VOLUME 1 - THE STRATEGIC PLAN

CHAPTER 6

Integrated Data and Analysis: Informed and Transparent Decision-Making

Data-collection flights over the Sierra Nevada Mountains. In April 2013, DWR and NASA's Jet Propulsion Laboratory conducted aerial snowpack surveys as part of the Airborne Snow Observatory Program. Aerial surveys measure snowpack depth; spectrometer readings gauge snowpack reflectivity. Combined with data from the traditional manual snow surveys and electronic sensors, this information provides a better estimate of California's water supply. Snowpack information informs reservoir operations for flood control and allows the major water projects to predict water allocations for the coming year.

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Chapter 6. Integrated Data and Analysis: Informed and Transparent Decision-Making

About This Chapter

Chapter 6 describes a roadmap and key actions needed to improve water resources information and analysis for integrated water management (IWM) by State government, particularly the California Department of Water Resources (DWR); many other research institutions; and federal, tribal, regional, and local water management entities. It describes how quality information, robust analysis, and public engagement can inform the key policy components of the California Water Plan (CWP), including desired outcomes, core values, statements of intent, and recommendations. The chapter concludes with needed enhancements to stakeholder process, analytical tools, and information needed to support IWM and more transparent decision-making. Refer to Chapter 8, “Roadmap For Action,” in this volume for the objectives and related actions involving integrated data and analysis and water technology.

This chapter is organized into the following sections:

- Purpose and Motivation.
- Informing California Water Plan Policy with Quality Information and Analysis.
- Integrated Data and Analysis.
- Technical Enhancements to Support Integrated Data and Analysis.
- Summary.

Purpose and Motivation

California encounters significant challenges with balancing many diverse interests affected by water policy decisions. These challenges are amplified by fragmented and poorly communicated information that is informed by analyses that cannot fully evaluate the many alternative and often competing water management objectives and tradeoffs. While extensive information affecting water management is collected by many federal, state and regional programs, the information often resides in separate silos. There is a critical need for information sharing and management to support water policy decisions that provide a common and transparent understanding of water problems and potential solutions across many organizations. Achieving IWM with multiple benefits requires a transparent description of dynamic linkages between water supply, flood management, water quality, land use, environmental water, and many other factors. The CWP promotes the use of collaborative processes and technical enhancements consistent with the CWP goals and objectives to assist decision-makers to move California toward a more sustainable future.

Arundo donax, a non-native reed-like grass, negatively affects water quality and supply, decreases flood protection, increases erosion and fire hazards, and displaces riparian habitat and wildlife. Collaborative efforts are underway to replace this invasive species with native riparian vegetation.

Informing the California Water Plan with Quality Information and Analysis

The CWP provides statewide water policy guidance in a numbers of ways. The CWP vision (as presented in the “Vision” section of Chapter 8, “Roadmap for Action”) describes a desired future where California has healthy watersheds and integrated, reliable, and secure water resources. The CWP describes several desired outcomes for the future, such as managing resources in a way that provides for public safety, environmental stewardship, and economic stability. Policy guidance is also provided in the core values, objectives, and related actions. During the *California Water Plan Update 2005 process*, DWR worked with the Public Advisory Committee to develop 28 policy questions that the CWP should address quantitatively. Some of the key questions are shown below. See Volume 4, *Reference Guide*, the article, “Policy Questions for the California Water Plan Needing Quantitative Information,” for the full list of questions.

- What are estimates of the local, regional, and statewide components of the hydrologic cycle in California?
- What are the current resource management strategies and uses, what are potential future strategies and uses, and how are these estimated for all sectors (agricultural/environment/urban) and all levels (local, regional, statewide)?
- What are some of the benefits and tradeoffs between different resources management strategies?
- How does water scarcity affect the economy, the environment, and all beneficial uses?
- What are the most pressing current and future local, regional, and statewide water management problems and what are potential solutions to the problems?
- How will climate change affect water management in the future?
- How should California manage flood events and floodplains?

It is essential to support policy guidance in the CWP with good science and quality information and analysis. The CWP is building an analytical framework that effectively and collaboratively links water policy with the best available information, science, and technical information and analytical tools. Information should be collected for not only evaluating specific problems, but also to measure the effectiveness of policies, programs, and projects. Analytical tools need to provide information about the benefits, costs, and tradeoffs to address the policy questions described above. The CWP must develop an analytical framework with public engagement that provides a road map for improving information management and analytical tools, and address the day-to-day realities of managing programs with limited resources.

Integrated Data and Analysis

IWM is a foundation of water planning in California and the CWP. This is a multi-objective approach that encourages using a mix of resource management strategies to provide broad benefits. These strategies include water use efficiency, water recycling, desalination, and storage as well as strategies for protecting and improving water quality, managing floodplains, runoff and watersheds, and restoring ecosystems. Volume 3, *Resource Management Strategies, of California Water Plan Update 2013* (Update 2013), identifies numerous strategies to help meet regional and statewide IWM objectives. Communities can plan, invest, and diversify their water portfolios by using these management strategies to become more self-reliant, relying on local supplies and resources, and minimize conflicts with other resource management efforts and other regions.

Currently, many integrated regional water management (IRWM) plans are only integrated in a conceptual sense and do not quantify how proposed regional actions might affect the water management system in other parts of the state. IWM needs better information and analytical tools to connect information about the benefits and tradeoffs about water quality, environmental objectives, economic performance, social equity objectives, and surface water and groundwater interaction. Today, it is difficult to access and compare, much less integrate, information from different local entities to understand and resolve regional water management issues, and it is even more difficult to understand the statewide linkages. To make significant progress toward a more comprehensive scientific understanding, California needs to improve water information exchange and management, and develop integrated analytical tools that can be used to document and share knowledge. Investments in information exchange and integrated analytical tools will help facilitate consensus-based decisions that are a key part of IWM.

