in Balance).

Salt and Nutrient Loading from Source Water, Santa Maria Valley, 2000

Agriculture - Source Water Salt/Nutrient Loading and N Balance

			Ave. Concentration			Pumped			Nitrate Balance			Returned		
Source	**Flow**	**Flow**	**Chloride**	**Nitrate**	**TDS**	**Chloride**	**Nitrate**	**TDS**	**Irrigated Acres (Ac)**	**Applied Nitrogen lb/Ac**	**Root Zone Efficiency**	**Chloride**	**Nitrate**	**TDS**
	AF	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb				Lb	Lb	Lb
Rotational Vegetables	89996	29325	75.8	20	971	18,550,653	4,894,631	237,634,352	38296	228	0.5	18,550,653	17,382,393	237,634,352
Strawberries	1367	445	75.8	15	971	281,776	55,760	3,609,562	976	183	0.5	281,776	373,313	3,609,562
Vineyard	6228	2029	75.8	3.1	971	1,283,762	52,502	16,445,028	5662	40	0.9	1,283,762	95,605	16,445,028
Total Pasture	4856	1582	75.8	3.1	971	1,000,955	40,936	12,822,263	1387	15	0.8	1,000,955	11,883	12,822,263
Field	0	0	75.8	3.1	971	-	-	-	877	150	0.8	-	116,553	-
Grain	215	70	75.8	3.1	971	44,317	1,812	567,707	717	90	0.8	44,317	56,884	567,707
Nursery	166	54	75.8	3.1	971	34,217	1,399	438,323	82	100	0.8	34,217	7,041	438,323
Total Orchard	2452	799	75.8	3.1	971	505,425	20,670	6,474,504	908	100	0.8	505,425	77,142	6,474,504
Total	102662	33453				21,161,464	5,045,643	271,078,913				21,161,464	18,036,632	271,078,913

Source of Data

Groundwater Chloride, Nitrate, and TDS conc. obtained from Luhdorff & Scalmanini (SMVMA_HistGWQ_LSCE)

Wells Used for	010N033W20H001S	011N036W35J002S
determining	010N034W29N001S	010N036W02Q001S
average	011N036W35J003S	010N036W02Q003S
groundwater	011N036W35J004S	010N036W02Q004S
concentration:	011N036W35J005S	010N036W02Q007S

The average concentrations of Cl, Nitrate, and TDS used in the table above were calculated based on the 10 wells (listed to the left) that were sampled in 2000.

Subsequent Use of Data

The "Pumped" values represent salt and nutrient removed from the basin ("Out" in Balance).

The "Returned" values represent salt and nutrient that are reintroduced to the basin ("In" in Balance).

Nitrate concentration of irrigation source water is increased for Rotational Vegetables and Stawberries (in comparison to previous decade) which reduces applied nitrogen in recognition of improved management; the inclusion of the management practices is based on grower information obatained at stakeholder meetings.

Root Zone Efficiency increased by 5-percent in each crop category in comparison to previous decade to represent improved nutrient and water mangement practices; root zone efficiency for N is related to applied water distribution uniformity for Vineyard, Pasture, Field, Grain, Nursery, and Orchard categories.

Salt and Nutrient Loading from Wastewater, Santa Maria Valley, 2000

Laguna Sanitation District WWTP - Effluent Salt/Nutrient Loading

Month	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Jan	76.57	300	26.7	1100	191,702	17,071	702,908
Feb	70.28	301	26.7	1060	176,541	15,668	621,706
Mar	76.26	270	26.7	1000	171,833	17,002	636,420
Apr	77.70	310	19.9	1100	201,016	12,874	713,281
May	81.84	310	19.9	1100	211,726	13,560	751,286
Jun	74.40	286	19.9	1110	177,577	12,327	689,197
Jul	75.95	300	18.1	1100	190,150	11,461	697,216
Aug	74.71	300	18.1	1100	187,045	11,274	685,833
Sep	75.00	286	18.1	1080	179,009	11,318	675,977
Oct	79.05	290	35.3	1100	191,314	23,318	725,674
Nov	74.70	291	35.3	1070	181,410	22,035	667,039
Dec	80.60	300	35.3	1100	201,792	23,775	739,903
Total	917				2,261,115	191,683	8,306,442

Source of Data

WWTP Flow and WQ data obtained from LCSD (LCSD Annual POTW Report - 2000)

Nitrate conc. is an average of 1990 and 2010 conc.

Subsequent Use of Data

WWTP data represents salt/nutrient reintroduced to the basin ("In" in Balance)

Laguna Sanitation District - Brine Injection (Program initiated in 2006)

Month	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Jan	-	-	-	-	-	-	-
Feb	-	-	-	-	-	-	-
Mar	-	-	-	-	-	-	-
Apr	-	-	-	-	-	-	-
May	-	-	-	-	-	-	-
Jun	-	-	-	-	-	-	-
Jul	-	-	-	-	-	-	-
Aug	-	-	-	-	-	-	-
Sep	-	-	-	-	-	-	-
Oct	-	-	-	-	-	-	-
Nov	-	-	-	-	-	-	-
Dec	-	-	-	-	-	-	-
Total	-				0	0	0

Salt and Nutrient Loading from Wastewater,
Santa Maria Valley, 2000

Santa Maria WWTP - Effluent Salt/Nutrient Loading

Month	Flow MG	Flow Gal	Chloride mg/L	Nitrate mg/L	TDS mg/L	Chloride Lb	Nitrate Lb	TDS Lb
Jan	6.73	6730000	207		711	11,626	-	39,933
Feb	7.05	7050000	182		670	10,708	-	39,419
Mar	6.97	6970000	141		632	8,202	-	36,762
Apr	7.20	7200000	149		630	8,953	-	37,855
May	7.61	7610000	164		677	10,415	-	42,995
Jun	7.87	7870000	162		683	10,640	-	44,858
Jul	7.80	7800000	151		636	9,829	-	41,400
Aug	8.09	8090000	149		623	10,060	-	42,061
Sep	7.79	7790000	144		592	9,362	-	38,486
Oct	8.03	8030000	161		759	10,789	-	50,863
Nov	7.30	7300000	190		692	11,575	-	42,158
Dec	6.90	6900000	198		886	11,401	-	51,019
Total	89.34	89340000				123,560	-	507,810

Source of Data

WWTP Flow data obtained from the City of Santa Maria (CSM WWTP Flows)

Chloride conc. obtained from the City of Santa Maria (WWTP Salt Data to GEI)

Nitrate conc. unavailable

TDS conc. obtained from the City of Santa Maria (WWTP Salt Data to GEI)

Subsequent Use of Data

WWTP effluent data represents salt/nutrient reintroduced to the basin ("In" in Balance)

Salt and Nutrient Loading from Wastewater, Santa Maria Valley, 2000

Guadalupe WWTP - Effluent Salt/Nutrient Loading

Month	Flow	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	AF	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Jan						0	0	0
Feb						0	0	0
Mar						0	0	0
Apr						0	0	0
May						0	0	0
Jun						0	0	0
Jul						0	0	0
Aug						0	0	0
Sep						0	0	0
Oct						0	0	0
Nov						0	0	0
Dec						0	0	0
Total	778	254				19,113	2,190	743,781

Source of Data

Monthly WWTP effluent data not available.

