# Conjunctive Management and Groundwater Storage

***Photo caption.*** Kern water bank.

# Contents

**Chapter 8. Conjunctive Management and Groundwater Storage ..... 8-5**
Introduction ..... 8-5
Fundamental Elements and Components ..... 8-5
Groundwater Storage ..... 8-8
Groundwater and Surface Water Interrelated ..... 8-8
Meeting Multiple Objectives ..... 8-9
Conjunctive Management and Groundwater Storage in California ..... 8-14
Data Collection and Management ..... 8-16
Potential Benefits of Conjunctive Management and Groundwater Storage ..... 8-18
Potential Costs of Conjunctive Management and Groundwater Storage ..... 8-23
Major Issues Facing Conjunctive Management and Groundwater Storage ..... 8-23
Uncertainty in Surface Water Availability from State and Federal Water Projects ..... 8-23
Uncertainty in Evaluating Impacts of Groundwater Pumping on Surface Water Flows and Aquatic Ecosystems ..... 8-23
Effects of Land Use Changes on Costs and Siting of New or Enlarged Recharge Facilities (and Recharge Area Protection) ..... 8-24
Inconsistency and Uncertainty in Regulatory Status with Respect to Recharge and Surface Commingling of Different Quality Water ..... 8-24
Lack of Data and Tools ..... 8-25
Denied Public Access to Well Completion Reports ..... 8-26
Infrastructure and Operational Constraints ..... 8-26
Surface Water and Groundwater Management ..... 8-27
Water Quality ..... 8-29
Environmental Concerns ..... 8-29
Climate Change Impact ..... 8-29
Funding ..... 8-30
Recommendations to Improve Conjunctive Management and Groundwater Storage ..... 8-30
References ..... 8-34

## Figures

Figure 8-1 Fundamental elements of conjunctive management ..... 8-6
Figure 8-2 Components of a conjunctive management project ..... 8-7
Figure 8-3 Distribution of AB 303 grants from 2001 to 2008 for local groundwater assistance (from DWR IWRIS) ..... 8-17

## Tables

Table 8-1 Possible benefits of conjunctive management implementation ..... 8-22

## Boxes

Box 8-1 Importance of Groundwater to California Water Supply ..... 8-10
Box 8-2 Groundwater and Surface Water, a Single Resource ..... 8-12
Box 8-3 Groundwater Recharge: Natural and Managed..... 8-13
Box 8-4 Conjunctive Management Case Study 1 in Southern California ..... 8-18
Box 8-5 Conjunctive Management Case Study 2 in Northern California ..... 8-19
Box 8-6 Example Regional Cooperative Arrangements in Northern California ..... 8-19
Box 8-7 Groundwater Overdraft and Conjunctive Management..... 8-20

# Chapter 8. Conjunctive Management and Groundwater Storage

## Introduction

Conjunctive management (use) refers to the coordinated and planned use and management of both surface water and groundwater resources to maximize the availability and reliability of water supplies in a region to meet various management objectives. Surface water and groundwater resources typically differ significantly in their availability, quality, management needs, and development and use costs. Managing both resources together, rather than in isolation, allows water managers to use the advantages of both resources for maximum benefit. Conjunctive management (use) thus involves the efficient use of both resources through the planned and managed operation of a groundwater basin and a surface water storage system combined through a coordinated conveyance infrastructure. Water is stored in the groundwater basin for later and planned use by intentionally recharging the basin when excess water supply is available, for example, during years of above-average surface water supply or through the use of recycled water. The necessity and benefit of conjunctive water management are apparent when surface water and groundwater are hydraulically connected. Well planned conjunctive management not only increases the reliability and the overall amount of water supply in a region, but provides other benefits such as flood management, environmental water use, and water quality improvement. Greater benefit can usually be achieved when it is applied to multiple regions or statewide.

*Conjunctive management (use) involves the efficient use of both resources through the planned and managed operation of a groundwater basin and a surface water storage system combined through a coordinated conveyance infrastructure.*

### Fundamental Elements and Components

One of the roles and goals of the State of California is to seek statewide water supply reliability and sustainability. Similarly, one of the roles and goals of DWR is to strive for sustainable groundwater supplies throughout the state. Conjunctive management is emerging as one major water resources management tool to attain these goals. The three fundamental elements of conjunctive management are:

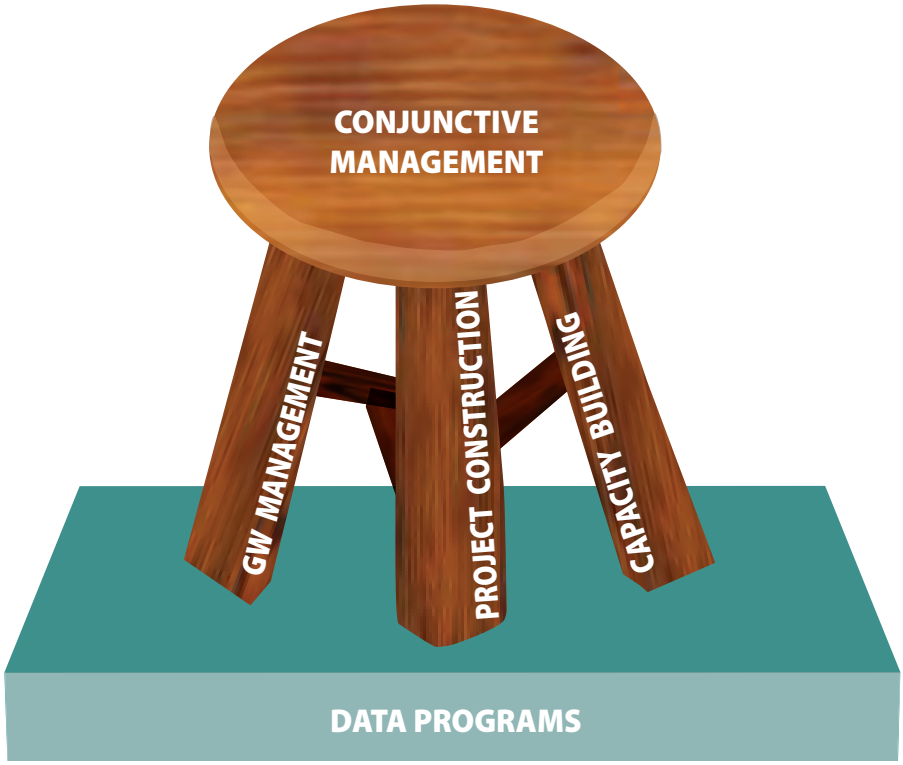
- Project Construction,
- Groundwater Management, and
- Capacity Building.

Project construction may include construction of treatment facilities, conveyance facilities, or spreading basins; installation of monitoring, production, and injection wells; and drilling of test holes.

Groundwater management is the planned and coordinated management of a groundwater basin or portion of a groundwater basin with a goal of long-term sustainability of the resource. In particular, groundwater management is directed toward improving specific aspects of the management of groundwater resources in individual basins or portions of basins, across a region or throughout the state. The improvements pertain to many

*Groundwater management is the planned and coordinated management of a groundwater basin or portion of a groundwater basin with a goal of long-term sustainability of the resource.*

**Figure 8-1** **Fundamental elements of conjunctive management**




aspects of groundwater management, including characterizing and increasing knowledge of individual groundwater basins, identifying basin management strategies or objectives, planning and conducting groundwater studies, and designing and constructing conjunctive management projects.

*Capacity building is the process of equipping entities, usually public agencies, with certain skills or competences, or of upgrading performance capability by providing assistance, funding, resources, and training.*

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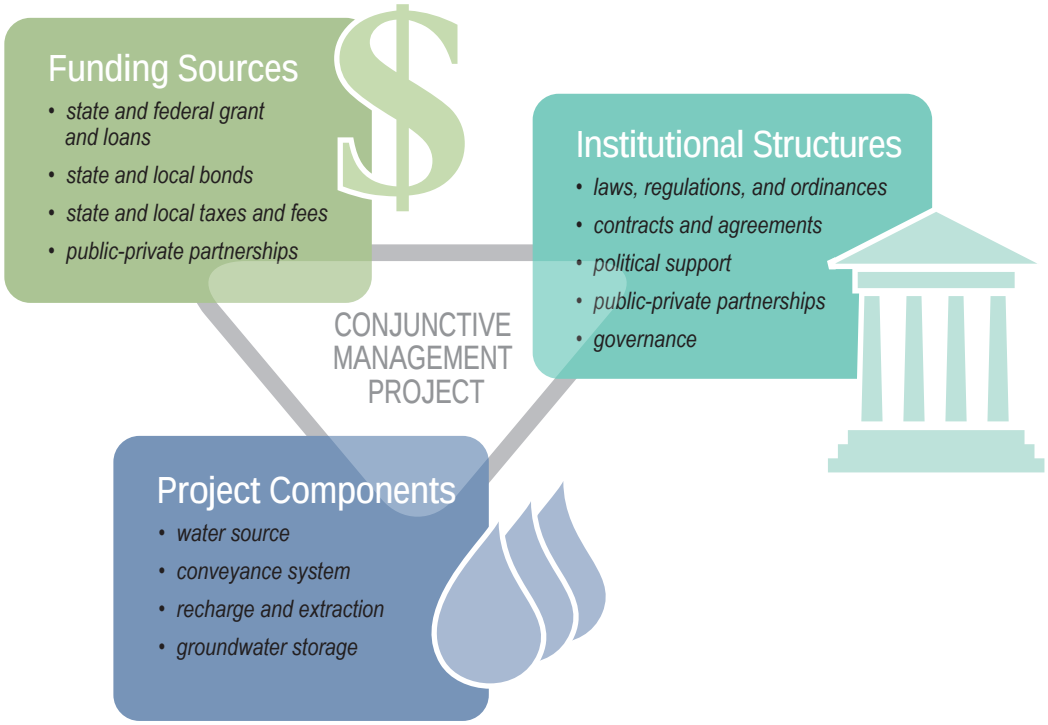
As depicted in Figure 8-1, the three fundamental elements of conjunctive management—project construction, groundwater management, and capacity building—are like the legs of a three-legged stool. Just as all three legs are essential to keep the stool standing, all three fundamental elements are indispensable for conjunctive management to be functional. Missing any of the fundamental elements will make conjunctive management impractical and unworkable.

In practical terms, these elements of conjunctive management blend together for a specific project or program through a combination of components:

- Project Components,
- Institutional Structures, and
- Funding Sources.

**Figure 8-2 Components of a conjunctive management project**




As illustrated in Figure 8-2, the confluence of these components embodies the conditions necessary to bring a conjunctive management project to fruition.