The following sections highlight three examples of analysis performed for IWM that have significantly increased the need for improved water management information with robust and transparent technical analysis.

Flood Management

Flood management seeks to include structural and non-structural methods to manage high water events and seeks to enhance the ability of undeveloped floodplains and open spaces to reduce the damage of flood events and the implementation of land use practices that minimize the risk to lives and property while enhancing environmental stewardship. This multifaceted approach to flood management relies on the integration of multiple strategies to achieve the broad goal of improving flood management and reducing risk. Analysis of flood management strategies requires water management information and analytical tools that are useful to daily or hourly time scales. It also requires accurate information on levee construction details, channel capacities, effects of in-channel vegetation and structures, existing and future land uses, and the environmental benefits associated with floodplain inundation.

Ecosystem Restoration and Ecosystem Services

Ecosystem restoration can include changing the flows in streams and rivers; restoring fish and wildlife habitat; controlling waste discharge into streams, rivers, lakes or reservoirs; or removing barriers in streams and rivers so anadromous fish like salmon and steelhead can reach spawning areas. Ecosystem restoration improves the condition of California's modified natural landscapes and biotic communities to provide for the sustainability and for the use and enjoyment of those ecosystems by current and future generations. In many cases, ecosystem restoration activities include economic benefits in the form of ecosystem services, which are economic goods and services derived from natural systems. Scientists are often only able to estimate environmental and economic benefits of restoration projects qualitatively because of scientific uncertainty about both the effects of proposed projects and how species respond to different environmental factors such as water flow and water temperature. In addition, only limited historical data is usually available on ecosystems, their relative health, and how they would respond to management actions.

Adapting to Climate Change

As a result of global climate change, California's future hydrologic conditions are changing from patterns observed during the past century. There is much scientific uncertainty about how each of the widely varying regions in California will be affected by climate change. Predictions include increased temperatures, reductions to the Sierra snowpack, earlier snowmelt, and a rise in sea level although the degree, extent, and timing of the changes remain uncertain. These changes could have major implications for water supply, flood management, and ecosystem health. See the articles "Climate Change Adaptation Strategies for California's Water" and "The State of Climate Change Science for Water Resources Operations, Planning, and Management" in Volume 4, *Reference Guide*, for a discussion of these changes.

Technical Enhancements to Support Integrated Data and Analysis

This section describes several currently unmet crosscutting actions that are critical for the long-term improvement of California's technical capabilities consistent with the Strategic Analysis Framework envisioned by the California Water and Environmental Modeling Forum (CWEMF) in its 2005 report. (See http://www.cwemf.org for additional information about CWEMF.) Although significant resources are needed to implement them, these activities would greatly enhance the ability of scientists and engineers to support IWM and decision-making in light of uncertainties. They must be viewed as long-term commitments to improve California's technical infrastructure through research, development, and collaboration.

Several agencies and institutions are engaged in long-term efforts to improve California's water resources information and analytical capabilities (see Box 6-1, "Entities Engaged in Long-Term Technical Improvements for Statewide Water Management"). These efforts are focused on detailed models that form the backbone of water management analysis in California. Developing simpler decision support tools ultimately must be verified against these detailed models. Each of the entities in Box 6-1 has long-term strategic plans for technical improvements for their particular area of responsibility. What are missing are the crosscutting actions that transcend the individual efforts to provide widespread integration of water resources information and analysis.

To support IWM, institutions should work together to prioritize and align the water resources information that is collected. Improvements in management of water resources information will make it easier for institutions to report, use, and analyze available information. As relationships between institutions develop, gaps in water management data will become transparent and resources can be allocated to address those data gaps to improve the overall understanding of

Box 6-1 Entities Engaged in Long-term Technical Improvements for Statewide Water Management

- The U.S. Geological Survey is active in a wide range of surface water and groundwater monitoring, development of analytical tools, and analysis of water resources problems.
- The U.S. Army Corps of Engineers is responsible for developing numerous analytical tools used for watershed and flood management analysis.
- DWR maintains several water monitoring programs and is responsible for the development of analytical tools of the Sacramento-San Joaquin Delta.
- DWR and the U.S. Bureau of Reclamation jointly maintain an analytical tool of the Central Valley Water Management System.
- Researchers at the University of California develop and maintain numerous analytical tools as part of specific research projects.

water in California in space and time. Integration of information should begin with the largest users or collectors of water information. The sections below describe three critical areas where technical enhancements are needed to support integrated data and analysis:

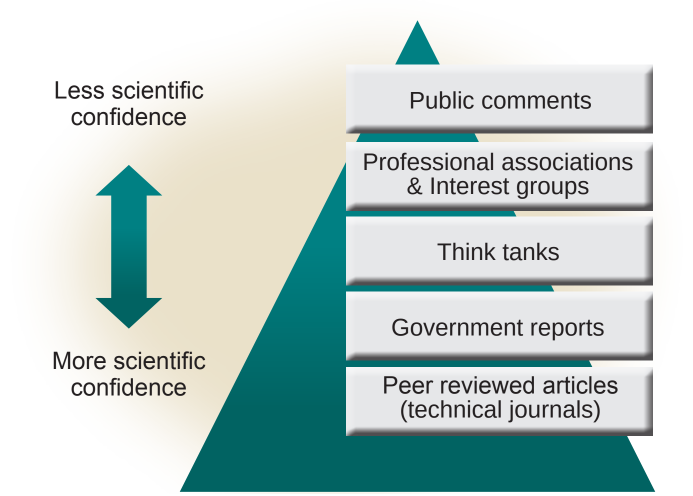
- Linking collaborative processes with technical enhancements.
- Providing effective analytical tools.
- Improving and sharing information.