Effluent Flow and salt/nutrient loading calculated asssuming 65% of source water (and associated salt/nutrient loading) returns to the groundwater basin.

Subsequent Use of Data

WWTP effluent data represents salt/nutrient reintroduced to the basin ("In" in Balance)

Salt and Nutrient Loading from Wastewater, Santa Maria Valley, 2000

Groundwater Movement - Salt/Nutrient Loading

Well	Flow	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	AFY	MG/Yr	mg/L	mg/L	mg/L	Lb/Yr	Lb/Yr	Lb/Yr
10N36W02Q007S	7000	2281	430	0.22	1300	2,924,808	406,884	25,174,480
11N36W35J003S			60.8	34.48	1260			
11N36W35J004S			69.4	33.2	1460			
11N36W35J005S			54.4	17.6	1270			
10N36W02Q001S	2000	652	22.5	1.99	729	127,085	10,497	4,037,344
10N36W02Q003S			20.9	1.99	722			
11N36W35J002S			26.7	1.81	776			
Total	9000	2933				3,051,893	417,381	29,211,824

Source of Data

Total average annual groundwater flow obtained from Luhdorff & Scalmanini
Groundwater flow from deep and shallow aquifers was estimated.
Water Quality data obtained from Historical TDS and N - Graphs See fig 4.2

WQ info from Wells 10/36 2Q1 and 2Q3, and 11/36 35J1 were used to represent the deep aquifer. No WQ info for 10/36 2Q2.

WQ info from Wells 10/36 2Q7 and 11/36 35J3, 35J4, and 35J5 were used to represent the shallow aquifer. No depth info for 10/36 2Q4.

The average Cl, Nitrate, and TDS conc. were calculated individually for the deep aquifer and shallow aquifer based on the representative wells.

Subsequent Use of Data

This table represents the movement of groundwater out of the basin, thus the data represents salt/nutrient removed from the basin ("Out" in Balance)

Salt and Nutrient Loading from Wastewater,
Santa Maria Valley, 2000

Surface Water Discharge to Groundwater basin/Ocean

			Ave. Concentration			Total			To Ocean				To Groundwater			
Water Body	Flow	Flow	**Chloride**	**Nitrate**	**TDS**	**Chloride**	**Nitrate**	**TDS**	**Flow**	**Chloride**	**Nitrate**	**TDS**	**Flow**	**Chloride**	**Nitrate**	**TDS**
	AFY	MG/Yr	mg/L	mg/L	mg/L	Lb/Yr	Lb/Yr	Lb/Yr	MG/Yr	Lb/Yr	Lb/Yr	Lb/Yr	MG/Yr	Lb/Yr	Lb/Yr	Lb/Yr
Cuyama River	32000	10427	55	0.8853	1100	4,786,074	77,041	95,721,490	-	-	-	-	10,427	4,786,074	77,041	95,721,490
Sisquoc River	38000	12382	20	0.8853	775	2,066,714	91,486	80,085,167	5,431	906,453	40,125	35,125,073	6,951	1,160,260	51,361	44,960,094
Orcutt Creek	1700	554		143.64	2070	-	664,056	9,569,430	486	-	583,073	8,402,426	68	-	80,982	1,167,004
Santa Maria River Total	71700	23364	[redacted]			6,852,788	832,583	185,376,086	5,917	906,453	623,199	43,527,499	17,446	5,946,335	209,384	141,848,587
Oso Flaco Creek	2900	945		38.91	1450	-	306,850	11,434,911	945	-	306,860	11,435,284	-	-	-	-

Source of Data

Flow data for each of the water bodies is the average annual flow, based on Luhdorff & Scalmanini and the CCAMP website
Cuyama River is a losing river; meaning that flows do not discharge to the ocean except in high-flow situations
Cuyama River Nitrate and TDS data obtained from CCAMP (Website; Data from 2007)
Cuyama River Cl obtained from Luhdorff & Scalmanini (Cl conc. not available from CCAMP)
Sisquoc River Nirtate and TDS data obtained from CCAMP (Website; Data from 2007)
Sisquoc River Cl obtained from Luhdorff & Scalmanini (Cl conc. not available from CCAMP)
Orcutt Creek Nitrate and TDS data obtained from CCAMP (Website; Mean Data used)
Orcutt Creek Cl data not available from CCAMP or Luhdorff & Scalmanini
Oso Flaco Creek Nitrate and TDS data obtained from CCAMP (Website; Mean Data used)
Oso Flaco Creek Cl data not available from CCAMP or Luhdorff & Scalmanini

Subsequent Use of Data

The "To Ocean" values represent salt and nutrient removed from the basin ("Out" in Balance).
The "To Groundwater" values represent salt and nutrient that are brought into the basin ("In" in Balance).

4.2-3. Estimated Annual Chloride and TDS Load Balance, Santa Maria Valley, 2000

Agency/Location	Source of Water	In		Out		Balance	
		Chloride	TDS	Chloride	TDS	Chloride	TDS
	Imported/SWP, Wells	Lb	Lb	Lb	Lb	Lb	Lb
City of Santa Maria - SWP Outside Landscape Infiltration	SWP	13,000	2,052,000			13,000	2,052,000
City of Santa Maria - WWTP Infiltration	SWP/Wells	124,000	508,000			124,000	508,000
City of Santa Maria - Municipal and Industrial Pumping	Wells			42,000	1,031,000	(42,000)	(1,031,000)
City of Santa Maria - Well Outside Landscape Infiltration	Wells	8,000	206,000			8,000	206,000
City of Guadalupe - WWTP Infiltration	Wells	19,000	744,000			19,000	744,000
City of Guadalupe - Municipal and Industrial Pumping	Wells			28,000	949,000	(28,000)	(949,000)
City of Guadalupe - Well Outside Landscape Infiltration	Wells	6,000	229,000			6,000	229,000
Golden State Water Co. - SWP Outside Landscape Infiltration	SWP	167,000	2,551,000			167,000	2,551,000
Golden State Water Co. - Municipal and Industrial Pumping	Wells			973,000	14,330,000	(973,000)	(14,330,000)
Golden State Water Co. - Well Outside Landscape Infiltration	Wells	20,000	288,000			20,000	288,000
Laguna Sanitation District - WWTP Infiltration	SWP/Wells	2,261,000	8,306,000			2,261,000	8,306,000
Laguna Sanitation District - Brine Disposal				-	-	-	-
Agriculture - Pumped	Wells			21,161,000	271,079,000	(21,161,000)	(271,079,000)
Agriculture - Deep Percolation (74.5%)	Wells	15,765,000	201,954,000			15,765,000	201,954,000
Santa Maria River	N/A					-	-
Cuyama River	N/A	4,786,000	95,721,000	-	-	4,786,000	95,721,000
Sisquoc River	N/A	1,160,000	44,960,000	906,000	35,125,000	254,000	9,835,000
Orcutt Creek	N/A	-	1,167,000	-	8,402,000	-	(7,235,000)
Oso Flaco Creek	N/A			-	11,435,000	-	(11,435,000)
Groundwater Discharge From Basin	N/A			3,052,000	29,212,000	(3,052,000)	(29,212,000)
High flows directly to Ocean	N/A	-	-	-	-	-	-
	Totals	**24,329,000**	**358,686,000**	**26,162,000**	**371,563,000**	**(1,833,000)**	**(12,877,000)**

Notes:

Estimated - 25% of the Agriculture-Pumped water and associated salts, are lost to surface runoff.