Project components may include water sources, conveyance systems, recharge and extraction, and groundwater storage. Water sources include imported water, local runoff, and treated wastewater. Conveyance systems include lined and unlined canals, pipelines, and streams. Recharge includes direct spreading, injection, in-lieu recharge, and induced natural recharge. Extraction may be for the purposes of direct use, pump back to conveyance systems, and surface water exchange. Groundwater storage may be used for increased conjunctive management and water banking.

Institutional structures include laws, regulations, and ordinances; contracts and agreements; political support, public-private partnerships, and governance. As with other types of projects, conjunctive management projects must also adhere to local ordinances in addition to State and federal laws and regulations.

Funding sources include State and federal grants and loans, State and local bonds, State and local taxes, assessments and fees, public-private partnerships, etc. As with other types of projects, a conjunctive management project also has cost components and financing/economics issues associated with it. As a result, available sources of funding have to be identified and secured to successfully plan, design, and implement a conjunctive management project.

## Groundwater Storage

As noted, groundwater storage is one of the critical issues that must be addressed to ensure the success of a conjunctive management project. Groundwater storage can be defined in three different ways depending on the context of its use: (a) the quantity of water that occurs beneath the land surface and fills the pore spaces of the alluvium, soil, or rock formation beneath the land surface; (b) the volume of usable physical space available to store water in the pore spaces of the alluvium, soil, or rock formation beneath the land surface; (c) the act of storing water in the pore spaces of the alluvium, soil, or rock formation beneath the land surface. These water-filled geologic materials, or aquifers, may receive the water, or be "recharged," from natural hydrologic processes, or the water may be introduced to the aquifer by active groundwater management. The water in these aquifers may be withdrawn through wells, or the water may discharge naturally, contributing to streamflow or to the supply of water for springs, seeps, and wetlands. Maximum attainable groundwater storage or groundwater storage capacity is defined as the maximum volume of usable void space that can be occupied by water in a given volume of a formation, aquifer, or groundwater basin.

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Groundwater remains an important water source for municipal drinking water, agriculture, and individual water users across California. Groundwater storage is less susceptible to adverse impacts from natural hazards and requires less maintenance compared to surface storage. Over the years, groundwater has played a leading role in transforming California into the nation's top agricultural producer, most populous state, and the 7th largest economy in the world. In 1995, an estimated 13 million Californians, nearly 43 percent of the state's population, were served by groundwater. Many small- to moderate-sized towns and cities (e.g., Fresno, Davis, Lodi) rely solely on groundwater for their drinking water supplies. In California, public water supply systems alone use more than 16,000 wells to supply water to the public (DWR, 2003). The demand on groundwater will continue to increase as California's population grows from 37 million (2005 estimate) to a projected 60 million by 2050, based on current trends (DWR, 2009a). To obtain a quantitative feel of the importance of groundwater to California water supply, see Box 8-1.

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## Groundwater and Surface Water Interrelated

In the past, water resources in many regions have been developed and managed with the underlying assumption that surface water and groundwater are separate resources. Although in a number of basins in California there has been an intuitive understanding of the interrelationship between surface water and groundwater, only in recent years has it become unmistakably recognized that development of one resource affects the other. Groundwater and surface water bodies are connected physically in the hydrologic cycle and interact with each other. At some locations or at certain times of the year, groundwater will be recharged through infiltration from the bed of a stream. At other locations or at other times, groundwater may discharge to the stream, contributing to its baseflow. Similarly, degradation of surface water quality may result in a corresponding degradation of groundwater quality. Pollution of groundwater

may result in a corresponding pollution of surface water. Thus changes in either the groundwater or surface water system will directly affect the other. Although this physical interconnection is understood in general terms, details of the physical and chemical relationships remain the topic of considerable current studies by various State and federal agencies. Effective conjunctive management acknowledges the interconnection of the two resources and incorporates the principles of groundwater/surface water exchange to maximize the beneficial uses of the integrated water system (see Box 8-2).

*Effective conjunctive management acknowledges the interconnection of groundwater and surface water resources and incorporates the principles of groundwater/surface water exchange to maximize the beneficial uses of the integrated water system. See Box 8-2 on Page 8-12.*

## Meeting Multiple Objectives

Conjunctive water management projects may be implemented to meet many objectives including improving local or regional water supply reliability, increasing flood protection, meeting environmental needs, improving groundwater quality, or reducing groundwater overdraft. One example of conjunctive water management is recharging groundwater storage using surface water when additional surface water supplies are available and affordable. The surface water may be introduced into the aquifer through injection wells, spreading the water on permeable ground surfaces in recharge ponds, or introducing the water into streams that are connected to the aquifer through permeable streambeds. The stored water in the aquifer can then be withdrawn at a later time when surface water is not available or too expensive to meet local demands. In some areas, "recharge" may be accomplished by providing surface water to users who would normally use groundwater (also called in-lieu recharge), thereby leaving more groundwater in place for restoring groundwater levels or for later use. For further discussion on natural and managed groundwater recharge, see Box 8-3.

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A sustainable conjunctive water management program consists of several components that include investigating the groundwater aquifer characteristics, estimating surface water and groundwater responses, and appropriate monitoring of groundwater level and quality. In addition, reliable institutional systems for ensuring environmental compliance, providing long-term system maintenance, and managing contractual and legal features of the program are critical to sustainability.

Conjunctive management and groundwater storage strategies are closely linked with the strategies groundwater remediation/aquifer remediation strategy and recharge area protection. Groundwater remediation may be implemented in areas where the usability of the aquifer for groundwater storage has been compromised by aquifer contamination, thereby partially or fully restoring the capacity of the aquifer for storage or limiting the extent of the water quality problem.

Although conjunctive management programs often involve artificial recharge of aquifers with water from other sources, most California aquifers, and therefore any conjunctive management programs using those aquifers, are heavily dependent on recharge from natural sources. As such, the resource management strategy for recharge area protection is critical to maintaining groundwater storage for long-term reliability of conjunctive management supplies.

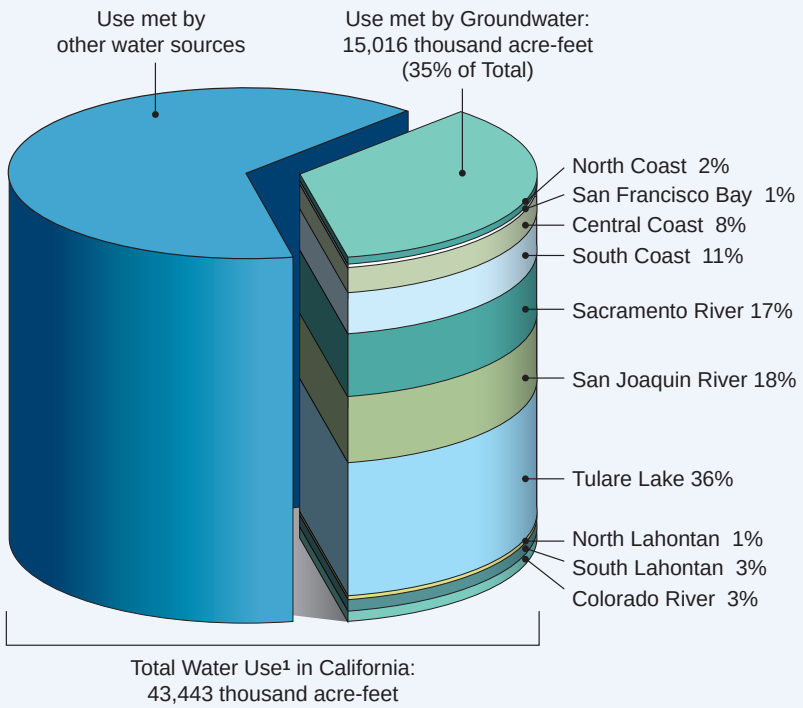
## Box 8-1 Importance of Groundwater to California Water Supply

In an average year (based on 1998-2005 data), groundwater meets about 35 percent of California's agricultural, urban, and managed wetlands water uses (about 15 million acre-feet per year). In dry years, this percentage increases to 40 percent or higher statewide; and as high as 60 percent or more in specific regions (DWR, 2009a; 2009b). The importance of groundwater as a resource varies regionally. Figures A and B depict the importance of groundwater as a local supply for agricultural, urban, and managed wetlands water uses in each of California's 10 hydrologic regions (regions). Figure A shows the percentage of groundwater extraction in each region relative to the total groundwater extraction in the state as a whole. Figure B shows the total water use as well as the water use met by groundwater in the different regions.

With more than 80 percent of water use met by groundwater in an average year, the Central Coast Hydrologic Region is heavily reliant on groundwater to meet its local uses. The Tulare Lake Hydrologic Region meets about 50 percent of its local uses from groundwater, and South Lahontan Hydrologic Region meets an estimated 70 percent of its local uses with groundwater. The North Coast, San Francisco Bay, South Coast, Sacramento River, San Joaquin River, and North Lahontan regions meet between 15 and 35 percent of their local uses with groundwater. Percentage wise, groundwater is a relatively minor source of supply in the Colorado River Hydrologic Region (Figure B).

As shown in Figure A, of all the groundwater extracted annually in the state in an average year (based on 1998-2005 data), more than 35 percent is produced from the Tulare Lake Hydrologic Region. More than 70 percent of groundwater extraction occurs in the Central Valley (Sacramento River, San Joaquin River, and Tulare Lake regions combined). Nearly 20 percent is extracted in the highly urbanized Central Coast and South Coast regions, while about 10 percent is extracted in the remaining five hydrologic regions combined (DWR, 2009a; 2009b). With the growing limitations on available surface water exported through the Sacramento-San Joaquin Delta and the potential impacts of climate change, reliance on groundwater through conjunctive management will become increasingly more important in meeting the state's future water uses.

