California Water Plan Update Bulletin 160-98

Executive Summary

November 1998

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Foreword

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In 1957, the Department published Bulletin 3, the *California Water Plan*. Bulletin 3 was followed by the Bulletin 160 series, published six times between 1966 and 1993, updating the *California Water Plan*. A 1991 amendment to the California Water Code directed the Department to update the plan every five years. Bulletin 160-98 is the latest in the series. The Bulletin 160 series assesses California's water needs and evaluates water supplies, to quantify the gap between future water demands and water supplies. The series presents a statewide overview of current water management activities and provides water managers with a framework for making decisions.

In response to public comments on the last update, Bulletin 160-93, this 1998 update evaluates water management options that could improve California's water supply reliability. Water management options being planned by local agencies form the building blocks for evaluations performed for each of the State's ten major hydrologic regions. Local options are integrated into a statewide overview that illustrates potential progress in reducing the State's expected future water shortages.

When the previous water plan update was released, California was just emerging from a six-year drought. This update follows the largest and most extensive flood disaster in California's history, the January 1997 floods. These two hydrologic events fittingly illustrate the complexity of water management in the State.

The Department appreciates the assistance provided by the Bulletin 160-98 public advisory committee, which met with the Department over a three-year period as the Bulletin was being prepared. The Department also appreciates the assistance provided by the many local water agencies who furnished information about their planned water management activities.

David N. Kennedy
Director

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The California Water Commission serves as a policy advisory body to the Director of the Department of Water Resources on all California water resources matters. The nine-member citizen commission provides a water resources forum for the people of the State, acts as a liaison between the legislative and executive branches of State government, and coordinates federal, State, and local water resources efforts.

1

Executive Summary

Introduction

In 1957, the Department published Bulletin 3, the *California Water Plan.* Bulletin 3 was followed by the Bulletin 160 series, published six times between 1966 and 1993, updating the *California Water Plan.* A 1991 amendment to the California Water Code directed the Department to update the plan every five years. Bulletin 160-98 is the latest in the series.

The Bulletin 160 series assesses California's agricultural, environmental, and urban water needs and evaluates water supplies, in order to quantify the gap between future water demands and the corresponding water supplies. The series presents a statewide overview of current water management activities and provides water managers with a framework for making water resources decisions.

The Department's Bulletin 160 series quantifies only California's managed or dedicated water uses—urban, agricultural, and environmental uses. Unmanaged uses, such as the precipitation consumed by native plants, are not quantified.

While the basic scope of the Department's water plan updates has remained unchanged, each update has taken a distinct approach to water resources planning, reflecting issues or concerns at the time of its publication. In response to public comments on the last update, Bulletin 160-93, the 1998 update evaluates water management actions that could be implemented to improve California's water supply reliability. Bulletin 160-93 analyzed 2020 agricultural, environmental, and urban water demands in considerable detail. These demands, together with water supply information, have been updated for the 1998 Bulletin, which also uses a

2020 planning horizon. However, much of Bulletin 160-98 is devoted to identifying and analyzing options for improving water supply reliability. Water management options available to, and being considered by, local agencies form the building blocks of evaluations prepared for each of the State's ten major hydrologic regions. (Water supplies provided by local agencies represent about 70 percent of California's developed water supplies.) These potential local options are integrated with options that are statewide in scope, such as the CALFED Bay-Delta program, to create a statewide evaluation.

The statewide evaluation represents a snapshot, at an appraisal level of detail, of how actions planned by California water managers could reduce the gap between supplies and demands. The evaluation does not present potential measures to reduce all shortages statewide to zero in year 2020. Such an approach would not reflect economic realities and current planning by local agencies. Not all areas of the State and not all water users can afford to reduce drought year shortages to zero. Bulletin 160-98 focuses on compiling those options that appear to have a reasonable chance of being implemented by water suppliers, to illustrate potential progress in reducing the State's future shortages.

Overview of California's Water Needs

Bulletin 160-98 estimates that California's water shortages at a 1995 level of development are 1.6 maf in average water years, and 5.1 maf in drought years. (As described later in the Bulletin, shortages represent the difference between water supplies and water demands.) The magnitude of shortages shown for drought conditions in the base year reflects the cutbacks in supply experienced by California water users during the recent six-year drought. Bulletin 160-98 forecasts increased shortages by 2020—2.4 maf in an average water year and 6.2 maf in drought years. The water management options identified as likely to be implemented could reduce those shortages to 0.2 maf in average water years and 2.7 maf in drought years.

Population growth is expected to drive the State's increased water demands. To put California's population into perspective, about one of every eight U.S.

Summary of Key Statistics

Shown below for quick reference are some key statistics presented in the Bulletin. Water use information is based on average water year conditions. The details behind the statistics are discussed in Chapter ES4.

	1995	*2020 Forecast*	*Change*
Population (million)	32.1	47.5	+15.4
Irrigated crops (million acres)	9.5	9.2	-0.3
Urban water use (maf)	8.8	12.0	+3.2
Agricultural water use (maf)	33.8	31.5	-2.3
Environmental water use (maf)	36.9	37.0	+0.1

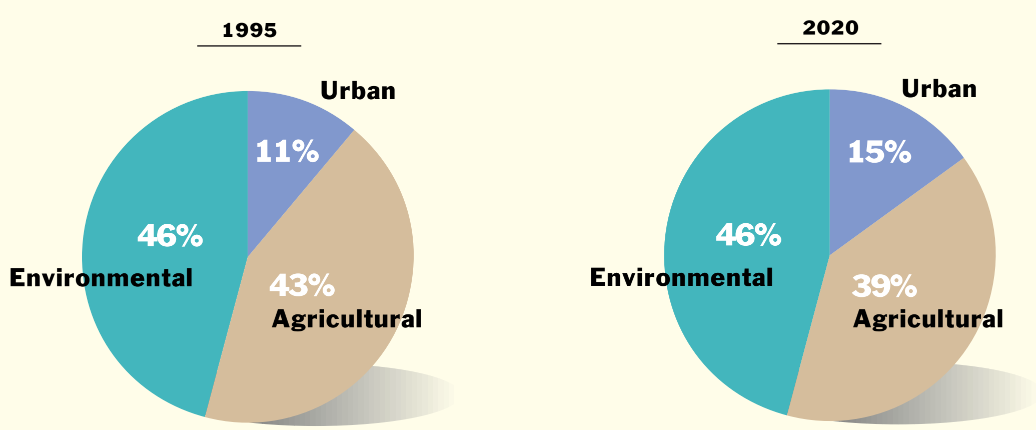
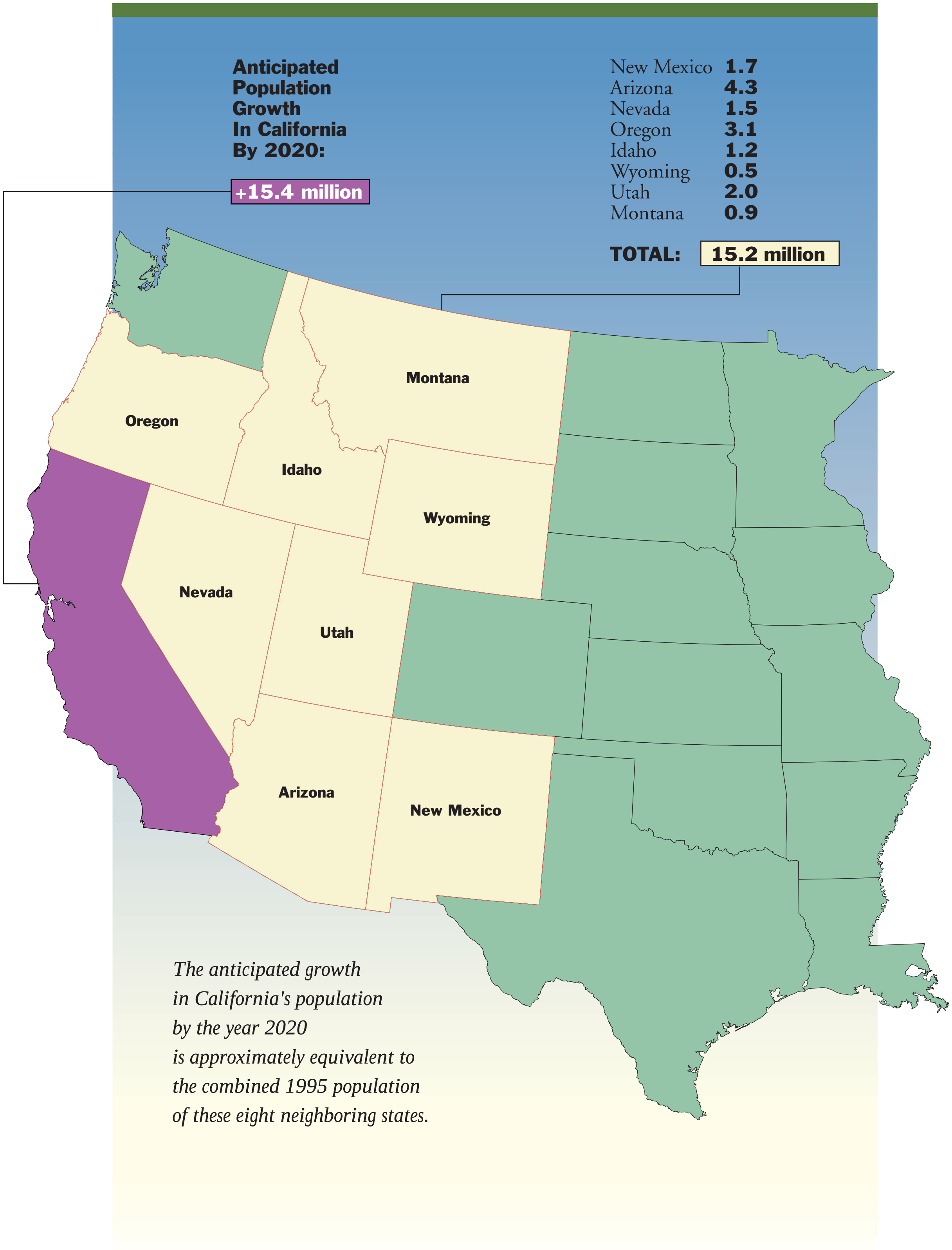


FIGURE ES1-1.

California's Expected Population Growth Versus Neighboring States' Populations



residents now lives in California. During the time period covered in the Bulletin (the 25 years from 1995 to 2020), California's population is forecast to increase by more than 15 million people, the equivalent of adding the present populations of Arizona, Nevada, Oregon, Idaho, Montana, Wyoming, New Mexico, and Utah to California, as shown in Figure ES1-1. Today, four of the nation's 15 largest cities (Los Angeles, San Diego, San Jose, and San Francisco) are located in the State.

The sidebar on page ES1-2 summarizes key statistics developed later in the Bulletin.

Bulletin 160-98 Hydrologic Regions

Figure ES1-2 shows California's ten hydrologic regions, corresponding to the State's major drainage basins. The Department subdivides the State into regions for planning purposes. The largest planning unit is the hydrologic region, a unit used extensively in this Bulletin. The next level of delineation below hydrologic regions is the planning subarea. Some of the Bulletin's regional water management evaluations discuss information at the PSA level. The smallest study unit used by the Department is the detailed analysis unit. California is divided into 278 DAUs. Most of the Departments' Bulletin 160 analyses begin at the DAU level, and the results are aggregated into hydrologic regions for presentation.

Agreements reached in the 1994 Bay-Delta Accord were widely hailed as a truce in California's water wars. The approach taken in the Bay-Delta exemplifies some hallmarks of today's water management activities—increased participation by local governments and other stakeholders in statewide water management issues, and significant efforts to carry out ecosystem restoration actions.

Changes Since the Last California Water Plan Update

The last *California Water Plan* update, Bulletin 160-93, was published in 1994 and used 1990-level information to represent base year water supply and demand conditions. At that time, California had recently emerged from the six-year drought and Bay-Delta issues were in a state of flux. Bulletin 160-98 uses 1995-level information to represent base year conditions, including new (interim) Bay-Delta standards.

Changes in Sacramento-San Joaquin River Delta conditions are a major difference between the two bulletins. Bulletin 160-93 was based on State Water Resources Control Board Decision 1485 regulatory conditions in the Delta, and used a range of 1 to 3 maf for unspecified future environmental water needs—a range that reflected uncertainties associated with Bay-Delta water needs and Endangered Species Act implementation. Bulletin 160-98 uses SWRCB's Order WR 95-6 as the base condition for Bay-Delta operations, and describes proposed CALFED actions for the Bay-Delta.

Bulletin 160-93 was the first *California Water Plan* update to examine the demand/supply balance for drought water years as well as for average water years, a response to water shortages experienced during the then-recent drought. Bulletin 160-98 retains the drought year analysis and also considers the other end of the hydrologic spectrum—flooding. Traditionally, water supply has been the dominant focus of the water plan updates. In response to the January 1997 flooding in Northern and Central California, Bulletin 160-98 highlights common areas in water supply and flood control planning and operations and emphasizes the benefits of multipurpose facilities.

Changes in Response to Bulletin 160-93 Public Comments

Other changes between the two reports resulted from public comments on Bulletin 160-93. The dominant public comment on Bulletin 160-93 was that it should show how to reduce the gap between existing supplies and future demands, in addition to making supply and demand forecasts. Bulletin 160-98 addresses that comment by presenting a compilation of local agencies' planning efforts together with potential water management options that are statewide in scope. Local agencies' plans form the base for this effort, since it is local water purveyors who have the

FIGURE ES1-2.

California's Hydrologic Regions

California's Hydrologic Regions

North Coast	Klamath River and Lost River Basins, and all basins draining into the Pacific Ocean from the Oregon stateline southerly through the Russian River Basin.
San Francisco Bay	Basins draining into San Francisco, San Pablo, and Suisun Bays, and into Sacramento River downstream from Collinsville; western Contra Costa County; and basins directly tributary to the Pacific Ocean below the Russian River watershed to the southern boundary of the Pescadero Creek Basin.
Central Coast	Basins draining into the Pacific Ocean below the Pescadero Creek watershed to the southeastern boundary of Rincon Creek Basin in western Ventura County.
South Coast	Basins draining into the Pacific Ocean from the southeastern boundary of Rincon Creek Basin to the Mexican boundary.
Sacramento River	Basins draining into the Sacramento River system in the Central Valley (including the Pit River drainage), from the Oregon border south through the American River drainage basin.
San Joaquin River	Basins draining into the San Joaquin River system, from the Cosumnes River basin on the north through the southern boundary of the San Joaquin River watershed.
Tulare Lake	The closed drainage basin at the south end of the San Joaquin Valley, south of the San Joaquin River watershed, encompassing basins draining to Kern Lakebed, Tulare Lakebed, and Buena Vista Lakebed.
North Lahontan	Basins east of the Sierra Nevada crest, and west of the Nevada stateline, from the Oregon border south to the southern boundary of the Walker River watershed.
South Lahontan	The closed drainage basins east of the Sierra Nevada crest, south of the Walker River watershed, northeast of the Transverse Ranges, north of the Colorado River Region. The main basins are the Owens and the Mojave River Basins.
Colorado River	Basins south and east of the South Coast and South Lahontan regions; areas that drain into the Colorado River, the Salton Sea, and other closed basins north of the Mexican border.

ultimate responsibility for meeting their service areas' needs.

Bulletin 160-98 excludes groundwater overdraft from the Bulletin's base year water supply estimate and is therefore the first water plan update to show an average water year shortage in its base year. (Both of the bulletins excluded future groundwater overdraft from future water supply estimates.) About 1.5 maf of the 1.6 maf base year shortage is attributable to groundwater overdraft.

Finally, Bulletin 160-98 uses applied water data, rather than the net water amounts historically used in the water plan series. This change was made in response to public comments that net water data were more difficult to understand than applied water data. This concept is explained in Chapter ES3.

Changes in Future Demand/Shortage Forecasts

Bulletin 160-93 used a planning horizon of 1990-2020. Bulletin 160-98 uses a planning horizon of 1995-2020. Bulletin 160-98 uses the 2020 planning horizon because no major data changes occurred between the two reports that would justify extending the planning horizon. Urban water demands depend heavily on population forecasts—the next U.S. Census will not be conducted until 2000.

The water plan series uses population forecasts from the Department of Finance. DOF reduced its 2020 forecast for California in the period between Bulletin 160-93 and Bulletin 160-98. The reduction reflects the impacts of the economic recession in California in the early 1990s. California experienced a record negative net domestic migration then, as more people moved out of the State than moved in. This reduction in the population forecast translates to a reduction in forecasted urban water use in Bulletin 160-98.

The 2020 forecasted agricultural water demands increased from Bulletin 160-93 to Bulletin 160-98, even though the forecasted crop acreage decreased slightly. This increase resulted from elimination of the "other" category of water use shown in Bulletin 160-93, which included conveyance losses. For Bulletin 160-98, water in the "other" category was reallocated back to the major water use categories to simplify information presentation. Most of the conveyance losses are associated with agricultural water use. Combining the "other" category into the major water use categories most affected the agricultural water demand forecast. When conveyance losses are factored out of the Bulletin 160-98 forecast, agricultural water use decreases between Bulletin 160-93 and Bulletin 160-98.

Bulletin 160-93 was the first water plan update to quantify environmental water use, recognizing the importance of the water that is dedicated to environmental purposes for maintaining those resources and that this water is unavailable for future development for other purposes. As illustrated earlier, the environmental sector is California's largest water using sector. Bulletin 160-98 uses the same definition and quantification procedure for environmental water use as did Bulletin 160-93.

The 2020 environmental water demand forecast increased substantially from Bulletin 160-93 to Bulletin 160-98. This increase results from implementation of the Bay-Delta Accord, inclusion of additional wild and scenic river flows, and increased instream flow requirements.

The shortage shown in Bulletin 160-98 is similar in magnitude to the low end of the shortage range reported in Bulletin 160-93. The treatment of forecasted Bay-Delta environmental water demands accounts for much of the difference. The range of potential future environmental water demands of 1 to 3 maf used in Bulletin 160-93 was added to that Bulletin's base environmental water demand forecast, rather than being evaluated through operations studies, because Bay-Delta regulatory assumptions could not be determined then. This conservative approach yielded higher demands than operations studies would have provided.

Preparation of Bulletin 160-98

Although the water plan updates are published only every five years, the Department continuously compiles and analyzes the annual data used to prepare them. After publication of Bulletin 160-93 in 1994, the remainder of that year was devoted to finishing data evaluation deferred during the Bulletin's production. Work on Bulletin 160-98 began in 1995. A citizens' advisory committee with more than 30 members, representing a wide range of interests, was established to assist the Department in its preparation of the next water plan update. The advisory committee met with Department staff 17 times during Bulletin 160-98 preparation, and in August 1997 reviewed an administrative draft that preceded release of the public review draft at the end of January 1998. The review period for the public draft extended through mid-April 1998, during which time public meetings were held and presentations were made to interested parties. The draft was also made available on the World Wide Web. Over 4,000 copies of the public review draft were distributed.

Public Comments on Draft

The Department received over 200 comment letters on the draft and additional comments from public meetings. Many comments were provided by local agencies whose facilities and projects are described in the public draft, and dealt with edits or corrections regarding those facilities or projects. Another major class of comments dealt with policy, conceptual, or analytical subjects. Many of these comments were influenced by discussions taking place in the CALFED Bay-Delta program and reflected the commenters' positions on CALFED issues. For example, proponents of CALFED's no conveyance improvements alternative generally expressed opposition to Bulletin 160-98's exclusion of groundwater overdraft as a supply, because this approach increases overall statewide shortages. The Department received positive public comments on Bulletin 160-93 when it excluded groundwater overdraft as a supply for the first time, and also received positive comments on its treatment of overdraft for Bulletin 160-98. Often, public comments conflicted with one another. For example, environmental organizations frequently stated that the Bulletin should include more future water conservation, while water purveyors frequently stated that levels assumed in the Bulletin were overly optimistic. Some comments suggested that the Bulletin's future water demands could be reduced by raising water prices, while others felt that the forecasted demands were too low and did not take into account future needs of California's population and agricultural economy. Likewise, some comments expressed philosophical opposition to constructing more reservoirs in California, while others emphasized the need for more storage and flood control reservoirs. The Department considered these comments in the context of the Bulletin's goal of accurately reflecting actions that water purveyors statewide would be reasonably likely to implement by year 2020.

Some comments suggested that Bulletin 160-98 (or the Department, or the State of California) advocate or express a vision on a variety of subjects—including State-funded water supply development, sustainable development, nonpoint source pollution, flood control, food production security, mandatory water pricing, and greater use of desalting (by entities other than the commenter). Such an approach is outside the scope of the Department's water plan update series. The role of the Bulletin 160 series is to evaluate present and future water supplies and demands given current social/economic policies, and to evaluate progress in meeting California's future water needs. As appropriate, the Bulletin discusses how other factors such as flood control may relate to water supply planning.

To develop 2020-level conditions, the Department makes a fundamental assumption that today's conditions—facilities, programs, water use patterns, and other factors—are the basis for predicting the future. (And, as one commenter correctly pointed out, Bulletin 160-98 also assumes that California's climate will remain unchanged over the Bulletin's 25-year planning horizon.) This approach differs distinctly from the approach of establishing a desired future goal or vision, and then preparing a plan that would implement that goal or vision. Such a plan would require broad public acceptance that simply does not exist today.

Many of the advocacy or vision comments described above are also not within the Department's jurisdiction or the jurisdiction of other State agencies. For example, the Department's role in developing water supply for local agencies is limited to fulfilling its State Water Project contractual obligations. (The Department may provide financial assistance to local agencies for various water management programs as authorized under bond measures enacted by the Legislature and approved by the voters.) The Department has no regulatory authority to mandate how local water agencies price their water supplies, or to require that local agencies adopt one type of water management option over another. Comments such as those suggesting that the Department plan for control of nonpoint source pollution or food production address the jurisdictional areas of other State agencies.

The subject of flood control merits special mention because of the direct relationship between operation of water supply projects and flood control projects. The purpose of the water plan update series is to evaluate water supplies, but those supplies can be affected by flood control actions such as increasing the amount of reservoir storage dedicated to flood control purposes. With memories of the disastrous January 1997 floods still fresh in people's minds, some commenters recommended that Bulletin 160-98 devote more attention to flood control needs, such as floodplain mapping programs, that are not directly related to water supply considerations. The 1997 *Final Report of the Governor's Flood Emergency Action Team* describes recommended actions to be taken based on the damages experienced in January 1997. Sections of that report are referenced throughout the Bulletin. Bulletin 160-98 emphasizes the interaction between water supply and flood control planning, and points out the benefits associated with multipurpose water projects.

As discussed in the following section, the Department received a number of comments requesting that Bulletin 160-98 quantify future water supply uncertainties associated with ongoing programs or regulatory actions, such as the CALFED Bay-Delta program, Federal Energy Regulatory Commission hydroelectric plant relicensing, and Endangered Species Act listings. Text has been added that quantifies those actions for which data are available.

The Department received some comments that could not be incorporated in Bulletin 160-98 because they suggested substantial changes in the scope or content of the Bulletin that could not be addressed before the Bulletin's due date to the Legislature, or suggested changes for the next update of the water plan. The scope of Bulletin 160-98 was established in coordination with the Bulletin's advisory committee in 1995, just as the scope of the next plan update (five years hence) will be established early in the process of preparing that update. The Department will consider these long-term comments when work begins on the next update.

Works in Progress and Uncertainties

The descriptions of major California water management activities provided in the Bulletin are generally current through July 1998. There are several pending activities that could be characterized as works in progress, including the CALFED Bay-Delta program and Colorado River water use discussions. For programs such as these, the Bulletin describes their current status and potential impacts, if known, on future water supplies. There are uncertainties associated with the outcomes of these activities, just as there are with any process that is evaluated in mid-course.

As noted at the beginning of this chapter, each water plan update focused on issues or concerns of special interest at the time of its publication. As an example of this focus, Bulletin 160-83 was the last water plan update to review water use for hydropower generation. No major changes have occurred since the late 1970s/early 1980s, when high energy prices and favorable tax treatment for renewable energy spurred a boom in small hydropower development. Today, uncertainties about water supply and water use associated with hydropower production are increasing, with the 1998 initiation of deregulation for California investor-owned power utilities and the prospect of FERC relicensing of several powerplants on major Sierra Nevada rivers between 2000 and 2010. Although there is presently little information available on which to base forecasts of resultant changes in water supplies, more information is likely to be available for the next water plan update.

Colorado River interstate issues are a new addition to a statewide water picture largely dominated by Delta and Central Valley Project Improvement Act issues in the recent past. Achieving a solution to California's need to reduce its use of Colorado River water to the State's basic apportionment (a reduction of as much as 900 taf from historical uses) requires consensus among California's local agencies that use the river's water, as well as concurrence in the plan by the other basin states.

Presentation of Data in Bulletin 160-98

Water budget and related data are tabulated by hydrologic region throughout the Bulletin. The statewide totals in these tables are generally presented as rounded values. As a result, individual table entries will not necessarily sum exactly to the rounded totals.

In the Chapter ES5 water budget appendices, regional water use/supply totals and shortages are not rounded. Individual table entries may not sum exactly to the reported totals due to rounding of individual entries for presentation purposes.