Estimated - 0.5% of the Agriculture-Pumped water and associated salts, are lost to crop harvest.

Estimated - 74.5% of the Agriculture-Pumped water and assiciated salts are assumed to return to the basin as Agriculture-Deep Percolation.

Positive values in the Balance columns indicate a general inflow of chloride/TDS into the basin.

Negative values (values in parentheses) in the Balance columns indicate a general removal of chloride/TDS from the basin.

Values in this table are based on those presented in Appendix E. These values have been rounded to reflect a reasonable level of certainty of the source information.

4.2-4. Estimated Annual Nitrate Load Balance, Santa Maria Valley, 2000

Agency/Location	Source of Water	In	Out	Balance	Balance NO3-N
		Nitrate	Nitrate	Nitrate	Equivalent
	Imported/SWP, Wells	Lb	Lb	Lb	Lb
City of Santa Maria - SWP Outside Landscape Infiltration	SWP	21,300	-	21,300	4,800
City of Santa Maria - WWTP Infiltration	SWP/Wells	-	-	-	-
City of Santa Maria - Municipal and Industrial Pumping	Wells		16,500	(16,500)	(3,700)
City of Santa Maria - Well Outside Landscape Infiltration	Wells	3,300		3,300	700
City of Guadalupe - WWTP Infiltration	Wells	2,200	-	2,200	500
City of Guadalupe - Municipal and Industrial Pumping	Wells		3,000	(3,000)	(680)
City of Guadalupe - Well Outside Landscape Infiltration	Wells	700		700	160
Golden State Water Co. - SWP Outside Landscape Infiltration	SWP	44,500	-	44,500	10,000
Golden State Water Co. - Municipal and Industrial Pumping	Wells		12,900	(12,900)	(2,900)
Golden State Water Co. - Well Outside Landscape Infiltration	Wells	4,800		4,800	1,100
Laguna Sanitation District - WWTP Infiltration	SWP/Wells	191,700		191,700	43,300
Laguna Sanitation District - Brine Disposal			-	-	-
Agriculture - Pumped	Wells		5,045,600	(5,045,600)	(1,139,000)
Agriculture - Deep Percolation	Wells	18,036,600		18,036,600	4,071,500
Santa Maria River	N/A			-	-
Cuyama River	N/A	77,000	-	77,000	17,400
Sisquoc River	N/A	51,400	40,100	11,300	2,600
Orcutt Creek	N/A	81,000	583,100	(502,100)	(113,300)
Oso Flaco Creek	N/A	-	306,900	(306,900)	(69,300)
Groundwater Discharge From Basin	N/A		417,400	(417,400)	(94,200)
High flows directly to Ocean	N/A	-	-	-	-
	Totals	**18,514,500**	**6,425,500**	**12,089,000**	**2,729,000**

Notes:

Positive values in the Balance columns indicate a general inflow of nitrate into the basin
Negative values (values in parentheses) in the Balance columns indicate a general removal of nitrate from the basin.
Values in this table are based on those presented in Appendix E. These values have been rounded to reflect a reasonable level of certainty.

Salt and Nutrient Loading from Source Water,
Santa Maria Valley, 1990

Santa Maria Source Water Salt/Nutrient Loading

Source	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Well 3S	0.15		3.5	850	-	4	1,029
Well 4S	0.05		3.5	850	-	1	348
Well 5S	40.12		3.5	850	-	1,172	284,595
Well 6S	135.99		3.5	850	-	3,972	964,671
Well 7S	913.24		3.5	850	-	26,675	6,478,143
Well 8S	951.95		3.5	850	-	27,805	6,752,764
Well 9S	696.49		3.5	850	-	20,344	4,940,636
Well 10S	455.88		3.5	850	-	13,316	3,233,840
Well 11S	734.99		3.5	850	-	21,468	5,213,739
Well 12S	0.00		3.5	850	-	-	-
Well 13S	0.00		3.5	850	-	-	-
Well 14S	0.00		3.5	850	-	-	-
State Water					-	-	-
Total	**3928.9**				**-**	**55,128**	**13,388,215**

Source of Data

Well flow data obtained from the City of Santa Maria (Production Data to GEI)
Well chloride conc. not available
Well nitrate conc. obtained from City of Santa Maria
Only available for Well 11S (SM Well 11S_wl and wq data 78-93) - used for all wells
Well TDS conc. obtained from the City of Santa Maria
Only available for Well 11S (SM Well 11S_wl and wq data 78-93) - used for all wells
State Water flow and conc. not available.

Subsequent Use of Data

Well data represent salt and nutrient removed from the basin ("Out" in Balance).
State Water data represent salt and nutrient brought in to the basin ("In" in Balance).

Salt and Nutrient Loading from Source Water, Santa Maria Valley, 1990

Golden State Water Company - Orcutt System Source Water Salt/Nutrient Loading

Source	Flow	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	AF	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Crescent #1	1050.9	342.4	39.7	5.3	564.3	113,455	15,146	1,612,657
Evergreen #1	133.2	43.4						
Evergreen #2	992.2	323.3						
Kenneth #1	1078.0	351.3	32.5	8.5	581.4	95,275	24,918	1,704,401
Mira Flores #1	301.3	98.2	51.1	15.5	513	41,863	12,698	420,268
Mira Flores #2	450.0	146.6	25.8	4.2	570	31,569	5,139	697,452
Mira Flores #3	621.5	202.5				-	-	-
Mira Flores #4	335.0	109.1	34.5	5.5	539.4	31,426	5,010	491,332
Mira Flores #5	611.0	199.1	33.4	4.8	612	55,495	7,975	1,016,857
Mira Flores #6	301.7	98.3	34	4.8	574.2	27,899	3,939	471,161
Mira Flores #7	0.0	0.0				-	-	-
Oak Plant #1	102.1	33.3				-	-	-
Orcutt #1	489.3	159.4				-	-	-
Sunrise #1	495.7	161.5				-	-	-
Woodmere #1	1185.1	386.2	27.3	5.6	580	87,978	18,047	1,869,125
Woodmere #2		0.0				-	-	-
State Water		0.0				-	-	-
Total	**5970.7**	**1945.5**				**371,504**	**77,726**	**6,670,597**

Source of Data

Well flow data obtained from GSWC (Orcutt_Monthly Groundwater 1990-2010)
Well chloride conc. obtained from GSWC (1990 GW TDS_NO3_Cl)
Well nitrate conc. obtained from GSWC (1990 GW TDS_NO3_Cl)
Well TDS conc. obtained from GSWC (1990 GW TDS_NO3_Cl)
State Water flow and conc. not available

Subsequent Use of Data

Well data represent salt and nutrient removed from the basin ("Out" in Balance).
State Water data represent salt and nutrient brought in to the basin ("In" in Balance).