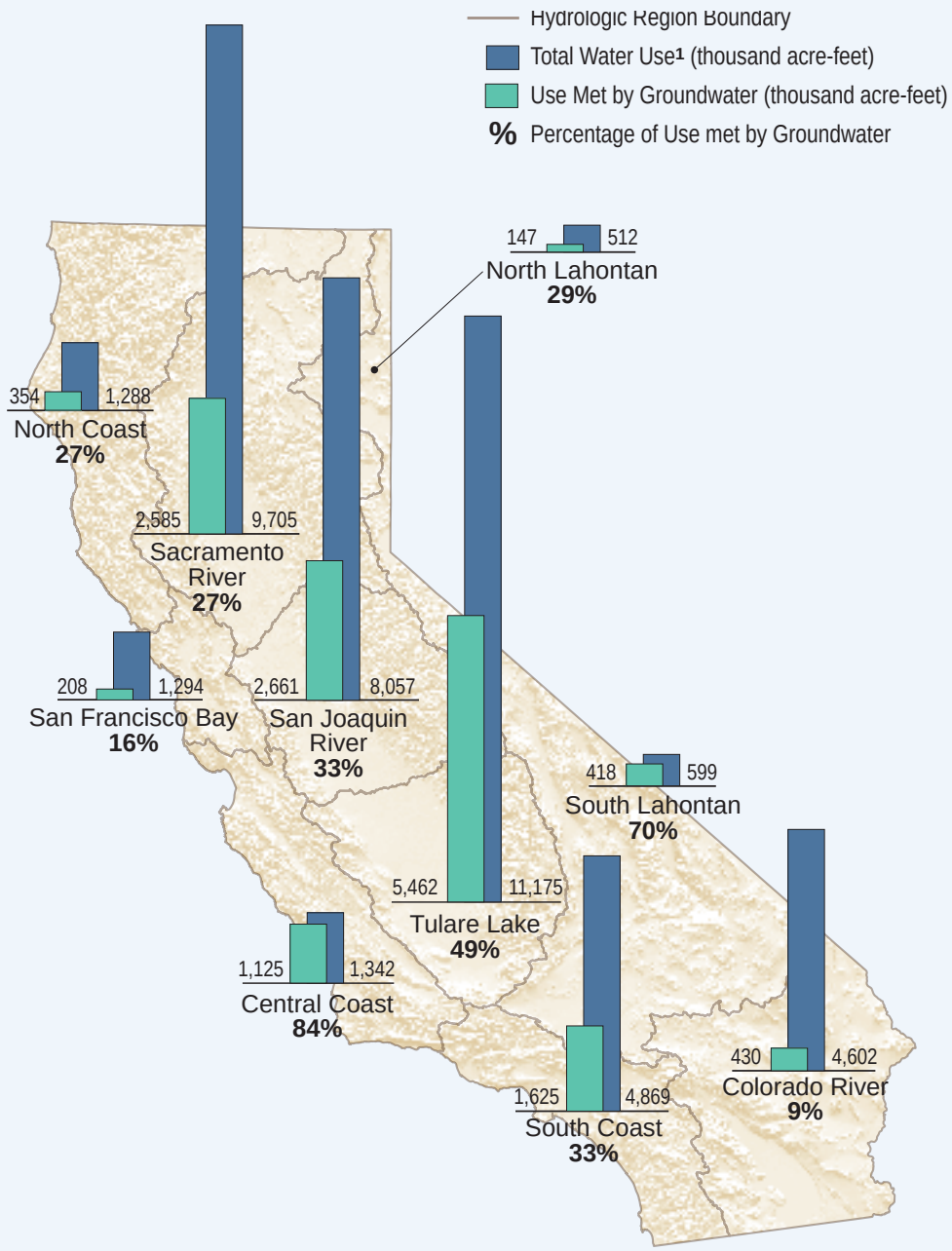
**Figure A Percentage of groundwater extraction in California, statewide and by hydrologic region (1998-2005 average annual data)**




**1.** *Total Water Use is defined as the sum of water uses for agricultural, urban, and managed wetlands.*

## Box 8-1 (continued) Importance of Groundwater to California Water Supply

**Figure B Groundwater contribution to California water supply by hydrologic region (1998-2005 average annual data)**




**1.** *Total Water Use is defined as the sum of water uses for agricultural, urban, and managed wetlands.*

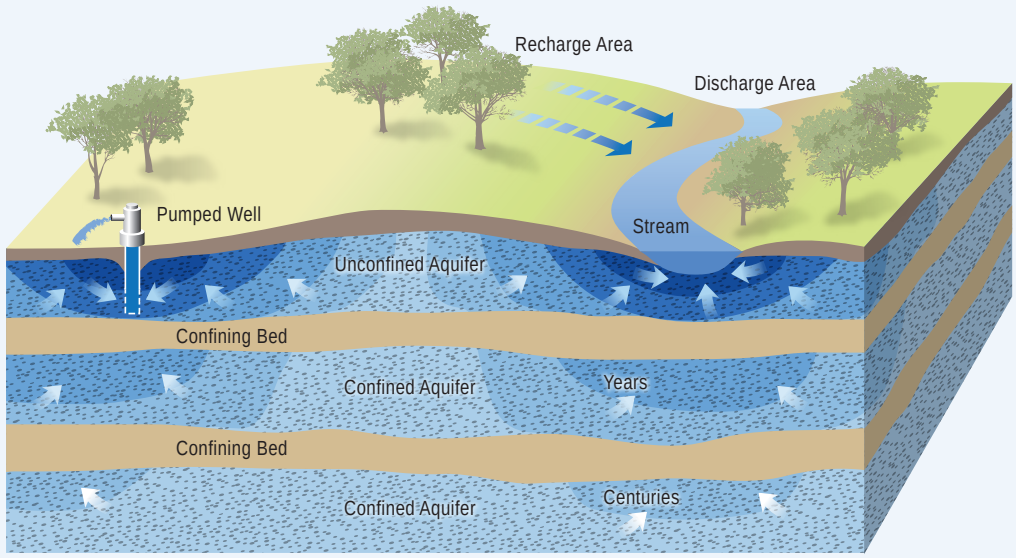
## Box 8-2 Groundwater and Surface Water, a Single Resource

Groundwater moves along flow paths of varying lengths from areas of recharge to areas of discharge. The generalized flow paths start at the water table, continue through the groundwater system, and terminate at the stream or at the pumped well. The source of water to the aquifer is infiltration through the unsaturated soil zone resulting from precipitation, irrigation applied water, managed recharge, etc. The flow paths through the various aquifers onto the stream can be tens to hundreds of feet in length and have corresponding travel times of days to several years or more (see Figure a below).

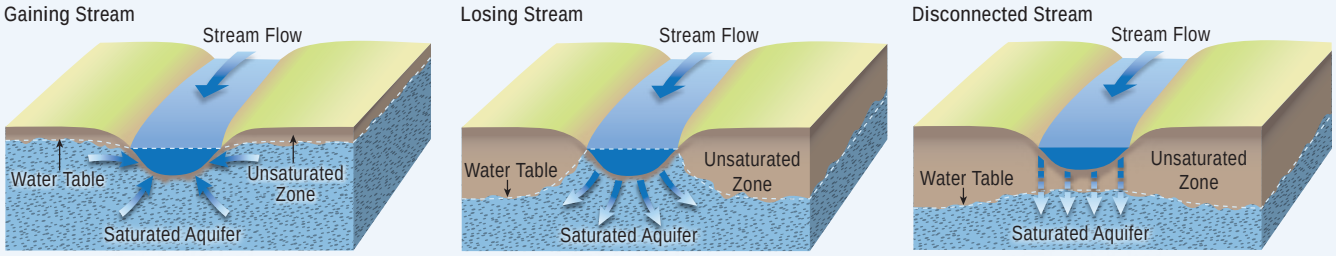
The interaction of streams with groundwater may take place in three different ways: streams may gain water from discharge of groundwater through the streambed (gaining stream), streams may lose water to groundwater by seepage through the streambed (losing stream), or streams may gain in some reaches (gaining reaches) and lose in rest of the reaches (losing reaches). As shown in Figure b, for streams to gain water from groundwater, the stream water surface elevation must be lower than the surrounding groundwater table elevation. In contrast, as shown in Figure c and Figure d, for streams to lose water to groundwater, the stream water surface elevation must be higher than the surrounding groundwater table elevation. Losing streams can be connected to the groundwater system by a continuous saturated zone (Figure c) or can be disconnected from the groundwater system by an unsaturated zone (Figure d). A distinguishing characteristic of a stream that is disconnected from groundwater is that shallow groundwater pumping in the vicinity of the stream does not necessarily induce additional seepage of water from the stream to groundwater (Winter et al., 1998).

The direction of flow between the stream and the groundwater system may change because of storms (or floodflows moving down the stream), causing water to flow from the stream to groundwater. The direction of flow between the stream and groundwater can alter as a result of groundwater pumping near the stream. In the case of a gaining stream, pumping is likely to decrease discharge from the aquifer to the stream and in some cases, high pumping rates can even modify a gaining stream to a losing stream. In the case of a losing stream, pumping is likely to further increase seepage from the stream to the aquifer (Winter et al., 1998).

The characteristics and extent of the interactions of groundwater and surface water in an area will likely define the success of conjunctive management projects. Therefore, a better understanding of the interconnection between groundwater and surface water is instrumental for effective conjunctive management.




a




b c d

## Box 8-3 Groundwater Recharge: Natural and Managed

Groundwater recharge is the mechanism by which surface water moves from the land surface, through the topsoil and subsurface, and into de-watered aquifer space, or through injection of water directly into the aquifer by wells. Groundwater recharge can be either natural or managed. Natural recharge occurs from precipitation falling on the land surface, from water stored in lakes, and from streams carrying storm runoff (Figure a). Managed recharge occurs when water is placed into constructed recharge or spreading ponds or basins, or when water is injected into the subsurface by wells. Managed recharge is also known as artificial, intentional, or induced recharge. Two widely used methods for managed groundwater recharge are recharge basins and injections wells:

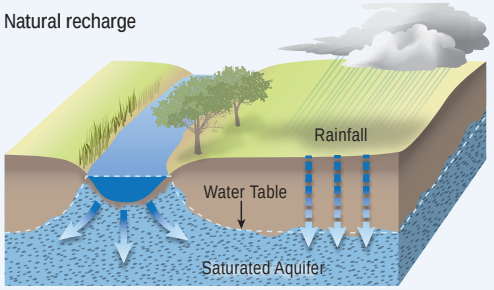
**Recharge Basins.** Recharge basins are frequently used to recharge unconfined aquifers. Water is spread over the surface of a basin or pond in order to increase the quantity of water infiltrating into the ground and then percolating to the water table. Recharge basins concentrate a large volume of infiltrating water on the surface. As a result, a groundwater mound forms beneath the basin. As the recharge starts, the mound begins to grow; when the recharge ceases, the mound recedes as the water spreads through the aquifer (Figure b). The infiltration capacity of recharge basins is initially high, and then as recharge progresses the infiltration rate decreases as a result of surface clogging by fine sediments and biological growth in the uppermost layer of the soil. It has been found that the operation of recharge basins with alternating flooding and drying-out periods maintains the best infiltration rates. Fine surface sediments may occasionally need to be removed mechanically to maintain the effectiveness of recharge basins.