2

Executive Summary

Current Events in California Water Management

This chapter highlights some significant infrastructure and institutional changes that have occurred since the publication of Bulletin 160-93, and reviews the status of selected high-profile programs.

Facilities

A common theme in previous *California Water Plan* updates has been the need to respond to the State's continually increasing population. Population growth brings with it the need for new or expanded infrastructure. California's water purveyors have made significant infrastructure improvements—including reservoirs, conveyance facilities, recycling and desalting facilities, and structural environmental restoration projects—since publication of the last *California Water Plan* update.

In 1998, Contra Costa Water District completed its 100 taf Los Vaqueros Reservoir, improving water quality and providing emergency storage for its service area. Metropolitan Water District of Southern California is constructing its Eastside Reservoir in Riverside County. When completed in 1999, this 800 taf reservoir will nearly double the region's existing surface storage capacity and will provide increased terminal storage for SWP and Colorado River supplies. Eastside Reservoir would provide the entire region with a six-month emergency supply after an earthquake or other disaster and would also provide water supply for drought protection and peak summer demands.

California's increasing population is a driving factor in future water management planning.

TABLE ES2-1

Major Water Conveyance Facilities Since 1992

Facility	*Constructing Agency*	*Status*	*Length (miles)*	*Maximum Capacity (cfs)*
Coastal Branch Aqueduct	Department of Water Resources	completed 1997	100	100
Eastside Reservoir Pipeline	Metropolitan Water District of Southern California	completed 1997	8	1,000
East Branch Enlargement	Department of Water Resources	completed 1996	100	2,880
Mojave River Pipeline	Mojave Water Agency	started 1997	71	94
Old River Pipelines (Los Vaqueros Project)	Contra Costa Water District	completed 1997	20	400
East Branch Extension	Department of Water Resources	started 1998	14	104
Inland Feeder Project	Metropolitan Water District of Southern California	started 1997	44	1,000
Morongo Basin Pipeline	Mojave Water Agency	completed 1994	71	100
New Melones Water Conveyance Project	Stockton East Water District and Central San Joaquin Water Conservation District	completed 1993	21	500

Several major conveyance projects were completed or began construction since the last water plan update. For example, the Department's Coastal Aqueduct, completed in 1997, now carries SWP water to San Luis Obispo and Santa Barbara Counties. Mojave Water Agency recently completed a major conveyance facility (71 miles long) and is constructing another of similar length to import surface water to its service area to alleviate longstanding groundwater overdraft problems. Large conveyance projects under construction or recently completed are listed in Table ES2-1.

Water recycling and desalting are becoming larger components of existing and potential future water supplies, especially for urban areas. Bulletin 160-98 estimates 1995-level total statewide water recycling to be 485 taf/yr, considerably higher than the Bulletin 160-93 total water recycling estimate of 384 taf/yr. Groundwater recharge and agricultural and landscape irrigation constitute the greatest uses of recycled water in the State. As advanced treatment technologies become more cost-effective, and as public acceptance increases, augmentation of surface water supplies may become another application for recycled water. The San Diego water repurification program, a proposed project to repurify 16 taf/yr of wastewater, would be the first example of highly treated recycled water being discharged directly into a surface reservoir.

Today, California has more than 150 desalting plants producing fresh water from brackish groundwater, municipal and industrial wastewater, and seawater. The capacity of these plants totals about 66 taf/yr; seawater desalting capacity accounts for only 8 taf/yr of total capacity. Most existing plants are small (less than 1 taf/yr) and have been constructed in coastal communities with limited water supplies. The Santa

DWR's extension of the Coastal Branch to serve San Luis Obispo and Santa Barbara Counties provides an imported surface water supply that can help reduce overdraft of coastal groundwater basins.

Barbara desalting plant, with a capacity of 7.5 taf/yr, is the largest seawater desalting plant in California. The plant was constructed during the 1987-92 drought and is now on long-term standby. In 1997, the Marina Coast Water District completed construction on a reverse osmosis seawater desalting plant. This $2.5 million plant produces about 340 af/yr.

Many large-scale environmental restoration projects and programs are being implemented. Facilities associated with these programs include the United States Bureau of Reclamation's Shasta Dam Temperature Control Device, USBR's Red Bluff Diversion Dam Research Pumping Plant, and many fish screens or fish passage improvements at local agency and privately-owned diversions. Financial assistance provided by programs such as CVPIA's anadromous fish restoration program and CALFED's Category III program has resulted in a major expansion of local agency screening and fish passage projects. Table ES2-2 lists some of the largest examples of recently completed structural fishery restoration projects.

Several more large fish screen facilities are nearing the final phases of design or construction, including diversions on the Sacramento River at the Glenn-Colusa Irrigation District, Reclamation District 108 near Grimes, Reclamation District 1004 near Princeton, the Princeton-Codora-Glenn Irrigation District and Provident Irrigation District consolidated diversion, and others. Construction of GCID's

USBR is evaluating the fishery impacts of different types of pump diversions to the Tehama-Colusa Canal. One alternative for improving fish passage at Red Bluff Diversion Dam would be to leave the dam's gates in the raised position and use a pumping plant to make TCC diversions. The research plant contains three pumps—one helical pump and two Archimedes screw pumps (right side of photo).

Hamilton City Pumping Plant screen began in spring 1998. This $70 million project will minimize fish losses near the pumping plant and will maximize GCID's ability to meet its water supply delivery obligations. Reclamation District 108 began construction in 1997

TABLE ES2-2

Large Structural Fishery Restoration Projects

Project	*Owner*	*Description*
Shasta Dam Temperature Control Device	USBR	An approximately $83 million modification to the dam's outlet works to allow temperature-selective releases of water through the dam's powerplant was completed in 1997.
Red Bluff Diversion Dam Research Pumping Plant	USBR	A $40 million experimental facility to evaluate fishery impacts of different types of pumps diverting Sacramento River water into the Tehama-Colusa and Corning Canals was constructed in 1995.
Butte Creek fish passage	Western Canal Water District and others	A multi-component project to improve fish passage by removing small irrigation diversion dams from the creek. By 1998, five diversion dams will have been removed.
Maxwell Irrigation District fish screen	Maxwell ID	An 80 cfs diversion on the Sacramento River was screened in 1994.
Pelger Mutual Water Company fish screen	PMWC	A 60 cfs diversion on the Sacramento River was screened in 1994.

on a new $10 million fish screen. The project, located at the district's Wilkens Slough diversion, will protect migrating winter-run chinook salmon. The district anticipates completing the project by the 1999 irrigation season. Reclamation District 1004 began construction of its $8 million fish screen in 1998. In addition to a fish screen, the project includes relocation of the Princeton Pumping Plant and conveyance facilities. In 1998, the Princeton-Codora-Glenn and Provident Irrigation Districts are expected to complete construction of an $11 million fish screen and pump consolidation project. The 600 cfs project eliminates three unscreened diversions.

Legislation

Proposition 204

In 1996, California voters approved Proposition 204, the Safe, Clean, Reliable Water Supply Act. The act authorized the issuance of $995 million in general obligation bonds to finance water and environmental restoration programs throughout the State. Approximately $600 million of these bonds would provide the State share of costs for projects benefitting the Bay-Delta and its watershed, including $390 million of this amount to implement CALFED's ecosystem restoration program for the Bay-Delta. These latter funds would be available after final federal and State environmental documents are certified and a cost-sharing agreement is executed between the federal and State governments. Table ES2-3 summarizes all programs authorized for Proposition 204 funding.

Proposition 218

Voter approval of Proposition 218 in November 1996 changed the procedure used by local government agencies for increasing fees, charges, and benefit assessments. Benefit assessments, fees, and charges that are imposed as an "incident of property ownership" are now subject to a majority public vote. Proposition 218 defines "assessments" as any levy or charge on real property for a special benefit conferred to the real property, including special assessments, benefit assessments, and maintenance assessments. Proposition 218 further defines "fee" or "charge" as any levy (other than an ad valorem tax, special tax, or assessment), which is imposed by an agency upon a parcel or upon a person as an incident of property ownership, including a user fee or charge for a property-related service.

Although there are many tests to determine if a fee or charge is subject to the provisions of Proposition 218, the most significant one is whether the agency has relied upon any parcel map for the imposition of the fee or charge. There is currently uncertainty in the interpretation of Proposition 218 requirements, especially as they relate to certain water-related fees and charges. From one point of view, Proposition 218 could be interpreted as a comprehensive approach to regulate all forms of agency revenue sources. This broad interpretation would include all fees and charges for services provided to real property. Types of water-related charges and fees that may be affected by Proposition 218's requirements include meter charges, acreage-based irrigation charges, and standby charges. Additional legislation or judicial interpretation may be needed to clarify the application of Proposition 218 to fees and charges used by water agencies. Several water industry groups are working on proposals for clarifying legislation. To date, there has been one water-related legislative clarification of Proposition 218. A 1997 statute clarified that assessments imposed by water districts and earmarked for bond repayment are not subject to the proposition's voter approval requirements.

Municipalities and special districts are beginning to seek voter approval of assessments as required by Proposition 218. Many assessments to fund existing programs have been receiving voter approval. There is at least one example, however, of a water agency whose proposed assessment was not approved. Monterey County Water Resources Agency did not receive voter approval for an assessment to support existing programs—groundwater quality monitoring, water conservation, and nitrate management outreach—funded by water standby charges. Examples of MCWRA's proposed assessment charges were $1.67 per irrigated acre for agricultural land use and $2.26 per parcel for single-family dwellings.

MTBE

Detection of methyl tertiary butyl ether in water supplies soon after it was approved for use as an air pollution-reducing additive in gasoline has raised concerns about its mobility in the environment. Legislation enacted in 1997 included several provisions dealing with MTBE regulation, monitoring, and studies. One provision required the Department of Health Services to establish a primary (health-based) drinking water standard for MTBE by July 1999, and a secondary (taste and odor) drinking water standard by July 1998.

MTBE can be detected by taste at very low concentrations, hence the early requirement for a secondary drinking water standard.

Safe Drinking Water Act

The Safe Drinking Water Act, administered by the U.S. Environmental Protection Agency in coordination with the states, is the chief federal regulatory legislation dealing with drinking water quality. The 104th Congress reauthorized and made significant changes to the SDWA, which had last been reauthorized in 1986. Major changes included:

- Establishing a drinking water state revolving loan fund, to be administered by states in a manner similar to the existing Clean Water Act State Revolving Fund. Loans would be made available to public water systems to help them comply with national primary drinking water regulations and to upgrade water treatment systems.
- The standard-setting process for drinking water contaminants established in the 1986 amendments was changed from a requirement that EPA adopt standards for a set number of contaminants on a fixed schedule to a process based on risk assessment and cost/benefit analysis. The 1996 amendments require EPA to publish (and periodically update) a list of contaminants not currently subject to national primary drinking water regulations, and to periodically determine whether to regulate at least five contaminants from that list, based on risk and benefit considerations.
- A requirement that states conduct vulnerability assessments in priority source water areas expanded existing source water quality protection provisions. States are authorized to establish voluntary, incentive-based source protection partnerships with local agencies. This activity may be funded from the new SRF.
- As a result of the 1996 amendments, EPA adopted a more ambitious schedule for promulgating the

TABLE ES2-3

Proposition 204 Funding Breakdown

Program	*Dollars (in millions)*
Delta Restoration	**193**
CVPIA State share	93
Category III State share	60
Delta levee rehabilitation	25
South Delta barriers	10
Delta recreation	2
CALFED administration	3
Clean Water and Water Recycling	**235**
State Revolving Fund Clean Water Act loans	80
Clean Water Act grants to small communities	30
Loans for water recycling projects	60
Loans for drainage treatment and management projects	30
Delta tributary watershed rehabilitation grants and loans	15
Seawater intrusion loans	10
Lake Tahoe water quality improvements	10
Water Supply Reliability	**117**
Feasibility investigations for specified programs	10
Water conservation and groundwater recharge loans	30
Small water project loans and grants, rural counties	25
Sacramento Valley water management and habitat improvement	25
River parkway program	27
CALFED Bay-Delta Ecosystem Restoration Program	**390**
Flood Control Subventions	**60**
Total	**995**

Disinfectant/Disinfection By-Products Rule and the Enhanced Surface Water Treatment Rule. The first phase of the D/DBP Rule is proposed to take effect in late 1998, as is an interim ESWTR. More stringent versions of both rules are proposed to follow in 2002.

Reclamation, Recycling, and Water Conservation Act of 1996

This act amended Title 16 of PL 102-575 by authorizing federal cost-sharing in additional wastewater recycling projects. (PL 102-575 had authorized federal cost-sharing in specified recycling projects.) The additional California projects are shown below, along with the nonfederal sponsors identified in the statute.

- North San Diego County area water recycling project (San Elijo Joint Powers Authority, Leucadia County Water District, City of Carlsbad, Olivenhain Municipal Water District)
- Calleguas Municipal Water District recycling project (CMWD)
- Watsonville area water recycling project (City of Watsonville)
- Pasadena reclaimed water project (City of Pasadena)
- Phase 1 of the Orange County regional water reclamation project (Orange County Water District and County Sanitation Districts of Orange County)
- Hi-Desert Water District wastewater collection and reuse facility (HDWD)
- Mission Basin brackish groundwater desalting demonstration project (City of Oceanside)
- Effluent treatment for the Sanitation Districts of Los Angeles County with the City of Long Beach (Water Replenishment District of Southern California, OCWD)
- San Joaquin area water recycling and reuse project (San Joaquin County, City of Tracy)

Federal cost-sharing in these projects is authorized at a maximum of 25 percent for project construction and federal contributions for each project are capped at $20 million. Funds are not to be appropriated for project construction until after a feasibility study and cost-sharing agreement are completed. Federal cost-sharing may not be used for operations and maintenance.

The act also authorizes the Department of Interior to cost-share up to 50 percent (planning and design) in a Long Beach desalination research and development project. Local sponsors are the City of Long Beach, Central Basin Municipal Water District, and MWDSC.

Water Desalination Act of 1996

This act authorizes DOI to cost-share in non-federal desalting projects at levels of 25 percent or 50 percent (for projects which are not otherwise feasible unless a federal contribution is provided). Cost-shared actions can be research, studies, demonstration projects, or development projects. The authorization provides $5 million per year for fiscal years 1997 through 2002 for research and studies, and $25 million per year for demonstration and development projects. The act requires DOI to investigate at least three different types of desalting technology and to report research findings to Congress.

Major Water Management Issues and Programs

Bay-Delta Accord and CALFED

Representatives from the California Water Policy Council, created to coordinate activities related to State long-term water policy, and the Federal Ecosystem Directorate, created to coordinate actions of federal agencies involved in Delta programs, signed a Framework Agreement for the Bay-Delta estuary in June 1994. Together, these agencies are known as CALFED. The Framework Agreement improved coordination and communication between State and federal agencies with resource management responsibilities in the estuary. It covered the water quality standards setting process; coordinated water project operations with requirements of water quality standards, endangered species laws, and CVPIA; and provided for cooperation in planning long-term solutions to problems affecting the estuary's major public values.

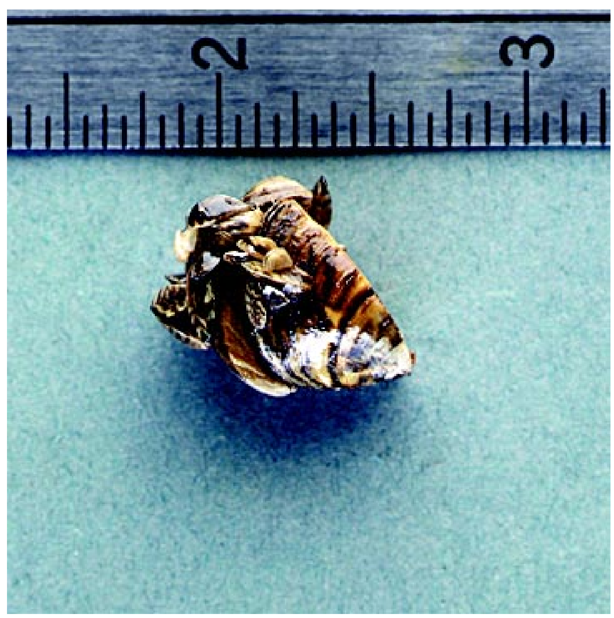
In December 1994 State and federal agencies, working with stakeholders, reached agreement on the "Principles for Agreement on Bay-Delta Standards Between the State of California and the Federal Government" (referred to as the Bay-Delta Accord) that would remain in effect for three years. Provisions of the Bay-Delta Accord covered water quality standard setting and water project operational constraints, ESA implementation and use of real-time monitoring data, and improvement of conditions not directly related to Delta outflow. Parties to the Accord committed to fund "non-flow Category III" measures at $60 million per year for the agreement's three-year term. The Accord was subsequently extended for a fourth year. An Operations Group composed of representatives from the State and federal water projects and the other CALFED agencies was established to coordinate project operations. Stakeholders from water agencies, and environmental and fishery groups participate in Operations Group meetings.

Water Quality Standard Setting. SWRCB adopted a water quality control plan for the Bay-Delta in May 1995, incorporating agreements reached in the Accord. In June 1995, SWRCB adopted Order WR 95-6, an interim order amending terms and conditions of SWRCB's Decision 1485 and the SWP's and Central Valley Project's water right permits to resolve inconsistencies with D-1485 requirements and the projects' voluntary implementation of Accord standards. The interim order will expire when a water right decision allocating final responsibilities for meeting the 1995 objectives is adopted, or on December 31, 1998, whichever comes first. SWRCB released a revised draft EIR for implementing the water quality control plan in 1998, and intends to issue a water right decision implementing the order by the end of 1998. The DEIR has eight flow alternatives:

(1) SWP and CVP Responsible for D-1485 Flow Objectives
(2) SWP and CVP Responsible for 1995 Bay-Delta Water Quality Control Plan Flow Objectives
(3) Water Right Priority Alternative—the CVP's Friant Unit is assumed to be an in-basin project.
(4) Water Right Priority Alternative—the CVP's Friant Unit is assumed to be an export project.
(5) Watershed Alternative—monthly average flow requirements are established for major watersheds based on Delta outflow and Vernalis flow objectives and the watersheds' average unimpaired flow. The parties responsible for providing the required flows are water users with storage in foothill reservoirs that control downstream flow to the Delta, and water users with upstream reservoirs that have a cumulative capacity of at least 100 taf who use water primarily for consumptive uses.
(6) Recirculation Alternative—USBR is required to make releases from the Delta-Mendota Canal to meet the Vernalis flow objectives.
(7) San Joaquin Basin Negotiated Agreement—San Joaquin Basin water right holders' responsibility to meet the plan objectives is based on an agreement titled "Letter of Intent among Export Interests and San Joaquin River Interests to Resolve San Joaquin River Issues Related to Protection of Bay-Delta Environmental Resources."
(8) San Joaquin Basin Negotiated Agreement—Vernalis flow objectives are replaced by target flows contained in the agreement.

CALFED Long-Term Solution-Finding Process for Bay-Delta. The June 1994 Framework Agreement called for a State-federal process to develop long-term solutions to Bay-Delta problems related to fish and wildlife, water supply reliability, natural disasters, and water quality. The CALFED program is managed by an interagency team under the policy direction of CALFED member agencies, with public input provided by the Bay-Delta Advisory Council. BDAC is a 31-member advisory panel representing California's agricultural, environmental, urban, business, fishing, and other interests who have a stake in the long-term solution to Bay-Delta problems.

The CALFED program's first phase identified problems and goals for the Bay-Delta, and developed a range of alternatives for long-term solutions. This phase concluded with a September 1996 report identifying three broad solutions, each of which included



Actions funded by the Category III program include fish screening, fish passage improvements, habitat acquisition, and control of non-native invasive species. The zebra mussel has caused millions of dollars of increased operations and maintenance costs to Great Lakes water users. Preventing the mussels' spread is a priority in invasive species management.

CALFED's Ecosystem Restoration Program calls for extensive creation of new habitat in the Delta. Construction of setback levees would allow restoration of riparian and riverine aquatic habitats, benefitting fish and wildlife.

a range of water storage options, a system for conveying water, and some programs that were common to all alternatives. The second phase consisted of preparing a programmatic EIR/EIS covering three main alternatives for conveyance of water across the Delta—an existing system alternative, a through-Delta alternative, and a dual Delta conveyance alternative. The first public review draft of the PEIR/PEIS was released in March 1998. CALFED expects to issue a second draft PEIR/PEIS by the end of 1998. The revised draft would identify CALFED's draft preferred alternative.

The third phase would involve staged implementation of the preferred alternative over a time period of several decades and will require site-specific environmental documents. Current plans are for an initial implementation period of 7 to 10 years, during which only common program elements would be implemented (water conservation measures, ecosystem restoration, levee improvements). Any conveyance or storage facilities would be constructed in a later phase of implementation.

ESA Administration. The December 1994 Bay-Delta Accord established several principles governing ESA administration in the Bay-Delta during the agreement's term.

- The Accord is intended to improve habitat conditions in the Bay-Delta to avoid the need for additional species listings during the agreement's term. If additional listings do become necessary, the federal government will acquire any additional water supply needed for those species by buying water from willing sellers.
- There is intended to be no additional water cost to the CVP and SWP resulting from compliance with biological opinion incidental take provisions for presently listed species. The CALFED Operations Group is to develop operational flexibility by adjusting export limits.
- Real-time monitoring is to be used to the extent possible to make decisions regarding operational flexibility. CALFED commits to devote significant resources to implement real-time monitoring.

Colorado River

A major issue facing California is its use of Colorado River water in excess of the amount apportioned to it by the existing body of statutes, court decisions, and agreements controlling use of the water supply among the seven basin states. California's basic apportionment of river water is 4.4 maf of consumptive use per year (plus a share of surplus flows, when available), as compared to its present consumptive use of up to 5.3 maf/yr. California's use has historically exceeded the basic apportionment because California has been able to divert and use Arizona's and Nevada's unused apportionments, and to divert surplus water. With completion of the Central Arizona Project and the 1996 enactment of groundwater banking legislation, Arizona projects that it will use almost all of its 2.8 maf apportionment for the first time in 1998. Nevada is projected to use about 280 taf of its 300 taf apportionment in 1998.

California local agencies, working through the Colorado River Board of California, have been developing a proposal for discussion with the other basin states to illustrate how, over time, California would reduce its use to the basic apportionment of 4.4 maf/yr. Drafts of the proposal, known as the draft Colorado River Board 4.4 Plan, have been shared with the other states. Efforts are being made to reach intrastate consensus on the plan in 1998. As Bulletin 160-98 goes to press, the most current version of the draft plan is the December 1997 version.

As formulated, the draft plan would be implemented in two phases. The first phase (between the present and 2010 or 2015) would entail implementing already identified measures such as water conservation and transfers to reduce California's Colorado River water use to about 4.6 to 4.7 maf/yr. The second phase would implement additional measures to reduce California's use to its basic annual 4.4 maf apportionment in those years when neither surplus water nor other states' unused apportionments were available. One of the fundamental assumptions made in the plan is that MWDSC's Colorado River Aqueduct will be kept full by making water transfers from agricultural users in the Colorado River Region to urban water users in the South Coast Region.

Actions included in the first phase were: core water transfers such as the existing Imperial Irrigation District/MWDSC agreement and the proposed Imperial Irrigation District/San Diego County Water Authority transfer; seepage recovery from unlined sections of the All American and Coachella Canals; drought year water transfers similar to the Palo Verde Irrigation District/MWDSC pilot project; groundwater banking in Arizona; and conjunctive use of groundwater in areas such as the Coachella Valley. The draft plan recognizes that transfers of conserved water must be evaluated in the context of preserving the Salton Sea's environmental resources, and also that plan elements must address environmental impacts on the lower Colorado River and its listed species.

Other actions to occur as part of the first phase would include implementation of the San Luis Rey Indian water rights settlement authorized in PL 100-675 and implementation of measures to administer agricultural water entitlements within the first three priorities of the Seven Party Agreement. An important element of the draft CRB 4.4 Plan is the concept that existing reservoir operating criteria be changed by USBR to make optimum use of the river's runoff and available basin storage capacity. California agencies developed new proposed operating criteria that are included in the draft CRB 4.4 Plan. The draft plan contemplates that changes in operating criteria would be part of both the first and second phases. The other basin states have been cautious in their reaction to California's proposals for reservoir reoperation, and have suggested, for example, that new criteria should not be implemented until California has prepared the environmental documents and executed the agreements that would be needed to begin implementation of the draft CRB 4.4 Plan.

The second phase of the draft CRB 4.4 Plan would include additional average year and drought year water transfers. Specifics on these transfers would be developed during the first phase of plan implementation. Other components of the second phase would include further transfers of conserved agricultural water to the South Coast and further work on reservoir operating criteria. Implementation of some elements of phase two of the plan may extend beyond the Bulletin 160-98 planning horizon.

Recent ESA Listings

Since publication of Bulletin 160-93, there has been action on federal listing of several fish species having statewide water management significance. In August 1997, the National Marine Fisheries Service listed two coastal steelhead populations as threatened (from the Russian River south to Soquel Creek, and from the Pajaro River south to the Santa Maria River), and one population as endangered (from the Santa Maria River south to Malibu Creek). NMFS deferred listing decisions for six months for other California populations—from the Elk River in Oregon to the Trinity River in California, from Redwood Creek to

USBR's Parker Dam on the Colorado River impounds Lake Havasu. At this location, the Colorado River forms the stateline between California and Arizona. MWDSC's Colorado River Aqueduct and the Central Arizona Project divert from Lake Havasu.

the Gualala River, and in the Central Valley—due to scientific disagreement about the sufficiency and accuracy of the data available for listing determinations. In March 1998, NMFS listed the Central Valley population as threatened, and deferred listing of the two north coast populations in favor of working with California and Oregon on state conservation plans.