Linking Collaborative Process to Technical Enhancements

This section describes some of the current processes the CWP has in place and proposes enhancements to this process to be more transparent about the information used to guide water policy. It is important for the CWP to be clear about the scientific confidence and the process it uses for vetting analytical tools and information used to guide water policy. The CWP uses information from many sources. Much of the information is generated by subject matter experts applying analytical tools developed specifically for the CWP. Other information is collected from a wide range of sources including peer-reviewed articles, government agencies, think tanks, professional associations, and public interest groups. Each of these information sources comes with its own scientific confidence with respect to how the information was developed. Figure 6-1 shows how the confidence associated with different information sources might vary.

The CWP employs a rigorous public process to receive feedback on the information used to guide water policy. This includes the use of external expert panels, policy advisory groups, and technical advisory groups to advise the appropriate application of available information and analytical tools. DWR convened the Statewide Water Analysis Network (SWAN) to assist with formulating recommendations on technical improvements needed to support the CWP. (See http://www.waterplan.water.ca.gov/swan for additional information about the activities of SWAN.) SWAN, a voluntary network of scientists and engineers, has met several times during development of Update 2013 to provide advice on the quantitative deliverables for the CWP, including the recommendations contained in this chapter. DWR has also convened a Climate Change Technical Advisory Group to advise DWR on the scientific aspects of climate change, its impacts on water resources, the use and creation of planning approaches and analytical tools,

Figure 6-1 Sources of Information



and the development of adaptation responses. (See http://www.water.ca.gov/climatechange/cctag.cfm for additional information about the Climate Change Technical Advisory Group.) DWR shares information regularly and meets periodically with these advisory groups for the purpose of receiving advice on the scientific confidence and policy relevance of CWP content. After considering all advice received, the CWP relies on the professional judgment of subject matter experts to evaluate sources of information and available analytical tools and decide what and how to apply the available information to develop key findings and recommendations.

Enhancement: Implement Shared Vision Planning

DWR is pursuing the approach and methods of Shared Vision Planning (SVP) in the CWP to achieve these technical goals and outcomes:

- Achieve better integration and consistency with other planning activities.
- Obtain consensus on quantitative deliverables.
- Build a common conceptual understanding of the water management system.
- Improve transparency of the California Water Plan information.

The term Shared Vision Planning is most closely associated with the U.S. Army Corps of Engineers' Institute for Water Resources that has implemented the approach and methods since the National Drought Study in the 1990s. (See http://www.SharedVisionPlanning.us for additional information.)

SVP integrates tried-and-true planning principles, systems modeling, and collaboration into a practical forum for making water resources management decisions. It addresses the need for broad involvement of decision-makers and stakeholders in the technical analysis. Aside from the intensive and continuous collaboration, what defines SVP is the use of collaboratively developed decision support tools that help with plan formulation and evaluation. These SVP tools are designed to be transparent and easy-to-use, and they integrate hydrologic simulations with economic, environmental, and other considerations that are relevant to understanding the water management system. Benefits that result from SVP are a shared understanding and vision of the system, identification of alternatives that are both technically and politically feasible, and increase consensus on implementation of decisions.

DWR believes that the SVP approach can be expanded beyond its current emphasis on model building at the watershed scale to the broader concept of improving California's technical analysis infrastructure (methods and tools) through greater interactions with stakeholders and decision-makers. Through SVP, the needs of stakeholders can inform the development of the analytical tools so that they are more relevant when responding to current and future problems. For further information, refer to Related Action 10.9 in Chapter 8, “Roadmap For Action.”

Enhancement: Form an IWM Technical Committee

Technical enhancements cannot occur in a vacuum. IWM requires a collaborative and coherent technical program among State and federal agencies and academia to provide the broadest and most cost-effective solutions to today’s technical challenges. Improving communication, cooperation, and collaboration among technical experts and government agency decision-makers is needed for data collection, management, and exchange and analytical tool development and applications. An institutional framework is needed to facilitate and sustain a collaborative and coherent technical program among State and federal agencies and academia. The IWM Technical Committee should consist of entities identified in Box 6-1 and coordinate with related efforts like the Delta Science Plan and ongoing activities of the California Water and Environment Modeling Forum. For further information, refer to Related Action 10.1 in Chapter 8, “Roadmap For Action.”

Providing Effective Analytical Tools

Decision-makers often must take action on issues that affect water management when there is significant uncertainty either about the basic scientific understanding of the water management system or about the political or social acceptance of particular water management alternatives. For example, scientists today cannot describe precisely what long-term climate change will mean for water and flood management in California. However, enough is known about the potential impacts to prompt decision-makers to enact a series of measures to reduce greenhouse gas emissions and implement adaptation strategies. Analytical approaches need to be improved to effectively quantify where scientific uncertainties exist, allow for collaborative decision-making to help overcome political and social disagreements, and identify actions that will have sustainable outcomes.

The CWP has identified several technical barriers in effectively evaluating California’s future water conditions. Often there is no detailed quantitative information about the costs, benefits, and tradeoffs associated with different water management strategies. Water resources information, analytical tool development, and information management and exchange have not kept pace with growing public awareness of the complex interactions among water-related resources. California lacks a consistent framework and standards for collecting, managing, and providing access to information on water and environmental resources essential for integrated regional resource management. For example, four separate statewide surveys of urban water use by different entities result in duplicative efforts by those reporting the information and these surveys often have inconsistent responses. Improvements to water resources information, information management, and analytical tools can reduce many uncertainties about the state’s current and future water resources, how water supplies, demands, and water quality respond to different resource management strategies, how ecosystem health and restoration can succeed, and how California can adapt its water system to reduce controversy and conflicts.