**Injection Wells.** Injection wells are used primarily to recharge confined aquifers. The design of an injection well for artificial recharge is similar to that of a water supply well. The principal difference is that water flows from the injection well into the surrounding aquifer under either a gravity head or a head maintained by an injection pump (Figure c). As a large amount of water is pushed through a small volume of aquifer near the well face, injection wells are prone to clogging, which is one of the most serious maintenance problems encountered. Clogging can occur in the well perforations, in the well-aquifer interface, and in the aquifer materials. It is suspected that a combination of a build-up of materials brought in by the recharging water and chemical changes brought about by the recharging water are the primary causes of clogging. The most economical way to operate artificial recharge by injection consists of using dual purpose wells (injection and pumping) so that cleaning of the well and the aquifer may be achieved during the pumping period. However, pretreatment of the water to be injected is always necessary to eliminate the suspended matter.

Another widely used method for managed recharge is through release of water into streams beyond what occurs from the natural hydrology (Figure d). Significant amounts of recharge can also occur either intentionally or incidentally from applied irrigation water and from water placed into unlined conveyance canals.

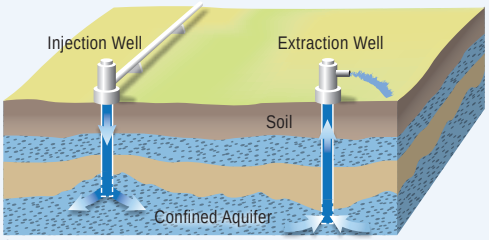
The major purpose of managed recharge is to increase water supply in an area by supplementing the existing groundwater supply. The use of managed recharge to enhance the availability and quality of groundwater has received increased attention in recent years. In California, numerous managed recharge projects have been implemented and others are planned.

Natural recharge



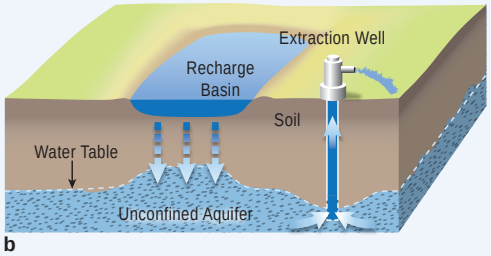

a

Managed recharge: injection wells



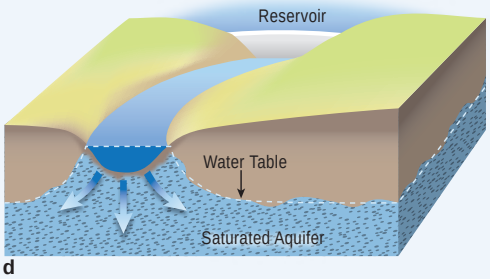

c

Managed recharge: recharge basins




b

Managed recharge: stream/canal seepage




d

Conjunctive management and groundwater storage, in the context of Integrated Regional Water Management (IRWM), may be intertwined with many other management strategies, including conveyance, desalination, drinking water treatment and distribution, ecosystem restoration, floodplain management, recycled municipal water, surface storage, urban land use management, water transfers, system reoperation, and watershed management. Examples of these relationships are discussed in this chapter and elsewhere in California Water Plan Update 2009.

## Conjunctive Management and Groundwater Storage in California

Conjunctive management has been practiced in California to varying degrees since the Spanish mission era. The first known managed recharge of groundwater in California occurred in Southern California during the late 1800s, and managed recharge has become an increasingly important part of integrated water management in many areas.

Unlike surface water use, groundwater use in California does not have a statewide management program or statutory permitting process. When the Water Commission Act became effective in 1914, surface water appropriative rights became subject to a statutory permitting process. The statutory permitting process is defined under California State law through which a water user must obtain, modify, or renew water rights permits from the State Water Resources Control Board (State Water Board). The Water Commission Act of 1914 was the predecessor to today's Water Code provisions governing appropriation. In addition to surface water, groundwater classified as underflow of a surface water system, a "subterranean stream flowing through a known and definite channel," was also made subject to statutory permitting process. However, most groundwater in California is presumed to be "percolating water," that is, water in underground basins and groundwater which has escaped from streams and is not subject to a permitting process. As a result, most of the body of law governing groundwater use in California today has evolved through a series of court decisions beginning in early 20th century (DWR, 2003).

The California Legislature has repeatedly held that groundwater management is a local responsibility (Sax, 2002). The State's role is to provide technical and financial assistance to local agencies for planning and implementing groundwater management efforts. There are three forms of groundwater management in California: local agency management, local groundwater ordinance, and court adjudication (DWR, 2003).

*There are three forms of groundwater management in California: local agency management, local groundwater ordinance, and court adjudication*

More than 20 types of local agencies are authorized by statute to provide water for various beneficial uses. Many of these agencies also have statutory authority to institute some form of groundwater management, but their specific authority related to groundwater management varies. In 1991, Assembly Bill (AB) 255 authorized local agencies overlying basins that are subject to critical conditions of overdraft, as defined in DWR's Bulletin 118-80, to establish voluntary groundwater management plans within their service areas (DWR, 2003).

The passage of AB 3030 in 1992 (California Water Code Section 10750 et seq.) greatly encouraged local agencies to adopt groundwater management plans for managing their groundwater resources whether or not the groundwater basin is in overdraft condition. In 2002, the Legislature passed SB 1938, which contained new requirements for local agency groundwater management plans and required adoption of these plans for groundwater projects to be eligible for public funds. At the time Bulletin 118 was published in 2003, more than 200 local agencies had adopted AB 3030 groundwater management plans. With the emphasis in recent years on integrated regional water planning and management, IRWM plans have been prepared for many regions throughout the state, and the portion of the state covered by an IRWM plan is continually expanding as new IRWM plans are developed. An important consideration in the coordination of surface water and groundwater resources in California is the question of potential adjudications of water rights by Tribal communities. Additionally, Tribal rights to groundwater in some areas could be significant, for example, in San Diego County. Tribal water rights and adjudications, pertaining to both surface water and groundwater, are issues that must be substantively addressed for viable, long-term water resources planning in California.

Over the past few years, to promote conjunctive management of surface water and groundwater, California voters and the Legislature have provided significant funding to local agencies for groundwater management. Proposition 13, approved by voters in 2000, provided $200 million for grants for feasibility studies, project design, and the construction of conjunctive use facilities; and $30 million for loans for local agency acquisition and construction of groundwater recharge facilities and grants for feasibility studies of groundwater recharge projects. AB 303, enacted in 2000, created the Local Groundwater Assistance (LGA) fund and authorized grants totaling $34.2 million from 2001 to 2008 to help local agencies develop better groundwater management strategies. Proposition 50, passed in 2002, provided $500 million for IRWM projects. Although this funding is not specifically targeted at groundwater projects, many of the projects in the regional proposals would expand groundwater storage, desalt brackish groundwater, or improve groundwater quality to make new supplies available. Proposition 84, approved in 2006, contained an additional $1 billion for IRWM projects.

Along with providing increased funding for IRWM projects as noted above, the State in 2009 enacted Senate Bill 6 (SB 6) Groundwater Monitoring of the 2009 Comprehensive Water Package (adds to and amends parts of Division 6 of the Water Code, specifically Part 2.11 Groundwater Monitoring). SB 6 requires that local agencies monitor and report the elevation of their groundwater basins to help better manage the resource during average water years and drought conditions. Specifically, this bill stipulates the following:

- DWR will establish a priority schedule for monitoring groundwater basins and the review of groundwater elevation reports and make recommendations to local entities to improve the monitoring system;
- DWR will assist local monitoring entities' compliance with this bill;

- Local entities will be allowed to determine regionally how best to set up groundwater monitoring program, crafting the program to meet their local circumstances;
- DWR will implement groundwater monitoring programs in regions where local agencies fail to implement a monitoring program or fail to provide the required reports;
- By January 2, 2012, DWR in conjunction with public agencies will report to the Governor and Legislature findings of investigations of the state's groundwater basins that will include geological and hydrological conditions and general patterns of groundwater pumping and recharge; and
- Findings will be reported to the Governor and Legislature thereafter in years ending in 5 and 0.

## Data Collection and Management

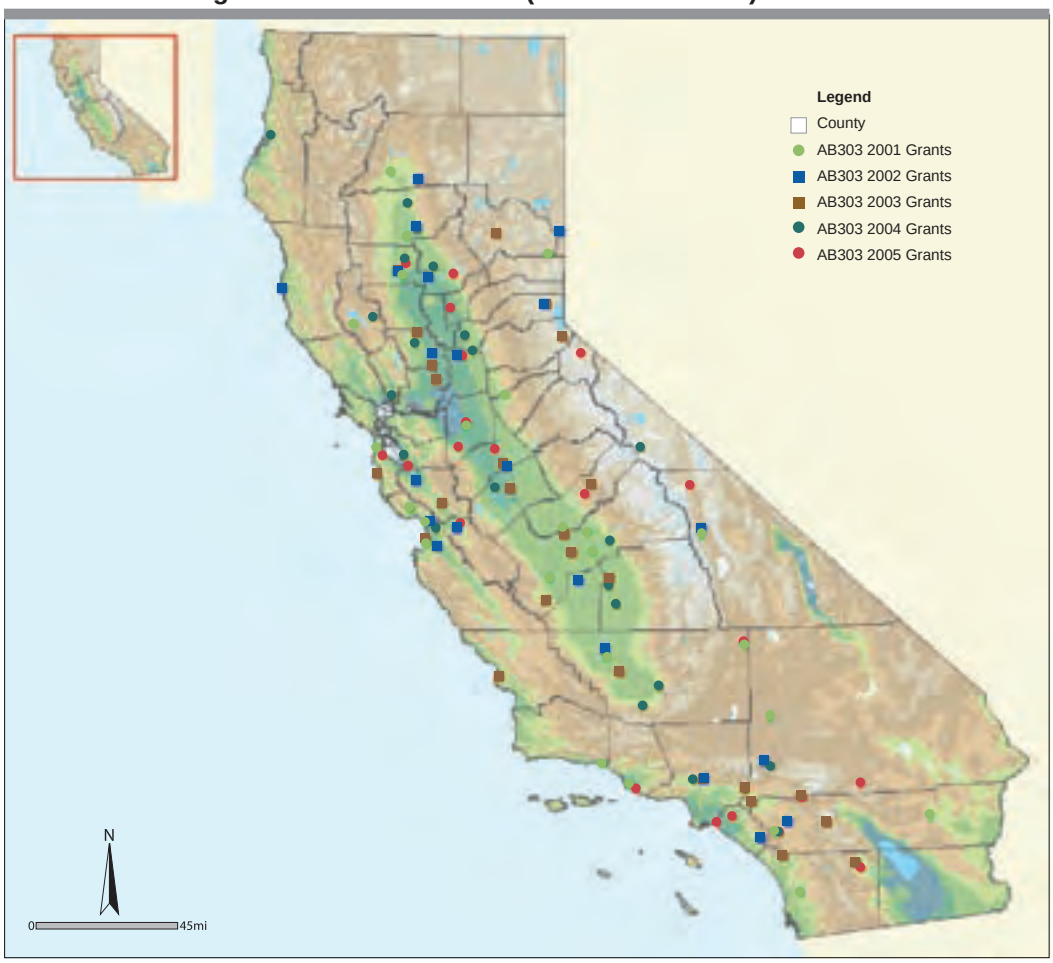
Statewide data are important in planning and developing the conjunctive water management strategies. The data should include, in addition to those collected as part of SB 6, groundwater management-related information, groundwater quantity and quality, and water use in the state. DWR's Bulletin 118 series (California's Groundwater) provides information about the state's groundwater resources and its current resource management practices.