Salt and Nutrient Loading from Source Water,
Santa Maria Valley, 1990

Guadalupe Source Water Salt/Nutrient Loading

Source	Flow	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	AF	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Obispo Well		0.0				0	0	0
State Water		0.0				0	0	0
Total	**0.0**	**0.0**				**0**	**0**	**0**

Source of Data

Well flow and conc. data not available

State Water flow and conc. not available

Subsequent Use of Data

Well data represent salt and nutrient removed from the basin ("Out" in Balance).

State Water data represent salt and nutrient brought in to the basin ("In" in Balance).

Salt and Nutrient Loading from Source Water, Santa Maria Valley, 1990

Agriculture - Source Water Salt/Nutrient Loading and N Balance

Source	Flow	Flow	Ave. Concentration: Chloride	Ave. Concentration: Nitrate	Ave. Concentration: TDS	Pumped: Chloride	Pumped: Nitrate	Pumped: TDS	Nitrate Balance: Irrigated Acres (Ac)	Nitrate Balance: Applied Nitrogen lb/Ac	Nitrate Balance: Root Zone Efficiency	Returned: Chloride	Returned: Nitrate	Returned: TDS
	AF	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb				Lb	Lb	Lb
Rotational Vegetables	78249	25498	74.5	4.43	993	15,852,649	942,647	211,297,729	31300	228	0.45	15,852,649	17,906,295	211,297,729
Strawberries	0	0	74.5	4.43	993	-	-	-	0	183	0.5	-	-	-
Vineyard	6174	2012	74.5	4.43	993	1,250,805	74,377	16,671,806	5145	40	0.85	1,250,805	147,911	16,671,806
Total Pasture	15021	4895	74.5	4.43	993	3,043,140	180,954	40,561,581	4292	15	0.75	3,043,140	116,539	40,561,581
Field	13113	4273	74.5	4.43	993	2,656,594	157,969	35,409,361	5245	150	0.75	2,656,594	910,818	35,409,361
Grain	178	58	74.5	4.43	993	36,061	2,144	480,658	595	90	0.75	36,061	59,843	480,658
Nursery	0	0	74.5	4.43	993	-	-	-	0	100	0.75	-	-	-
Total Orchard	1918	625	74.5	4.43	993	388,572	23,106	5,179,223	710	100	0.75	388,572	84,409	5,179,223
Total	114653	37360				23,227,822	1,381,198	309,600,359				23,227,822	19,225,814	309,600,359

Source of Data

Groundwater Chloride, Nitrate, and TDS conc. obtained from Ludhorf & Scalmanini (SMVMA_HistGWQ_LSCE)

Wells Used for determining average groundwater concentration:			
	009N032W08N001S	010N036W02Q001S	011N036W35J003S
	010N034W26H002S	010N036W02Q003S	011N036W35J004S
	010N034W29N001S	010N036W02Q004S	011N036W35J005S
	010N035W14D003S	010N036W02Q007S	011N036W35J002S

The average concentrations of Cl, Nitrate, and TDS used in the table above were calculated based on the 12 wells (listed to the left) that were sampled in 1990.

Subsequent Use of Data

The "Pumped" values represent salt and nutrient removed from the basin ("Out" in Balance).
The "Returned" values represent salt and nutrient that are reintroduced to the basin ("In" in Balance).

Nitrate concentration of irrigation source water is not recognized as available N, therefore, nitrates in the source water are added to the Applied Nitrogen which increases applied nitrogen in recognition of no improved management; no inclusion of management practices for this decade is based on grower information obatained at stakeholder meetings.

A reasonable nutrient efficieny for the Rotational Vegetables and Strawberries was found in the UC Davis Report and calculated based on UCCE publications; root zone efficiency for N is related to applied water distribution uniformity for Vineyard, Pasture, Field, Grain, Nursery, and Orchard categories as a simplifying assumption in this relative analysis and was started at lower level of irrigation distribution efficiency to represent lower level of water and nutrient management practices implemented in the 1980's.

Salt and Nutrient Loading from Wastewater, Santa Maria Valley, 1990

Laguna Sanitation District WWTP - Effluent Salt/Nutrient Loading

Month	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Jan	66.42	310	22	1100	171,825	12,194	609,701
Feb	59.79	360	22	1200	179,643	10,978	598,811
Mar	63.61	340	22	1200	180,497	11,679	637,047
Apr	60.65	360	22	1100	182,198	11,134	556,717
May	63.46	480	22	1200	254,212	11,651	635,531
Jun	60.72	390	22	1200	197,620	11,148	608,062
Jul	62.75	320	22	1100	167,573	11,521	576,031
Aug	63.11	340	22	1200	179,075	11,587	632,031
Sep	62.30	300	22	1100	155,983	11,439	571,938
Oct	64.46	320	22	1100	172,141	11,835	591,734
Nov	63.01	310	22	1200	163,023	11,569	631,058
Dec	65.43	310	22	1200	169,284	12,014	655,295
Total	755.72				2,173,076	138,749	7,303,956

Source of Data

WWTP Flow and WQ data obtained from LCSD (LCSD Monitoring Data - 1990)

Conc. values based on monthly reporting.

Subsequent Use of Data

WWTP data represents salt/nutrient reintroduced to the basin ("In" in Balance)

Laguna Sanitation District - Brine Injection (Program initiated in 2006)

Month	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Jan	-	-	-	-	-	-	-
Feb	-	-	-	-	-	-	-
Mar	-	-	-	-	-	-	-
Apr	-	-	-	-	-	-	-
May	-	-	-	-	-	-	-
Jun	-	-	-	-	-	-	-
Jul	-	-	-	-	-	-	-
Aug	-	-	-	-	-	-	-
Sep	-	-	-	-	-	-	-
Oct	-	-	-	-	-	-	-
Nov	-	-	-	-	-	-	-
Dec	-	-	-	-	-	-	-
Total	-				0	0	0

Salt and Nutrient Loading from Wastewater,
Santa Maria Valley, 1990

Santa Maria WWTP - Effluent Salt/Nutrient Loading

Month	Flow	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	MG	Gal	mg/L	mg/L	mg/L	Lb	Lb	Lb
Jan			396		1454	0	0	0
Feb			372		1415	0	0	0
Mar			370		1473	0	0	0
Apr			387		1495	0	0	0
May			387		1495	0	0	0
Jun			391		1477	0	0	0
Jul			393		1509	0	0	0
Aug			386		1531	0	0	0
Sep			372		1503	0	0	0
Oct			365		1508	0	0	0
Nov			388		1507	0	0	0
Dec			386		1526	0	0	0
Total	0.00	0				0	0	0