Enhancement: Develop a Common Conceptual Understanding of the Water Management System

One of the greatest obstacles to quantifying consensus-based water management strategies is the lack of a common means of describing quantitatively, clearly, and concisely how water is managed and how it flows in the environment. For example, there are several alternative and scientifically valid ways of approximating the complex relationships between streamflow, groundwater recharge, water diversions, and applied water use. The result is that technical experts, decision-makers, and stakeholders have an extremely difficult time communicating with one another about important features and interdependencies of the water management system. Analytical tools used for complex analyses are too obscure for all but a few people, but decision-makers and stakeholders are often asked to accept results from these complex analyses on faith.

It is necessary to develop a way to describe the different pieces of the water management system conceptually and how the pieces interact with each other. One approach is to use the iterative development process that is widely used in the software development industry to assist with the development of a conceptual model of the water management system. This iterative approach is based on object-oriented thinking and allows a team to identify and describe the relevant aspects of the real world that should be represented in an analytical tool. The conceptual model will be developed collaboratively to document the requirements of the system and a shared understanding of the water management system. For example, Figure 6-2 shows a conceptual model of the water management system with relationships among its components. Figure 6-3 represents a sample schematic of the water management system from the Water Evaluation and Planning System model (see http://www.weap21.org). These two figures represent alternative views of the water management system.

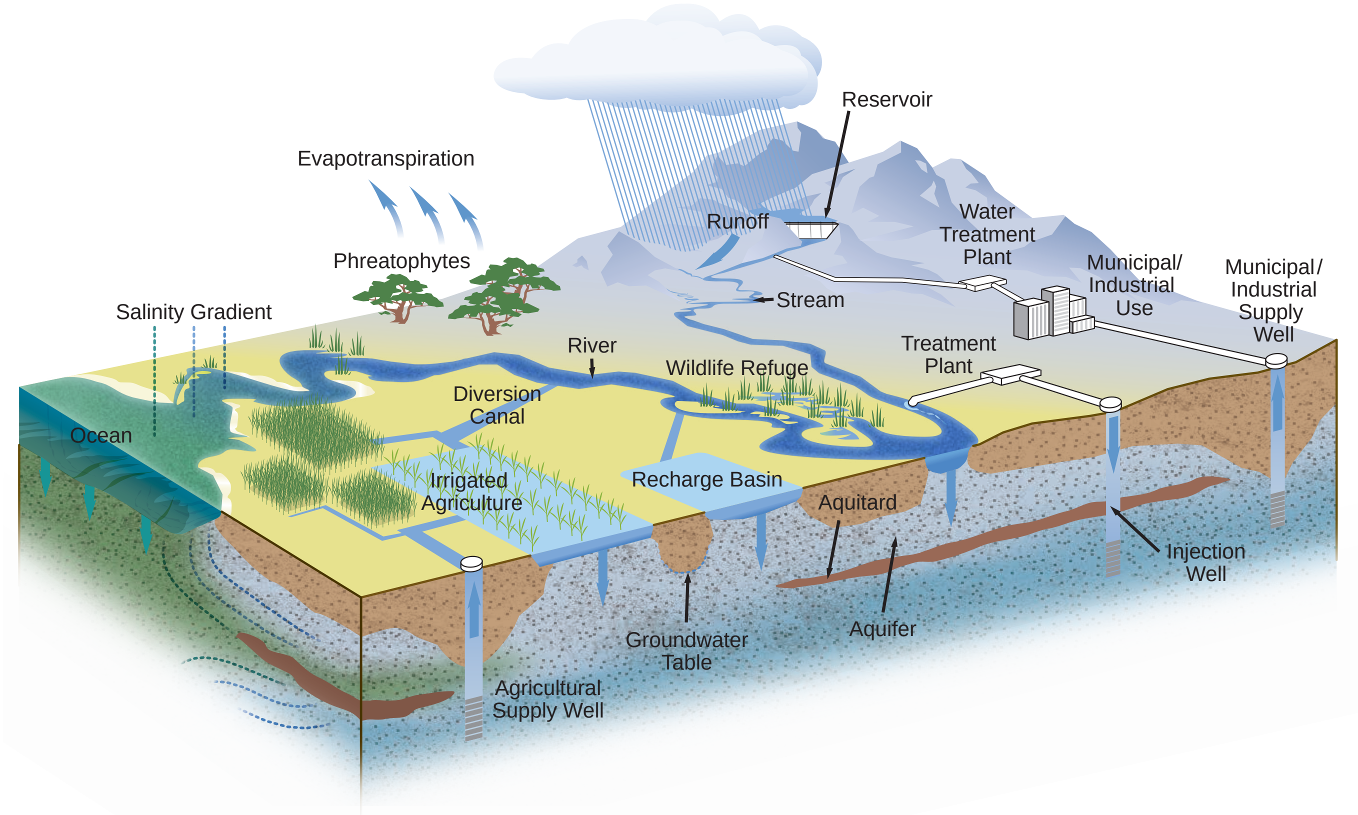
One method for documenting the products developed through an iterative process uses the Unified Modeling Language, which is a visual modeling language based on standard notation to describe systems in terms of objects, relationships, interactions, sequence diagrams, and state changes. Figure 6-4 shows an example describing the relationships between water users and water providers by using Unified Modeling Language standard notation. For further information, refer to Related Action 10.11 in Chapter 8, “Roadmap For Action.”