*The Integrated Water Resources Information System (IWRIS), released by DWR in 2008, is the first centralized groundwater data management system developed to help local and regional water management entities integrate and analyze existing data about their groundwater system and potential value of current groundwater management in their integrated planning processes.*

The Integrated Water Resources Information System (IWRIS), released by DWR in 2008, is the first centralized groundwater data management system developed to help local and regional water management entities integrate and analyze existing data about their groundwater system and potential value of current groundwater management in their integrated planning processes. It serves as a centralized information system for accessing the data about groundwater as well as groundwater management and some DWR grant program funding statewide. Figure 8-3 shows a distribution of the AB 303 Grants from 2001 to 2008 for helping the development of groundwater management plans which usually include conjunctive management strategies. Figure 8-3 was generated from DWR IWRIS, and is available at http://app1.iwris.water.ca.gov/iwris/.

Although provisions in SB 6 are steps in the right direction, there is no comprehensive statewide data monitoring network for the purpose of planning and implementation of conjunctive management. The availability of information is increasing as local and regional water management entities analyze the existing and potential value of active groundwater management in their integrated planning processes. It is important to have updated information on the various conjunctive water management planning and implementation activities statewide to achieve better coordination among future conjunctive water management planning activities and avoid potential conflicts. DWR is developing a statewide inventory of conjunctive use that will be included in future California Water Plan updates.

**Figure 8-3 Distribution of AB 303 grants from 2001 to 2008 for local groundwater assistance (from DWR IWRIS)**




Source: DWR's IWRIS system. Available at http://app1.iwris.water.ca.gov/iwris/

This resource management strategy chapter deals with general and statewide issues associated with conjunctive water management. Issues specific to individual hydrologic regions are discussed in their respective reports, part of *Volume 3, Regional Reports, California Water Plan Update 2009* (DWR, 2009b). However, for general illustrative purposes, two case studies—one from Southern California and one from Northern California—are provided here (see Box 8-4 and Box 8-5).

As noted, conjunctive management and groundwater storage is considered an integral element of IRWM, actively promoted and supported by the State. In the context of the rapidly evolving IRWM effort in California, the issue of cooperative arrangement among regional water partners is gaining momentum. Box 8-6 provides a brief description of the "Four County" program in Northern California initiated to promote cooperation among participating counties for resolving regional water management issues across jurisdictional boundaries.

**Box 8-4 Conjunctive Management Case Study 1 in Southern California**

Groundwater storage plays an important role in providing a reliable water supply in areas with limited surface water supplies. The Metropolitan Water District of Southern California (MWD) has performed a groundwater assessment study to analyze groundwater use from 1985-2004. The study shows that groundwater provides nearly 40 percent of the total annual water needs within MWD's service area. Between 1995 and 2004, an average of 1.56 million acre-feet (MAF) of water per year was produced from the groundwater basins. The study also shows that groundwater production varies as much as 30 percent between the wettest and driest year (MWD, 2007).

Groundwater is an important part of MWD's Integrated Water Resource Plan (IRP) for ensuring water supply reliability. To maintain baseline annual production during dry years, the IRP sets out reliability strategies for dry years, and has targeted a dry-year yield from service-area groundwater basins of 275,000 acre-feet per year (AFY) by 2010, and 300,000 AFY by 2020/25. Because MWD plans for the potential of three consecutive dry years, the yield targets are multiplied by three resulting in dry-year storage targets of 825,000 AF by 2010 and 900,000 AF by 2020/25 (MWD, 2007).

Conjunctive management not only uses groundwater storage for water supply, but also provides recharge and protection to groundwater storage. The 20-year study shows that an average recharge of 758,000 AFY resulted from active recharge programs (MWD, 2007). About 90 percent of the groundwater recharge—approximately 681,000 AFY—was from direct recharge methods (injection or spreading) using imported water, treated recycled water and local runoff, and the remaining 10 percent was from in-lieu recharge (MWD, 2007). When surface water supplies are available, MWD encourages in-lieu groundwater recharge by providing financial incentives. As a result of more groundwater recharge facilities becoming available during the period 1995-2004 as compared to the period of 1985-1994, active recharge using local runoff increased by 7 percent while the proportion of imported water used for recharge declined by 5 percent during the later period (1995-2004). Treated recycled water can be used to prevent salt water intrusion to protect existing groundwater resources and maintain valuable groundwater storage. For example, as part of MWD's conjunctive management, recycled water has been spread at Montebello Forebay and injected in the Central Basin of MWD service areas to control sea water intrusion. Recycled water meeting certain water quality standards are also used for irrigation and recharging the groundwater.

The total developed groundwater management capacity in MWD's service area currently includes the following (MWD, 2007):

- More than 4,300 active production wells (municipal, agricultural, industrial, and private),
- 36 ASR (Aquifer Storage Recovery) wells,
- 5,000 acres of spreading basins,
- 400 acres of water quality wetlands to improve quality of inflows to groundwater,
- 7 seawater intrusion barriers, and
- 16 desalters.

## Potential Benefits of Conjunctive Management and Groundwater Storage

Conjunctive management is used to improve water supply reliability and sustainability, to reduce groundwater overdraft and land subsidence, to protect water quality, and to improve environmental conditions. Overdraft is defined as the condition of a groundwater basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which the water

### Box 8-5 Conjunctive Management Case Study 2 in Northern California

The Santa Clara Valley Water District (SCVWD) is the comprehensive water management agency for the residents of Santa Clara County. It supplies clean and safe water, manages local groundwater basins, implements flood protection projects and provides watershed stewardship. It serves approximately 2 million people—1.8 million residents and 200,000 commuters—in 15 cities and unincorporated areas in the 1,300-square-mile county (SCVWD, 2008).

Similar to many other parts of California, the areas served by the SCVWD also witnessed remarkable agricultural and urban development in the last two centuries. These developments began in the latter half of the 19th century post-Gold Rush era and continued throughout the 20th century. The intense urban and agricultural growth resulted in increased groundwater extraction, which in turn, culminated in groundwater level declines of more than 200 feet and land subsidence of nearly 12 feet. To meet the water needs in the valley, in the late 1920s the SCVWD (or its predecessor) was formed (SCVWD, 2009). This set in motion a long succession of facilities construction for surface storage to increase water supply availability and recharge ponds to facilitate conjunctive management through managed groundwater recharge. Since the 1960s, the SCVWD has imported surface water to meet growing demands and reduce dependence on groundwater supplies. Currently, the SCVWD operates and maintains 18 major recharge systems, which consist of both instream and offstream facilities. Local reservoir water and imported water are released in over 30 local creeks for managed instream recharge. In addition, the SCVWD releases locally conserved and imported water to 71 recharge ponds which range in size from less than 1 acre to more than 20 acres. Through these streams and recharge ponds, the SCVWD recharges the groundwater basin with about 156,000 acre-feet of water each year (Parker, T, 2007).

### Box 8-6 Example Regional Cooperative Arrangements in Northern California

An example of a regional effort that attempts to reach across jurisdictional boundaries is the Four County program. This program revolves around a cooperative Memorandum of Understanding (MOU), currently signed by the counties of Butte, Glenn, Tehama, and Colusa, and under consideration by Shasta and Sutter. The MOU outlines how the counties will work together across jurisdictional boundaries on water management issues that are of concern to their collective constituencies. The MOU is accompanied by an addendum which lays out how information regarding activities in neighboring counties will be conveyed to other counties within the region to ensure that all processes are transparent and each jurisdiction is aware of activities that have the potential to impact their citizenry. Although local ordinances may not cross jurisdictional boundaries, board members in each county have expressed that they do not want to cause harm to their neighbors. The cooperative efforts outlined in the MOU, and its addendum, discuss how the various boards intend to communicate and cooperate with each other to that end (Board of Supervisors of Butte, Colusa, Glenn, and Tehama Counties, 2006; 2007).

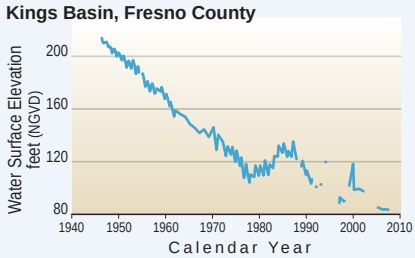
supply conditions approximate average conditions (DWR, 2003). Overdraft may cause land subsidence and damage to the environment and increase energy cost in pumping. An example illuminating the beneficial outcome of conjunctive water management in ameliorating groundwater overdraft is included in Box 8-7.

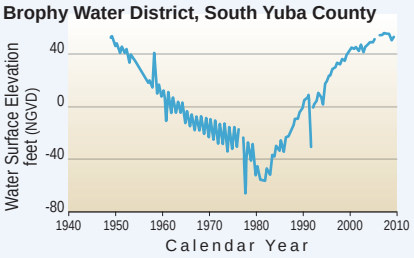
*Overdraft is defined as the condition of a groundwater basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which the water supply conditions approximate average conditions. Overdraft may cause land subsidence and damage to the environment and increase energy cost in pumping.*

As noted previously, the potential benefits from conjunctive management are highly dependent on how well the surface water and groundwater are managed as a single source to adapt to the climate system to maximize use of the water in the managed area. Because precipitation and snow are the ultimate sources of water, effective conjunctive

### Box 8-7 Groundwater Overdraft and Conjunctive Management

The two hydrographs below show the response of groundwater levels to differing water management regimes. The first hydrograph shows groundwater levels declining in response to agricultural development in the San Joaquin Valley. Groundwater levels recover somewhat during the wet period of the early 1980s, but continue to decline through the 1980s and 1990s in the absence of a focused conjunctive water management action. The second hydrograph shows a similar groundwater level decline in response to development in southern Yuba County. However, groundwater levels begin to recover in the early 1980s when surface water imports from Yuba County Water Agency began, resulting in conjunctive water management. The hydrograph shows a decline in groundwater levels during the early 1990s drought as surface water imports were curtailed and groundwater was more heavily relied upon. Thereafter, continued conjunctive water management action resulted in the refilling of the South Yuba Groundwater Subbasin, which continues up to present.




management should maximize the capture of excess water when available and optimize the beneficial use of the water in the system.