Also in 1997, NMFS listed the Southern Oregon/Northern California coast evolutionarily-significant unit of coho salmon as threatened. In 1996, NMFS listed coho salmon in the central coast ESU (from Punta Gorda in Humboldt County south to the San Lorenzo River) as threatened.

In 1998, NMFS proposed several runs of chinook salmon for listing—the spring-run in the Central Valley ESU as endangered, the fall and late-fall runs in the Central Valley ESU as threatened, and the spring and fall runs in the Oregon/California coastal ESU as threatened. (The spring-run chinook salmon has been listed as a candidate species under the California ESA.) NMFS expects to make its decision on listing in 1999.

USFWS proposed in 1994 to list a resident Delta fish species, the Sacramento River splittail, but a congressional moratorium on listing of new species prevented USFWS from working on the proposal until 1996. USFWS again proposed to list splittail in 1996, but received significant public comments on new scientific information for splittail. The extended public comment period ended July 1998. USFWS is expected to make a decision after reviewing comments.

USFWS has also listed or proposed for listing species whose limited range would result in localized water management impacts. For example, the red legged frog, found primarily in the Central Coast area, was listed as threatened in 1996. Another example is the Santa Ana sucker, found in the Santa Ana River, proposed for listing in 1998.

January 1997 Central Valley Floods

The January 1997 flood event was notable for its sustained rainfall intensity, the volume of floodwater, and the extent of the storm pattern—from the Oregon border down to the southern end of the Sierra. Over a three day period, warm moist winds from the southwest blew over the Sierra Nevada, pouring over 30 inches of rain on watersheds already saturated by one of the wettest Decembers on record. In many major river systems, flood control dams reduced flood flows by half or more, saving lives and significantly reducing property damage. However, in some areas, leveed flood control systems were overwhelmed, causing approximately $2 billion in damages.

Most of the large reservoirs in Northern California were full or nearly full within the first days in January. Several Sacramento Valley reservoirs—including Shasta, Oroville, and New Bullards Bar—experienced record inflows during the January 1997 flood event. American River inflow to Folsom Reservoir was similar to the amount recorded during the February 1986 flood. Levees of the federal Sacramento River Flood Control Project (see sidebar) sustained moderate to heavy damage, including two major levee breaks (one near the town of Arboga) and several relief cuts. Flooding in the Marysville-Yuba City area resulted in 35,000 people being evacuated from the Marysville area and 75,000 people being evacuated downstream in Sutter County.

The volume of runoff exceeded the flood control capability of New Don Pedro Reservoir on the Tuolumne River and Millerton Lake on the Upper San Joaquin River. While the peak flood release from New Don Pedro Dam was less than half the peak Tuolumne River inflow of 120,000 cfs, it was more than six times the downstream channel's flow restrictions of 9,000 cfs. In all, 36 levee failures occurred along the San Joaquin River system, along with extensive damage related to high flows and inundation. Most of the damage occurred downstream of the Tuolumne River confluence.

The January 1997 floods demonstrated the need for increased Central Valley flood protection. The 1997 *Final Report of the Governor's Flood Emergency Action Team* identified many actions that could be taken to increase valley flood protection, including better emergency preparedness, floodplain management actions, levee system improvements, construction of new floodways, temporary storage of floodwaters on wildlife refuges, reoperation or enlargement of existing reservoirs to increase flood storage, and construction of new reservoirs.

The Sacramento River Flood Control Project's ability to provide protection for growing urban areas is the primary flood control issue facing the Sacramento Valley. Additional flood protection is needed in the Yuba River Basin, particularly in the greater Marysville-Yuba City area. Additional flood protection is also needed in the American River Basin for the Sacramento metropolitan area, as discussed in the accompanying sidebar. The 1997 FEAT report detailed several recommendations and possible actions for the Sacramento

The Sacramento metropolitan area has one of the lowest flood protection levels in the nation, for a community of its size. Without interim reoperation of Folsom Dam, the community is estimated to have only a 1-in-60 year level of protection. (With reoperation, the level of protection is 1-in-77 years). This photo shows the American River in January 1997, and the high-density urban development adjacent to the levee.

Valley, including new flood storage, enlarged flood bypasses, and increasing channel capacity through measures such as dredging and setback levees.

The primary flood control issue facing the San Joaquin River watershed is the lack of flood channel capacity. Channels and levees are generally designed for 50-year flood protection. Insufficient channel capacity is especially problematic in the lower San Joaquin River below the Merced River. At the lower end of the system, sediment deposition continues to raise the river bed and reduce channel capacity. Sediment deposition also promotes vegetation growth, thereby increasing channel roughness and further impeding flows. As urban development occurs on lands formerly used for agriculture, the need for higher levels of flood protection becomes more important. The 1997 FEAT report

American River Flood Protection

Following the floods of February 1986, the United States Army Corps of Engineers reanalyzed American River Basin hydrology and concluded that Folsom Dam did not provide an adequate level of flood protection to the downstream Sacramento area, significantly less than the 250-year protection estimated in the late 1940s when the dam was designed. The 977 taf reservoir has a normal winter flood control reservation of 400 taf (estimated to provide the Sacramento area with protection from a storm having a 1-in-60-year return period).

Three main flood protection alternatives have been evaluated by USACE. Two of the alternatives would increase flood control storage in Folsom, modify the dam's spillway and outlet works, and improve downstream levees. The third alternative would construct a detention dam at Auburn, with downstream levee improvements. USACE studies identified the detention dam as the plan that maximized national economic benefits. The State Reclamation Board endorsed the detention dam as the best long-term solution to reliably provide greater than 1-in-200 year flood protection.

The Central Valley's January 1997 flood disaster prompted another examination of American River hydrology. Based on that hydrologic review, the 1986 and 1997 floods are now considered to be about 60-year events. The 1997 flooding also triggered payback provisions of the Sacramento Area Flood Control Agency's agreement with USBR, under which USBR sets aside up to 270 taf of additional winter flood control space in Folsom. (This additional flood control space in the reservoir raises Sacramento's level of protection to about a 77-year event level.) Reoperation of Folsom for additional flood control resulted in a loss of supply to USBR. SAFCA and the federal government purchased 100 taf to offset the loss of supply—50 taf from Yuba County Water Agency, 35 taf from Placer County Water Agency, and 15 taf from GCID.

In 1998, the Reclamation Board restated its conclusion that the best long-term engineering solution to reliably provide greater than 1-in-200 year flood protection is to develop additional flood detention storage at Auburn. As an incremental measure to increase the level of flood protection, the Board also resolved to support SAFCA's plan for modifying Folsom Dam's outlets to increase flood protection to approximately a 1-in-110 year level. As of June 1998, SAFCA was seeking congressional authorization for USACE participation in Folsom Dam modifications and downstream levee enlargements.

The January 1997 flood disaster was the largest in the State's history. Flooding forced more than 120,000 people from their homes, and over 55,000 people were housed in temporary shelters. Nearly 300 square miles of agricultural land were flooded. Livestock and wildlife were trapped by the flooding.

detailed several recommendations and possible actions for the San Joaquin River watershed, including new flood storage, development restrictions and land acquisitions in the floodplain, and increasing channel capacity through measures such as dredging, setback levees, and improving bridge crossings.

CVPIA Implementation

CVPIA made significant changes to the CVP's legislative authorization, amending the project's purposes to place fish and wildlife mitigation and restoration on a par with water supply, and to place fish and wildlife enhancement on a par with power generation. Key areas of CVPIA implementation are summarized below. USBR and U.S. Fish and Wildlife Service released a draft programmatic EIS on CVPIA implementation for public review in November 1997. The draft PEIS describes, among other things, estimated water supply impacts of federal implementation of the act, and illustrates the consequences of different alternatives for fish and wildlife supplemental water acquisition. A final EIS is scheduled to be released in 1999.

Renewal of CVP Water Service Contracts. CVPIA prohibited execution of new CVP water service contracts (with minor exceptions), except for fish and wildlife purposes, until all of the many environmental restoration actions specified in the statute had been completed. The act also provided that existing long-term water service contracts be renewed for 25-year terms, as opposed to their previous 40-year terms. Only interim renewals (not more than three years) are allowed until the PEIS required by the act is completed. Beginning in October 1997, most existing long term contracts are subject to a monetary hammer clause encouraging early renewal. Renewed contracts will in-

Sacramento River Flood Control Project

Congress authorized the Sacramento River Flood Control Project in 1917 after a series of major Sacramento Valley floods in the late 1800s and early 1900s. The project was built with local, State, and federal funding. The project includes levees, overflow weirs, bypass channels, and channel enlargements. Overflow weirs allow excess water in the main river channel to flow into bypasses in the Sutter Basin and Yolo Basin. The bypass system was designed to carry 600,000 cfs of water past Sacramento—110,000 cfs in the Sacramento River through downtown Sacramento and West Sacramento, and the remainder in the Yolo Bypass. The system has worked exceedingly well over the years.

The capacity of the SRFCP was increased upon completion of Shasta Dam in 1945 and Folsom Dam in 1956. The Feather and Yuba River systems did not share in the SRFCP's flood control benefits; however, supplemental protection was provided by the completion of Oroville Dam on the Feather River in 1968 and New Bullards Bar Dam on the Yuba River in 1970. These are large multipurpose reservoirs in which flood control functions share space with water supply functions.

corporate new provisions required by CVPIA, such as tiered water pricing. Since USBR has not completed the PEIS, all contract renewals to date have been interim renewals. USBR has had more than 60 interim contract renewals from the date of enactment through 1996, representing over 1 maf/yr of supply.

Fish and Wildlife Restoration Actions. One of the most controversial elements of CVPIA implementation has been management of the 800 taf of CVP yield (see sidebar) dedicated by the act to fishery restoration purposes. This water is available for use on CVP controlled streams (river reaches downstream from the project's major storage facilities on the Sacramento River, American River, and Stanislaus River) and in the Bay-Delta.

The ambiguity of the statutory language and the use of dedicated water in the Bay-Delta Accord have generated many questions, including whether the water may be exported from the Delta after the water has been used for instream flow needs in upstream rivers, and if the water may be used for Bay-Delta purposes beyond Accord requirements. Initially, USBR and USFWS attempted to develop guidelines or criteria for its management. Subsequent to CALFED's creation, the CALFED Operations Group became a forum for attempting to resolve dedicated water. In November 1997, DOI released its final administrative proposal on management of the dedicated water. The proposal's release was subsequently challenged in legal action filed by some CVP water contractors.

A main purpose of the dedicated water is meeting the act's goal of doubling natural production of Central Valley anadromous fish populations (from their average 1967-91 levels) by year 2002. Release of water to the San Joaquin River from Friant Dam is excluded from this program. CVPIA authorizes USBR and USFWS to acquire additional, supplemental water from willing sellers to help achieve the doubling goal. CVPIA further allocates additional CVP water supply for instream use in the Trinity River by reducing the quantity of water which the project could otherwise divert, requiring that an instream flow of 340 taf/yr be maintained through water year 1996 while USFWS finishes a long-term instream flow study. (USFWS now recommends instream flows much greater than 340 taf/yr.)

CVPIA enumerates specific physical restoration measures that the federal government must complete for fishery and waterfowl habitat restoration. The largest completed measures are a temperature control device at Shasta Dam, at a cost of over $83 million, and a research pumping plant at Red Bluff Diversion Dam. CVPIA allocated part of the costs of some restoration measures to the State; the remaining costs are being paid by federal taxpayers and by CVP water and power contractors. Some of the smaller restoration actions include individual fish-screening projects that USBR and USFWS are cost-sharing with local agencies under the anadromous fish screening program.

CVPIA required USBR to impose a surcharge on CVP water and power contracts for deposit into a Restoration Fund created by the act. Monies deposited into the fund are appropriated by Congress to help fund CVPIA environmental restoration actions. The act authorizes appropriation of up to $50 million (1992 dollars) per year for the restoration actions. Annual deposits into the fund vary with water and power sales. CVPIA environmental restoration actions can be funded from the general federal treasury, as well as from the Restoration Fund.

Land Retirement Program. CVPIA authorized DOI to carry out an agricultural land retirement program for lands receiving CVP water. USBR published interim guidelines for administration of a pilot program, pending formal promulgation of rules and regulations. The federal guidelines were developed in

CVPIA's Dedicated Water

Section 3406(b)(2) describes the dedicated water as follows:

Upon enactment of this title dedicate and manage annually 800,000 acre-feet of Central Valley Project yield for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes and measures authorized by this title; to assist the State of California in its efforts to protect the waters of the San Francisco Bay-San Joaquin Delta Estuary; and to help meet such obligations as may be legally imposed upon the Central Valley Project under State or Federal law following the date of enactment of this title, including but not limited to additional obligations under the federal Endangered Species Act. For the purpose of this section, the term "Central Valley Project yield" means the delivery capability of the Central Valley Project during the 1928-1934 drought period after fishery, water quality, and other flow and operational requirements imposed by terms and conditions existing in licenses, permits, and other agreements pertaining to the Central Valley Project under applicable State or Federal law existing at the time of enactment of this title have been met.

coordination with a State land retirement program established in 1992 under Water Code Section 14902 *et seq*. The State statute limited the retirement program to drainage-impaired lands. The State land retirement program has never been funded, and thus no State acquisitions have been made. By November 1997, the federal land retirement program had made one purchase—about 600 acres of drainage-impaired land in Westlands Water District that would be managed for wildlife habitat. Recently, USBR solicited proposals from landowners wishing to participate in the retirement program and received offers to sell lands amounting to 31,000 acres.

Other Programs and Reports. From a water supply standpoint, certain CVPIA-mandated reports are of special interest. USFWS has prepared several draft documents relating to estimated Central Valley environmental water needs and water management actions for the AFRP. The most recent draft of the AFRP was published in May 1997. In 1995, USBR released an appraisal-level least-cost CVP yield increase plan, required by the act to identify options for replacing the water supply dedicated to environmental purposes. Although the act directed that the plan be prepared, USBR was not required to implement it.

SWP Monterey Agreement Contract Amendments

The Monterey Agreement among the Department and SWP water contractors was signed in December 1994. This agreement set forth principles for making changes in SWP water supply contracts, which would then be implemented by an amendment (Monterey Amendment) to each contractor's SWP contract. The amendment has been offered to all SWP contractors. Those contractors that sign the amendment will receive the benefits of it, while those that do not will have their water supply contracts administered such that they will be unaffected by the amendment. As of July 1998, 26 of the 29 contractors had signed the amendment.

Changes to SWP Water Allocation Rules. The amendment states that during drought years project supplies are to be allocated proportionately on the basis of contractors' entitlements. The amendment allocates water to urban and agricultural purposes on an equal basis, deleting a previous initial supply reduction to agricultural contractors.

Permanent Sales of Entitlement. The amendment provides for transfer of up to 175 taf of entitlement from agricultural use. The first transfer made was relinquishment of 45 taf of entitlement (40,670 af from Kern County Water Agency, 4,330 af from Dudley Ridge Water District) back to the SWP, as part of the transfer of the Kern Water Bank property to these agencies. This relinquishment reduces the total SWP contractual commitment. The amendment provides for an additional 130 taf of existing agricultural entitlement to be sold on a permanent basis to urban contractors, on a willing buyer-willing seller basis.

Storing Water Outside a Contractor's Service Area; Transfers of Non-Project Water. This provision allows a contractor to store water in another agency's reservoir or groundwater basin. Examples include water storage programs with Semitropic Water Storage District, a member agency of Kern County Water Agency. The amendment also provides a mechanism for using SWP facilities to transport non-project water for SWP water contractors. (The Department uses other contractual arrangements for wheeling water for the CVP and for other non-SWP water users.)

Annual Turnback Pool. Prior to the amendment, water allocated to contractors that was not used during a year would revert to the SWP at the end of the year. No compensation was provided to the contractor for this water, and no other contractors could make use of these supplies during the year. The turnback pool is an internal SWP mechanism which provides for pooling potentially unused supplies early in the year for purchase by other SWP contractors at a set price. If neither the SWP nor individual SWP contractors wish to use water placed into the pool, that water may then be sold to entities that are not SWP contractors.

Other Operational Changes. The amendment established a procedure to transfer ownership of the Department's KWB property to KCWA and Dudley Ridge Water District. The amendment allows contractors repaying costs of constructing the Castaic and Perris terminal reservoirs to increase their control and management of a portion of the storage capacity of each reservoir, to optimize the operation of local and SWP facilities. This is expected, for example, to improve dry year supplies for MWDSC, Castaic Lake Water Agency, and Ventura County Flood Control and Water Conservation District.

Environmental Restoration Activities

Several major environmental restoration activities are ongoing throughout the State, in addition to the intensive effort focused on the Bay-Delta. Projects focused on fishery and habitat restoration on the State's three most important river systems—the Sacramento, San Joaquin, and Colorado Rivers—are described below, followed by a brief mention of restoration and mitigation projects in other watersheds.

Sacramento River System. The extensive structural environmental restoration actions being performed in the Sacramento River system were described earlier in this chapter. These actions include major projects such as USBR's Shasta Dam Temperature Control Device and research pumping plant at Red Bluff Diversion Dam, as well as fish screen installations at many of the larger irrigation diversions on the Sacramento River mainstem. Many more restoration actions are being planned, such as additional fish passage improvements on Butte and Clear Creeks and at Anderson-Cottonwood Irrigation District's diversion dam. Many of the actions on the river's mainstem were in response to the need to protect listed winter-run chinook salmon. Actions are also being taken to protect spring-run chinook salmon, a species proposed for listing under the federal ESA and a State candidate species.

In 1995, State legislation restricted future water development on Mill and Deer Creeks to protect spring run chinook salmon habitat. In addition, local landowners formed the Mill and Deer Creek Watershed Conservancies. The conservancies have begun a watershed planning and management process, with funding assistance from an EPA grant. The Department has participated with Mill Creek landowners in a test project to construct wells to provide groundwater supplies in lieu of creek diversions for irrigation during spring fish migration periods. A similar project is being negotiated with Deer Creek water users.

San Joaquin River System. One of the first overviews of San Joaquin River restoration needs was provided by the Resources Agency's 1995 San Joaquin River Management Program Plan, which evaluated potential actions on part of the river's mainstem and on the lower reaches of its main tributaries. Structural restoration work performed to date has focused largely on spawning gravel placement and related habitat improvements. Several other projects are now in planning, including replacement of Central California Irrigation District's Mendota Dam and a potential new fish hatchery on the Tuolumne River. Increased instream flows have been provided in the river system through SWRCB Order WR 95-6 requirements and through a FERC settlement agreement for the Tuolumne River.

The San Joaquin River Conservancy, a State agency charged with acquiring and managing public lands within the San Joaquin River Parkway, is working to expand lands preserved by the parkway. The parkway includes the San Joaquin River and about 5,900 acres of land on both sides of the river, extending about 22 miles from Friant Dam downstream to the Highway 99 crossing of the river. The parkway is planned as a riparian corridor with public access trails, boating access points, wildlife areas, and education areas. Approximately 1,900 acres are located in Madera County and 4,000 acres in Fresno County, of which approximately 1,600 acres are now in public ownership.

In February 1998, two large cylindrical fish screens were installed at one of the largest Delta diversions located on Sherman Island.

Lower Colorado River System. In 1995, DOI executed partnership agreements with California, Nevada, and Arizona to develop a multi-species conservation program for ESA-listed species and many non-listed, but sensitive, species within the 100-year floodplain of the lower Colorado River, from Glen Canyon Dam downstream to the Mexican border. In 1996, a joint participation agreement was executed to provide funding for the program. USFWS has designated the Lower Colorado River Multi-Species Conservation Program steering committee as an ecosystem conservation and recovery implementation team pursuant to ESA. The steering committee is composed of representatives from the three states, DOI, Indian tribes, water agencies, power agencies, environmental organizations, and others.

The conservation program will work toward recovery of listed and sensitive species while providing for current and future use of Colorado River water and power resources, and includes USBR's Colorado River operations and maintenance actions for the lower river. Over 100 species will be considered in the program, including the southwestern willow flycatcher, Yuma clapper rail, and four fish species listed under the federal ESA: Colorado squawfish, razorback sucker, humpback chub, and bonytail chub. Developing the program is estimated to take three years. Costs of program development and implementation of selected interim conservation measures, estimated at $4.5 million, are to be split equally between DOI and the non-federal partners.

USBR initiated a formal Section 7 consultation process with USFWS, who issued a five-year biological opinion on USBR operation and maintenance activities from Lake Mead to the southerly international boundary with Mexico in 1997. USBR has estimated that the cost of implementing the biological opinion's reasonable and prudent alternatives and measures could be as high as $26 million.

The steering committee is currently participating in funding several interim conservation measures. These include a razorback sucker recovery program at Lake Mojave, restoration of Deer Island near Parker, Arizona, and a "Bring Back the Natives" program sponsored by the National Fish and Wildlife Foundation.

Other Watersheds. Major environmental restoration activities are ongoing in other watersheds throughout the State, including the Russian and Kings Rivers and Lake Tahoe.

A Russian River Action Plan, prepared by Sonoma County Water Agency in 1997, provides a regional assessment of needs in the Russian River watershed and identifies fishery habitat restoration projects in need of funding. The SWRCB is promoting a coordinated Russian River fishery restoration plan.

Kings River Conservation District and the Kings River Water Association are cooperating with USACE in a feasibility study of Kings River fishery habitat improvements. One component of the study includes a new multi-level intake structure for the reservoir, to better manage downstream river temperatures. USACE is also implementing a related project to install a bypass pipe at the dam's powerplant so that releases can be made through the existing penstocks when the turbines are not in operation. This project will provide temperature control for the downstream trout fishery.

The Tahoe Regional Planning Agency, a bi-state agency created by Congress, has identified nearly $500 million in capital improvements needed to achieve environmental targets in the Lake Tahoe watershed. Federal, state, and local governments have invested nearly $90 million in erosion control, storm water drainage, stream zone restoration, public transit, and other capital projects. The U.S. Forest Service has implemented a watershed restoration program and a land acquisition program to prevent development of sensitive private lands. The State of Nevada approved a $20 million bond measure to perform erosion control and other measures on the east side of the lake. In California, Proposition 204 provides $10 million in bond funds for land acquisition and programs to control soil erosion, restore watersheds, and preserve environmentally sensitive lands.

Mitigation Projects. Significant habitat improvements are also resulting from land management or mitigation projects being carried out by water agencies. For example, the Department purchased much of Sherman and Twitchell Islands in the Delta, and is implementing management plans on them to control subsidence and soil erosion, while providing significant wetland and riparian habitat for wildlife. The plans also provide recreational opportunities such as walking trails and wildlife viewing.

CCWD established over 18,000 acres of preserve as part of its Los Vaqueros construction project. This land is being managed to protect listed species such as the San Joaquin kit fox. The project impacted 174 acres of valley oaks and 9 acres of alkali wetlands. To mitigate, CCWD is creating or enhancing 394 acres of woodland habitat and 49 acres of wetlands.

Kern Water Bank Authority set aside about 10,000 acres for habitat purposes as part of its 20,000-acre Kern Fan Element project. ESA listed species found in the project area include the kit fox, kangaroo rat, and blunt-nosed leopard lizard.

As part of its Eastside Reservoir project, MWDSC purchased 3,700 acres for the Nature Conservancy's Santa Rosa Plateau Ecological Reserve. MWDSC also purchased 9,000 acres for the Southwestern Riverside County Multi-Species Reserve, including lands around the reservoir, Lake Skinner, and the 2,500-acre Dr. Roy E. Shipley Reserve.

Behind Prado Dam in Riverside County, Orange County Water District operates 465 acres of constructed freshwater wetlands to reduce the nitrogen levels in the Santa Ana River. The river provides much of the county's coastal plain groundwater recharge. The Prado wetlands are home to several rare and endangered bird and waterfowl species. More than 226 acres are set aside as habitat for the endangered least Bell's vireo and southwestern willow flycatcher.

Implementation of Urban Water Conservation MOU

The 1991 *Memorandum of Understanding Regarding Urban Water Conservation in California* defined a set of urban best management practices and procedures for their implementation, and established a California Urban Water Conservation Council composed of MOU signatories (local water agencies, environmental groups, and other interested parties). More than 200 entities have signed the MOU. The CUWCC has monitored implementation of BMPs and reported progress annually to the SWRCB. The Council developed a plan providing for ongoing review of BMPs and potential BMPs. In late 1996, the Council initiated a review of the BMPs to clarify expectations for implementation and to develop an implementation evaluation methodology. Revised BMPs were adopted in 1997.

Implementation of Agricultural Efficient Water Management Practices MOU

The Agricultural Efficient Water Management Practices Act of 1990 (AB 3616) required the Department to establish an advisory committee to develop EWMPs for agricultural water use. Negotiations among agricultural water users, environmental interests, and governmental agencies on a memorandum of understanding to implement EWMPs were completed in 1996. The MOU established an Agricultural Water Management Council to oversee EWMP implementation, much like the organizational structure that exists for urban BMPs, and also provided a mechanism for its signatories to evaluate and endorse water management plans. By May 1998, the MOU had been signed by 31 agricultural water suppliers irrigating about 3 million acres of land, as well as by over 60 other entities.