Enhancement: Develop Common Schematics of the Water Management System

California’s water system is large and complex and has multiple challenges, including a disconnection between areas of water demand and areas of water supply both in space and time. An organized information system is needed that reveals water sources, water supply infrastructure, water needs, water quality, ecosystem functions, flood management, and climate change to identify effective water management actions and potential water system vulnerabilities. It is necessary to create an integrated water resources information system for California where the connectivity between water sources, water supply infrastructure, and water demands are related with their associated data.

Numerous existing schematics of California’s water management system are used by local, State, and federal agencies to perform water planning studies. These schematics are embedded in several planning models that provide incomplete, overlapping, and often inconsistent representations of California’s water management system. For example, models like the Water Resource Integrated Modeling System (WRIMS, formerly known as CALSIM), the California

Figure 6-2 Conceptual Model of Water Management System

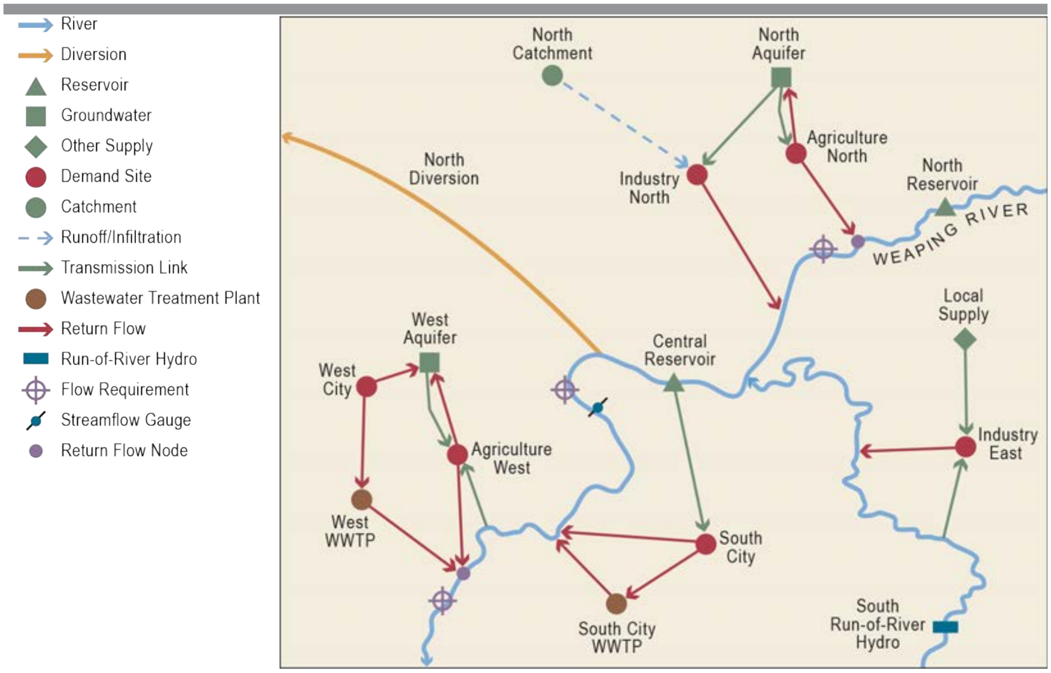


Value Integrated Network Model (CALVIN), Water Evaluation and Planning System (WEAP), and Central Valley Production Model (CVPM) represent water management in portions of the Central Valley, but it is difficult to share data among them and determine whether they use information consistently. These models often represent the water management system at a coarse level and may not provide information at the scale needed for planning by a local water agency. Development of common schematics would facilitate a better understanding of California's water management systems and allow integration with other models and sources of information. A common schematic accompanied by a geodatabase is needed to show the connectivity of California's water resource systems and to serve as a repository of information where data can be shared among governmental and non-governmental institutions. For further information, refer to Related Action 10.8 in Chapter 8, "Roadmap For Action."

Enhancement: Establish Modeling Protocols and Standards

The movement toward IWM has increased the desire and need for integration of water management information and analysis. A critical part of integrated analysis is the development of modeling protocols and standards to allow analytical tools to be linked to each other or used in concert more effectively. This is consistent with the need for standards and protocols for information exchange. CWEMF developed modeling protocols (California Water and Environmental Modeling Forum 2000) that need to be updated and implemented by the entities responsible for model development activities. The objective of the CWEMF modeling protocols is to provide guidance to water stakeholders, decision-makers, and their technical staff as models

Figure 6-3 Sample Schematic of Water Management System



Source: Stockholm Environment Institute 2013

are developed and used to solve California's water and environmental problems. CWEMF identified the following benefits that would be achieved by California's water community from adherence to modeling protocols:

- Improved development of models.
- Better documentation of models and modeling studies.
- Easier professional and public access to models and modeling studies.
- More easily understood and transparent models and modeling studies.
- Increased confidence in models and modeling studies.