The climate in California can usually be described as consisting of a wet season and a dry season in a water year. Most water (as precipitation and snow) is in the northern part of the state. However, most people live in the southern part. Successful conjunctive water management should recognize this climate and maximize the use of water throughout the state. To maintain sustainability of water supply, issues related to climate change should also be considered in conjunctive management. More information on using conjunctive management as a climate change adaptation strategy can be found in the climate change white paper, *Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water* (DWR, 2008). See Volume 4 Reference Guide articles on climate change.

*A sustainable conjunctive management strategy should optimize the beneficial use of the water in the system while balancing all of the objectives. Because of the uncertainty in water demand and climate system, risk management should be considered in conjunctive management planning. A good conjunctive management computer-aided tool can help identify and quantify the benefit and potential risk.*

Any conjunctive management strategy or natural climate variation (not climate change) will produce changes to the water system. However, protecting the environment does not mean restoring the water environment to any "predevelopment" condition, but rather restoring the water environment to certain aspects of earlier conditions prior to significant adverse human impacts. A sustainable conjunctive management strategy should optimize the beneficial use of the water in the system while balancing all of the objectives. Because of the uncertainty in water demand and climate system, risk management should be considered in conjunctive management planning. A good

conjunctive management computer-aided tool can help identify and quantify the benefit and potential risk.

Table 8-1 lists some of the many possible benefits of conjunctive management and highlights some of the major constraints that influence the usefulness and level of benefit that might be obtained. Example 1 in Table 8-1 can be used anywhere in the state to adapt to the two-season pattern so that more water can be captured in the wet season for beneficial use. Example 2 recognizes the fact of the relatively "wet" northern part of the state and shows the benefit of using groundwater storage in the reoperation of the State Water Project (SWP) and the Central Valley Project (CVP) to capture more floodflows, provide flood control benefits, and improve water supply availability and reliability. The range of average annual precipitation from 1971 to 2000 in California can be found in figures furnished in *Chapter 4 California Water Today, Vol. 1, The Strategic Plan, California Water Plan Update 2009* (DWR, 2009a), which can be used as a guide for identifying the relatively "wet" areas in the state. Example 3 demonstrates a way of transferring agricultural groundwater to urban water use to relieve drought emergencies and provide induced groundwater recharge. Example 4 shows use of surface water for preventing salt water intrusion in coastal areas. Example 5 provides not only a solution to reduce or contain the flood risks resulting from the increased runoff due to urbanization but also maintain the natural groundwater recharge in the project areas and provide opportunity for treating storm water in detention/retention ponds.

Currently conjunctive management in Southern California provides more than 2.5 MAF of average annual water supply (Montgomery Watson and Water Education Foundation, 2000). Conservative estimates of additional implementation of conjunctive management indicate the potential to increase average annual water deliveries throughout the state by 0.5 MAF.[1] This estimate is based on the assumption of increased available groundwater through reoperation of existing groundwater system. More aggressive estimates from studies indicate the potential to increase average annual water deliveries by 2 MAF. The more aggressive estimates are based on assumptions that require major reoperation of existing surface water storage and groundwater storage to achieve the benefits and do not fully consider the conveyance capacity constraints for exports through the Delta and other conveyance facilities.[1] This estimate could be considerably lower if either major reoperation of existing surface water storage and groundwater storage is not feasible, or existing conveyance capacity constraints for exports through the Delta and other conveyance facilities are taken into consideration.

1 Information was derived from six sources: 1) Proposition 13 Groundwater Storage Applications to DWR for fiscal year 2001-2002, 2) A year 2000 report entitled, "Groundwater and Surface Water in Southern California: A Guide to Conjunctive Use" (Montgomery Watson and Water Education Foundation, 2000), 3) A 1998 report entitled, "Feasibility Study of a Maximal Program of Groundwater Banking" (Purkey et al., 1998), 4) A year 2002 report entitled, "Estimating the Potential for In Lieu Conjunctive Water Management in the Central Valley of California" (Purkey and Mansfield, 2002), 5) A year 2002 report entitled, "Conjunctive Use for Flood Protection" (USACE, 2002), and 6) A year 2008 draft (unpublished) statewide survey entitled, "Survey Results and Summary: Groundwater Banking Programs Survey" (Kennedy/Jenks, 2008).

**Table 8-1 Possible benefits of conjunctive management implementation**

| Possible benefit of managed groundwater storage | Example | Major constraints |
|---|---|---|
| **Improved local water supply reliability** | 1. Imported surface water supplies and/or floodflows are recharged to local groundwater basin during wet years/seasons, increasing local water supply reliability. | • Availability of surface water supplies.<br>• Limited capacity to capture and recharge high volume, short duration floodflows.<br>• Water quality concern of the recharged water and the impact to the aquifer itself. |
| **Improved statewide water supply reliability** | 2. Groundwater storage in the northern part of the state can be used as backup supplies to allow more aggressive operation of surface storages such as Oroville and Shasta reservoirs by permitting reduced carryover storages so that more floodflows in the wet seasons can be captured. This would increase SWP and CVP operational flexibility and result in improved statewide water supply reliability and sustainability. The reduced carryover storage will be replaced annually by utilizing groundwater storage. | • Availability of a multi-regional / statewide conjunctive water management tool to accurately model surface water and groundwater (including water temperature) responses and to evaluate the proposed management strategy for its benefits, the impacts to third parties and the environment, project cost, etc.<br>• Legal and water rights issues (associated impacts could perhaps be mitigated by compensation to injured parties if any, using the above tool if it were available). |
| **Drought relief for urban water users and potential induced groundwater recharge** | 3. Groundwater substitution transfer and agricultural water transfer. | • A lack of widely recognized mathematical model to accurately quantify the impact to other groundwater and surface water users and the environment.<br>• Potential land subsidence and its quantification and evaluation. |
| **Protection from salt water intrusion** | 4. Recharge groundwater using captured floodflows or recycled water in the vicinity of salt water interface to raise groundwater levels and prevent migration of saline water into freshwater production portions of the aquifer. | • Availability of freshwater supply.<br>• Considerable infrastructure requirements. |
| **Improved flood control and groundwater storage** | 5. Development of detention/ retention ponds at proposed residential subdivisions located in the groundwater recharge protection areas can offset the increased urban runoff due to the development while maintaining natural groundwater recharge. | • Possible water quality problems at detention/retention ponds requiring effective urban storm water management.<br>• Requiring adoption of local ordinance or legislation to support implementation. |

## Potential Costs of Conjunctive Management and Groundwater Storage

Costs for implementation of conjunctive management and groundwater storage may include a wide range of facilities and depend on the site-specific nature of the program; accordingly, the cost for a unit increase in water supply or delivery is highly variable.

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Some projects require relatively minor changes in operations or upgrades of existing infrastructure, such as increased sizing of pumps in existing wells or increased releases of water from existing conveyance canals. Other projects may require extensive new facilities such as canal turnout structures, new pipelines and pumps, injection or extraction wells, or construction of new recharge basins. The highly variable nature of implementation costs requires that feasibility of new conjunctive management projects or programs be evaluated carefully on a case-by-case basis; generalizations of implementation costs, without site-specific information on issues such as access to existing conveyance, are rarely accurate.

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The wide range of costs results from many factors including project complexity, regional differences in construction and land costs, availability and quality of recharge supply, availability of infrastructure to capture, convey, recharge, and extract water, intended use of water, and treatment requirements. In general, urban uses can support higher project costs than agricultural uses.

## Major Issues Facing Conjunctive Management and Groundwater Storage

### Uncertainty in Surface Water Availability from State and Federal Water Projects

For many regions in the state, water supply from SWP and CVP is a potential source for groundwater recharge. However, its availability has become increasingly uncertain because of the deterioration of environmental conditions in the Delta. Recent legal decisions (Wanger, 2007a; 2007b; 2008a; 2008b) have narrowed the time window of Delta pump operations. As a result, less water can be exported for delivery to south of the Delta. Information about SWP water supply reliability (updated every two years) can be obtained at http://baydeltaoffice.water.ca.gov/swpreliability/. The increased uncertainty in surface water availability from SWP and CVP could be a critical limiting factor to manage water resources effectively and to derive optimal benefit from conjunctive management practices.

*The increased uncertainty in surface water availability from SWP and CVP could be a critical limiting factor to manage water resources effectively and to derive optimal benefit from conjunctive management practices.*

### Uncertainty in Evaluating Impacts of Groundwater Pumping on Surface Water Flows and Aquatic Ecosystems

Groundwater and surface water are usually hydraulically connected. Conjunctive water management can change existing surface water and groundwater interaction

significantly. There are some regional groundwater flow models available for the Central Valley, and they can be used to evaluate the surface water and groundwater flow interaction. However, the accuracy of analysis, model resolution, and the size of the modeling area often limit their application, especially, for statewide conjunctive water management planning. Impacts to aquatic ecosystems often require the modeling of water temperatures and solute transport, land subsidence analysis, and identification of environmental flow targets. These modeling tools are not well developed or integrated for the purpose of conjunctive management planning as discussed in the "Lack of Data and Tools" sub-section.

### Effects of Land Use Changes on Costs and Siting of New or Enlarged Recharge Facilities (and Recharge Area Protection)

A natural recharge area may be eliminated because of a new development or contamination from a development. The protection and the improvement of natural recharge areas are important in maintaining and improving groundwater storage. In California, floodplains and wetlands that provide natural recharge areas are being urbanized at an alarming rate. Proximity of some developments to existing groundwater recharge facilities precludes further expansion of recharge area.

With the cost of land increasing, better land use planning is required to preserve natural recharge areas by either limiting the encroaching development or purchasing the land. However, protecting an important natural recharge area sometimes may not be a high priority for the county or local land use authorities. Although federal, State, county and local requirements may exist to mitigate impacts of increased runoff resulting from new developments, these requirements may need to be further strengthened by additional legislative provisions. These provisions must be geared toward ensuring that new developments incorporate detention/retention ponds so that the increased runoff and lost natural recharge can be offset by the planned detention/retention ponds, accomplished in a way such that groundwater quality is not compromised. The proposed detention/retention ponds can provide flood protection and also help maintain natural recharge. Managed recharge facilities may be used to inject the increased runoff to the underlying groundwater basin. This issue is further discussed in *Chapter 19 Urban Runoff Management* and *Chapter 25 Recharge Area Protection, Vol. 2, Resource Management Strategies, California Water Plan Update 2009* (DWR, 2009c).