Source of Data

WWTP Flow data not available

Chloride conc. obtained from the City of Santa Maria (WWTP Salt Data to GEI)

Nitrate conc. not available

TDS conc. obtained from the City of Santa Maria (WWTP Salt Data to GEI)

Subsequent Use of Data

WWTP effluent data represents salt/nutrient reintroduced to the basin ("In" in Balance)

Salt and Nutrient Loading from Wastewater, Santa Maria Valley, 1990

Guadalupe WWTP - Effluent

Month	Flow	Flow	Chloride	Nitrate	TDS	Chloride	Nitrate	TDS
	AF	MG	mg/L	mg/L	mg/L	Lb	Lb	Lb
Jan						0	0	0
Feb						0	0	0
Mar						0	0	0
Apr						0	0	0
May						0	0	0
Jun						0	0	0
Jul						0	0	0
Aug						0	0	0
Sep						0	0	0
Oct						0	0	0
Nov						0	0	0
Dec						0	0	0
Total	0	0				0	0	0

Source of Data

Monthly WWTP effluent data not available.

Effluent Flow and salt/nutrient loading calculated asssuming 65% of source water (and associated salt/nutrient loading) returns to the groundwater basin.

Production data is not available, thus effluent data cannot be calculated.

Subsequent Use of Data

WWTP effluent data represents salt/nutrient reintroduced to the basin ("In" in Balance)

Salt and Nutrient Loading from Wastewater,
Santa Maria Valley, 1990

Groundwater Movement - Salt/Nutrient Loading

Well	Flow AFY	Flow MG/Yr	Chloride mg/L	Nitrate mg/L	TDS mg/L	Chloride Lb/Yr	Nitrate Lb/Yr	TDS Lb/Yr
10N36W02Q007S	7000	2281	430	0.22	1300	2,924,808	406,884	25,174,480
11N36W35J003S			60.8	34.48	1260			
11N36W35J004S			69.4	33.2	1460			
11N36W35J005S			54.4	17.6	1270			
10N36W02Q001S	2000	652	22.5	1.99	729	127,085	10,497	4,037,344
10N36W02Q003S			20.9	1.99	722			
11N36W35J002S			26.7	1.81	776			
Total	9000	2933				3,051,893	417,381	29,211,824

Source of Data

Total average annual groundwater flow obtained from Luhdorff & Scalmanini
Groundwater flow from deep and shallow aquifers was estimated.
Water Quality data obtained from Historical TDS and N - Graphs See fig 4.2

WQ info from Wells 10/36 2Q1 and 2Q3, and 11/36 35J1 were used to represent the deep aquifer. No WQ info for 10/36 2Q2.

WQ info from Wells 10/36 2Q7 and 11/36 35J3, 35J4, and 35J5 were used to represent the shallow aquifer. No depth info for 10/36 2Q4.

The average Cl, Nitrate, and TDS conc. were calculated individually for the deep aquifer and shallow aquifer based on the representative wells.

Subsequent Use of Data

This table represents the movement of groundwater out of the basin, thus the data represents salt/nutrient removed from the basin ("Out" in Balance)

Salt and Nutrient Loading from Wastewater,
Santa Maria Valley, 1990

Surface Water Discharge to Groundwater basin/Ocean

Water Body	Flow	Flow	**Ave. Concentration**			**Total**			**To Ocean**				**To Groundwater**			
			Chloride	**Nitrate**	**TDS**	**Chloride**	**Nitrate**	**TDS**	**Flow**	**Chloride**	**Nitrate**	**TDS**	**Flow**	**Chloride**	**Nitrate**	**TDS**
	AFY	MG/Yr	mg/L	mg/L	mg/L	Lb/Yr	Lb/Yr	Lb/Yr	MG/Yr	Lb/Yr	Lb/Yr	Lb/Yr	Gal/Yr	Lb/Yr	Lb/Yr	Lb/Yr
Cuyama River	32000	10427	65	0.025	1200	5,656,270	2,175	104,423,443	-	-	-	-	10,427	5,656,270	2,175	104,423,443
Sisquoc River	38000	12382	15	0.41	750	1,550,035	42,368	77,501,774	5,431	679,840	18,582	33,992,006	6,951	870,195	23,785	43,509,768
Orcutt Creek	1700	554		35.752	2012.8	-	165,278	9,304,999	486	-	145,122	8,170,243	68	-	20,156	1,134,756
Santa Maria River Total	71700	23364	[redacted]			7,206,305	209,822	191,230,216	5,917	679,840	163,705	42,162,249	17,446	6,526,465	46,117	149,067,967
Oso Flaco Creek	2900	945		38.91	1450	-	306,850	11,434,911	945	-	306,860	11,435,284	-	-	-	-

Source of Data

Flow data for each of the water bodies is the average annual flow, based on Luhdorff & Scalmanini and the CCAMP website
Cuyama River is a losing river; meaning that flows do not discharge to the ocean except in high-flow situations
Cuyama River Nitrate and TDS data obtained from CCAMP (Website; Data from 2007)
Cuyama River Cl obtained from Luhdorff & Scalmanini (Cl conc. not available from CCAMP)
Sisquoc River Nirtate and TDS data obtained from CCAMP (Website; Data from 2007)
Sisquoc River Cl obtained from Luhdorff & Scalmanini (Cl conc. not available from CCAMP)
Orcutt Creek Nitrate and TDS data obtained from CCAMP (Website; Mean Data used)
Orcutt Creek Cl data not available from CCAMP or Luhdorff & Scalmanini
Oso Flaco Creek Nitrate and TDS data obtained from CCAMP (Website; Mean Data used)
Oso Flaco Creek Cl data not available from CCAMP or Luhdorff & Scalmanini

Subsequent Use of Data

The "To Ocean" values represent salt and nutrient removed from the basin ("Out" in Balance).
The "To Groundwater" values represent salt and nutrient that are brought into the basin ("In" in Balance).