Klamath River Fishery Issues

The primary water management issue in the interstate Klamath River basin is the restoration of fish populations that include listed species such as the Lost River and shortnose suckers, coho salmon, and steelhead trout. The Lost River sucker is native to Upper Klamath Lake and its tributaries, and the shortnose sucker is found in the Lost River, Clear Lake, Tule Lake, and Upper Klamath Lake. Both species spawn during the spring. Higher water levels in Upper Klamath Lake have been identified as an aid to recovery of these fisheries. Coho and steelhead were recently listed, and water supply implications will not be known until management plans are completed and recovery goals are established.

To address the need for greater certainty in project operations, USBR began preparing a long-term Klamath Project Operations Plan in 1995. Several issues have delayed completion of the long-term plan. USBR has issued an annual operations plan each year since 1995. The Klamath River Compact Commission is facilitating discussions on water management alternatives to address water supply needs. This three-member commission was established by an interstate compact ratified by Congress in 1957 to facilitate integrated management of interstate water resources. The KRCC, USBR, and both states are cooperatively developing water supply options. Members include a representative from the Department, the Director of the Oregon Water Resources Department, and a presidentially-appointed federal representative.

Truckee-Carson River System

The Truckee-Carson-Pyramid Lake Water Rights Settlement Act (Title II of Public Law No. 101-618) settled several water rights disputes affecting the waters of Lake Tahoe, the Truckee River, and the Carson River. Of most importance to California, the act made an interstate apportionment of these waters between the States of California and Nevada. (It was the first congressional apportionment since the Boulder Canyon Project Act of 1928.) The act addresses several other issues, including settlement of water supply disputes between the Pyramid Lake Paiute Tribe of Indians and other users of the Truckee and Carson Rivers. The act also addresses environmental concerns, such as recovery of listed fish species in Pyramid Lake.

Many of the act's provisions—including the interstate apportionment between California and Nevada—will not take effect until several conditions have been satisfied, including dismissal of specified lawsuits and negotiation and adoption of a Truckee River Operating Agreement. The act requires that a TROA be negotiated among DOI and California and Nevada, after consultation with other parties as may be designated by DOI or by the two states. The TROA addresses interstate water allocation and implements an agreement between Sierra Pacific Power Company and the United States which provides for storing water in upstream reservoirs for Pyramid Lake fish and emergency drought water supplies for the Reno-Sparks area. TROA negotiation has been ongoing since 1991. A draft TROA is analyzed in an EIS/EIR prepared by DOI. (The Department is the State lead agency for compliance with the requirements of CEQA.) The draft EIS/EIR was released for public review in 1998 and is expected to be completed in 1999.

City of Los Angeles' Water Supply from Owens Valley

In 1913, the City of Los Angeles began diverting water from Owens Valley through the Los Angeles Aqueduct. A second aqueduct, completed in 1970, increased the Los Angeles Department of Water and Power's capacity to divert both surface and groundwater from the Owens Valley. LADWP's water diversions have resulted in degradation of the valley's environmental resources. Recent issues have revolved around rewatering the lower Owens River and dust control on the Owens Lakebed.

Rewatering Lower Owens River. In 1972, Inyo County initially filed suit against the city, claiming that increased groundwater pumping from the second aqueduct was harming the Owens Valley environment. An EIR was subsequently prepared jointly by LADWP and the county, and in 1991 both parties executed a long-term water management agreement delineating how groundwater pumping and surface water diversions would be managed to avoid significant decreases in vegetation, water-dependent recreational uses, and wildlife habitat. Several agencies, organizations, and individuals challenged the adequacy of the EIR and were granted *amici curiae* status by the Court of Appeals, allowing them to enter in the EIR review process. Another agreement was subsequently executed in 1997, ending 25 years of litigation between Los Angeles and Inyo County.

The lower Owens River project, a major provision of the agreement, was developed to rewater approximately 60 miles of the Owens River channel from the LAA diversion downstream to Owens Lake. The project is also identified in the EIR as compensatory mitigation for impacts that occurred between 1970 and 1990 that were considered difficult to quantify or mitigate directly. Four significant physical features of the LORP and agreement are: provision of year-round flows in the lower Owens River (with a pumpback station just above the Owens River delta to return some of the water to the LAA), provision of flows past the pumpback station to create new wetlands in the Owens Lake delta, enhancement of off-river lakes and ponds, and development of a new 1,500-acre waterfowl habitat area.

The majority of planning work is expected to be completed by December 1998. Los Angeles will pay the costs of implementing the project, with the county repaying one half of the costs up to a maximum of $3.75 million. To date, the federal government has committed $300,000 for the design of the pumpback system. Congress has approved another $250,000 for planning and development work. LADWP and the county will jointly prepare an EIR on the LORP, with a draft expected by June 2000. Rewatering of the river channel will begin within 6 years after the pumpback system is completed.

Dust Control on Owens Lakebed. Owens Lake became a dry lakebed by 1929. On windy days, airborne particulates from the dry lakebed violate air quality standards in the southern Owens Valley. In 1997, the Great Basin Unified Air Pollution Control District ordered the City of Los Angeles to implement control measures at Owens Lake to mitigate the dust problems. Under the order, 8,400 acres of lakebed would be permanently flooded with a few inches of water, another 8,700 acres would be planted with grass and irrigated, and 5,300 acres would be covered with a 4 inch layer of gravel. This order, which was appealed by the city, could reduce the city's potential diversion by 50 taf/yr or about 15 percent of its supply.

In July 1998, a compromise was reached when

LADWP agreed to begin work at Owens Lake by 2001 and to ensure that federal clean air standards would be met by 2006. In turn, the APCD agreed to scale back the improvements sought in its 1997 order. Under this compromise, LADWP's dust-control strategy may include shallow flooding, vegetation planting, and gravel placement. The implementation schedule requires that 6,400 acres of lakebed be treated by the end of 2001. By the end of 2006, an additional 8,000 acres would be treated, plus any additional lakebed necessary to bring particulate counts into compliance with federal air quality standards. The plan hinges on final approval from the Los Angeles City Council, the APCD's board, and the State Air Resources Board.

Mono Basin

Mono Lake and its tributaries have been the subject of extensive litigation between the City of Los Angeles and environmental groups since the late 1970s. In 1983, the California Supreme Court ruled that SWRCB has authority to reexamine past water allocation decisions and the responsibility to protect public trust resources where feasible. SWRCB issued a final decision on Mono Lake (Decision 1631) in 1994. Amendments to LADWP's water right licenses are set forth in the order accompanying the decision.

The order sets instream flow requirements for fish in each of the four streams from which LADWP diverts water. The order also establishes water diversion criteria to protect wildlife and other environmental resources in the Mono Basin. These water diversion criteria prohibit export of water from Mono Basin until the lake level reaches 6,377 feet, and restrict Mono Basin water exports to allow the lake level to rise to an elevation of 6,391 feet in about 20 years. Once the water level of 6,391 feet is reached, it is expected that LADWP will be able to export about 31 taf of water per year from the basin. The order requires LADWP to prepare restoration plans for the four streams from which it diverts and to restore part of the waterfowl habitat which was lost due to lake level decline. In May 1997, parties to the restoration planning process presented a signed settlement on Mono Basin restoration to the SWRCB. If approved, the settlement would guide restoration activities and annual monitoring through 2014.

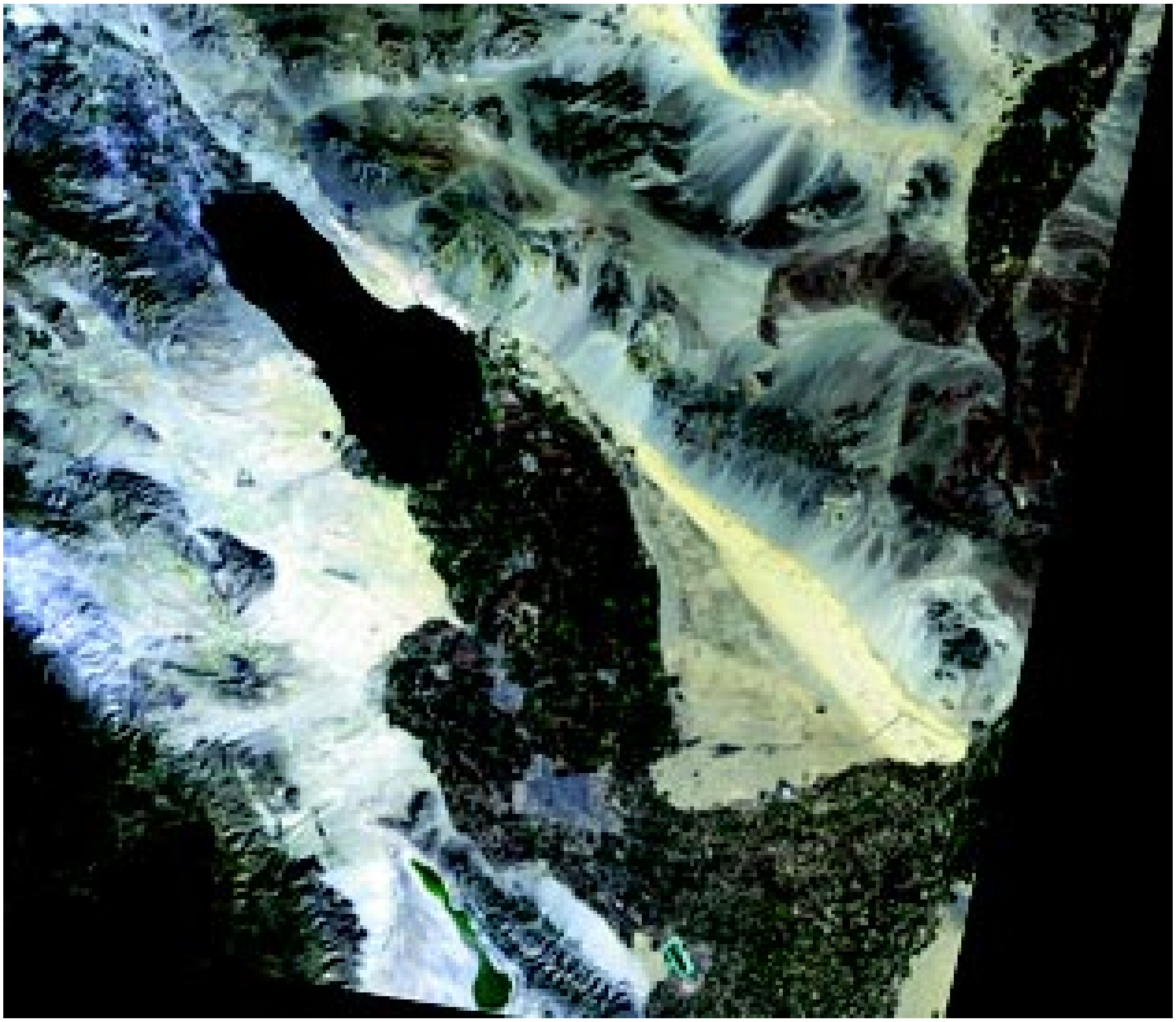
Key features of the stream restoration plans include restoring peak flows to Rush, Lee Vining, Walker, and Parker Creeks; reopening abandoned channels in Rush Creek; and developing a monitoring plan. One of the restoration actions required by SWRCB—bypassing sediment around LADWP diversion dams—was deferred for further analysis. The waterfowl habitat restoration plan proposes that a Mono Basin waterfowl habitat restoration foundation administer a $3.6 million trust established by LADWP. Five of the parties to the agreement would serve as initial members of the foundation. Activities would include annual monitoring, restoring open water habitat adjacent to the lake, and rewatering Mill Creek. LADWP would continue its brine shrimp productivity studies, open several channels on Rush Creek, and make its Mill Creek water rights available for rewatering Mill Creek, based on the recommendations of the foundation. The plans are being considered by SWRCB and a decision is expected at the end of 1998.

Salton Sea

The present day Salton Sea was formed in 1905, when Colorado River water flowed through a break in a canal that had been constructed along the U.S./Mexican border to divert the river's flow to agricultural lands in the Imperial Valley. Over the long term, the sea's elevation has gradually increased, going from a low on the order of -250 feet in the 1920s to its present level of about -226 feet. The Salton Sea is the largest lake located entirely within California, with a volume of about 7.5 maf at its present elevation of -226 feet. The sea occupies a closed drainage basin—if there were no inflows to maintain lake levels, its waters would evaporate. The sea receives over 1 maf annually of inflow, primarily from agricultural drainage. The largest sources of inflow (about 80 percent of the total) are the New and Alamo Rivers, which drain agricultural lands in the Mexicali and Imperial Valleys and flow into the sea's southern end.

The sea supports water-based recreational activities and has had a popular corvina fishery. During the 1950s, the highest per capita sport fishing catches in California were from the Salton Sea. Over the years, concerns about the sea's salinity have been voiced in the context of maintaining the recreational fishery that was established with introduced species able to tolerate high salinities.

The sea also provides important wintering habitat for many species of migratory waterfowl and shorebirds, including some species whose diets are based exclusively on the fish in the sea. Wetlands near the sea and adjoining cultivated agricultural lands offer the avian population a mix of habitat types and food sourc-



A natural-color infrared satellite image of the Salton Sea (January 1998 Landsat 5). The irrigated areas in Imperial Valley are clearly visible to the south of the sea, as are the Algodones Dunes to the southeast. The City of Mexicali and irrigated acreage in the Mexicali Valley can also be seen.

es. An area at the sea's south end was established as a national wildlife refuge in 1930, although most of that area is now under water as a result of the sea's rising elevation. Some of the 380 bird species wintering in the area include pelicans, herons, egrets, cranes, cormorants, ibises, ducks, grebes, falcons, plovers, avocets, sandpipers, and gulls. The Salton Sea is considered to be a major stopover point for birds migrating on the Pacific flyway, and has one of the highest levels of bird diversity of refuges in the federal system.

Historically, salinity has been the water quality constituent of most concern at the sea. Present levels are about 44,000 mg/L TDS (seawater is about 35,000 mg/L TDS). This high level of salinity reflects long-term evaporation and concentration of salts found in its inflow. Selenium has been a more recent constituent of interest, due to its implications for aquatic species. Although selenium levels in the water column in the sea are less than the federal criterion of 5 *u*g/l, this concentration can be exceeded in seabed sediment and in influent agricultural drainage water. Agricultural drain flows also contribute significant nutrient loading to the sea, which supports large algal blooms at some times of the year.

Over the years, USBR and others have considered potential solutions to stabilize the sea's salinity and elevation. Most recently, the Salton Sea Authority (a joint powers authority consisting of Riverside and Imperial Counties, Imperial Irrigation District, and Coachella Valley Water District) and others have been performing appraisal level evaluations of some of the frequently suggested alternatives. Maintaining a viable Salton Sea has several water management implications. First will be the actions needed to stabilize the sea's salinity in the near-term, such as the authority's diking proposal. Eventually, a long-term solution will need to be developed. A wide range of costs has been mentioned for a long-term solution, including amounts in the billion-dollar range. Some of the possible long-term solutions suggested would entail constructing facilities in Mexico, bringing a greater level of complexity to their implementation.

Other water management programs in the region, such as proposals to transfer conserved agricultural water supplies, will have to be evaluated in terms of their impacts on the sea. Recent proposals to desalt water in the Alamo or New Rivers and to transport that water in the Colorado River Aqueduct to the South Coast for urban water supply have raised concerns about maintaining the sea's environmental productivity. Such proposals might be implemented as part of the second phase of CRB's draft 4.4 Plan.

Roadrunners are one of the bird species found year-round in the Salton Sea area.

Congressional legislation introduced in 1998 would authorize expenditure of federal funds for a multi-year study of the sea's resources and potential solutions for managing its salinity.

3

Executive Summary

Water Supplies

This chapter describes how water supplies are calculated and summarized within a water budget framework. A description of California's existing supplies–surface water, groundwater, recycled water, and desalted water–and how a portion of these supplies are reallocated through water marketing follows. This chapter concludes with a review of water quality considerations that influence how the State's water supplies are used.

Water Supply Calculation

Bulletin 160-98 calculates existing water supply and demand, then balances forecasted demand against existing supply and future water management options. The balance, or water budget, with existing supply is presented on a statewide basis in Chapter ES5 and on a regional basis in Appendix ES5A. The water budget with future water management options is also presented in Chapter ES5.

Definition of Bulletin 160 Water Supplies

The SWP's California Aqueduct is the only conveyance facility that moves water from the Central Valley to Southern California.

The Bulletin 160 water budgets do not account for the State's entire water supply and use. In fact, less than one-third of the State's precipitation is quantified in the water budgets. Precipitation provides California with nearly 200 maf of total water supply in average years. Of this renewable supply, about 65 percent is depleted through evaporation and transpiration by trees and other plants. This large volume of water is excluded from the Bulletin 160 water supply

Key Water Supply and Water Use Definitions

Chapters ES3 and ES4 introduce California's water supplies and urban, agricultural, and environmental water uses. Certain key concepts, defined below, provide an essential foundation for presenting and analyzing water supplies and water use.

Applied Water: The amount of water from any source needed to meet the demand of the user. It is the quantity of water delivered to any of the following locations:

- The intake to a city water system or factory.
- The farm headgate or other point of measurement.
- A managed wetland, either directly or by drainage flows.

For instream use, applied water is the quantity of stream flow dedicated to instream use (or reserved under federal or State wild and scenic rivers legislation) or to maintaining flow and water quality in the Bay-Delta pursuant to the SWRCB's Order WR 95-6.

Net Water: The amount of water needed in a water service area to meet all demands. It is the sum of evapotranspiration of applied water in an area, the irrecoverable losses from the distribution system, and agricultural return flow or treated urban wastewater leaving the area.

Irrecoverable Losses: The amount of water lost to a salt sink, lost by evapotranspiration, or lost by evaporation from a conveyance facility, drainage canal, or fringe areas.

Evapotranspiration: ET is the amount of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces.

Evapotranspiration of Applied Water: ETAW is the portion of the total ET which is provided by applied irrigation water.

Depletion: The amount of water consumed within a service area that is no longer available as a source of supply. For agricultural and certain environmental (i.e., wetlands) water use, depletion is the sum of irrecoverable losses and the ETAW due to crops, wetland vegetation, and flooded water surfaces. For urban water use, depletion is the ETAW due to landscaping and gardens, wastewater effluent that flows to a salt sink, and incidental ET losses. For environmental instream use, depletion is the amount of dedicated flow that proceeds to a salt sink.

and water use calculations. The remaining 35 percent stays in the State's hydrologic system as runoff. (Figure ES3-1.)

Over 30 percent of the State's runoff is not explicitly designated for urban, agricultural, or environmental uses. This water is depleted from the State's hydrologic system as outflow to the Pacific Ocean or other salt sinks. (Some of this non-designated runoff is captured by reservoirs, but is later released for flood control.) Similar to precipitation depletions by vegetation, non-designated runoff is excluded from the Bulletin 160 water supply and water use calculations.

The State's remaining runoff is available as renewable water supply for urban, agricultural, and environmental uses in the Bulletin 160 water budgets. In addition to this supply, Bulletin 160 water budgets include a few supplies that are not generated by intrastate precipitation. These supplies include imports from the Colorado and Klamath Rivers and new supplies generated by water recycling and desalting.

Applied Water Methodology

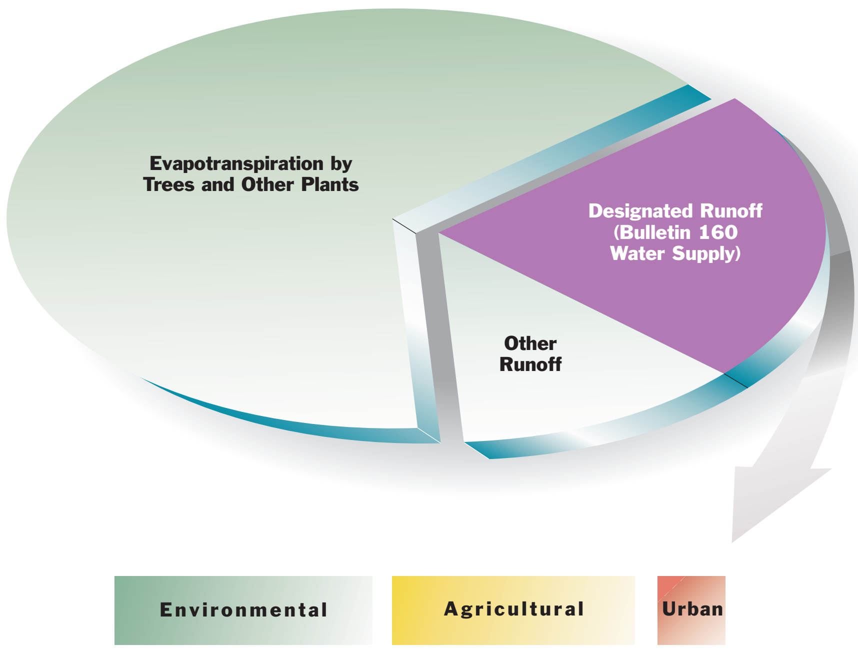
Bulletin 160-98 water supplies are computed using applied water data. As defined in the sidebar, applied water refers to the amount of water from any source employed to meet the demand of the user. Previous editions of Bulletin 160 computed water supplies using net water data. Bulletin 160-98 switched from a net water methodology to an applied water methodology in response to public comments on Bulletin 160-93. Because applied water data are analogous to agency water delivery data, water supply data based on an applied water methodology are easier for local water agencies to review. Net water supply values are smaller than applied water supply values because they exclude that portion of demand met by reapplication of surface and groundwater supplies.

Reapplication can be a significant source of water in many hydrologic regions of California. An applied water budget explicitly accounts for this source. However, because of reapplication, applied water budgets do not translate directly into the supply of water needed to meet future demands. The approach used to compute the new water required to meet future demands with applied water budgets is presented in Chapter ES5.

Normalized Data

Water budget data used to represent the base planning year do not necessarily match the historical conditions observed in 1995. Instead, Bulletin 160-98's base year applied water budget data are developed

FIGURE ES3-1.
Disposition of California's Average Annual Precipitation



from "normalized" water supply, land use, and water use data. Through the normalizing process, year-to-year fluctuations caused by weather and market abnormalities are removed from the data. For example, water year 1998 would greatly underestimate average annual water use, as rainfall through May and early June provided the necessary moisture needed to meet crop and landscape water demands. In most years, much of California would require applied water supplies during May and early June. The procedures used to normalize water supply and water use data are described in the sidebar on page ES3-4.

Water Supply Scenarios

California is subject to a wide range of hydrologic conditions and water supply variability. Knowledge of water supplies under a range of hydrologic conditions is necessary to evaluate reliability needs that water managers must meet. Two water supply scenarios—average year conditions and drought year conditions—were selected from among a spectrum of possible water supply conditions to represent variability in the regional and statewide water budgets.

The average year supply scenario represents the average annual supply of a system over a long planning horizon. Average year supplies from the CVP and SWP are defined by operations studies for a base (1995) level of development and for a future (2020) level of development. Project delivery capabilities are defined over a 73-year hydrologic sequence. For other water supply projects, historical data are normalized to represent average year conditions. For required environmental flows, average year supply is estimated for each of its components. Wild and scenic river flow is calculated from long-term average unimpaired flow data. Instream flow requirements are defined for an average year under specific agreements, water rights, court decisions, and congressional directives. Bay-Delta outflow requirements are estimated from operations studies.

For many local water agencies, and especially urban agencies, drought water year supply is the critical factor in planning for water supply reliability. Traditional drought planning often uses a design drought hydrology to characterize project operations under future conditions. For a planning region with the size and hydrologic complexity of California, selecting an appropriate statewide design drought presents a challenge. The 1990-91 water years were selected to represent the drought year supply scenario for Bulletin 160-98. (The 1990-91 water years were also used to represent the drought year scenario in Bulletin 160-93.)

Procedures for Normalizing Water Supply and Water Use Data

On the supply side, normalized water project delivery values are computed by averaging historical delivery data. Normalized "average year" project supplies are typically computed from 3 to 5 recent non-deficient water years. Normalized "drought year" project supplies are computed by averaging historical delivery data from 1990 and 1991. A notable exception to the above procedure is the development of normalized CVP and SWP project deliveries. Supplies from these projects are developed from operations studies rather than from historical data. Operations studies provide an average project delivery capability over a multi-year sequence of hydrology under SWRCB Order WR 95-6 Bay-Delta standards.

On the demand side, base year urban per capita water use data are normalized to account for factors such as residual effects of the 1987-92 drought. In any given year, urban landscape and agricultural irrigation requirements will vary with precipitation, temperature, and other factors. Base year water use data are normalized to represent ETAW requirements under average and drought year water supply conditions. Land use data are also normalized. The Department collects land use data through periodic surveys; however, the entire State is not surveyed in any given year (such as 1995). To arrive at an estimate of historical statewide land use for a specific year, additional sources of data are consulted to interpolate between surveys. After a statewide historical land use base is constructed, it is evaluated to determine if it was influenced by abnormal weather or crop market conditions and is normalized to remove such influences.