### Inconsistency and Uncertainty in Regulatory Status with Respect to Recharge and Surface Commingling of Different Quality Water

Groundwater recharge involves using water from different sources to recharge a groundwater basin. The water quality of water used for recharge is usually different from the water in the receiving groundwater basin. Uncertainty in regulatory status with regard to water quality of recharging and receiving waters increases the uncertainty in the planning effort of conjunctive management and may increase cost or even make a conjunctive water management project infeasible during implementation.

## Lack of Data and Tools

Data and tools are very important in developing a reliable and advanced conjunctive water management strategy. Data are needed to understand the groundwater resource, monitor and measure the progress of water management strategies, and calibrate and validate computer modeling tools. However, data are often lacking. Tools are also not readily available for use and may need to be developed.

Data are needed to evaluate conditions and trends laterally and vertically in a geographic area and over time. Currently, there are few comprehensive basin-wide networks to monitor groundwater levels, water quality, land subsidence, and interaction of groundwater with surface water and the environment. There is no centralized database or integrated information system providing access to various groundwater monitoring networks operated by different State and local agencies. DWR released the first such product called the Integrated Water Resources Information System (IWRIS) in May 2008 to the public, but IWRIS does not include or provide access to much of the available water quality data.

*Currently, there are few comprehensive basin-wide networks to monitor groundwater levels, water quality, land subsidence, and interaction of groundwater with surface water and the environment.*

To understand the groundwater resources on a statewide basis, data from throughout the state are needed. Data are especially needed in the areas among the geographic boundaries of counties and local agencies or in remote areas. Although data in remote areas may not be available or monitored by local authorities, it is still important for understanding the statewide groundwater system. A statewide groundwater modeling tool can help identify cost effective and necessary locations and frequency of groundwater monitoring. An integrated statewide data and information management system such as IWRIS can also help visually identify the spatial data gaps in the state. Because of the lack of resources, incentives, or conflicts of interest, individuals or local agencies are usually not able to fill the spatial data gaps outside their management areas. State agencies could help fill the data gaps by providing the necessary resources to local agencies. Better cooperation and coordination are also needed among the agencies to best use available resources to develop a statewide groundwater monitoring program by minimizing data gaps and overlaps.

One important aspect in data collection effort that is often overlooked is its coordination with the development of computer models. Computer models help identify potentially critical data collection locations (stations) and the desired frequency of collection, leading to improved monitoring of groundwater systems and performance measurement of management strategies. The coordination between data collection and model development would also help improve model calibration and reduce cost of data collection by minimizing data gaps and overlaps. To facilitate better conjunctive water management, an easy-to-use computer aided conjunctive management tool is needed for assessing the management strategies and quantifying the values of the strategies. The tool should be based on optimization techniques and allow managers to define and prioritize objectives and specify constraints in an easy-to-use interface. The tool should also be able to perform integrated surface water and groundwater modeling, land subsidence analysis, and economic evaluation.

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Computer models have been and continue to be developed to assist water resources planning and management in the state. CalSim II (Close et al., 2003), jointly developed by DWR and USBR, is a recognized water resources planning model for SWP and CVP operations running in monthly time step. Groundwater models are also under development for selected hydrologic regions in the State. One of the groundwater models covering the Central Valley is the California Central Valley Groundwater-Surface Water Model (C2VSIM); it simulates three groundwater layers and is currently undergoing calibration efforts (Brush, 2008). However, before C2VSIM can be used for local groundwater management, its modeling resolution needs to be improved. Another recent effort to integrate C2VSIM with an updated version of CalSim II termed CalSim III (DWR, 2009d) may offer a broader water resources modeling system in California and provide an opportunity for developing an integrated groundwater and surface water modeling system for the entire state (Young, 2007; Joyce, 2007). To be a good conjunctive water management tool, more modeling capabilities need to be added and integrated in the modeling system (such as water temperature modeling, daily time step modeling of CalSim instead of monthly time step, a user-friendly interface and the capability to specify management objectives and constraints, groundwater modeling beyond the Central Valley to cover possible salt water intrusion, environmental and economic analysis.) Other available models or modeling system also lack these capabilities.

The lack of tools to accurately evaluate the groundwater and surface water interaction has hindered conjunctive water management and water transfer practices because of the failure to quantify compensations to injured parties. The inability to fully identify the impact of groundwater pumping on surface water and aquatic ecosystems adds to the risk of conjunctive water management planning.

### Denied Public Access to Well Completion Reports

Although there are many wells in the state, the well completion reports are not accessible to the public because of confidentiality requirements (Section 13752 of the California Water Code). If the relevant Water Code sections are changed to remove confidentiality of well completion reports, the geologic and groundwater related information in the existing well completion reports would be accessible to the public, which could save money and time for collecting aquifer and groundwater information.

### Infrastructure and Operational Constraints

Physical capacities of existing storage and conveyance facilities are often not large enough to capture surface water when it is available in wet years. Conveyance capacity for surplus imported water supplies is most available during the wetter and cooler months when water demand is low. However, this wetter period also coincides with reduced ability to accomplish in-lieu recharge (due to lower water demands) and with increased spreading of local runoff, which may limit the ability to recharge other sources of water. During the very wet year of 2004/05, active recharge throughout the

MWD service area used only 60 percent of the total recharge facility capacity available throughout the course of the year (MWD, 2007).

Operational constraints may also limit the ability to use the full physical capacity of facilities. For example, permitted export capacity and efforts to protect fisheries and water quality in the Delta often limit the ability to move water to groundwater banks south of the Delta. Facilities that are operated for both temporary storage of flood water and groundwater recharge require more frequent maintenance to clean out excessive sediment often present in flood water.

The need to improve coordination of infrastructure and operations for flood control and recharge of storm flows for conjunctive management cannot be overstated. In Southern California as well as in other areas of California, the considerable opportunity to enhance groundwater recharge of local runoff remains unrealized because of a lack of streamlined and effective coordination.

Another issue that cannot be overstated is the urgent and crucial need for increased capacities for both surface water storage systems and Delta conveyance facilities. As a result of more stringent regulatory requirements, coupled with potentially detrimental effects of climate change, availability of surface water is anticipated to follow more extreme cycles of extended dry spells intervened by short, high intensity wet spells. In the new reality, absence of additional surface water storage and Delta conveyance would be critical limiting factors to manage water resources effectively and to derive optimal benefit from conjunctive management practices.

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## Surface Water and Groundwater Management

In California, as in other states, water management practices and the water rights system traditionally have treated surface water and groundwater as two unconnected resources. However, as explained previously, there is often a high degree of hydraulic connection between the two. Under predevelopment conditions, many streams receive dry-weather flow or baseflow from groundwater, and streams provide wet weather recharge to groundwater. Water quality and the environment can also be influenced by the interaction between surface water and groundwater. Incomplete understanding of these connections can lead to unintended consequences. The planning of conjunctive management should consider and evaluate potential impacts resulting from groundwater and stream interaction, including that on the environment. For example, studies by the University of California, Davis, indicate that long-term groundwater pumping in Sacramento County has reduced or eliminated dry season baseflow in sections of the Cosumnes River with potential impacts on riparian habitat and anadromous fish (Fleckenstein, et al., 2004).

*The planning of conjunctive management should consider and evaluate potential impacts resulting from groundwater and stream interaction, including that on the environment.*

In California, authority for managing different aspects of groundwater and surface water resources is separated among federal, Tribal, State, and local agencies. Several examples highlight this issue: (1) State Water Board regulates surface water rights dating from 1914, but not rights prior to 1914; (2) Regional Water Quality Control Board regulates

groundwater quality, but not the rights to use groundwater; (3) County groundwater ordinances and local agency groundwater management plans often only apply to a portion of the groundwater basin, and counties or local agencies with overlapping boundaries of responsibility within the same groundwater basin do not necessarily have consistent management objectives in their groundwater ordinances or management plans; and (4) Except in adjudicated basins and areas with adopted groundwater management plans, individuals have few restrictions on how much groundwater they can use, provided the water is put to beneficial use. Because of the connection between surface water and groundwater, the unmanaged groundwater use will eventually affect other water users and may have significant impacts on the environment and economy.

Failure to integrate surface water and groundwater management across jurisdictions makes it difficult to manage water for multiple benefits and provide for sustainable use including the ability to identify and protect or mitigate potential impacts on third parties, ensure protection of legal rights of water users, establish rights to use vacant aquifer space and banked water, protect the environment, recognize and protect groundwater recharge and discharge areas, and safeguard natural resources under the public trust doctrine.

*Sustainable conjunctive water management is an important strategy to deal with the existing and future water supply challenges in the state. To be effective, it requires management of the entire groundwater basin or hydrologic region.*

Because most groundwater systems are slow responding systems, any damage to the system may require long periods to recover. Planning is the key for successful groundwater management. Sustainable conjunctive water management is an important strategy to deal with the existing and future water supply challenges in the state. To be effective, it requires management of the entire groundwater basin or hydrologic region. Conjunctive management will be more effective and efficient if multiple hydrologic regions or even statewide management is implemented so that the weaknesses and strengths of regions can be coordinated and used for mutual benefit. However, the existing legal and regulatory framework on groundwater use will make it very difficult to plan any large scale conjunctive water management strategies because groundwater management is a local responsibility (Sax, 2002). Under this legal framework, the conjunctive management strategy that can be pursued with minimal effort is limited to groundwater recharge at the local level with local surface water. The State's role in conjunctive management is limited to providing funding to help willing local agencies plan and implement conjunctive management.

Most groundwater management ordinances restrict out-of-county groundwater uses. Some groundwater management plans specify trigger levels for groundwater levels in the basin management objectives (BMOs) to prevent overdraft or other water quality problems. However, in many cases, there are no mechanisms to address the non-compliance with the BMOs. The current groundwater ordinances, AB 3030 groundwater management plans, and local BMO activities, which were intended for localized groundwater management, appear not to be well suited for implementing regional groundwater management. The above limitation in the current set of groundwater ordinances and management plans will thus seriously hinder the effectiveness of conjunctive management in the state.

## Water Quality

Groundwater quality can be degraded by naturally occurring or human-introduced chemical constituents, low quality recharge water, or chemical reactions caused by mixing water of differing qualities. Protection of human health, the environment, and groundwater quality are all concerns for programs that recharge urban runoff or reclaimed/recycled water into groundwater. The intended end use of the water can also influence the implementation of conjunctive management projects. For example, agriculture can generally use water of lower quality than needed for urban use, but certain crops can be sensitive to some constituents such as boron.