Table 4.2-1. Estimated Annual Chloride and TDS Load Balance, Santa Maria Valley, 1990

Agency/Location	Source of Water	In		Out		Balance	
		Chloride	TDS	Chloride	TDS	Chloride	TDS
	Imported/SWP, Wells	Lb	Lb	Lb	Lb	Lb	Lb
City of Santa Maria - SWP Outside Landscape Infiltration	SWP	-	-			-	-
City of Santa Maria - WWTP Infiltration	SWP/Wells	-	-			-	-
City of Santa Maria - Municipal and Industrial Pumping	Wells			-	27,868,000	-	(27,868,000)
City of Santa Maria - Well Outside Landscape Infiltration	Wells	-	5,574,000			-	5,574,000
City of Guadalupe - WWTP Infiltration	Wells	-	-			-	-
City of Guadalupe - Municipal and Industrial Pumping	Wells			-	-	-	-
City of Guadalupe - Well Outside Landscape Infiltration	Wells	-	-			-	-
Golden State Water Co. - SWP Outside Landscape Infiltration	SWP	-	-			-	-
Golden State Water Co. - Municipal and Industrial Pumping	Wells			485,000	8,283,000	(485,000)	(8,283,000)
Golden State Water Co. - Well Outside Landscape Infiltration	Wells	10,000	167,000			10,000	167,000
Laguna Sanitation District - WWTP Infiltration	SWP/Wells	2,173,000	7,304,000			2,173,000	7,304,000
Laguna Sanitation District - Brine Disposal				-	-	-	-
Agriculture - Pumped	Wells			23,228,000	309,600,000	(23,228,000)	(309,600,000)
Agriculture - Deep Percolation (74.5%)	Wells	17,305,000	230,652,000			17,305,000	230,652,000
Santa Maria River	N/A					-	-
Cuyama River	N/A	5,656,000	104,423,000	-	-	5,656,000	104,423,000
Sisquoc River	N/A	870,000	43,510,000	680,000	33,992,000	190,000	9,518,000
Orcutt Creek	N/A	-	1,135,000	-	8,170,000	-	(7,035,000)
Oso Flaco Creek	N/A			-	11,435,000	-	(11,435,000)
Groundwater Discharge From Basin	N/A			3,052,000	29,212,000	(3,052,000)	(29,212,000)
High flows directly to Ocean	N/A	-	-	-	-	-	-
	Totals	**26,014,000**	**392,765,000**	**27,445,000**	**428,560,000**	**(1,431,000)**	**(35,795,000)**

Notes:

Estimated - 25% of the Agriculture-Pumped water and associated salts, are lost to surface runoff.

Estimated - 0.5% of the Agriculture-Pumped water and associated salts, are lost to crop harvest.

Estimated - 74.5% of the Agriculture-Pumped water and assiciated salts are assumed to return to the basin as Agriculture-Deep Percolation.

Positive values in the Balance columns indicate a general inflow of chloride/TDS into the basin.

Negative values (values in parentheses) in the Balance columns indicate a general removal of chloride/TDS from the basin.

Values in this table are based on those presented in Appendix E. These values have been rounded to reflect a reasonable level of certainty of the source information.

Table 4.2-2. Estimated Annual Nitrate Load Balance, Santa Maria Valley, 1990

Agency/Location	Source of Water	In	Out	Balance	Balance NO3-N
		Nitrate	Nitrate	Nitrate	Equivalent
	Imported/SWP, Wells	Lb	Lb	Lb	Lb
City of Santa Maria - SWP Outside Landscape Infiltration	SWP	-		-	-
City of Santa Maria - WWTP Infiltration	SWP/Wells	-		-	-
City of Santa Maria - Municipal and Industrial Pumping	Wells		114,800	(114,800)	(25,900)
City of Santa Maria - Well Outside Landscape Infiltration	Wells	23,000		23,000	5,200
City of Guadalupe - WWTP Infiltration	Wells	-		-	-
City of Guadalupe - Municipal and Industrial Pumping	Wells		-	-	-
City of Guadalupe - Well Outside Landscape Infiltration	Wells	-		-	-
Golden State Water Co. - SWP Outside Landscape Infiltration	SWP	-		-	-
Golden State Water Co. - Municipal and Industrial Pumping	Wells		92,900	(92,900)	(21,000)
Golden State Water Co. - Well Outside Landscape Infiltration	Wells	1,900		1,900	400
Laguna Sanitation District - WWTP Infiltration	SWP/Wells	138,700		138,700	31,300
Laguna Sanitation District - Brine Disposal			-	-	-
Agriculture - Pumped	Wells		1,381,200	(1,381,200)	(311,800)
Agriculture - Deep Percolation	Wells	19,225,800		19,225,800	4,339,900
Santa Maria River	N/A			-	-
Cuyama River	N/A	2,200	-	2,200	500
Sisquoc River	N/A	23,800	18,600	5,200	1,200
Orcutt Creek	N/A	20,200	145,100	(124,900)	(28,200)
Oso Flaco Creek	N/A	-	306,900	(306,900)	(69,300)
Groundwater Discharge From Basin	N/A		417,400	(417,400)	(94,200)
High flows directly to Ocean	N/A	-	-	-	-
	Totals	**19,435,600**	**2,476,900**	**16,958,700**	**3,828,000**

Notes:

Positive values in the Balance columns indicate a general inflow of nitrate into the basin

Negative values (values in parentheses) in the Balance columns indicate a general removal of nitrate from the basin.

Values in this table are based on those presented in Appendix E. These values have been rounded to reflect a reasonable level of certainty.

Appendix F

Technical Support Memorandum for Root Zone Estimates

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MEMORANDUM

APPENDIX F: Technical Support Memorandum for Root Zone Estimates

April 16, 2013

To: Santa Maria Groundwater Report Files

From: Rob Almy, Project Director and Sam Schaefer, P.E.

Subject: Nitrogen Management Practices related to Basin Balance Spreadsheet

This memo documents the methodology to develop inputs that represent a number of nitrogen management practices in the basin balance spreadsheet "Salt and Nutrient Balance" and Figure 4-2 in the Groundwater Assessment report. These inputs are summarized in Table F-1 of this memorandum. The nutrient and salt estimates provided in the Groundwater Assessment are a relative analysis representing nitrogen practices across three decades, 1981-1900, 1991-2000, and 2001-2010. One element of the estimates shows qualitative changes in nitrate inputs and outputs. This memorandum describes the approach to estimating the sources and fate of NO_3 in the shallow soils used for agriculture, called for convenience the "root zone."

The applied N values used in the support spreadsheet are based on available information found in UCCE publications, Harder et al. (2012), information gained from stakeholders, and professional judgment. For this analysis, simplifying assumptions were made in using the nitrogen in root zone balance equation since detailed information was not readily available to determine each variable. Except for the rotational vegetables and strawberry crop types, the DU was used to represent both water and nitrogen efficiency in the root zone.

Available data are insufficient to develop a detailed calculation of actual N use and NO_3 movement within the basin. The level of analysis used in this report is intended to provide a relative indication of effects of management measures employed in the basin in the past and over three decades of time. Extrapolation of general trends may indicate how changes in management practices could affect nitrate loading in the future.

The general terminology and inputs and outputs of N in the root zone are shown on Figure 4.2. The objective of the analysis was to employ a nitrogen balance equation to represent the amount of nitrate estimated to reach the groundwater as a result of changing fertilizer and water management practices. A spreadsheet was developed to represent the various elements of figure 4.2. In the spreadsheet, several factors are used to represent the effect of management practices on the mobility and migration of Nitrogen as NO_3.