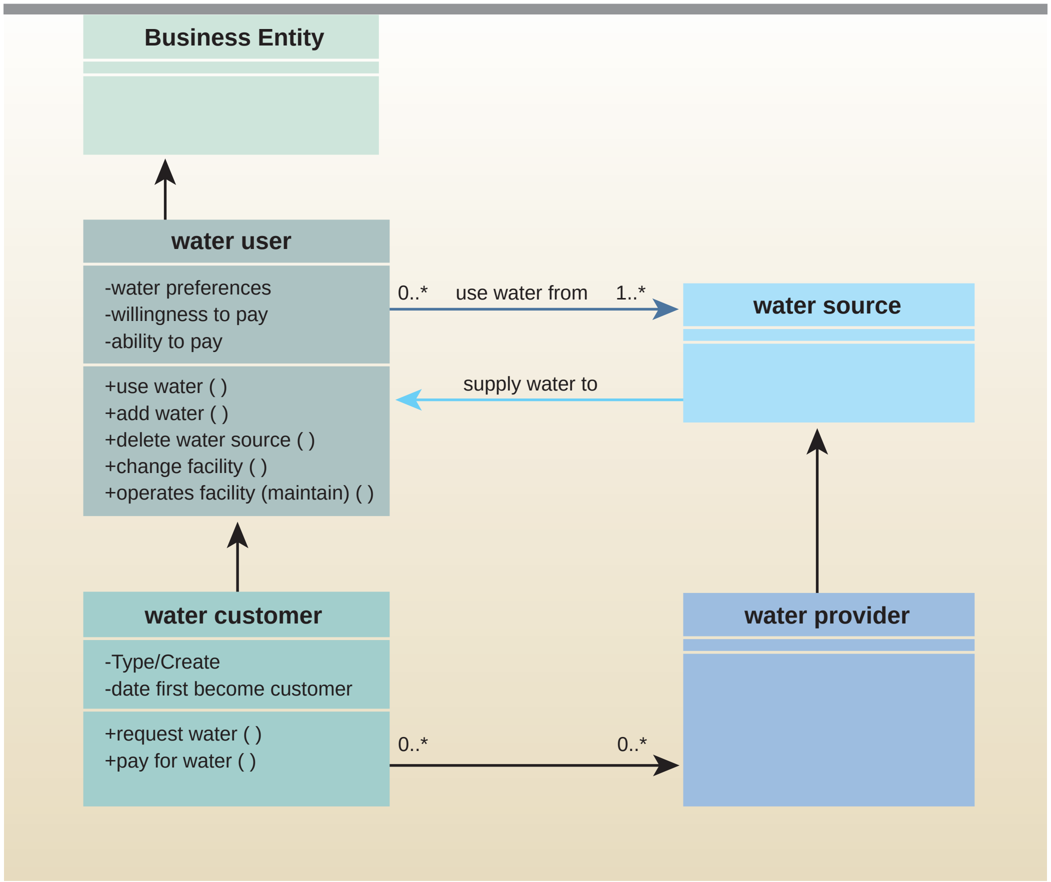
For further information, refer to Related Action 10.12 in Chapter 8, "Roadmap For Action."

Enhancement: Supporting Analysis for the California Water Plan

Many of the policy questions the CWP should address can be quantified in relationship to the resource management strategies described in Volume 3. While there is no existing analytical tool that can quantitatively capture all the complex issues, the CWP is employing analytical tools to systematically evaluate the performance of regional resource management strategies in the face of a number of critical uncertainties, including population growth, land use decisions, and climate change. Chapter 5, "Managing an Uncertain Future," describes uncertainties confronting water managers and how the CWP is quantifying these uncertainties.

The CWP is employing the following guidelines to link policy questions more effectively with quantifiable information:

Figure 6-4 Example Diagram Using Unified Modeling Language Standard Notation



- Apply SVP to develop a common conceptual understanding of the water management system, and seek consensus on the technical studies. See the section above, Linking Collaborative Processes with Technical Enhancements to learn about Shared Vision Planning.
- Develop an integrated analytical framework that captures dynamic linkages between water supplies, flood management, water quality, land use, and environmental stewardship.
- Use an integrated analytical framework to evaluate the full spectrum of uncertainties that confront water planning in California, including climate change, land use decisions, demographic changes, and other factors.
- Evaluate the results of these analyses using an appropriate set of performance metrics, considering robustness and risk.
- Develop a strategy to help evaluate the effectiveness of policy recommendations in the CWP.
- Develop an information exchange system to share results of studies more effectively.

DWR has initiated several technical enhancements that are directly relevant to production of the CWP and are improvements to existing procedures used to quantify core CWP content described in the Assumptions and Estimates Report (see http://www.waterplan.water.ca.gov/cwpu2013/ae). These enhancements have been identified through the CWP collaborative processes and by the technical experts conducting the work. It is expected that implementation will occur over many years and even decades due to the technical complexity of these activities combined with the scarce resources to perform the work. The following is a summary of key CWP deliverables, with a brief description of the technical enhancements underway.

Water Portfolios

The water portfolios are estimates of present water balances of water uses and supplies for each region in California (see Chapter 3, "California Water Today"). The water portfolios are aggregated to spatial scales unique to the CWP, including the detailed analysis unit, planning area, and hydrologic region. Technical enhancements will allow this information to be evaluated at boundaries used by water purveyors and regional water management groups. A significant part of this work is to transition from the existing spreadsheet-based data storage of the water portfolio information to an enterprise data management system that will facilitate sharing of information through the Internet. Additional enhancements are underway to describe the hydrologic cycle components more fully within the water portfolios, groundwater in particular.

Future Scenarios

The future scenarios are part of the CWP analysis to evaluate resource management strategy performance for a range of population growth projections, water demand and supply assumptions, and climate uncertainty. Chapter 5, "Managing an Uncertain Future," describes the work completed for Update 2013 on the future scenarios and provides a summary of the limitations. Future technical enhancements will expand the analysis beyond the Sacramento River, San Joaquin River, and Tulare Lake regions, and explore ways to quantify flood risk reduction and water quality benefits. For further information, refer to Related Action 10.10 in Chapter 8, "Roadmap For Action."

Water Sustainability

The water sustainability deliverable includes the development and application of an analytical framework for identifying, computing, and evaluating sustainability indicators. Chapter 5, "Managing an Uncertain Future," describes the water sustainability work completed for Update 2013. Future technical enhancements will expand the number of indicators evaluated, will refine the spatial scale of indicators to focus on regional sustainability, and will improve upon the decision support tool described next.