Normalizing allows Bulletin 160-98 to define an existing level of development (i.e., the 1995 base year) that is compatible with a forecasted level of development (i.e., the 2020 forecast year). Future year shortage calculations implicitly rely on a comparison between future water use and existing water supply, as water supplies do not change significantly (without implementation of new facilities and programs) over the planning horizon. Therefore, the normalizing procedure is necessary to provide an appropriate future year shortage calculation. Normalizing also permits more than one water supply condition to be evaluated for a given level of development. If historical data were used to define the base year, only one specific hydrologic condition would be represented. (Historical data for 1995 would represent a wet year.) But through normalizing, a base level of development can be evaluated under a range of hydrologic conditions.

The 1990-91 drought year scenario has a recurrence interval of about 20 years, or a 5 percent probability of occurring in any given year. This is typical of the drought level used by many local agencies for routine water supply planning. For extreme events such as the 1976-77 drought, many agencies would implement shortage contingency measures such as mandatory rationing. Another important consideration in selecting water years 1990-91 was that, because of their recent occurrence, local agency water demand and supply data were readily available.

The statewide occurrence of dry conditions during the 1990-91 water years was another key consideration in selecting them as a representative drought. Because of the size of California, droughts may or may not occur simultaneously throughout the entire state.

Sources of Water Supply

Table ES3-1 shows California's estimated water supply, for average and drought years under 1995 and 2020 levels of development, with existing facilities and programs. Facility operations in the Delta are assumed to be in accordance with Order WR 95-6. The State's 1995-level average year water supply is about 77.9 maf, including about 31.4 maf of dedicated flows for environmental uses. As previously discussed, this supply is based on an applied water methodology and therefore includes considerable amounts of reapplication within hydrologic regions.

Even with a reduction in Colorado River supplies to California's 4.4 maf basic apportionment, annual average statewide supply is projected to increase about 0.2 maf by 2020 without implementation of new water supply options. While the expected increase in average year water supplies is due mainly to higher CVP and SWP deliveries (in response to higher 2020-level demands), new water production will also result from groundwater and from recycling facilities currently under construction.

The State's 1995-level drought year water supply is about 59.6 maf, of which about 16.6 maf is dedicated for environmental uses. Annual drought year supply is expected to increase slightly by 2020 without implementation of new water supply options. The expected increase would come from higher CVP

TABLE ES3-1

California Water Supplies with Existing Facilities and Programs[a] (taf)

Supply	*1995*		*2020*	
	Average	*Drought*	*Average*	*Drought*
Surface				
CVP	7,004	4,821	7,347	4,889
SWP	3,126	2,060	3,439	2,394
Other Federal Projects	910	694	912	683
Colorado River	5,176	5,227	4,400	4,400
Local Projects	11,054	8,484	11,073	8,739
Required Environmental Flow	31,372	16,643	31,372	16,643
Reapplied	6,441	5,596	6,449	5,575
Groundwater[b]	12,493	15,784	12,678	16,010
Recycled and Desalted	324	333	415	416
Total (rounded)	**77,900**	**59,640**	**78,080**	**59,750**

[a] Bulletin 160-98 presents water supply data as applied water, rather than net water. This distinction is explained in a previous section. Past editions of Bulletin 160 presented water supply data in terms of net supplies.

[b] Excludes groundwater overdraft

and SWP deliveries and new production from surface water, groundwater, and recycling facilities currently under construction.

Surface Water Supplies

Surface water includes developed supplies from the CVP, SWP, Colorado River, other federal projects, and local projects. Figure ES3-2 shows the location of the State's major water projects. Surface water also includes the supplies for required environmental flows. Required environmental flows are comprised of undeveloped supplies designated for wild and scenic rivers, supplies used for instream flow requirements, and supplies used for Bay-Delta water quality and outflow requirements. Finally, surface water includes supplies available for reapplication downstream. Urban wastewater discharges and agricultural return flows, if beneficially used downstream, are examples of reapplied surface water.

Groundwater Supplies

In an average year, about 30 percent of California's urban and agricultural applied water is provided by groundwater extraction. In drought years when surface supplies are reduced, groundwater supports an even larger percentage of use. The amount of water stored in California's aquifers is far greater than that stored in the State's surface water reservoirs, although only a portion of California's groundwater resources can be economically and practically extracted for use.

Bulletin 160-98 excludes long-term basin extractions in excess of long-term basin inflows in its definition of groundwater supply. This long-term average annual difference between extractions and recharge, defined in the Bulletin as overdraft, is not a sustainable source of water and is thus excluded from the base year and forecast year groundwater supply estimates. (In response to public comments on the Bulletin 160-93, Bulletin 160-98 is the first water plan update to exclude overdraft from the base year groundwater supply estimate.)

In wet years, recharge into developed groundwater basins tends to exceed extractions. Conversely, in dry years, groundwater basin recharge tends to be less than groundwater basin extraction. By definition, overdraft is not a measure of these annual fluctuations in groundwater storage volume. Instead, overdraft is a measure of the long-term trend associated with these annual fluctuations. The period of record used to evaluate overdraft must be long enough to produce data that, when averaged, approximate the long-term average hydrologic conditions for the basin. Table ES3-2 shows the Department's estimates of 1995 and 2020-level groundwater overdraft by hydrologic region. Within some regions, overdraft occurs in some well-defined subareas, while additional groundwater development potential may exist in other subareas.

For the 1995 base year, Bulletin 160-98 estimates a statewide increase in groundwater overdraft (160 taf) above the 1990 base year reported in Bulletin 160-93. Most of the statewide increase in overdraft occurred in the San Joaquin and Tulare Lake Regions, two regions

FIGURE ES3-2.

California's Major Water Projects

TABLE ES3-2

1995 and 2020 Level Overdraft by Hydrologic Region (taf)

	1995		*2020*	
Region	*Average*	*Drought*	*Average*	*Drought*
North Coast	0	0	0	0
San Francisco Bay	0	0	0	0
Central Coast	214	214	102	102
South Coast	0	0	0	0
Sacramento River	33	33	85	85
San Joaquin River	239	239	63	63
Tulare Lake	820	820	670	670
North Lahontan	0	0	0	0
South Lahontan	89	89	89	89
Colorado River	69	69	61	61
Total (rounded)	**1,460**	**1,460**	**1,070**	**1,070**

where surface water supplies have been reduced in recent years by Delta export restrictions, CVPIA implementation, and ESA requirements. CVP contractors in these regions who rely on Delta exports for their surface water supply have experienced supply deficiencies of up to 50 percent subsequent to implementation of export limitations and CVPIA requirements. Many of these contractors have turned to groundwater pumping for additional water supplies. This long-term increase in groundwater extractions exacerbated a short-term decline in water levels as a result of the 1987-92 drought.

As shown in Table ES3-2, groundwater overdraft is expected to decline from 1.5 maf/yr to 1.1 maf/yr statewide by 2020. Overdraft in the Central Coast Region is expected to decline as demand shifts from groundwater to imported SWP supplies, provided through the recently completed Coastal Branch of the California Aqueduct. The reduction in irrigated acreage in drainage problem areas on the west side of the San Joaquin Valley, as described in the 1990 report of the San Joaquin Valley Interagency Drainage Program, is expected to reduce groundwater demands in the San Joaquin River and Tulare Lake regions by 2020. Some increases in groundwater overdraft are expected in Sacramento, Placer, and El Dorado Counties of the Sacramento River Region.

Water Marketing

In recent years, water marketing has received increasing attention as a tool for addressing statewide imbalances between water supply and water use. Experiences with water markets during and since the 1987-92 drought bolstered interest in using marketing as a local and statewide water supply augmentation option. While water marketing does allow water agencies to purchase additional water supply reliability during both average and drought years, water marketing does not create new water. Therefore, water markets alone cannot meet California's long-term water supply needs.

In this update of the *California Water Plan*, water marketing may include:

- A permanent sale of a water right by the water right holder.
- A lease from the water right holder (who retains the water right), allowing the lessee to use the water under specified conditions over a specified period of time.
- A sale or lease of a contractual right to water supply. Under this arrangement, the ability of the holder to transfer a contractual water right is usually contingent upon receiving approval from the supplier. An example of this type of arrangement is a sale or lease by a water agency that receives its supply from the CVP, SWP, or other water wholesaler.

Water marketing is not an actual statewide source of water, but rather is a means to reallocate existing supplies. Therefore, marketing is not explicitly itemized as a source of water supply from existing facilities and programs in the Bulletin 160 water budgets. (Water marketing agreements in place by 1995 are considered to be existing programs and are implicitly part of the water budgets.) Water marketing is identified as a potential water supply augmentation option in the Bulletin 160 water budgets. Potential water marketing options have several characteristics that must

TABLE ES3-3

Recently Completed Long-Term Water Marketing Agreements

Participants	*Region(s)*
Westside Water District, Colusa County Water District	Sacramento River
Semitropic Water Storage District, Santa Clara Valley Water District	Tulare Lake, San Francisco Bay
Semitropic Water Storage District, Alameda County Water District	Tulare Lake, San Francisco Bay
Semitropic Water Storage District, Zone 7 Water Agency	Tulare Lake, San Francisco Bay
Semitropic Water Storage District, Metropolitan Water District of Southern California	Tulare Lake, South Coast
Kern County Water Agency, Mojave Water Agency	Tulare Lake, South Lahontan
Arvin-Edison Water Storage District, Metropolitan Water District of Southern California	Tulare Lake, South Coast
Mojave Water Agency, Solano County Water Agency	South Lahontan, San Francisco Bay
Imperial Irrigation District, Metropolitan Water District of Southern California	Colorado River, South Coast

be captured in the water budgets incorporating supplies from future management options. For example, through changes in place of use, water marketing options can reallocate supplies from one hydrologic region to another. And through changes in type of use, water marketing options can reallocate supplies from one water use sector to another. Finally, for a given place and type of use, water marketing options can reallocate supplies among average years and drought years.

While several long-term agreements have been completed in recent years (see Table ES3-3), short-term agreements have made up the majority of water marketing. Short-term agreements, with terms less than one year, can be an effective means of alleviating the most severe drought year impacts. Short-term agreements can be executed on the spot market; however, water purveyors are increasingly interested in negotiating longer-term agreements for drought year transfers. In such future agreements, specific water supply conditions may be the triggers to determine whether water would be transferred in a specific year.

Two examples of programs for acquiring water through short-term agreements are the Drought Water Bank and the CVPIA interim water acquisition program. Beyond these programs, data on short-term water marketing arrangements are difficult to locate and verify. Agreements executed for less than one year do not need SWRCB approval (unless there is a change in place of use or point of diversion) and thus are not tracked by outside entities. Data are also difficult to evaluate, as it is often difficult to distinguish between exchanges and marketing arrangements.

Water Recycling and Desalting Supplies

Water recycling is the intentional treatment and management of wastewater to produce water suitable for reuse. Several factors affect the amount of wastewater treatment plant effluent that local agencies are able to recycle, including the size of the available market and the seasonality of demands. Local agencies must plan their facilities based on the amount of treatment plant effluent available and the range of expected service area demands. In areas where irrigation uses constitute the majority of recycled water demands, winter and summer demands may vary greatly. (Where recycled water is used for groundwater recharge, seasonal demands are more constant throughout the year.) Also, since water recycling projects are often planned to supply certain types of customers, the proximity of these customers to each other and to available pipeline distribution systems affects the economic viability of potential recycling projects.

Technology available today allows many municipal wastewater treatment systems to produce water supplies at competitive costs. More stringent treatment requirements for disposal of municipal and industrial wastewater have reduced the incremental cost for higher levels of treatment required for recycled water. The degree of additional treatment depends on the intended use. Recycled water is used for agricultural and landscape irrigation, groundwater recharge, and industrial and environmental uses. Some uses are required to meet more stringent standards for public health protection. An example is the City of San Diego's planned 18 mgd wastewater repurification facility. This water project would produce about 16 taf/yr of repurified water to augment local municipal supplies. If implemented, the project would be California's first planned indirect potable reuse project that discharges repurified water directly into a surface reservoir.

The use of recycled water can lessen the demand for new water supply. However, not all water recycling produces new water supply. Bulletin 160 counts water that would otherwise be lost to the State's hydrologic system (i.e., water discharged directly to the ocean or to another salt sink) as recycled water supply. If water recycling creates a new demand which would not otherwise exist, or if it treats water that would have otherwise been reapplied by downstream entities or recharged to usable groundwater, it is not considered new water supply. Water recycling provides multiple benefits such as reduced wastewater discharge and improved water quality.

The Department, in coordination with the WateReuse Association of California, conducted a 1995 survey to update the Association's 1993 survey of local agencies' current and planned water recycling. By 2020, total water recycling is expected to increase from 485 taf/yr to 577 taf/yr, due to greater production at existing treatment plants and new production at plants currently under construction. This base production is expected to increase new recycled supplies from 323 taf/yr to 407 taf/yr. All new recycled water is expected to be produced in the San Francisco Bay, Central Coast, and South Coast Regions. Table ES3-4 shows future potential options for water recycling.

TABLE ES3-4

2020 Level Total Water Recycling and New Water Supply (taf)

Projects	*Total Water Recycling*	*New Water Supply*
Base	577	407
Options	835	655
Total	1,412	1,062

By 2020, water recycling options could bring total water recycling potential to over 1.4 maf/yr, potentially generating as much as 1.1 maf/yr of new supply, if water agencies implemented all projects identified in the survey.

The capacity of California's existing desalting plants totals about 66 taf annually; feedwater sources are brackish groundwater, wastewater, and seawater. Total seawater desalting capacity is currently about 8 taf/yr statewide. Most existing plants are small (less than 1 taf/yr) and have been constructed in coastal communities with limited water supplies. The Santa Barbara desalting plant, with capacity of 7.5 taf/yr, is currently the only large seawater desalting plant. The plant was constructed during the 1987-92 drought and is now on long-term standby. In the 1995-level water budget, 8 taf of seawater desalting is included as a drought year supply. In the 2020-level water budget, 8 taf of seawater desalting is included as average and drought year supplies.

Water Supply Summary by Hydrologic Region

Table ES3-5 summarizes average year water supplies by hydrologic region assuming 1995 and 2020 levels of development and existing facilities and programs. Similarly, Table ES3-6 summarizes drought year water supplies by hydrologic region for existing and future levels of development. Regional water supplies, along with water demands presented in the following chapter, provide the basis for the statewide water budget developed in Chapter ES5 and regional water budgets developed in Appendices ES5A and ES5B.

Water Quality

A critical factor in determining the usability and reliability of any particular water source is water quality. The quality of a water source will significantly affect the beneficial uses of that water. Water has many potential uses, and the water quality requirements for each use vary. Sometimes, different water uses may have conflicting water quality requirements. For example, water temperatures ideal for irrigation of some crops may not be suitable for fish spawning.

The establishment and enforcement of water quality standards for water bodies in California fall under the authority of SWRCB and the nine regional water quality control boards. The RWQCBs protect water quality through adoption of region-specific water quality control plans, commonly known as basin plans. In general, water quality control plans designate beneficial uses of water and establish water quality objectives designed to protect them. The designated beneficial uses of water may vary between individual water bodies.

Water quality objectives are the limits or levels of water quality constituents or characteristics which are established to protect beneficial uses. Because a particular water body may have several beneficial uses, the water quality objectives established must be protective of all designated uses. When setting water quality objectives, several sources of existing water quality limits are used, depending on the uses designated in a water quality control plan. When more than one water quality limit exists for a water quality constituent or characteristic (e.g., human health limit vs. aquatic life limit), the more restrictive limit is used as

TABLE ES3-5

California Average Year Water Supplies by Hydrologic Region (with existing facilities and programs, in taf)

Region	1995				2020			
	Surface	*Groundwater*[a]	*Recycled & Desalted*	*Total (rounded)*	*Surface*	*Groundwater*[a]	*Recycled & Desalted*	*Total (rounded)*
North Coast	20,331	263	13	20,610	20,371	288	13	20,670
San Francisco Bay	7,011	68	35	7,110	7,067	72	37	7,180
Central Coast	318	1,045	18	1,380	368	1,041	42	1,450
South Coast	3,839	1,177	207	5,220	3,625	1,243	273	5,140
Sacramento River	11,881	2,672	0	14,550	12,196	2,636	0	14,830
San Joaquin River	8,562	2,195	0	10,760	8,458	2,295	0	10,750
Tulare Lake	7,888	4,340	0	12,230	7,791	4,386	0	12,180
North Lahontan	777	157	8	940	759	183	8	950
South Lahontan	322	239	27	590	437	248	27	710
Colorado River	4,154	337	15	4,510	3,920	285	15	4,220
Total (rounded)	**65,090**	**12,490**	**320**	**77,900**	**64,990**	**12,680**	**410**	**78,080**

[a] Excludes groundwater overdraft.

TABLE ES3-6

California Drought Year Water Supplies by Hydrologic Region (with existing facilities and programs, in taf)

Region	1995				2020			
	Surface	*Groundwater*[a]	*Recycled & Desalted*	*Total (rounded)*	*Surface*	*Groundwater*[a]	*Recycled & Desalted*	*Total (rounded)*
North Coast	10,183	294	14	10,490	10,212	321	14	10,550
San Francisco Bay	5,285	92	35	5,410	5,417	89	37	5,540
Central Coast	160	1,142	26	1,330	180	1,159	42	1,380
South Coast	3,196	1,371	207	4,780	3,130	1,462	273	4,870
Sacramento River	10,022	3,218	0	13,240	10,012	3,281	0	13,290
San Joaquin River	6,043	2,900	0	8,940	5,986	2,912	0	8,900
Tulare Lake	3,693	5,970	0	9,660	3,593	5,999	0	9,590
North Lahontan	557	187	8	750	557	208	8	770
South Lahontan	259	273	27	560	326	296	27	650
Colorado River	4,128	337	15	4,480	3,909	284	15	4,210
Total (rounded)	**43,530**	**15,780**	**330**	**59,640**	**43,320**	**16,010**	**420**	**59,750**

[a] Excludes groundwater overdraft.

the water quality objective.

Drinking water standards for a total of 81 individual drinking water constituents are in place under the mandates of the 1986 SDWA amendments. By the new SDWA standard setting process established in the 1996 amendments, EPA will select at least five new candidate constituents to be considered for regulation every five years. Selection of the new constituents for regulation must be geared toward contaminants posing the greatest health risks.

Occasionally, drinking water regulatory goals may conflict. For example, concern over pathogens such as *Cryptosporidium* spurred a proposed rule requiring more rigorous disinfection. At the same time, there was considerable regulatory concern over trihalomethanes and other disinfection by-products resulting from disinfecting drinking water with chlorine. However, if disinfection is made more rigorous, disinfection by-product formation is increased. Poor quality source waters with elevated concentrations of organic precursors and bromides further complicate the problem of reliably meeting standards for disinfection while meeting standards for disinfection by-products. The regulatory community will have to balance the benefits and risks associated with pursuing the goals of efficient disinfection and reduced disinfection by-products.

EPA promulgated its Information Collection Rule in 1996 to obtain the data on the tradeoff posed by simultaneous control of disinfection by-products and pathogens in drinking water. The ICR requires all large public water systems to collect and report data on the occurrence of disinfection by-products and pathogens (including bacteria, viruses, *Giardia*, and *Cryptosporidium*) in drinking water over an 18-month period. With this information, an assessment of health risks due to the presence of disinfection by-products and pathogens in drinking water can be made. EPA can then determine the need to revise current drinking water filtration and disinfection requirements, and the need for more stringent regulations for disinfectants and disinfection by-products.

There has been growing concern over the potential human health threat of pathogens in groundwater. This concern stems from pathogens such as *Giardia*, *Cryptosporidium*, bacteria, and viruses being found in water taken from wells. The concern about pathogens in groundwater has led to regulatory discussions on disinfection requirements for groundwater. It is currently estimated that the Groundwater Disinfection Rule will be proposed sometime in 1999 and will become effective in 2002. The data obtained through the ICR will provide the necessary information to assess the extent and severity of risk.

The SDWA requires states to implement wellhead protection programs designed to prevent the contamination of groundwater supplying public drinking water wells. Wellhead protection programs rely heavily on local efforts to be effective, because communities have the primary access to information on potential contamination sources and can adopt locally-based measures to manage these potential contamination sources.

CCWD's Los Vaqueros Dam under construction. The reservoir does not provide new water supply, but provides terminal storage for CCWD's existing supply and improves service area water quality.

4

Executive Summary

Urban, Agricultural, and Environmental Water Use

This chapter describes present and forecasted urban, agricultural, and environmental water use. The chapter is organized into three major sections, one for each category of water use.

Water use information is presented at the hydrologic region level of detail under normalized hydrologic conditions. Forecasted 2020-level urban and agricultural water use have not changed greatly since publication of Bulletin 160-93. Forecasted urban water use depends heavily on population forecasts. Although the Department of Finance has updated its California population projections since the last Bulletin, U.S. census data are an important foundation for the projections, and a new census will not be performed until 2000. The Department's forecasts of agricultural water use change relatively slowly in the short-term, because the corresponding changes in forecasted agricultural acreage are a small percentage of the State's total irrigated acreage. Changes in base year and forecasted environmental water use from the last Bulletin reflect implementation of SWRCB's Order WR 95-6 for the Bay-Delta.

Nursery products are California's third largest farm product in gross value. The nursery industry is affected by the availability of both agricultural and urban water supplies.

Urban Water Use

Forecasts of future urban water use for the Bulletin are based on population information and per capita water use estimates. Factors influencing per capita water use include expected demand reduction due to implemen-

-tation of water conservation programs. The Department has modeled effects of conservation measures and socioeconomic changes on per capita use in 20 major water service areas to estimate future changes in per capita use by hydrologic region. An urban water agency making estimates for its own service area would be able to incorporate more complexity in its forecasting, because the scope of its effort is narrow. For this reason, and because DOF population projections seldom exactly match population projections prepared by cities and counties, the Bulletin's water use forecasts are expected to be representative of, rather than identical to, those of local water agencies.

Population Growth

Data about California's population—its geographic distribution and projections of future populations and their distribution—come from several sources. The Department works with base year and projected year population information developed by DOF for each county in the State. The decadal census is a major benchmark for population projections. DOF works from census data to calculate the State's population in noncensus years, and to project future populations. Figure ES4-1 shows DOF's projected growth rates by county for year 2020. (State policy requires that all State agencies use DOF population projections for planning, funding, and policymaking activities.)

Population projections used in Bulletin 160-98 are based on DOF's *Interim County Population Projections (April 1997)*. Table ES4-1 shows the 1995 through 2020 population figures for Bulletin 160-98 by hydrologic region.

TABLE ES4-1
California Population by Hydrologic Region (in thousands)

Region	*1995*	*2020*
North Coast	606	835
San Francisco Bay	5,780	7,025
Central Coast	1,347	1,946
South Coast	17,299	24,327
Sacramento River	2,372	3,813
San Joaquin River	1,592	3,025
Tulare Lake	1,738	3,296
North Lahontan	84	125
South Lahontan	713	2,019
Colorado River	533	1,096
Total (rounded)	**32,060**	**47,510**

DOF periodically updates its population forecasts to respond to changing conditions. Its 2020 population forecast used for Bulletin 160-93 was 1.4 million higher than the 2020 forecast used in Bulletin 160-98. The latter forecast incorporated the effects of the recession of the early 1990s. Small fluctuations in the forecast do not obscure the overall trend—an increase in population on the order of 50 percent.

The Department apportioned county population data to Bulletin 160 study areas based on watershed or water district boundaries. Factors considered in distributing the data to Bulletin 160 study areas included population projections prepared by cities, counties, and local councils of governments, which typically incorporate expected future development from city and county general plans. The local agency projections indicate which areas within a county are expected to experience growth, and provide guidance in allocating DOF's projection for an entire county into smaller Bulletin 160 study areas.

Factors Affecting Urban Per Capita Water Use

Urban per capita water use includes residential, commercial, industrial, and institutional uses of water. Each of these categories can be examined at a greater level of detail. Residential water use, for example, includes interior and exterior (e.g., landscaping) water use. Forecasts of urban water use for an individual community may be separated into components and forecasted individually. It is not possible to use this level of detail for each community in the State in Bulletin 160-98. Bulletin 160-98 modeled components of urban use for representative urban water agencies in each of the State's ten hydrologic regions and extrapolated those results to the remainder of each hydrologic region.

Demand reduction achieved by implementing water conservation measures is important in forecasting per capita water use. Bulletin 160-98 incorporates demand reductions from implementation of urban best management practices contained in the 1991 *Memorandum of Understanding Regarding Urban Water Conservation in California*. Bulletin 160-98 assumes implementation of the urban MOU's BMPs by 2020, resulting in a demand reduction of about 1.5 maf over the year 2020 demand forecast without BMP implementation.