A key factor is the efficiency of nitrate utilized in the root zone, which is used to reflect improved nitrogen (N) management practices and increased applied water efficiency over time. The applied water efficiency was varied by use of the term distribution uniformity (DU), the uptake or plant removal of N from the root zone can be represented by the root

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zone efficiency. The net removal is the N harvested for a crop since it is equal to the plant uptake minus the residual return. The applied N values used in the spreadsheet are based on available information found in UCCE publications, information gained from stakeholders, and professional judgment. For this analysis, simplifying assumptions were made in using the nitrogen in root zone balance equation since detailed information was not readily available to determine each variable. Except for the rotational vegetables and strawberry crop types, the DU was used to represent both water and nitrogen efficiency in the root zone.

Another key factor was how to recognize, or acknowledge credit towards the targeted fertilizer application, the amount of available nitrate in the source irrigation water. For all crop categories, during the first 10-yr period (1981-1990) the logic represented in the spreadsheet analysis does not subtract the source water N from the applied N; source water N is added to applied N as a method to recognize growers may not have implemented this management practice until the 1990's and 2000's.

For the Groundwater Assessment of Santa Maria Basin, root zone efficiency for Rotational Vegetables was started at 45-percent, based on UCCE information on the amount of nitrate removed at harvest divided by the average nitrate input. This was compared with information found in the UC Davis report by Harter that indicated nutrient root zone efficiencies of around 35 to 45-percent.[1] The calculation of the nitrogen root zone efficiency recognized some amount of volatilization occurs.[2] The nitrate root zone efficiency was raised 5-percent for each of the next two decades in recognition of improvements to fertilizer application methods, such as fertigation. Distribution uniformity (DU) representing changes to applied water (AW) practices are both set at the lower end of reasonable, representative values for irrigation practices in 1981-1990 than 1991-2000 and 2001-2010; the DU was raised 5-percent each decade for the crop categories with known improvements in irrigation methods, such as drip irrigation. The range of DU for the various crop types is within 75 to 95 percent. These are assigned values and not based on a documented study.

The increase by 5-percent for the 1991-2000 and 2001-2010 periods for the Root zone efficiency and DU representing fertilizer application improvements and AW methods improvements is an estimate based on professional knowledge of improved irrigation practices since detailed data was not readily available. The adjustment provides recognition of changes in management practices over time. In addition, applied N is reduced to recognize

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[1] "The partial nutrient balance (PNB), which is the ratio of harvested N to cropland N inputs, varies from less than 35% in Tulare County to nearly 45% in Fresno County." (Harder et al. 2012. Page 17).

[2] An example root zone efficiency, based on UCCE information on Rotational Vegetables, is N removed at harvest divided by N applied to meet target yield is 38 percent (86 lbs/Acre / 228 lbs/Acre = 38 percent). If up to 10-percent of input N is retained in soil available through mineralization that offsets a need for N applied or volatized it can be represented as added to the harvested amount since it represents removal, 22 lbs + 86 lbs = 108 lbs. And, 108/228 = 47 percent. If both occurred at same time, starting nitrogen root zone efficiency may be above 50-percent. The starting assignment of 45-percent is reasonable assigned nitrogen root zone efficiency for Rotational Vegetables.

the amount of nitrate in the water source and the soil monitoring component by factoring in a reduction of total target N to apply since growers utilized better management practices of testing soil for N and source water for nitrate content. In the spreadsheet, increasing the concentration of nitrogen (measured as NO_3) in source water for the Rotational Vegetable category and the Strawberry group, the equation subtracts a portion of nitrogen in the AW (based on the DU since part of the AW would move below the root zone as Deep Percolation). The result or effect in the spreadsheet is a portion of the nitrogen applied is displaced by the source water (AW) nitrogen, in effect, reducing the loading of nitrates to the groundwater in the balance.

It is recognized that rainfall can move NO_3 from the root zone between and during growing seasons of rotational vegetables and other crop categories; rainfall that move NO_3 from the root zone lowers the annual root zone efficiency. The analysis does recognize the possibility to reduce the applied N for Rotational Vegetable crop by recognizing increased source water concentration, thereby reducing the N loading to the groundwater in the balance portion of the spreadsheet. For the purpose of this relative analysis, by holding components of the N balance equation constant, including $N_{Fixation}$, $N_{Denit/Volatilile}$, $N_{Drainage}$, and $N_{Erosion}$, the applied N for Rotational Vegetable Crops is lowered in correlation with the recognized management practices. Changes in management practices are simulated by use of the root zone efficiency and DU representing AW efficiency; both are increased in the second and third 10-year periods to recognize soil and irrigation water sampling (effectively reducing the applied N to meet yield target).

This spreadsheet approach captures representative logic and expected effects of management measures based on what has been discussed at the working group meetings. It relies on information regarding general practices and studies in lieu of available local data on N loading.

For consistency, the tables use pounds of NO_3. Some of the initial calculations provide pounds of N applied in lbs/acre to allow comparison between forms of fertilizer and for presentation of the information purposes. The output from the balance is also converted to equivalent pounds or tons of N for growers and other stakeholders. At a minimum, it is necessary to contain a comparison in terms of pounds of N as equivalent NO_3-N; units for values used in the balance table are NO_3, which can appear to be a factor of 4.43 higher if not clearly noted as pounds of equivalent N.

Reference

Harder et al. for California State Water Resources Control Board. 2012. *Addressing Nitrate in California's Drinking Water. Technical Report 2: Nitrogen Sources and Loading to Groundwater*. Center for Watershed Sciences, University of California, Davis. http://groundwaternitrate.uscdavis.com

The following is text from the Harder et al. (2012)

Technical Report 2: Nitrogen Sources and Loading to Groundwater

Section 2.6.1 Basic Concepts

Deriving current and historical estimates of nitrate loading to groundwater for a particular cropped field (cropland) requires, at minimum, two pieces of information: 1) the amount of N inputs to a field, Ninput, including fertilizer, organic amendments (manure, effluent, biosolids, etc.), atmospheric deposition, and irrigation source water nitrate and 2) the amount of known N outputs from a field, Noutput, including harvested N, atmospheric losses, and runoff (see sections 2.6.2 and 2.6.3):

NGW = Ninput – Noutput (Eqn. 1)

Where NGW is the mass of total nitrogen leached to groundwater (kg N/ha), mostly in form of nitrate nitrogen (or a nitrate precursor).

Field-level N mass balances make one important assumption, in that they assume long-term (decadal or multi-decadal) steady state dynamics of soil N. That is, the amount of N mineralized from soil organic matter is equal to that immobilized by microbes. Hence, long-term N storage changes in soil structure are assumed to be negligible. The applicability of this assumption for California croplands, systems, and soils is unclear. It has been shown that the N in cultivated California soils has increased somewhat over the past 50 years, but the effect was only marginal (approximately 0.20%) (Singer 2001). The N accumulation is likely greatest soon after cultivation begins and decreases over time. The only study that directly tested the steady state assumption showed mixed results. Lund et al. (1982) examined long-term cropping on a variety of soils at four sites, mostly in the Santa Maria Valley. The results demonstrate that steady state assumption was valid for two of the four sites.