New and changing understanding of water quality constituents, including emerging contaminants, and their risks to human and ecological health result in changing water quality standards. While this may lead to more healthful water supplies, it also adds uncertainty to planning and implementing conjunctive management projects. A water source may, at the time it is used for recharge, meet all drinking water quality standards. Over time, however, detection capabilities improve and new or changed water quality standards become applicable. As a result, contaminants that were not previously identified or detected may become future water quality problems creating potential liability. In some cases, conjunctive management activities may need to be coordinated with groundwater cleanup activities to achieve multiple benefits to both water supply and groundwater quality.

When water is diverted from streams providing inflows to the Delta, there should be an evaluation of the possible impacts on Delta salinity. Increasing surface storage releases is an option to reduce the impacts on Delta salinity. Various alternative options to address salinity and other critical issues in the Delta are being analyzed and evaluated under the Bay-Delta Conservation Plan (CNRA, 2009).

## Environmental Concerns

Environmental concerns related to conjunctive management projects include potential impacts on habitat, water quality, and wildlife caused by shifting or increasing patterns of groundwater and surface water use. For example, floodwaters are typically considered water "available" for recharge. However, floodflows serve an important function in the ecosystem. Removing or reducing peak floodflows may negatively impact the ecosystem. A key challenge is to balance the instream flow and other environmental needs with the water supply aspects of conjunctive management projects. There may also be environmental impacts from construction and operation of groundwater recharge basins and new conveyance facilities. Conversely, groundwater recharge facilities in some locations may provide important habitat for a variety of wildlife.

## Climate Change Impact

The anticipated climate change in California will result in more floods in the winter, less snowpack, and a rise in sea level. The planning of conjunctive management should consider these potential impacts and include projects to offset them. The projects may

include surface water storage and groundwater recharge facilities to capture floodflows, injection wells to prevent salt water intrusions, and conveyance facilities to move water to drought affected areas. More information and exhaustive discussions on the impact of climate change can be found in the following references:

- Objective 3, Chapter 7 Implementation Plan, Vol. 1, The Strategic Plan, *California Water Plan Update 2009* (DWR, 2009e);
- *Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water* (DWR, 2008);
- *The State of Climate Change Science for Water Resources Operations, Planning, and Management* (Anderson, 2009); and
- *Climate Action Team: Biennial Report* (CAT, 2009)

### Funding

There is generally limited funding to develop the infrastructure and monitoring capability for conjunctive management projects. Funding is available as incentives to local agencies to cooperate in the development and implementation of IRWM and groundwater management plans; to study and construct conjunctive management projects; and to track (both statewide and regionally) changes in groundwater levels, groundwater flows, groundwater quality (including the location/spreading of contaminant plumes), land subsidence, surface water flow, surface water quality, and the interaction of surface water and groundwater.

## Recommendations to Improve Conjunctive Management and Groundwater Storage

*Encourage local water management agencies to coordinate with Tribes and other agencies involved in activities that might affect long term sustainability of water supply and water quality.*

1. Encourage local water management agencies to coordinate with Tribes and other agencies involved in activities that might affect long term sustainability of water supply and water quality. Such regional coordination may take different forms in each area because of dissimilar political, legal, institutional, technical, and economic constraints and opportunities, but will likely include agencies with authority over managing groundwater and surface water quantity and quality, land use planning, human health, and environmental protection. Basin-wide groundwater management plans should be developed with assistance from an advisory committee of stakeholders to help guide the development, educational outreach, and implementation of the plans. Advanced tools development should be pursued as part of planning basin-wide groundwater management to help quantify the benefit and assess robustness of management strategies.

*Continue State funding to implement monitoring, assessment, and maintenance of baseline groundwater levels, including the fractured rock hydrogeology.*

2. Continue State funding to implement monitoring, assessment, and maintenance of baseline groundwater levels, including the fractured rock hydrogeology. The Legislature has enacted Senate Bill 6 (SB 6) Groundwater Monitoring of the 2009 Comprehensive Water Package (adds to and amends parts of Division 6 of the Water Code, specifically Part 2.11 Groundwater Monitoring). SB 6 requires that local agencies monitor and report the elevation of their groundwater basins to help

better manage the resource during average water years and drought conditions. Specifically, this bill stipulates the following:

- DWR will establish a priority schedule for monitoring groundwater basins and the review of groundwater elevation reports and make recommendations to local entities to improve the monitoring system;
- DWR will assist local monitoring entities' compliance with this bill;
- Local entities will be allowed to determine regionally how best to set up groundwater monitoring program, crafting the program to meet their local circumstances;
- DWR will implement groundwater monitoring programs in regions where local agencies fail to implement a monitoring program or fail to provide the required reports;
- By January 2, 2012, DWR in conjunction with public agencies will report to the Governor and Legislature findings of investigations of the state's groundwater basins that will include geological and hydrological conditions and general patterns of groundwater pumping and recharge; and
- Findings will be reported to the Governor and Legislature thereafter in years ending in 5 and 0.

3. Continue State funding for local groundwater monitoring and management activities, and feasibility studies that increase the coordinated use of groundwater and surface water by giving priority to projects that include filling regional and statewide data gaps and conjunctive management conducted in accordance with an IRWM plan. Thus, in addition to the provisions in SB 6, encourage or require local water management agencies to implement groundwater monitoring programs to provide additional data and information needed to adequately characterize a groundwater basin, subbasin, aquifer or aquifers under the jurisdiction of the agency.

*Continue State funding for local groundwater monitoring and management activities, and feasibility studies that increase the coordinated use of groundwater and surface water by giving priority to projects that include filling regional and statewide data gaps and conjunctive management conducted in accordance with an IRWM plan.*

Data collection programs should include:

- Hydrogeologic characterization of the aquifers,
- Changes in groundwater levels,
- Groundwater flow,
- Groundwater quality,
- Land subsidence,
- Surface water flow,
- Surface water quality, and
- Interaction of surface water and groundwater.

Conjunctive management projects will:

- Increase water supplies,
- Provide other benefits,
- Provide sustainable use of groundwater,
- Increase regional self-sufficiency,
- Improve water quality, and
- Improve environmental quality.

*Encourage or require local water management agencies to establish a water budget that quantifies the amount of water flowing into and flowing out of the basin, subbasin, aquifer or aquifers, using the groundwater monitoring data, stream flow data, and groundwater extraction data that are collected by the local agency*

4. Using the additional data and information collected as part of recommendation (3) above, encourage or require local water management agencies to establish the following :
   - A water budget that quantifies the amount of water flowing into and flowing out of the basin, subbasin, aquifer or aquifers, using the groundwater monitoring data, stream flow data, and groundwater extraction data that are collected by the local agency;
   - Electronic submittal of monitoring data by local groundwater monitoring entities;
   - Guidelines and computer protocols developed by DWR for the collection and reporting of monitoring data by local water management agencies; and
   - A system developed by DWR for electronic reporting, storage, and retrieval of monitoring data in useful formats.

   The water budget for each basin, subbasin and aquifer under the jurisdiction of the local agency will be developed using the equation, Inflow – Outflow = Change in storage.

   Inflow:
   - Infiltration of precipitation,
   - Infiltration from stream channels and unlined canals,
   - Groundwater flow into the aquifer,
   - Artificial recharge, and
   - Deep percolation from irrigation.

   Outflow:
   - Contribution of groundwater to surface water flow out of the basin,
   - Groundwater flow out of the aquifer,
   - Groundwater extraction (pumping),
   - Consumptive use, and
   - Evapotranspiration.

*Establish a System Reoperation Task Force composed of state personnel, federal agency, Tribal representatives, as well as regional and local governments, agencies, and organizations to quantify the potential costs, benefits, and impacts of system reoperation for water supply reliability, flood management, conjunctive water management, hydropower, water quality, fish passage, cold-water management for fisheries, and other ecosystem needs*

5. Establish a System Reoperation Task Force composed of state personnel, federal agency, Tribal representatives, as well as regional and local governments, agencies, and organizations to:
   - Quantify the potential costs, benefits, and impacts of system reoperation for water supply reliability, flood management, conjunctive water management, hydropower, water quality, fish passage, cold-water management for fisheries, and other ecosystem needs;
   - Support the update of US Army Corps of Engineers operations guidelines (“rule curves”) for Central Valley reservoirs;
   - Support the update of flood frequency analyses on all major rivers and streams in the State;
   - Evaluate the need to amend flow objectives;
   - Expand the study of forecast-based operations for incorporation into reservoir operations guidelines;
   - Identify key institutional obstacles that limit system reoperation benefits; and
   - Promote and communicate results from demonstration projects to encourage broader participation in system re-operation investigations.

6. Develop a statewide comprehensive data management system to compile and track available information about groundwater and conjunctive management projects throughout the state. Develop on a priority basis a conjunctive management tool that may used to identify conjunctive management opportunities (projects) and evaluate regional and statewide implementation constraints including availability of water for recharge, available means to convey water from source to destination, water quality issues, environmental issues, costs and benefits and potential interference between a proposed project and existing projects.

*Develop a statewide comprehensive data management system to compile and track available information about groundwater and conjunctive management projects throughout the state.*

7. Create a framework to assess groundwater management throughout the state to gain an understanding of how local agencies are implementing actions to use and protect groundwater, which actions are working at the local level, and how State programs can be improved to help agencies prepare effective groundwater management plans.

8. Improve coordination and cooperation among local, State, and federal agencies with differing responsibilities for groundwater and surface water management and monitoring, and thus facilitate conjunctive management, ensure efficient use of resources, provide timely regulatory approvals, prevent issuance of conflicting rules or guidelines, and promote easy access to information by the public.

*Improve coordination and cooperation among local, State, and federal agencies with differing responsibilities for groundwater and surface water management and monitoring.*

9. Encourage local groundwater management authorities to manage the use of available aquifer space for managed recharge and to develop multi-benefit projects that generate source water for groundwater storage by capturing water not used by other water users or the environment.

10. Identify and evaluate local and regional opportunities to reduce runoff and increase recharge on residential, school, park, and other unpaved areas.

11. Encourage local and regional coordination of groundwater recharge and flood control activities to enhance recharge of storm flows. Provide a source of funds for studies jointly sponsored by cooperating groundwater and flood control agencies to identify additional opportunities for recharge and the needs for advancing those opportunities.

12. Streamline the environmental permitting process for the development of conjunctive management facilities, such as recharge basins, when they are designed with pre-defined benefits or mitigation to wildlife and wildlife habitat.

13. Streamline the State Water Resources Control Board water rights permitting process to facilitate water transfers associated with the development of statewide and basin-wide conjunctive water management strategies.

*Streamline the State Water Resources Control Board water rights permitting process.*

14. Consider changes to Section 13752 of the California Water Code to allow public access to geologic and groundwater information in the Well Completion Reports.

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