The relationship of water pricing to water consumption, and the role of pricing in achieving water conservation, has been a subject of discussion in recent years. Elected board members of public water

FIGURE ES4-1.
Projected Growth Rates by County, 1995-2020

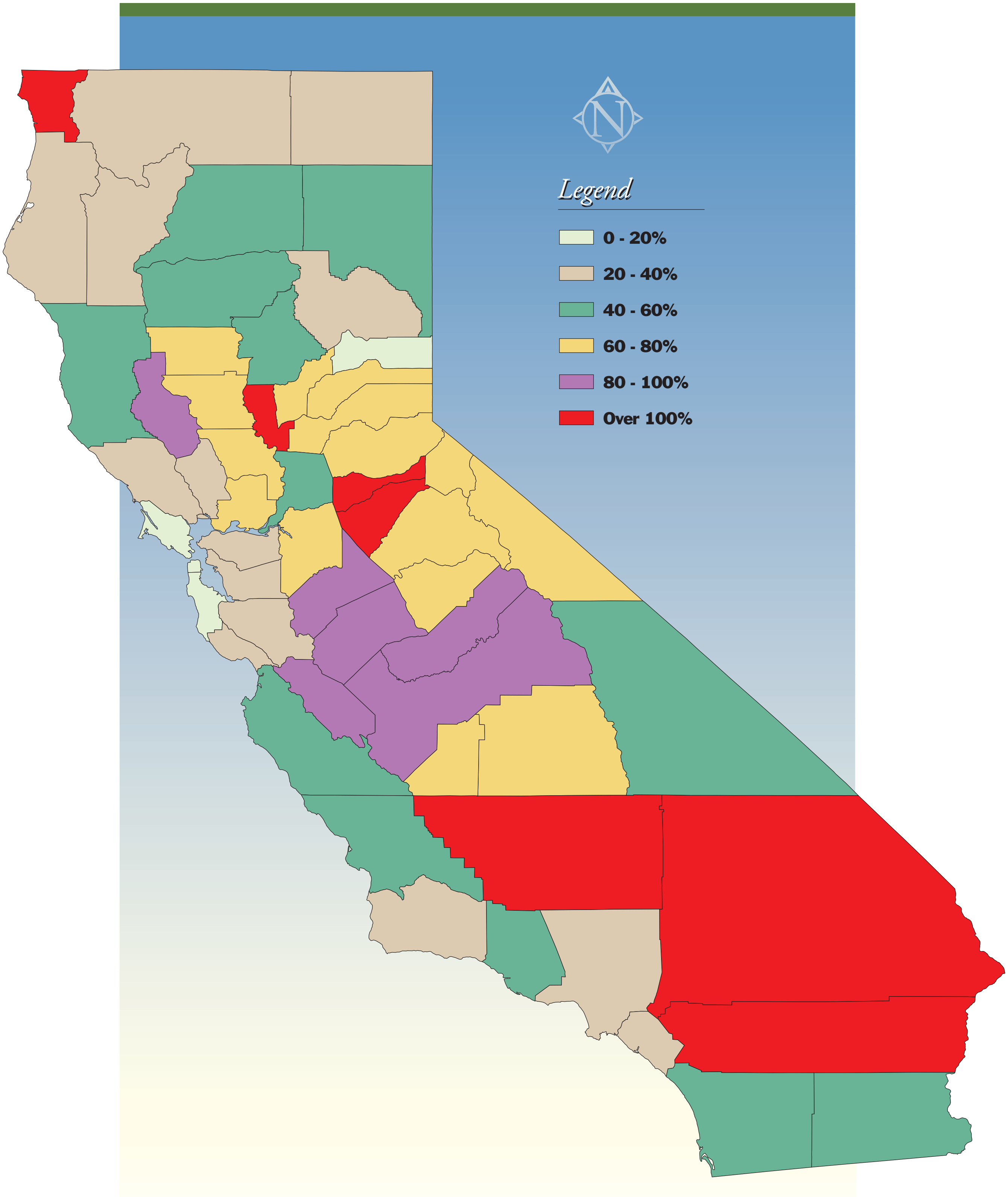


TABLE ES4-2

Effects of Conservation on Per Capita Water Use[a] by Hydrologic Region (gallons per capita per day)

Region	*1995*	*2020*	
		without conservation	*with conservation*
North Coast	249	236	215
San Francisco Bay	192	188	166
Central Coast	179	188	166
South Coast	208	219	191
Sacramento River	286	286	264
San Joaquin River	310	307	274
Tulare Lake	298	302	268
North Lahontan	411	390	356
South Lahontan	282	294	268
Colorado River	564	626	535
Statewide	**229**	**243**	**215**

[a] Includes residential, commercial, industrial, and landscape use supplied by public water systems and self-produced surface and groundwater. Does not include recreational use, energy production use, and losses from major conveyance facilities. These are normalized data.

agencies ultimately have the responsibility for balancing desires to achieve demand reduction through water pricing with desires to provide affordable water rates to consumers. Urban water rates in California vary widely and are affected by factors such as geographic location, source of supply, and type of water treatment provided. Water rates are set by local agencies to recover costs of providing water service, and are highly site-specific. According to several price elasticity studies for urban water use, residential water demand is usually inelastic, i.e., water users were relatively insensitive to changes in price for the price ranges evaluated. Water price currently plays a small role in relation to other factors affecting water use—public education, plumbing retrofit programs, etc.

High efficiency horizontal axis washing machines (front loading washers) are being used in commercial applications, but are just becoming available for home use. A check of large appliance dealers in 1998 showed that two brands of horizontal axis washers are commonly in stock, at prices ranging from $700 to $1,100. Comparable standard washers cost from $100 to $600 less. Some utilities are offering their customers rebates on the order of $100 to $150 for purchasing the horizontal axis machines.

Urban Water Use Forecasting

The Department forecasted change in per capita water use by 2020 in each hydrologic region to estimate 2020 urban applied water by hydrologic region. Variables included changes in population, income, economic activity, water price, and conservation measures (implementation of urban BMPs and changes to State and federal plumbing fixture standards). The general forecasting procedure was to determine 1995 base per capita water use, estimate the effects of conservation measures and socioeconomic change on future use for 20 major representative water service areas in California, and calculate 2020 base per capita water use by hydrologic region from the results of service area forecasts. (See Table ES4-2.)

Summary of Urban Water Use

Table ES4-3 summarizes Bulletin 160-98 urban applied water use by hydrologic region. Statewide urban use at the 1995 base level is 8.8 maf in average water years and 9.0 maf in drought years. (Drought year demands are slightly higher because less precipitation is available to meet exterior urban water uses, such as landscape watering.) Projected 2020 use increases to 12.0 maf in average years and 12.4 maf in drought years. Full implementation of urban BMPs is estimated to result in demand reduction of 1.5 maf in average year water use by 2020. Without implementation of urban BMPs, average year use would have increased to 13.5 maf.

As indicated in the Table ES4-3, the South Coast and San Francisco Bay Hydrologic Regions together amount to over half of the State's total urban water use. The table also illustrates that precipitation plays a small role in meeting urban outdoor water needs (landscape water needs) in arid regions such as the Tulare Lake, South Lahontan, and Colorado River Regions.

Agricultural Water Use

The Department's estimates of agricultural water use are derived by multiplying water use requirements for different crop types by their corresponding statewide irrigated acreage, and summing the results to obtain a total for irrigated crops in the State. This section begins by covering crop water use requirements. A description of the process for estimating future irrigated acreage, and factors affecting acreage forecasts, follows. Forecasted 2020 agricultural water demands are summarized at the end of the section.

Crop Water Use

The water requirement of a crop is directly related to the water lost through evapotranspiration. The amount of water that can be consumed through ET depends in the short term on local weather and in the long term on climatic conditions. Energy from solar radiation is the primary factor that determines the rate of crop ET. Also important are humidity, temperature, wind, stage of crop growth, and the size and aerodynamic roughness of the crop canopy. Irrigation frequency affects ET after planting and during early growth, because evaporation increases when the soil surface is wet and is exposed to sunlight. Growing season ET varies significantly among crop types, depending primarily on how long the crop actively grows.

Direct measurement of crop ET requires costly investments in time and in sophisticated equipment. There are more than 9 million acres of irrigated crop land in California, encompassing a wide range of climate, soils, and crops. Even where annual ET for two areas is similar, monthly totals may differ. For example, average annual ET for Central Coast interior valleys is similar to that in the Central Valley. Central Valley ET is lower than that in coastal valleys during the winter fog season, and higher during hot summer weather. Obtaining actual measurements for every combination of environmental variables would be prohibitively difficult and expensive. A more practical approach is to estimate ET using methods based on correlation of measured ET with observed evaporation, temperature, and other climatologic conditions. Such methods can

TABLE ES4-3

Applied Urban Water Use by Hydrologic Region (taf)

	1995		*2020*	
Region	***Average***	***Drought***	***Average***	***Drought***
North Coast	169	177	201	212
San Francisco Bay	1,255	1,358	1,317	1,428
Central Coast	286	294	379	391
South Coast	4,340	4,382	5,519	5,612
Sacramento River	766	830	1,139	1,236
San Joaquin River	574	583	954	970
Tulare Lake	690	690	1,099	1,099
North Lahontan	39	40	50	51
South Lahontan	238	238	619	619
Colorado River	418	418	740	740
Total (rounded)	**8,770**	**9,010**	**12,020**	**12,360**

be used to transfer the results of measured ET to other areas with similar climates.

The Department uses the ET/evaporation correlation method to estimate growing season ET. Concurrent with field measurement of ET rates, the Department developed a network of agroclimate stations to determine the relationship between measured ET rates and pan evaporation. Data from agroclimatic studies show that water evaporation from a standard water surface (the Department uses the U.S. Weather Bureau Class A evaporation pan) closely correlates to crop evapotranspiration. The ET/evaporation method estimates crop water use to within ± 10 percent of measured seasonal ET.

Crop coefficients are applied to pan evaporation data to estimate evapotranspiration rates for specific crops. (Crop coefficients vary by crop, stage of crop growth, planting and harvest dates, and growing season duration.) The resulting data, combined with information on effective rainfall and water use efficiency, form the basis for calculating ETAW and applied water use. Crop applied water use includes the irrigation water required to meet crop ETAW and cultural water requirements.

The amount of water applied to a given field for crop production is influenced by considerations such as crop water requirements, soil characteristics, the ability of an irrigation system to distribute water uniformly on a given field, and irrigation management practices. In addition to ET, other crop water requirements can include water needed to leach soluble salts below the crop root zone, water that must be applied for frost protection or cooling, and water for seed germination. The amount required for these uses depends upon the crop, irrigation water quality, and weather conditions.

Part of a crop's water requirements can be met by rainfall. The amount of rainfall beneficially used for crop production is called effective rainfall. Effective rainfall is stored in the soil and is available to satisfy crop evapotranspiration or to offset water needed for special cultural practices such as leaching of salts. Irrigation provides the remainder of the crop water requirement. Irrigation efficiency influences the amount of applied water needed, since a portion of each irrigation goes to system leaks and deep percolation of irrigation water below the crop root zone.

The Bulletin's 1995 base applied agricultural water use values were computed from normalized data to account for variation in annual weather patterns and water supply. Normalizing entails applying crop coefficients to long-term average evaporative demand data. Actual applied crop water use during 1995 was less than the Bulletin 160-98 base in many areas due to wet hydrologic conditions that increased effective rainfall, thus decreasing crop ETAW. Likewise, applied water use during a dry year (assuming no constraints on water supplies) would likely exceed the base due to less than average effective rainfall with an attendant increase in crop ETAW.

Bulletin 160-98 quantifies agricultural water conservation based on assumed statewide implementation of the 1996 agricultural MOU. This conservation is expected to reduce agricultural applied water demands by about 800 taf annually by 2020.

Quantifying Base Year Irrigated Acreage

Forecasts of agricultural acreage start with land use data that characterize existing crop acreage. The Department has performed land use surveys since the 1950s to quantify acreage of irrigated land and corresponding crop types, and currently maps irrigated acreage in six to seven counties per year. The base data for land use surveys are obtained from aerial photography or satellite imagery, which is superimposed on a cartographic base. Site visits are used to identify or verify crop types growing in the fields. From this information, maps showing locations and acreage of crop types are developed.

The Department's land use surveys focus on quantifying irrigated agricultural acreage. Although fields of dry-farmed crops are mapped in the land use surveys, their acreage is not tabulated for calculating water use. In certain areas of the State, climate and market conditions are favorable for producing multiple crops per year on the same field (for example, winter vegetables followed by a summer field crop). In these cases, annual irrigated acreage is counted as the sum of the acreage of the individual crop types. In the years between county land use surveys, the Department estimates crop types and acreage using data collected from county agricultural commissioners, local water agencies, University of California Cooperative Extension Programs, and the California Department of Food and Agriculture.

The starting point for determining Bulletin 160-98 1995 base acreage was normalized 1990 irrigated acreage from Bulletin 160-93. Changes in crop acreage between 1990 and 1995 were evaluated to determine if they were due to short-term causes (e.g., drought or abnormal spring rainfall), or if there was an actual change in cropping patterns. Base year acreage was normalized to represent the acreage that would most likely occur in the absence of weather and market related abnormalities.

Crop acreage by region for the normalized 1995 base is presented in Table ES4-4. The 1995 base irrigated land acreage is about 9.1 million acres, which, when multiple cropped areas are tabulated, becomes a base irrigated cropped acreage of about 9.5 million acres.

Forecasting Future Irrigated Acreage

The Department's 2020 irrigated acreage forecast was derived from staff research, a crop market outlook study, and results from the Central Valley Production Model. As with any forecast of future conditions, there are uncertainties associated with each of these approaches. The Department's integration of the results from three independent approaches is intended to represent a best estimate of future acreage, absent major changes from present conditions. It is important to emphasize that many factors affecting future cropped acreage are based on national (federal Farm Bill programs) or international (world export markets) circumstances. California agricultural products compete with products from other regions in the global economy, and are affected by trade policies and market conditions that reach far beyond the State's boundaries.

The Federal Agriculture Improvement and Reform Act of 1996, for example, affects agricultural markets nationwide, by changing federal price supports for specified agricultural commodities. Under the terms of that act, federal payments to growers will be reduced by 2002, and prior farm bill provisions that required growers to reduce planted acreage of regulated commodities are no longer in force. (Commodities with significant federal price support include wheat, feed grains, rice, cotton, dairy products, sugar, and peanuts.) The overall impact of the act to California, however, may be less than its impact to states whose agriculture is less diversified and who are less active in export markets. In 1994, for example, federal farm bill production payments to California growers represented about one percent of California's agricultural revenue. The potential impacts of FAIRA to California's agricultural market are considered in Bulletin 160-98 by the crop market outlook study.

Intrastate factors considered in making acreage forecasts included urban encroachment onto agricultural land and land retirement due to drainage problems. Urbanization on lands presently used for irrigated agriculture is a significant consideration in the South Coast Region and in the San Joaquin Valley, based on projected patterns of population growth. DOF 2020 population forecasts, along with information gathered from local agency land use plans, were used to identify irrigated lands most likely to be affected by urbanization. Local water agencies and county farm advisors were interviewed to assess their perspective on land use changes affecting agricultural acreage. For example, urbanization may eliminate irrigated acreage in one area, but shift agricultural development onto lands presently used as non-irrigated pasture. Soil types and landforms are important constraints in agricultural land development. If urbanization occurs on prime Central Valley farmland, some agricultural production may be able to shift to poorer quality soils on hilly lands adjoining the valley floor. A consequent shift in crop types and irrigation practices would likely result—for example, from furrow-irrigated row crops to vineyards on drip irrigation.

The Department's crop market outlook, a form of Delphi analysis, was developed using information and expert opinions gathered from interviews with more than 130 University of California farm advisors, agricultural bankers, commodity marketing specialists,

Factors that influence the conversion of irrigated lands to urban use include the lands' proximity to existing urban areas and transportation corridors, and local agency land use planning and zoning policies.

TABLE ES4-4

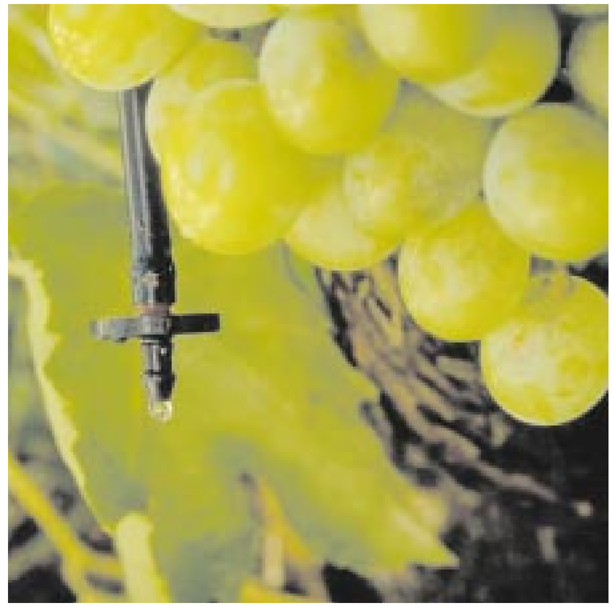
California Crop and Irrigated Acreage by Hydrologic Region, 1995 Level
(thousands of acres)

Irrigated Crop	*NC*	*SF*	*CC*	*SC*	*SR*	*SJ*	*TL*	*NL*	*SL*	*CR*	*Total*
Grain	72	2	26	11	270	180	260	7	2	70	900
Rice	0	0	0	0	494	22	0	1	0	0	517
Cotton	0	0	0	0	9	185	1,026	0	0	24	1,244
Sugar beets	6	0	3	0	54	47	30	0	0	38	178
Corn	1	1	3	4	92	212	116	0	0	9	438
Other field	3	1	16	4	155	120	97	0	1	70	467
Alfalfa	53	0	21	10	149	231	296	44	34	256	1,094
Pasture	122	5	18	20	352	199	49	107	18	43	933
Tomatoes	0	0	10	7	138	82	111	0	0	9	357
Other truck	23	11	382	87	56	130	194	2	3	172	1,060
Almond/pistachios	0	0	0	0	106	251	177	0	0	0	534
Other deciduous	7	6	18	3	219	154	191	0	3	1	602
Subtropical	0	0	19	161	28	8	202	0	0	37	455
Grapes	36	39	56	6	17	184	378	0	0	20	736
Total Crop Area	**323**	**65**	**572**	**313**	**2,139**	**2,005**	**3,127**	**161**	**61**	**749**	**9,515**
Multiple Crop	0	0	142	30	52	56	63	0	0	104	447
Irrigated Land Area	323	65	430	283	2,087	1,949	3,064	161	61	645	9,068

managers of cooperatives, and others. Three basic factors guided the CMO: current and future demand for food and fiber by the world's consumers; the share California could produce to meet this worldwide demand; and technical factors, such as crop yields, pasture carrying capacities, and livestock feed conversion ratios that affect demand for agricultural products. (Milk and dairy products are California's largest agricultural product, in terms of gross value. The demand for these products is reflected in the markets for alfalfa, grains, and other fodder used by dairies.) The CMO forecasts a statewide crop mix and estimates corresponding irrigated acreage. The major findings of the CMO for year 2020 were that grain and field crop acreage would decrease, while acreage of truck crops and permanent crops would increase.

The Central Valley Production Model is a mathematical programming model that simulates farming decisions by growers. Inputs include detailed information about production practices and costs as well as water availability and cost by source. The model also uses information on the relationship between production levels of individual crops and crop market prices. The model's geographic coverage is limited to the Central Valley, which represents about 80 percent of the State's irrigated agricultural acreage. The CVPM results also indicated future crop shifting, from grains and field crops to vegetables, trees, and vines. The CVPM forecast showed a small reduction in crop acreage from 1995 to 2020.

One factor not included in Bulletin 160-98 irrigated acreage forecasts is the potential large-scale conversion of agricultural land to wildlife habitat for reasons other than westside San Joaquin Valley problems. The CALFED program represents the largest pending example of potential conversion of irrigated agricultural lands to habitat, as described in CALFED's March 1998 first draft programmatic EIR/EIS and supporting documents. CALFED's potential land conversion amounts have not been included in the Bulletin 160-98 irrigated acreage forecast because they are preliminary at this time (a site-specific environmental document with an implementation schedule for land conversion has not yet been prepared), and because CALFED's preliminary numbers are so large relative to the Bulletin's market-based forecast of irrigated acreage that they would negate the results of the forecast. Overall, CALFED program activities as presently planned could convert up to 290,000 irrigated acres to habitat and other uses, an amount almost as great as the 325,000-acre reduction in irrigated acreage forecast in the Bulletin. Water use implications of large-scale land conversions are not included in the Bulletin 160-98 forecast. Impacts of such land conversions are expected to be addressed in the next water plan update, when CALFED's program may be better defined.



There is a perception that only drip irrigation is an efficient agricultural water use technology. High efficiencies are possible with a variety of irrigation techniques. Considerations such as soil type, field configuration, and crop type influence the choice of irrigation technique.

The difficulty in estimating impacts from large-scale land conversion programs stems from the domino effect that changes in acreage in one location have on acreage and crop types in other areas, and how crop markets determine which crop shifts are feasible. For example, CALFED's preliminary reports suggest that up to 190,000 irrigated acres in the Delta could be converted to other land uses. This amount represents about 40 percent of Delta irrigated acreage, whose principal crops are corn, alfalfa, tomatoes, grain, orchard crops, and truck crops (e.g., asparagus). Some land conversion in the Delta might result in production on new agricultural lands—most likely, rolling hills on the edge of the valley floor which are only suitable for limited crop types (orchards and vineyards). Some of the land conversion might result in increased demand in other areas for the affected crops, such as increased demand for asparagus from the Imperial and Salinas Valleys.

Table ES4-5 shows the 2020 irrigated acreage fore-

TABLE ES4-5

California Crop and Irrigated Acreage by Hydrologic Region, 2020 Level (thousands of acres)

Irrigated Crop	*NC*	*SF*	*CC*	*SC*	*SR*	*SJ*	*TL*	*NL*	*SL*	*CR*	*Total*
Grain	66	1	21	5	249	152	201	8	0	97	800
Rice	0	0	0	0	484	15	0	1	0	0	500
Cotton	0	0	0	0	15	171	888	0	0	46	1,120
Sugar beets	6	0	2	0	52	18	13	0	0	29	120
Corn	2	0	3	2	90	188	101	1	0	3	390
Other field	3	1	14	1	154	139	110	0	0	33	455
Alfalfa	62	0	20	6	147	181	238	50	24	217	945
Pasture	123	5	16	6	316	165	26	103	18	32	810
Tomatoes	0	0	8	4	141	93	130	0	0	14	390
Other truck	28	11	373	43	79	197	300	2	1	231	1,265
Almond/pistachios	0	0	0	0	127	270	198	0	0	0	595
Other deciduous	7	6	20	3	234	153	199	0	2	1	625
Subtropical	0	0	18	117	33	10	215	0	0	32	425
Grapes	38	41	75	3	29	183	366	0	0	15	750
Total Crop Area	**335**	**65**	**570**	**190**	**2,150**	**1,935**	**2,985**	**165**	**45**	**750**	**9,190**
Multiple Crop	0	0	150	10	70	80	100	0	0	145	555
Irrigated Land Area	335	65	420	180	2,080	1,855	2,885	165	45	605	8,635

TABLE ES4-6

Applied Agricultural Water Use by Hydrologic Region (taf)

Region	1995 Average	1995 Drought	2020 Average	2020 Drought
North Coast	894	973	927	1,011
San Francisco Bay	98	108	98	108
Central Coast	1,192	1,279	1,127	1,223
South Coast	784	820	462	484
Sacramento River	8,065	9,054	7,939	8,822
San Joaquin River	7,027	7,244	6,450	6,719
Tulare Lake	10,736	10,026	10,123	9,532
North Lahontan	530	584	536	594
South Lahontan	332	332	257	257
Colorado River	4,118	4,118	3,583	3,583
Total (rounded)	**33,780**	**34,540**	**31,500**	**32,330**

cast. The total irrigated crop acreage is forecasted to decline by 325,000 acres from 1995 to 2020, primarily in the San Joaquin Valley and South Coast areas. Reductions in crop acreage are due to urban encroachment, drainage problems in the westside San Joaquin Valley, and a more competitive economic market for California agricultural products. Grain and field crops are forecasted to decline by about 631,000 acres. Truck crops and permanent crops are forecasted to increase by about 238,000 and 68,000 acres, respectively. Acreage with multiple cropping is forecasted to increase by 108,000 acres, reflecting the expected increased production of truck crops. These statewide findings are used in developing the base year and forecasted agricultural water demands.

Summary of Agricultural Water Use

Crop water use information and irrigated acreage data are combined to generate the 2020 agricultural water use by hydrologic region shown in Table ES4-6. As previously noted, the 2020 forecasted values take into account EWMP implementation, which results in a 2020 applied water reduction of about 800 taf.

Environmental Water Use

Bulletin 160-98 defines environmental water as the sum of:

- Dedicated flows in State and federal wild and scenic rivers
- Instream flow requirements established by water right permits, DFG agreements, court actions, or other administrative documents
- Bay-Delta outflows required by SWRCB
- Applied water demands of managed freshwater wildlife areas

This definition recognizes that certain quantities of water have been set aside or otherwise managed for environmental purposes, and that these quantities cannot be put to use for other purposes in the locations where the water has been reserved or otherwise managed. This definition also recognizes that these uses of environmental water can be quantified. Unlike urban and agricultural water use, much of this environmental water use is brought about by legislative or regulatory processes. Certainly the environment uses more water than is encompassed in this definition—the rainfall that sustains the forests of the Sierra Nevada and the North Coast, the winter runoff that supports flora and fauna in numerous small streams, the shallow groundwater that supports riparian vegetation in some ephemeral streams—but the Bulletin's definition captures uses of water that are managed (in one fashion or another) and quantifiable. As described earlier, average annual statewide precipitation over California's land surface amounts to about 200 maf. About 65 percent of this precipitation is consumed through evaporation and transpiration by the State's forests, grasslands, and other vegetation. The remaining 35 percent comprises the State's average annual runoff of about 71 maf. The environmental water demands discussed in this section are demands that would be met through a designated portion of that average annual runoff. As with urban and agricultural water use, environmental water use is shown on an applied water basis.