Despite its limitations, the mass balance approach presents clear advantages for estimating historical leaching rates. To begin with, using a mass balance approach allows one to calculate a field or soil N balance as the difference between the amount of N harvested and removed from the field in products and the amount of N fertilizer (organic or inorganic) applied. Calculating the rate of N applied in excess of plant uptake, referred to as "surplus", is important because it is nearly all released into the environment, with the majority transiting to groundwater. Further, isotopic N research has shown that less than 10% of the applied N is taken up in subsequent seasons (Ladha et al. 2005). It is possible that N immobilized into the soil may be released at time frames longer than 1-3 years following application, but N release at these timescales is not well constrained (Gardner & Drinkwater 2009). For this reason, we compute the nitrogen mass balance over an extended time period.

How large is the potential error due to the steady state assumption? If the total soil N increase was 0.2% over 50 years (Singer 2001), the total nitrogen flux into permanent soil storage would be 400 kg N/ha (360 lb N/ac). This amounts to an annual nitrogen flux into fixed soil storage of 8 kg N/ha/yr (7 lb/ac/yr), a fraction of the annual average nitrogen *fertilizer and other N fluxes in agricultural lands (Section 1). Hence, the steady state-based mass balance approach is well suited for a post hoc analysis of long-term, decadal to multi-decadal, average nitrogen fluxes into and out of the root zone of agricultural lands.*

<u>Harder Report, Section 2.6.2. Field Nitrogen Mass Balance in Cropland: Conceptual and Mathematical Model</u>

Groundwater nitrate loading from agricultural fields is computed based on a mass balance of the known or estimated inputs and outputs. The nitrogen mass balance is performed on the root zone of each field and considers only annualized fluxes into and out of the root zone.

On the input side, each field root zone receives nitrogen from the following sources:

- *N from atmospheric deposition, Ndeposit*
- *N contained in the source irrigation water (well, stream), Nirrig*
- *N from synthetic fertilizer, Nfertil*
- *N from manure, where applied, Nmanure*
- *N from WWTP/FP effluent or biosolids, where applied, NWWTP-FP*

On the output side, the following pathways are considered:

- *N in the harvest, Nharvest*
- *N losses to the atmosphere via volatilization or denitrification, Nloss*
- *N loading to groundwater, NGW*
- *N in surface runoff, Nrunoff*

Derive estimates of all of the above terms independent of the mass balance computation, except NGW, which is estimated as closure to the basic mass balance equation:

NGW = Ndeposit + Nirrig + Nfertil + Nmanure + NWWTP-FP – Nharvest – Nloss – Nrunoff

Table F-1. Assigned Values for Nitrogen in the Root zone

Crop Category	Nitrogen needed to meet Reasonable Crop Yield Target[1,2,3,4,5,6]			Nitrogen Present in Soil[7]	Plant Uptake	Nitrogen Removed at Harvest[8]	Crop Residue return to Soil	Nitrate Present in Irrigation Water[9]		Soil borne/ Waterborne Erosion[10]	Nitrogen Fixation[10]	Denitrification[10]	Volatilization of NH3[10]
	Low	High	Average										
	(Lbs. N/A)	(Lbs. N/A)	(Lbs. N/A)	(Lbs. N/A)	(Lbs. N/A)	(Lbs. N/A)	(Lbs. N/A)	(mg/L)	(Lbs. N/A)	Percent	Percent	Percent	Percent
Rotational Vegetables	180	275	228	Field Measured	180	86	94	Assigned	Convert to N	Reduced over time	Constant	Constant	Constant
Broccoli	175	250											
Cauliflower	175	300											
Celery	250	350											
Lettuce	120	200											
Strawberries[2]	175	190	183	Field Measured		Estimated		Assigned	Convert to N	Reduced over time	Constant	Constant	Constant
Vineyard[3]	30	50	40	Field Measured		Estimated		Assigned	Convert to N	Reduced over time	Constant	Constant	Constant
Total Pasture[4]	Uncertain	Uncertain	Estimated as 15	Uncertain		Uncertain		Assigned	Convert to N	Constant	Constant	Constant	Constant
Field[5]	65	220	Estimated as 150	Field Measured		Estimated		Assigned	Convert to N	Reduced over time	Constant	Constant	Constant
Grain[6]	Uncertain	Uncertain	Estimated as 90	Uncertain		Estimated		Assigned	Convert to N	Reduced over time	Constant	Constant	Constant
Nursery[6]	Uncertain	Uncertain	Estimated as 100	Uncertain		Estimated		Assigned	Convert to N	Reduced over time	Constant	Constant	Constant
Total Orchard[6]	Uncertain	Uncertain	Estimated as 100	Uncertain		Estimated		Assigned	Convert to N	Reduced over time	Constant	Constant	Constant

Notes: [1] Rotational Vegetables - Average Nitrogen added for crop is based on Nutrient Management in Cool-Season Vegetables. Publication 8098 University of CA, Div. of Agriculture and Natural Resources

[2] Strawberries - Average Nitrogen added for crop based on conversation with Tim Hartz; Presentation "Strawberry Plant Nutrient Sufficiency Levels Revised"; Strawberry Field Day, Manzanita Berry Farms, Santa Maria,

[3] Vineyard - Average Nitrogen added for crop based on information obtained at a field visit to local vineyard and University of California Cooperative Extension, Pub NG4-96, Best Management Practices for Nitrogen Fertilization of Grapevines.

[4] Nitrogen added on pasture assigned a reasonably small amount since fertilizer needs are low and crop residue regularly removed.

[5] Field - Average Nitrogen added for field crops is uncertain since the land use changed from various field crops to vegetables; a range of values for field crops was found in Table 8.8 Typical Nitrogen Uptake Values for Selected Crops, in Natural Wastewater Treatment Systems reference; a higher root zone efficiency for N is assigned to account for deeper root zone and higher amount removal of field crops at harvest than vegetable

[6] Nitrogen estimated for Grain, Nursery, and Total Orchard crop categories based on professional judgment; higher N efficiency assigned in nutrient balance since much or the N update remains in plant material not returned as crop residue to the soil.

[7] Nitrogen Present in Soil is determined through soil sampling and monitored with field measurements to determine long term balance; for this assessment, assigned as a relative constant annual value.

[8] Nitrogen removed at harvest is estimated by average Plant Uptake minus average Crop Residue that returns to the soil; Rotational Vegetables based on UCCE Publication 8097; Strawberry was assigned higher than Rotational Veg based on information from Strawberry Field Day; for all other crops the N root zone efficiency was assigned similar value as distribution uniformity.

[9] Nitrate present in irrigation water was assigned a concentration based on USGS well sample data and limited sample information representing shallow drain water; N concentration in irrigation water for Rot Vegetables and Strawberries was increased in the 1991-2000 and 2001-2010 to reflect management practice to utilize N in source water to finish crop growth.

[10] Nitrogen terms in root zone balance assigned a percentage and treated as a constant for this relative analysis since data was limited data and uncertain regarding each term.