Water Sustainability Decision Support Tool

Assessing water sustainability requires information about natural and human components of water systems. This information can be conveyed to improve knowledge in a number of ways. Narrative description of how processes work, or how management improves or degrades sustainability, helps to build one type of understanding. Other ways include map-based approaches, showing where opportunities for action exist, and charting and graphing approaches, which can show when or how something is changing. A combination of these approaches can contribute to the knowledge base required to inform sound decisions about sustainability and is the basis of

Snow surveyors measure the water content of the Sierra snowpack, to forecast water supply conditions for the upcoming dry season.

the water sustainability Decision Support Tool (DST) for California collaboratively developed by University of California, Davis, DWR, and the U.S. Environmental Protection Agency (EPA) Region 9 Office. The DST includes the water sustainability indicators discussed in Chapter 5. Additionally, the DST includes two indices (ecological footprint and water footprint) and two indicators based on satellite remote-sensing data (the total water and groundwater flux indicator based on the Gravity Recovery and Climate Experiment [GRACE] satellite data) and the plant growth index (PGI) of land cover change. The purposes for developing the DST include:

1. Reporting status and trends of social, economic, and ecological condition indicators attributable to water sustainability goals and objectives.

2. Visualizing and understanding data and results from the water footprint and water sustainability indicators analyses.

3. Providing policy-relevant planning and implementation information for agency staff and support for public input into planning processes. The overarching goal is to engage state and local policy-makers, planning decision-makers, planning staff, and interested citizens in a conversation about water sustainability.

Available at http://indicators.ucdavis.edu, the DST provides information from global resources about sustainability indicators. It also gives access to the California Water Sustainability Indicators Framework, a foundational document describing the process of developing sustainability indicators, collecting and analyzing data, reporting results, and interpreting the meaning of results for decision-making. It catalogs the indicators proposed for the CWP and gives examples of sustainability indicators evaluated for California. Finally, it provides information about the ecological and water impacts of production and consumption in California, which can contribute to understanding how to become more sustainable.

Finance Decision Support System

The Update 2013 Finance Planning Framework is based on the best available data, tools, models, and subject matter expert opinion. Many technical capabilities will require continued development and refinement to increase uniformity, accuracy, quantitative analysis, and comparability of information and approaches; advance scientific understanding; and generally reduce uncertainty. Here is a partial list of uncertainties to be addressed in future CWP updates:

- Co-dependence of activities.
- Systemic analysis and optimization.
- Standardization of methods, information, and estimates.
- Identification of leveraging opportunities, return on/value of investments, and diminishing returns.
- Assigning economic value to environmental assets and services.
- Avoiding double counting of costs.

Improving and Sharing Information

Water-related information is collected and maintained by many local, regional, State, federal, and tribal governments, agencies, and organizations. A wealth of information already exists, but remains siloed in multiple institutions that do not share information effectively with one another.

There is a need to improve ways of sharing information as quickly as it is collected or generated to support daily operational decisions. Some entities,such as the Metropolitan Water District of Southern California, have made inroads into effective integration of information from its water retailers. In contrast, the CWP does not have a fully transparent linkage between the information collected from local entities and reported at the hydrologic region. In part, this is a result of the labor-intensive process of collecting relevant information across the state and converting it into a useful format for the CWP.

Enhancement: Reduce Information Gaps and Limitations

The CWP describes much of the current water resource information in regional water-flow diagrams (see Volume 2, *Regional Reports*, and Volume 5, *Technical Guide*). Flow diagrams characterize a region's hydrologic cycle. Completing more comprehensive regional flow diagrams and water balances requires more detailed information on land and water use, surface and groundwater supplies, and the ability to differentiate between applied and consumptive water uses. The following categories of information are not uniformly available throughout the state for use by the CWP:

- Land use — native vegetation, urban footprints, nonirrigated and irrigated agriculture.
- Groundwater — total natural recharge, subsurface inflow and outflow, recharge of applied water, extractions, groundwater levels, pumping-induced land subsidence, and water quality. Senate Bill 6, enacted in November 2009, provides a significant improvement in access to groundwater information by requiring local agencies to monitor and publish groundwater levels.
- Surface water — natural and incidental runoff, local diversions, return flows, total stream flows, conveyance seepage and evaporation, runoff to salt sinks, and water quality. Senate Bill 8, enacted in November 2009, provides for improved accounting of location and amounts of surface water diversions.
- Consumptive use — evaporation and evapotranspiration from native vegetation, wetlands, urban runoff, and nonirrigated agricultural production.
- Soil moisture characteristics — water saturation, porosities, and field capacities.
- Environmental/biological data — species monitoring and their habitat water requirements.
- Land elevations and channel bathymetry.
- Current and future price of water by supply source.

The information highlighted above is available for some regions and not for others. For example, methods and data to estimate natural runoff are available for regions such as the Sacramento Valley, where the Sacramento-San Joaquin Delta (Delta) is a central outflow measurement location. In such areas like the South Coast Hydrologic Region, with no central point for outflow measurement and substantial groundwater extraction, the natural runoff is more difficult to estimate. Existing data are not easily gathered or disaggregated to provide convenient access for all areas of interest. In addition, budget constraints limit the data collection and management activities necessary to quantify and track all the water in the state. The result can be data sets consisting only of older, less current information or significant gaps in available information. For further information, refer to Related Actions 10.2, 10.3, and 10.5 in Chapter 8, "Roadmap For Action."

Enhancement: Develop a Strategic Plan to Improve Water-Related Information

The strategy to improve water-related information should include a method to identify and unify institutional data sets, and also to state the objectives of unifying data sets clearly and how information exchange can benefit the diverse needs of different institutions. The goal is not to construct a single repository of water-related information, but to share the available information across many entities effectively. There are many diverse water needs and uses that require specific information to meet the objectives of each institution: supply (both urban and agricultural), quality, land use, flood protection, and environmental water needs. It is important for institutions to understand available data and develop a long-term data management policy that will benefit all institutions involved in water management.