TABLE ES4-7
Wild and Scenic River Flows by Hydrologic Region (taf)

Region	1995 Average	1995 Drought	2020 Average	2020 Drought
North Coast	17,800	7,900	17,800	7,900
San Francisco Bay	0	0	0	0
Central Coast	98	28	98	28
South Coast	69	51	69	51
Sacramento River	1,733	736	1,733	736
San Joaquin River	1,974	939	1,974	939
Tulare Lake	1,614	751	1,614	751
North Lahontan	271	154	271	154
South Lahontan	0	0	0	0
Colorado River	0	0	0	0
Total (rounded)	**23,560**	**10,560**	**23,560**	**10,560**

Wild and Scenic River Flows

Flows in wild and scenic rivers constitute the largest environmental water use in the State. Figure ES4-2 is a map of California's State and federal wild and scenic rivers.

The 1968 National Wild and Scenic Rivers Act, codified to preserve the free-flowing characteristics of rivers having outstanding natural resources values, prohibited federal agencies from constructing, authorizing, or funding the construction of water resources projects having a direct or adverse effect on the values for which the river was designated. (This restriction also applies to rivers designated for potential addition to the national wild and scenic rivers system.) There are two methods for having a river segment added to the federal system—congressional legislation, or a state's petition to the Secretary of the Interior for federal designation of a river already protected under state statutes. No new federal designations have been made since publication of Bulletin 160-93.

A number of river systems within lands managed by federal agencies are being studied as candidates. For example, USFS draft environmental documentation in 1994 and 1996 recommended designation of five streams (129 river miles) in Tahoe National Forest and 160 river miles in Stanislaus National Forest. These waterways drain to the Central Valley where their flows are used for other purposes, and wild and scenic designation would not affect the existing downstream uses.

The California Wild and Scenic Rivers Act of 1972 prohibited construction of any dam, reservoir, diversion, or other water impoundment on a designated river. As shown on Figure ES4-2, some rivers are included in both federal and State systems. No new State designations have been made since Bulletin 160-93, although the Mill and Deer Creeks Protection Act of 1995 (Section 5093.70 of the Public Resources Code) gave portions of these streams special status similar to wild and scenic designation by restricting construction of dams, reservoirs, diversions, or other water impoundments.

Table ES4-7 shows the wild and scenic river flows used in Bulletin 160-98 water budgets by hydrologic region. The flows shown are based on the rivers' unimpaired flow. (The unimpaired flow in a river is the flow measured or calculated at some specific location that would be unaffected by stream diversions, storage, imports or exports, and return flows.) For the average year condition, the long-term unimpaired flow from the Department's Bulletin 1 was used. The estimated average unimpaired flow for the 1990-91 water years was used for the drought condition.

Instream Flows

Instream flow is the water maintained in a stream or river for instream beneficial uses such as fisheries, wildlife, aesthetics, recreation, and navigation. Instream flow is a major factor influencing the productivity and diversity of California's rivers and streams.

Instream flows may be established in a variety of ways—by agreements executed between DFG and a water agency, by terms and conditions in a water right permit from SWRCB, by terms and conditions in a FERC hydropower license, by a court order, or by an agreement among interested parties. Required flows on most rivers vary by month and year type, with wet year requirements generally being higher than dry year requirements. Converting from net water use analyses performed for prior editions of Bulletin 160 to the

FIGURE ES4-2.

California Wild and Scenic Rivers

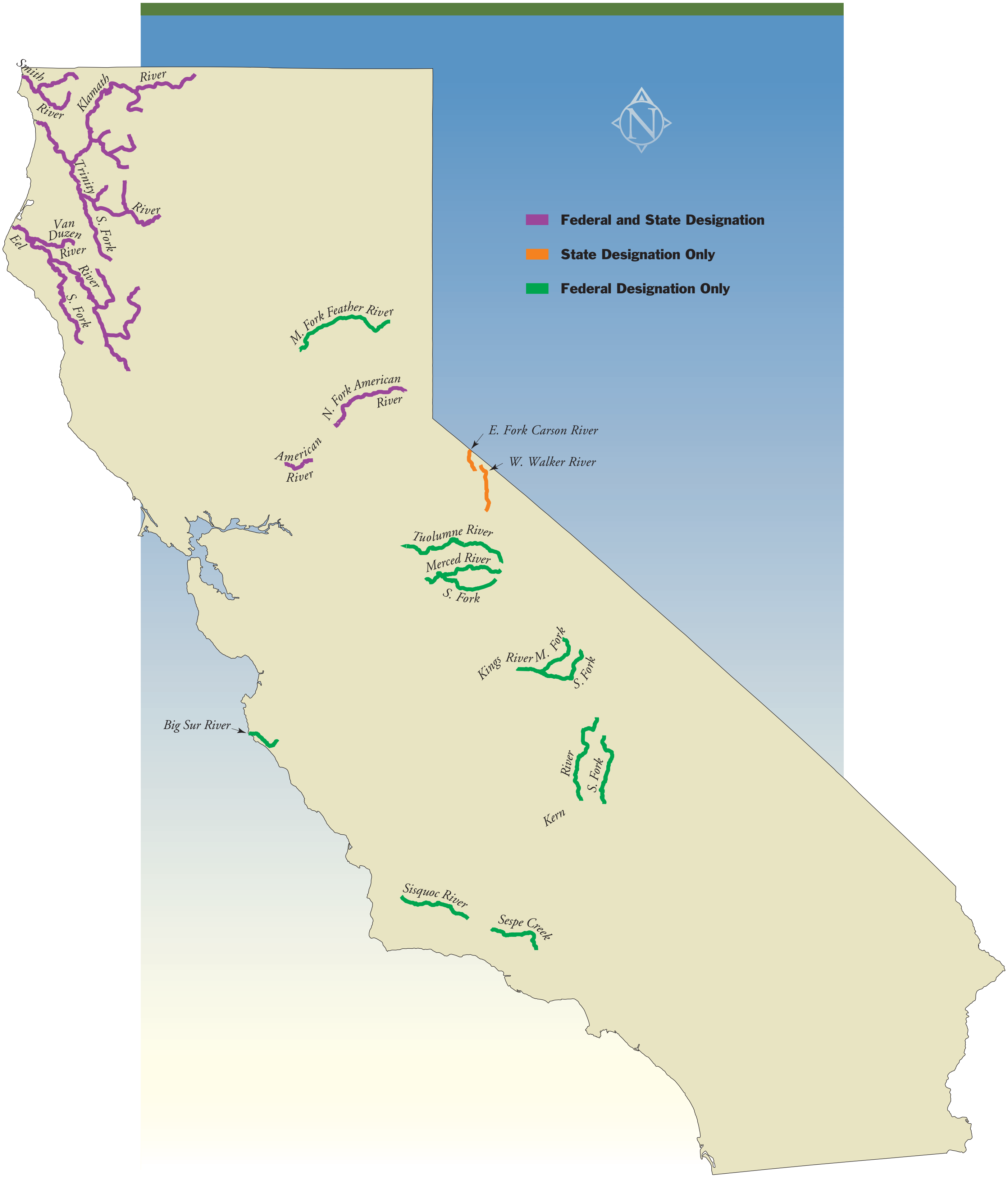


TABLE ES4-8

Instream Flow Requirements by Hydrologic Region (taf)

Region	1995 Average	1995 Drought	2020 Average	2020 Drought
North Coast	1,410	1,285	1,410	1,285
San Francisco Bay	17	9	17	9
Central Coast	20	9	20	9
South Coast	4	4	4	4
Sacramento River	3,397	2,784	3,397	2,784
San Joaquin River	1,169	712	1,169	712
Tulare Lake	0	0	0	0
North Lahontan	85	84	85	84
South Lahontan	107	81	107	81
Colorado River	0	0	0	0
Total (rounded)	**6,210**	**4,970**	**6,210**	**4,970**

applied water budgets used in Bulletin 160-98 created a challenge in properly accounting for multiple instream flows within a river basin. Bulletin 160-98 used a simplified approach in which only the largest downstream flow requirement was included in the water budgets. This simplified approach undercounts applied instream flow requirements on streams having multiple requirements. The Department is developing a new modeling approach for the next water plan update that will more accurately quantify applied instream flows.

Since the determination of 1990-level instream flow values used as base conditions in Bulletin 160-93, subsequent agreements or decisions have increased or added instream flow requirements for the Trinity River, Mokelumne River, Stanislaus River, Tuolumne River, Owens River, Putah Creek, and Mono Lake tributaries. In addition, ten new waterways have been added to the Bulletin 160-98 instream flow water budgets—the Mad River, Eel River, Russian River, Truckee River, East Walker River, Nacimiento River, San Joaquin River (at Vernalis), Walker Creek, Lagunitas Creek, and Piru Creek.

Table ES4-8 shows instream flows used in Bulletin 160-98 water budgets by hydrologic region. The drought year scenario shown in the tables represents the minimum annual required flow volume. For average water years, the annual required flow volume is computed by combining the expected number of years in each year type (wet, above normal, normal, below normal, and/or dry, as specified in existing agreements or orders).

Bay-Delta Outflow

Environmental water use for Bay-Delta outflow is computed by using operations studies to quantify SWRCB Order WR 95-6 requirements. Order WR 95-6 established numerical objectives for salinity, river flows, export limits, and Delta outflow. Operations studies were used to translate these numerical objectives into Delta outflow requirements for average and drought year scenarios. The studies computed outflow requirements of approximately 5.6 maf in average years and 4.0 maf in drought years.

Wetlands

The wetlands component of environmental water use is based on water use at freshwater managed wetlands, such as federal national wildlife refuges and State wildlife management areas. In general, wetlands can be divided into saltwater and brackish water marshes (usually located in coastal areas) and freshwater wetlands (generally located in inland areas).

Five areas of California contain the largest remaining wetlands acreage in the State—the Central Valley, Humboldt Bay, San Francisco Bay, Suisun Marsh, and Klamath Basin. The majority of the State's wetland protection and restoration efforts are occurring in these areas. Nontidal wetlands usually depend on a supplemental water supply, and protecting or restoring them may create demands for freshwater supplies.

Bulletin 160-98 quantifies applied water needs only for managed wetlands, because other wetlands types such as vernal pools or coastal wetlands use naturally-occurring water supply (precipitation or tidal action). Managed wetlands are defined for the Bulletin as impounded freshwater and nontidal brackish water wetlands. Managed wetlands may be State and federal wildlife areas or refuges, private wetland preserves owned by nonprofit organizations,

TABLE ES4-9

Wetlands Water Use by Hydrologic Region (taf)

Region	1995 Average	1995 Drought	2020 Average	2020 Drought
North Coast	325	325	325	325
San Francisco Bay	160	160	160	160
Central Coast	0	0	0	0
South Coast	27	27	31	31
Sacramento River	632	632	632	632
San Joaquin River	230	230	240	240
Tulare Lake	50	50	53	53
North Lahontan	18	18	18	18
South Lahontan	0	0	0	0
Colorado River	39	38	44	43
Total (rounded)	**1,480**	**1,480**	**1,500**	**1,500**

TABLE ES4-10

Applied Environmental Water Use by Hydrologic Region (taf)

Region	1995 Average	1995 Drought	2020 Average	2020 Drought
North Coast	19,544	9,518	19,545	9,518
San Francisco Bay	5,762	4,294	5,762	4,294
Central Coast	118	37	118	37
South Coast	100	82	104	86
Sacramento River	5,833	4,223	5,839	4,225
San Joaquin River	3,396	1,904	3,411	1,919
Tulare Lake	1,672	809	1,676	813
North Lahontan	374	256	374	256
South Lahontan	107	81	107	81
Colorado River	39	38	44	43
Total (rounded)	**36,940**	**21,240**	**36,980**	**21,270**

private duck clubs, or privately owned agricultural lands flooded for cultural practices such as rice straw decomposition. Some of the largest concentrations of privately owned wetlands are the duck clubs in the Suisun Marsh and the flooded rice fields in the Sacramento Valley. (Acreage of rice fields flooded to enhance decomposition of stubble remaining after harvest and to provide habitat for overwintering waterfowl was identified by Department land use surveys.) Table ES4-9 shows wetlands water demands by region.

Summary of Environmental Water Use

Table ES4-10 shows base 1995 and forecasted 2020 environmental water use by hydrologic region. The large values in the North Coast Region illustrate the magnitude of demands for wild and scenic rivers in comparison to other environmental water demands.

Water Use Summary by Hydrologic Region

Tables ES4-11 and ES4-12 summarize California's average and drought year applied water use by hydrologic region. The tables combine the urban, agricultural, and environmental water use described in this chapter. Also included are related minor uses such as conveyance losses and self-supplied industrial and powerplant cooling water. These demands, together with the water supply information presented in Chapter ES3, are used to prepare the statewide water balance shown in Chapter ES5 and the regional water balances shown in Appendix ES5A.

TABLE ES4-11

California Average Year Water Use by Hydrologic Region (taf)

Region	*1995*				*2020*			
	Urban	*Agricultural*	*Environmental*	*Total (rounded)*	*Urban*	*Agricultural*	*Environmental*	*Total (rounded)*
North Coast	169	894	19,544	20,610	201	927	19,544	20,670
San Francisco Bay	1,255	98	5,762	7,110	1,317	98	5,762	7,180
Central Coast	286	1,192	118	1,600	379	1,127	118	1,620
South Coast	4,340	784	100	5,220	5,519	462	104	6,080
Sacramento River	766	8,065	5,833	14,660	1,139	7,939	5,839	14,920
San Joaquin River	574	7,027	3,396	11,000	954	6,450	3,411	10,820
Tulare Lake	690	10,736	1,672	13,100	1,099	10,123	1,676	12,900
North Lahontan	39	530	374	940	50	536	374	960
South Lahontan	238	332	107	680	619	257	107	980
Colorado River	418	4,118	39	4,570	740	3,583	44	4,370
Total (rounded)	**8,770**	**33,780**	**36,940**	**79,490**	**12,020**	**31,500**	**36,980**	**80,500**

TABLE ES4-12

California Drought Year Water Use by Hydrologic Region (taf)

Region	*1995*				*2020*			
	Urban	*Agricultural*	*Environmental*	*Total (rounded)*	*Urban*	*Agricultural*	*Environmental*	*Total (rounded)*
North Coast	177	973	9,518	10,670	212	1,011	9,518	10,740
San Francisco Bay	1,358	108	4,294	5,760	1,428	108	4,294	5,830
Central Coast	294	1,279	37	1,610	391	1,223	37	1,650
South Coast	4,382	820	82	5,280	5,612	484	86	6,180
Sacramento River	830	9,054	4,223	14,110	1,236	8,822	4,225	14,280
San Joaquin River	583	7,244	1,904	9,730	970	6,719	1,919	9,610
Tulare Lake	690	10,026	809	11,530	1,099	9,532	813	11,440
North Lahontan	40	584	256	880	51	594	256	900
South Lahontan	238	332	81	650	619	257	81	960
Colorado River	418	4,118	38	4,570	740	3,583	43	4,370
Total (rounded)	**9,010**	**34,540**	**21,240**	**64,790**	**12,360**	**32,330**	**21,270**	**65,960**

5

Executive Summary

Balancing Supply and Demand

This chapter assesses California's water future, based on today's conditions and on options being considered by California's water purveyors. The Department's Bulletin 160 series does not forecast a particular vision for the future, but instead attempts to forecast the future based on today's data, economic conditions, and public policies.

Although no forecast of the future can be perfect, several key trends appear inevitable. California's population will increase dramatically by 2020. How growth is accommodated and the land use planning decisions made by cities and counties have important implications for future urban and agricultural water use. California's agricultural acreage is forecasted to decline slightly by 2020 (reflecting the State's increasing urbanization), as is its agricultural water use. (California agriculture is still anticipated to lead the nation's agricultural production because of advantages such as climate and proximity to domestic and export markets.) As the State's population expands, greater attention will be directed to preserving and restoring California ecosystems and to maintaining the natural resources which have attracted so many people to California.

The 1848 discovery of gold at Sutter's Mill on the American River led to California's statehood in 1850. California celebrates its sesquicentennial in 2000.

Miners in the Sierra,
Detail of painting by Charles Nahl and Frederick Wenderoth, 1851.

Courtesy of Smithsonian Institution

This chapter begins by reviewing water supply and demand information and the statewide applied water budget with existing facilities and programs. Water management options identified as likely to be implemented are then tabulated and included in a statewide applied water budget with options. The chapter ends with an evaluation of how actions planned by water purveyors statewide would affect forecasted water shortages, and then summarizes key findings.

Future with Existing Facilities and Programs

Table ES5-1 shows the California water budget with existing facilities and programs. Regional water budgets with existing facilities and programs are shown in Appendix ES5A.

Water Supply

As described in Chapter ES3, average annual statewide precipitation over California's land surface is about 200 maf. About 65 percent of this precipitation is consumed through evaporation and transpiration by California's forests, grasslands, and vegetation. The remaining 35 percent comprises the State's average annual intrastate runoff of about 71 maf. Over 30 percent of this runoff is not explicitly designated for urban, agricultural, or environmental uses.

The State's 1995-level average water year applied water supply—from intrastate sources, interstate sources, and return flows—is about 78 maf. Even assuming a reduction in Colorado River supplies to California's 4.4 maf basic apportionment, average year statewide supply is projected to increase 0.2 maf by 2020 without additional water supply options. This projected increase in water supply is due mainly to higher CVP and SWP deliveries in response to higher 2020 level demands. Additional groundwater extraction and facilities now under construction will also provide new supplies. The State's 1995-level drought year supply is about 60 maf. Drought year supply is projected to increase slightly by 2020 without future water supply options, for the same reasons that average year supplies are expected to increase.

Bulletin 160-98 estimates statewide groundwater overdraft of about 1.5 maf/yr at a 1995 level of development. Increasing overdraft in the 1990s reverses the trend of basin recovery seen in the 1980s. Most increases are occurring in the San Joaquin and Tulare Lake regions, due primarily to Delta export restrictions associated with the SWRCB Order WR 95-6, ESA requirements, and reductions in CVP supplies.

Water recycling is a small, yet growing, element of California's water supply. At a 1995 level of development, water recycling and desalting produce about 0.3 maf/yr of new water (reclaiming water that would otherwise flow to the ocean or to a salt sink), up significantly from the 1990 annual supply of new water. The California Water Code urges wastewater treatment agencies located in coastal areas to recycle as much of their treated effluent as possible, recognizing that this water supply would otherwise be lost to the State's hydrologic system. Greater recycled water production at existing treatment plants and additional production at plants now under construction are ex-

TABLE ES5-1

California Water Budget with Existing Facilities and Programs (maf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	8.8	9.0	12.0	12.4
Agricultural	33.8	34.5	31.5	32.3
Environmental	36.9	21.2	37.0	21.3
Total	**79.5**	**64.7**	**80.5**	**66.0**
Supplies				
Surface Water	65.1	43.5	65.0	43.4
Groundwater	12.5	15.8	12.7	16.0
Recycled and Desalted	0.3	0.3	0.4	0.4
Total	**77.9**	**59.6**	**78.1**	**59.8**
Shortage	**1.6**	**5.1**	**2.4**	**6.2**

pected to increase new recycled and desalted supplies by nearly 30 percent to 0.4 maf/yr by 2020.

Water Demand

California's estimated demand for water at a 1995 level of development is about 80 maf in average years and 65 maf in drought years. California's water demand in 2020 is forecasted to reach 81 maf in average years and 66 maf in drought years. California's increasing population is a driving force behind increasing water demands.

California's population is forecasted to increase to 47.5 million people by 2020 (about 15 million people more than the 1995 base). Forty-six percent of the State's population increase is expected to occur in the South Coast Region. Even with extensive water conservation, urban water demand will increase by about 3.2 maf in average years. (Bulletin 160-98 assumes that all urban and agricultural water agencies will implement BMPs and EWMPs by 2020, regardless of whether they are cost-effective for water supply purposes.)

Irrigated crop acreage is expected to decline by 325,000 acres—from the 1995 level of 9.5 million acres to a 2020 level of 9.2 million acres. Reductions in forecasted irrigated acreage are due primarily to urban encroachment and to impaired drainage on lands in the western San Joaquin Valley. Increases in water use efficiency combined with reductions in irrigated acreage are expected to reduce average year agricultural water demand by about 2.3 maf by 2020. Shifts from lower to higher value crops are expected to continue, with an increase in permanent plantings such as orchards and vineyards. This trend would tend to harden agricultural demands associated with permanent plantings, making it less likely that this acreage would be temporarily fallowed during droughts.

Average and drought year water needs for environmental use are forecasted to increase by about 0.1 maf by 2020. Drought year environmental water needs are considerably lower than average year environmental water needs, reflecting the variability of unimpaired flows in wild and scenic rivers. North Coast wild and scenic rivers constitute the greatest component of environmental water demands. CVPIA implementation, Bay-Delta requirements, new ESA restrictions, and FERC relicensing could significantly modify environmental demands within the Bulletin 160-98 planning period.

Water Shortages

The shortage shown in Table ES5-1 for 1995 average water year conditions reflects the Bulletin's assumption that groundwater overdraft is not available as a supply. Forecasted water shortages vary widely from region to region, as presented in Figure ES5-1. For example, the North Coast and San Francisco Bay Regions are not expected to experience future shortages during average water years but are expected to see shortages in drought years. Most of the State's remaining regions experience average year and drought year shortages now, and are forecasted to experience increased shortages in 2020. The largest future shortages are forecasted for the Tulare Lake and South Coast Regions, areas that rely heavily on imported water supplies. These regions of the State are also where some of the greatest increases in population are expected to occur.

The shortages shown in Figure ES5-1 highlight the need for future water management actions to reduce the gap between forecasted supplies and demands. As Californians experienced during the most recent drought (especially in 1991 and 1992), drought year shortages are large. Urban residents faced cutbacks in supply and mandatory rationing, some small rural communities saw their wells go dry, agricultural lands were fallowed, and environmental water supplies were reduced. By 2020, without additional facilities and programs, these conditions will worsen.

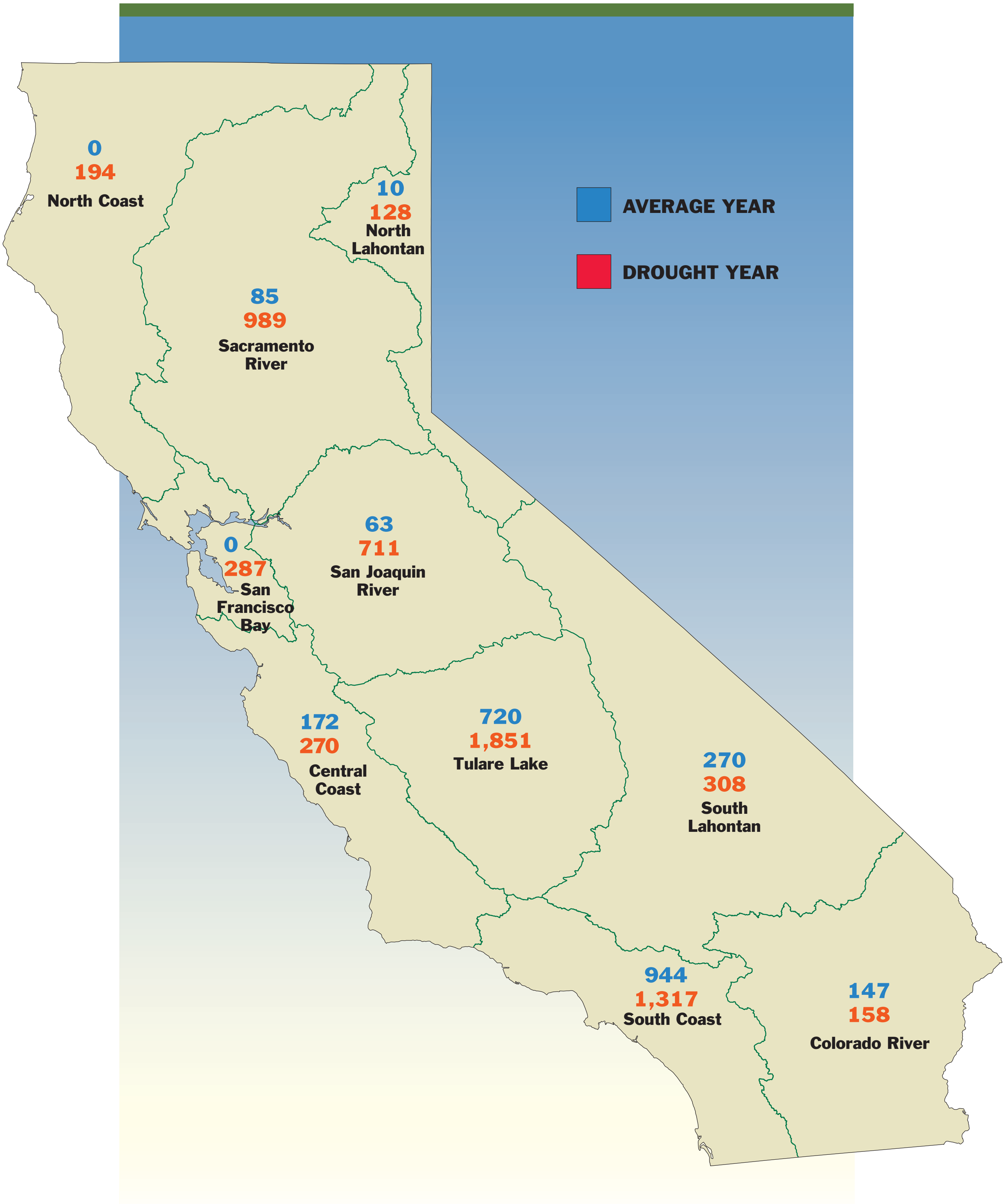
Future water shortages have direct and indirect economic consequences. Direct consequences include costs to residential water users to replace landscaping lost during droughts, costs to businesses that experience water supply cutbacks, or costs to growers who fallow land because supplies are not available. Indirect consequences include decisions by businesses and growers not to locate or to expand their operations in California, and reductions in the value of agricultural lands. Other consequences of shortages are less easily measured in economic terms—loss of recreational activities or impacts to environmental resources, for example.