The following steps should be considered when developing a strategic plan for water information:

- Identify what information is collected by different institutions involved in water management and determine how it fits together.
- Collaborate with custodians of water information to identify mission-critical information needs, and focus on the most important areas of information collection and management.
- Identify where there is overlap in information collection and look for areas of institutional collaboration.
- Determine the data needs of local water suppliers and water management agencies. What kind of data would local water management officials like to see and what data should be provided to them from a water management perspective that they do not have access to?
- Construct an agreement for institutions on a method of sharing information that contributes to an understanding of local, regional, and statewide water management.
- Develop methods for water suppliers to communicate with each other and guide discussions about water information management.

For further information, refer to Related Actions 10.2, 10.3, and 10.5 in Chapter 8, "Roadmap For Action."

Enhancement: Integrating Urban Water Management Plans, Integrated Regional Water Management Plans, and the California Water Plan

Urban water management plans and the CWP are required by law to be updated in five-year cycles. Both plans require significant resources to develop information about current and future water uses and water supplies. Both plans are also used to make significant planning and policy decisions about how to invest and how much to invest in California's local and statewide water management systems. Better integration is needed to ensure that both plans are using the best available information so that decision-makers can have confidence in water policy decisions and the public can have confidence in these investments. Similarly, better integration is also needed to ensure consistency between the CWP and integrated regional water management plans.

Enhancement: Water Planning Information Exchange

DWR is building an online information exchange system called the Water Planning Information Exchange (Water PIE) to share water-related information among state, regional, and local agencies and governments, universities, and the public. This type of online information exchange system is being designed to support regional partnerships by providing a common way of developing and sharing information. It will support streamlined development and evaluation of IRWM, agricultural water management, urban water management, and groundwater management plans by providing a common vocabulary, basic information needed to develop effective plans, and a venue for sharing information generated by the plans. The exchange will facilitate collection of water-related information and data across wide ranges of entities that collect and store these types of information and data. An information management system such as Water PIE will also enhance the opportunities for collaboration with academic and research institutions by improving access to the most current information throughout the state. A prototype system called the Integrated Water Resources Information System (IWRIS) was developed by DWR as the first step for Water PIE (see Box 6-2 ,“IWRIS — A Working Information System”). For further information regarding Water PIE, refer to Related Action 10.7 in Chapter 8, “Roadmap For Action.”

Enhancement: Hobbes Data and Analytical Tool Management System

The University of California, Davis, is leading the development of a software system, Hobbes, to create an open, organized, and documented quantitative representation of the state’s intertied water resources system. Geocoded elements in this database can be interactively converted into tiered networks that can be downloaded and solved by multiple modeling platforms with the appropriate translators depending on user preferences. Many Hobbes tools will be web-based, with exporting capabilities to the most common analytical and modeling software.

The Hobbes Project will include:

- Database standardization and data documentation.
- Geocoded data element representations.
- Open platform with web access.
- Ability to transform database elements into documented model inputs via co-development.
- Focus on data and database structure, organization, and documentation, not specific model platforms.

For further information regarding Hobbes, refer to Related Action 10.8 in Chapter 8, “Roadmap For Action.”

Using Trimble R8 Rovers, DWR engineers collect GPS Real Time Kinematic topographic observations to capture the channel cross-sectional geometry at Chowchilla Bifurcation Structure. Topographic data also was collected along the top of the levees and at structures to periodically track the general subsidence trends in the area. Identified trends in the topographic data help hydraulic modelers determine how the conveyance capacity of the channel is changing over time.

Box 6-2 IWRIS — A Working Information System

In May 2008, DWR launched a working prototype of the Water Planning Information Exchange (Water PIE) called the Integrated Water Resources Information System (IWRIS). IWRIS is a data management tool for water resources data. It is a Web-based geographic information system (GIS) application that allows users to access, integrate, query, and visualize multiple sets of data. Some of the databases include DWR Water Data Library, California Data Exchange Center, U.S. Geological Survey streamflow, and Local Groundwater Assistance Grants (AB 303), as well as data from local agencies. IWRIS can be accessed at http://www.water.ca.gov/iwris/.

Enhancement: Applying Tools for Data Visualization and Analytics

Data visualization tools help communicate key messages contained within the volumes of data collected or results generated, which can bring new insights into the behavior of the system or problem being studied. Data visualization represents information through graphical means, such as charts, maps, and animations. Simple examples of data visualization are showing a graph of water flow for a specific location over time or showing reservoir storage over time compared to median values for the same period. Access to innovative and meaningful visualizations can inform decision-makers on the variability of flow or storage within the system and can be combined with other information on channel capacities to consider flood risk or with biological data to assess threats to endangered species. There are numerous existing tools available to visualize and analyze water data and a growing number that allow data to be visualized through the Internet. Water management agencies that collect water data should embrace the application of data visualization tools to assist with making water resources information more accessible to the public and decision-makers.

Summary

California needs significant improvements in its analytical tools and data to evaluate the costs, benefits, and tradeoffs of alternative resource management strategies effectively, and to support decision-making. These improvements must be done in a way that promotes IWM and fosters collaboration. A tremendous amount of work needs to be done to provide the desired quantitative deliverables for future CWP updates. This work will have to be done with limited budgets and considerable uncertainty related to the health of the Delta, future climate change, and droughts. This chapter describes some of the critical activities undertaken recently to improve California's technical information and identifies several critical activities that must be conducted for the next CWP update to continue progress. Refer to Chapter 8, "Roadmap For Action," for the objectives and related actions for integrated data and analysis and water technology.

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