The Bulletin 160-98 Planning Process

At an appraisal level of detail, the Bulletin draws upon integrated resources planning techniques to evaluate alternatives for meeting California's future water needs. IRP evaluates water management options—both demand reduction options and supply

FIGURE ES5-1.

2020 Shortages by Hydrologic Region with Existing Facilities and Programs



augmentation options—against a fixed set of criteria and ranks the options based on costs and other factors. Although the IRP process includes economic evaluations, it also incorporates environmental, institutional, and social considerations which cannot be expressed easily in monetary terms.

The development of likely regional water management options uses information prepared by local agencies. The regional water management options evaluations are not intended to replace local planning efforts, but to complement them by showing the relationships among regional water supplies and water needs and the statewide perspective. Local water management options form the basis of the regional summaries which are combined into the statewide options evaluation.

Major Steps in Planning Process

The major steps involved in the Bulletin 160-98 water management options evaluation process included:

- Identify water demands and existing water supplies on a regional basis.
- Compile comprehensive lists of regional and statewide water management options.
- Use initial evaluation criteria to either retain or defer options from further evaluation. For options retained for further evaluation, some were grouped by categories and others were evaluated individually.
- Identify characteristics of options or option categories, including costs, potential demand reduction or supply augmentation, environmental considerations, and significant institutional issues.
- Evaluate each regional option or category of options in light of identified regional characteristics using criteria established for this Bulletin. If local agencies have performed their own evaluation, review and compare their evaluation criteria with those used for the Bulletin.
- Evaluate statewide water management options.
- Develop tabulation of likely regional water management options.
- Develop a statewide options evaluation by integrating the regional results.

The first step in evaluating the regional water management options was to prepare applied water budgets for the study areas to identify the magnitude of potential water shortages for average and drought year conditions. In addition to identifying shortages, other water supply reliability issues in the region were identified. Once the shortages were identified, a list of local water management options was prepared. Where possible, basic characteristics of these options (e.g., yields, cost data, significant environmental or institutional concerns) were identified.

After the options were identified, they were compared with the initial screening criteria shown in the sidebar. For options deferred from further evaluation, the major reasons for deferral were given. Options retained for further evaluation were categorized (some options within each category were further combined into groups based upon their estimated costs) and were evaluated and scored against the set of fixed criteria shown in the options category evaluation sidebar.

The Bulletin 160-98 options evaluation process relied heavily upon locally developed information.

Initial Screening Criteria

The criteria used for initial screening of water management options were:

- Engineering—an option was deferred from further evaluation if it was heavily dependent on the development of technologies not currently in use, it used inappropriate technologies given the regional characteristics (e.g., desalting in the North Lahontan Region), or it did not provide new water (e.g., water recycling in the Central Valley).
- Economic—an option was deferred from further evaluation if its cost estimates (including environmental mitigation costs) were extraordinarily high given the region's characteristics.
- Environmental—an option was deferred from further evaluation if it had potentially significant unmitigable environmental impacts or involved use of waterways designated as wild and scenic.
- Institutional/Legal—an option was deferred from further evaluation if it had potentially unresolvable water rights conflicts or conflicts with existing statutes.
- Social/Third Party—an option was deferred from further evaluation if it had extraordinary socioeconomic impacts, either in the water source or water use areas.
- Health—an option was deferred from further evaluation if it would violate current health regulations or would pose significant health threats.

Options Category Evaluation

Evaluation Criteria	*What is Measured?*	*How is it Measured?*	*Score*
Engineering	Engineering feasibility	Increase score for greater reliance upon current technologies	
	Operational flexibility	Increase score for operational flexibility with existing facilities and/or other options	
	Drought year supply	Increase score for greater drought year yield/ reliability	
	Implementation date	Increase score for earlier implementation date	
	Water quality limitations	Increase score for fewer water quality constraints	
Engineering Score			0 - 4
Economics	Project financial feasibility	Increase score for lower overall costs and the ability to finance	
	Project unit cost	Increase score for lower overall unit cost (including mitigation costs)	
Economics Score			0 - 4
Environmental	Environmental risk	Increase score for least amount of environmental risk	
	Irreversible commitment of resources	Increase score for least amount of irreversible commitment of resources	
	Collective impacts	Increase score for least amount of collective impacts	
	Proximity to environmentally sensitive resources	Increase score for little or no proximity to sensitive resources	
Environmental Score			0 - 4
Institutional/Legal	Permitting requirements	Increase score for least amount of permitting requirements	
	Adverse institutional/legal effects upon water source areas	Increase score for least amount of adverse institutional/legal effects	
	Adverse institutional/legal effects upon water use areas	Increase score for least amount of adverse institutional/legal effects	
	Stakeholder consensus	Increase score for greater amount of stakeholder consensus	
Institutional/Legal Score			0 - 4
Social/Third Party	Adverse third party effects upon water source areas	Increase score for least amount of adverse third party effects	
	Adverse third party effects upon water use areas	Increase score for least amount of adverse third party effects	
	Adverse social and community effects	Increase score for least amount of adverse social and community effects	
Social/Third Party Score			0 - 4
Other Benefits	Ability to provide benefits in addition to water supply	Increase score for environmental benefits	
		Increase score for flood control benefits	
		Increase score for recreation benefits	
		Increase score for energy benefits	
		Increase score for additional benefits	
		Increase score for improved compliance with health and safety regulations	
Other Benefits Score			0 - 4
Total Score			0 - 24

Methods used to develop this information vary from one local agency to the next, thus making direct comparisons between cost estimates difficult. To make cost information comparable, a common approach for estimating unit cost (cost per acre-foot) was developed for this Bulletin. Where project information was readily available, costs were normalized using this approach. However, due to time constraints and lack of detailed information, not all option costs were normalized. Option unit cost estimates took into account capital costs associated with construction and implementation, including any needed conveyance facilities, and annual operations, maintenance, and replacement costs.

Water management options can serve purposes other than water supply; they can also provide flood control, hydroelectric power generation, environmental enhancement, water quality enhancement, and recreation. In recognition of the multipurpose benefits provided by some water management options, the options evaluation scoring process assigned a high value to multipurpose options, as shown in the sidebar. However, since the focus of the Bulletin 160 series is water supply, cost estimates were based solely on the costs associated with water supply.

Once options had been evaluated and scored, they were ranked according to their scores. This ranking was used to prepare a tabulation of likely regional water management options, taking into account options that might be mutually exclusive or could be optimized if implemented in conjunction with other options. Depending on a region's characteristics, its potential options, and its ability to pay for new options, the tabulation of likely options might not meet all of a region's water shortages (especially in drought years). In regions where options do not meet all shortages, the economic costs of accepting shortages would be less than the costs of acquiring additional water supplies through the options identified in this Bulletin.

This appraisal-level evaluation of options at a statewide level of detail is based on the information presently available. The ultimate implementability of any water management option is dependent on factors such as the sponsoring entity's ability to complete the appropriate environmental documentation, obtain the necessary permits, and finance the proposed action.

Shortage Management

Water agencies may choose to accept less than 100 percent water supply reliability, especially under drought conditions, depending on the characteristics of their service areas. Shortage contingency measures, such as restrictions on residential outdoor watering or deficit irrigation for agricultural crops, can be used to help respond to temporary shortages. However, demand hardening is an important consideration in evaluating shortage contingency measures. Implementing water conservation measures such as plumbing retrofits and low water use landscaping reduces the ability of water users to achieve future drought year water savings through shortage contingency measures.

The impacts of allowing planned shortages to occur in water agency service areas are necessarily site-specific, and must be evaluated by each agency on an individual basis. In urban areas where conservation measures have already been put into place to reduce landscape water use, imposing rationing or other restrictions on landscape water use can create significant impacts to homeowners, landscaping businesses, and entities that manage large turf areas such as parks and golf courses. Drought year cutbacks in the agricultural sector create economic impacts not only to individual growers and their employees, but also to local businesses that provide goods and services to the growers.

Using Applied Water Budgets to Calculate New Water Needs

Some municipal wastewater discharges, agricultural return flows, and required environmental instream flows are reapplied several times before finally being depleted from the State's hydrologic system. An applied water budget explicitly accounts for this unplanned reuse of water. Because reapplication has the potential to account for a substantial portion of a region's water supply, applied water budgets may overstate the supply of water actually needed to meet future water demands. Therefore, shortages calculated from an applied water budget must be interpreted with caution to determine new water needs for a region.

The amount of new water required to meet a region's future needs depends on several factors, including the region's applied water shortage, opportunities to reapply water in the region, and the types of water management options that are implemented in the region. If no water reapplication opportunities exist, then the region's new water need is equivalent to its applied water shortage. In this extreme case, the new water need would be independent of the types of water management options that are implemented. However, if opportunities are available to reapply water in a region, then the region's new water need is less than its applied water shortage. In this case, the new water need depends on the types of water management options that are implemented.

Not all water management options are created equal in their ability to meet new water needs. Because supply augmentation options provide new water to a region, the opportunity exists for the options' effectiveness to be multiplied through reapplication. For example, a supply augmentation option may provide 100 taf of new water to a region. But through reapplication within the region, the option effectively meets applied water demands in excess of 100 taf. Demand reduction options, on the other hand, do not provide new water to a region. Hence, the opportunity does not exist to multiply the options' effectiveness through reapplication. To satisfy an applied water shortage of 100 taf, a demand reduction option must conserve 100 taf of water.

Based on the above discussion, calculation of regional and statewide new water needs is more complex than computing regional and statewide applied water shortages—new water needs also depend on reapplication and implemented water management options. An applied water shortage provides an upper bound on the new water need. A lower bound on the new water need can be estimated for each region by assuming that new water supplies are reapplied in the same proportion that existing supplies are reapplied.

The tabulations of likely regional water management options utilize minimum new water needs (rather than applied water shortages) as target values for selecting the appropriate number of regional options. If a region is unable to meet minimum new water needs as a result of regional characteristics, lack of potential options, or inability to pay for potential options, specifying minimum new water needs rather than applied water shortages as regional target values has no impact on options selection. On the other hand, if a region is able to meet its minimum new water needs, this does not necessarily guarantee that all applied water shortages would be met. The remaining applied water shortages would depend on the selected option mix—the more water conservation selected, the greater the remaining applied water shortages would be (as water conservation options do not provide reapplication opportunities.) This approach is consistent with Bulletin 160-93, which used net water shortages as target values for selecting regional options. Because data in net water budgets factor out reapplied water, net water shortages are essentially the same as minimum new water needs.

Summary of Options Likely to be Implemented

The options summarized in this section represent water purveyors' strategies for meeting future needs. This information relies heavily on actions identified by local water agencies, which collectively provide about 70 percent of the State's developed water supply. As described earlier, water management options likely to be implemented were selected based on a ranking process that evaluated factors such as technical feasibility, cost, and environmental considerations. This process is most effective in hydrologic regions where local agencies have prepared plans for meeting future needs in their service areas. Affordability is a key factor for local agencies in deciding the extent to which they wish to invest in alternatives to improve their water service reliability. Water agencies must balance costs and quantity of supply (and sometimes quality of supply) based on their service area needs.

The Bulletin 160 series focuses on water supply. The statewide compilation of likely options has not been tailored to meet other water-related objectives such as flood control, hydropower generation, recreation, or nonpoint source pollution control. The evaluation process used to select likely options rated the options based on their ability to provide multiple benefits, as described in the previous section.

Options shown in Table ES5-2 include demand reduction beyond BMP and EWMP implementation included in Table ES5-1. Future demand reduction options are options that would produce new water supply through reduction of depletions. For these optional water conservation measures to have been identified as likely, they must be competitive in cost with water supply augmentation options.

Local supply augmentation options comprise the largest potential new source of drought year water for California. (Local options include implementation of the draft CRB 4.4 Plan to reduce California's use of Colorado River water.) In Table ES5-2 and in the water budgets, only water marketing options that result in a change of place of use of the water (from one hydrologic region to another), or a change in type of use (e.g., agricultural to urban) have been included. Considerably more marketing options are described in the Bulletin than are shown in the water budgets, reflecting local agencies' plans to purchase future supplies

TABLE ES5-2

Summary of Options Likely to be Implemented by 2020, by Option Type (taf)

Option Type	*Average*	*Drought*
Local Demand Reduction Options	507	582
Local Supply Augmentation Options		
Surface Water	110	297
Groundwater	24	539
Water Marketing	67	304
Recycled and Desalted	423	456
Statewide Supply Options		
CALFED Bay-Delta Program	100	175
SWP Improvements	117	155
Water Marketing (Drought Water Bank)	—	250
Multipurpose Reservoir Projects	710	370
Expected Reapplication	141	433
Total Options	**2,199**	**3,561**

from sources yet to be identified. Where the participants in a proposed transfer are known, the selling region's average year or drought year supply has been reduced in the water budgets. Presently, the only transfers with identified participants that are large enough to be visible in the water budgets are those associated with the draft CRB 4.4 Plan. Water agencies' plans to acquire water through marketing arrangements will depend on their ability to find sellers and on the level of competition for water purchases among water agencies and environmental restoration programs (such as CVPIA's AFRP or CALFED's ERP).

Possible statewide options include actions that could be taken by CALFED to develop new water supplies. The timing and extent of new water supplies that CALFED might provide are uncertain at the time of the Bulletin's printing, since CALFED has not identified a draft preferred alternative and a firm schedule for its implementation. CALFED's current schedule calls for a first phase of program implementation spanning seven to ten years, at the end of which time a final decision would be made about the extent of any storage and conveyance facilities that might be constructed. Given the long lead time required for implementing large storage projects, no CALFED facilities may be in service within the Bulletin's 2020 planning horizon.

Bulletin 160-98 uses a placeholder analysis for new CALFED water supply development to illustrate the potential magnitude of new water supply the program might provide. The placeholder does not address specifics of which surface storage facilities might be selected, since this level of detail is not available.

Other statewide options include specific projects to improve SWP water supply reliability, the State's drought water bank, and two multipurpose reservoirs. A third potential multipurpose reservoir option, an enlarged Shasta Lake, was recommended for further study because additional work is needed to quantify benefits and costs associated with different reservoir sizes.

The two multipurpose reservoir projects included as statewide options—Auburn Reservoir and enlarged Millerton Lake—were included to emphasize the interrelationship between water supply needs and the Central Valley's flood protection needs. Each reservoir would offer significant flood protection benefits. Both projects have controversial aspects, and neither of them is inexpensive. However, they merit serious consideration.

The potential future water management options summarized in this section are still being planned. Their implementation is subject to completion of environmental documents, permit acquisition, and compliance with regulatory requirements such as those of ESA. These processes will address mitigating environmental impacts and resolving third-party impacts. If water management options are delayed or rendered infeasible as a result of these processes, or if their costs are increased to the point that the options are no longer affordable for the local sponsors, statewide shortages will be correspondingly affected.

Floodflows on the American River in 1986 breached the cofferdam that USBR had constructed when it began its initial work at the Auburn damsite. This flood event produced record flows in the American River through metropolitan Sacramento.

Implementing Future Water Management Options

Table ES5-3 was developed by combining the regional and statewide analyses of water management options with the water budget with existing facilities and programs (Table ES5-1). Table ES5-3 illustrates the effect these options would have on forecasted future shortages. (Appendix ES5B shows regional water budgets with option implementation.) The table indicates that water management options now under consideration by water purveyors throughout the State will not reduce shortages to zero in 2020. The difference between average water year and drought year water shortages is significant. Water purveyors generally consider shortages in average years as basic deficiencies that should be corrected through long-term demand reduction or supply augmentation measures. Shortages in drought years may be managed by such long-term measures in combination with short-term actions used only during droughts. Short-term measures could include purchases from the State's drought water bank, urban water rationing, or agricultural land fallowing. Agencies may evaluate the marginal costs of developing new supplies and conclude that the cost of their development exceeds that of shortages to their service areas, or exceeds the cost of implementing contingency measures such as transfers or rationing. As water agencies implement increasing amounts of water conservation in the future (especially plumbing fixture changes), there will be a correspondingly lessened ability to implement short-term drought response actions such as rationing. Demand hardening will influence agencies' decisions about their future mix of water management actions.

Ability to pay is another consideration. Large urban water agencies frequently set high water service reliability goals and are able to finance actions necessary to meet the goals. Agencies supplying small rural communities may not be able to afford expensive projects. Small communities have limited populations over which to spread capital costs and may have difficulty obtaining financing. If local groundwater resources are inadequate to support expected growth, these communities may not be able to afford projects such as pipelines to bring in new surface water supplies. Small rural communities that are geographically isolated from population centers cannot readily interconnect with other water systems.

Agricultural water agencies may be less able to pay for capital improvements than urban water agencies. Much of the State's earliest large-scale water development was for agriculture, and irrigation works were constructed at a time when water development was inexpensive by present standards. Agricultural users today may not be able to compete with urban users for development of new supplies. Some agricultural water users have historically been willing to accept lower water supply reliability in return for less expensive water supplies. It may be less expensive for some agricultural users to idle land in drought years rather

TABLE ES5-3

California Water Budget with Options Likely to be Implemented (maf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	8.8	9.0	11.8	12.1
Agricultural	33.8	34.5	31.3	32.1
Environmental	36.9	21.2	37.0	21.3
Total	**79.5**	**64.7**	**80.1**	**65.5**
Supplies				
Surface Water	65.1	43.5	66.4	45.4
Groundwater	12.5	15.8	12.7	16.5
Recycled and Desalted	0.3	0.3	0.8	0.9
Total	**77.9**	**59.6**	**79.9**	**62.8**
Shortage	**1.6**	**5.1**	**0.2**	**2.7**

than to incur capital costs of new water supply development. This can be particularly true for regions faced with production constraints such as short growing seasons or lower quality lands—areas where the dominant water use may be irrigated pasture. In areas such as the North Lahontan Region, for example, local agencies generally do not have plans for new programs or facilities to reduce agricultural water shortages in drought years. Figure ES5-2 shows forecasted shortages by hydrologic region to illustrate the effects of option implementation on a regional basis.

Local agencies that expect to have increased future demands generally do more water supply planning than do agencies whose demands remain relatively level. Most agricultural water agencies are not planning for greater future demands, although some agencies are examining ways to improve reliability of their existing supplies. Cost considerations limit the types of options available to many agricultural users. The agricultural sector has thus developed fewer options that could be evaluated in statewide water supply planning. Many options have been generated from planning performed by urban agencies, reflecting Urban Water Management Planning Act requirements that urban water suppliers with 3,000 or more connections, or that deliver over 3 taf/yr, prepare plans showing how they will meet service area needs.

Geography plays a role in the feasibility of implementing different types of options, and not solely with respect to the availability of surface water and groundwater supplies. Water users in the Central Valley, Bay Area, and Southern California having access to major regional conveyance facilities have greater opportunities to rely on water marketing arrangements and conjunctive use options than do water users isolated from the State's main water infrastructure.

Bulletin 160-98 Findings

Bulletin 160-98 forecasts water shortages in California by 2020, as did the previous water plan update. The water management options identified in the Bulletin as likely to be implemented by 2020 would reduce, but not completely eliminate future shortages. Water agencies faced with meeting future needs must determine how those needs can be met within the statutory and regulatory framework affecting water use decisions, including how the needs can be met in a manner equitable to existing water users. Land use planning decisions made by cities and counties—locations where

Options identified as likely are still in the planning stages. Agencies implementing the options must complete environmental documentation and obtain the necessary permits. The permitting and environmental documentation process must consider impacts to listed species such as this San Joaquin Valley kit fox.

FIGURE ES5-2.
2020 Shortages by Hydrologic Region with Likely Options

future growth will or will not be allowed, housing densities, preservation goals for open space or agricultural reserves—will have a significant influence on California's future water demands. Good coordination among local land use planning agencies and water agencies, as well as among water agencies themselves at a regional level, will facilitate finding solutions to meeting future needs.

Bulletin 160-98 makes no specific recommendations regarding how California water purveyors should meet the needs of their service areas, because it is the water purveyors who are responsible for meeting those needs. The purpose of Bulletin 160-98 is to predict future water needs based on today's conditions. Clearly, different agencies and individuals have different perspectives about how the future should be shaped. The CALFED discussions, for example, illustrate conflicting values among individuals and agencies.

There is not one magic bullet for meeting California's future water needs—not new reservoirs, not new conveyance facilities, not more groundwater extraction, not more water conservation, not more water recycling. Each of these options has its place. The most frequently used methods of providing new water supplies have changed with the times, reflecting changing circumstances. Much of California's early water development was achieved by constructing reservoirs and diverting surface water. Advances in technology, in the form of deep well turbine pumps, subsequently allowed substantial groundwater development. More recent improvements in water treatment technology have made water recycling and desalting feasible options. Today, water purveyors have an array of water management options available to meet future water supply reliability needs. The magnitude of potential shortages, especially drought year shortages, demonstrates the urgency of taking action. The do-nothing alternative is not an alternative that will meet the needs of 47.5 million Californians in 2020.

California water agencies have made great strides in water conservation since the 1976-77 drought. Bulletin 160-98 forecasts substantial demand reduction from implementing presently identified urban BMPs and agricultural EWMPs, and assumes a more rigorous level of implementation than water agencies are now obligated to perform. Presently, about half of California's urban population is served by retailers that have signed the urban memorandum of understanding for water conservation measures. Less than one-third of California's agricultural lands are served by agencies that have signed the corresponding agricultural MOU. Bulletin 160-98 assumes that all water purveyors statewide will implement BMPs and EWMPs by 2020, even if the actions are not cost-effective from a water supply perspective. Water conservation offers multipurpose benefits such as reduced urban water treatment costs and potential reduction of fish entrainment at diversion structures. The Bulletin also identifies as likely additional demand reduction measures that would create new water and would be cost-competitive with supply augmentation options. These optional demand reductions are almost as large as the average year water supply augmentation options planned by local agencies.

California water agencies have also made great strides in water recycling. As discussed earlier, the new water supply produced from recycling has almost doubled between 1990 and 1995. By 2020, recycling could potentially contribute almost 1.4 maf of total water to the State's supplies, which would exceed the goal expressed in Section 13577 of the Water Code that total recycling statewide be 1 maf by 2010. (The potential 2020 recycling of 1.4 maf would represent about 2 percent of the State's 2020 water supply.) Water recycling offers multipurpose benefits, such as reduction of treatment plant discharges to waterbodies. Cost is a limiting factor in implementing recycling projects. Bulletin 160-98 forecasts that projects implemented by local agencies by 2020 will increase the State's new water supply from recycling to about 0.8 maf.

Clearly, conservation and recycling alone are not sufficient to meet California's future needs. Bulletin 160-98 has included all of the conservation and recycling measures likely to be implemented by 2020. Adding supply augmentation options identified by California's water purveyors still leaves a shortfall in meeting forecasted future demands. Review of local agencies' likely supply augmentation options shows that relatively few larger-scale or regional programs are in active planning, especially among small and mid-size water agencies. This outcome reflects local agencies' concerns about perceived implementability constraints associated with larger-scale options, and their affordability.

In the interests of maintaining California's vibrant economy, it is important that the State take an active role in assisting water agencies in meeting their future needs. New storage facilities are an important part of the mix of options needed to meet California's future needs. Just as water conservation and recycling provide multiple benefits, storage facilities offer flood control, power generation, and recreation in addition to water supply benefits. The devastating January 1997 floods in the Central Valley emphasized the need for increased attention to flood control. It is important for small and mid-size water agencies who could not develop such facilities on their own to have access to participation in regional projects. The more diversified water agencies' sources of supply are, the better their odds of improved water supply reliability.

An appropriate State role would be for the Department to take the lead in performing feasibility studies of potential storage projects—not on behalf of the SWP, but on behalf of all potentially interested water agencies. State funding support is needed to identify likely projects, so that local agencies may determine how those projects might benefit their service areas. In concept, the Department could use State funding to complete project feasibility studies, permitting, and environmental documentation for likely new storage facilities, removing uncertainties that would prevent smaller water agencies from funding planning studies themselves. Agencies wishing to participate in projects shown to be feasible would repay their share of the State planning costs as a condition of participation in a project. Feasible projects would likely be constructed by a consortium of local agencies acting through a joint powers agreement or other contractual mechanism.

Meeting California's future needs will require cooperation among all levels of government—federal, State, and local. Likewise, all three of California's water-using sectors—agricultural, environmental, and urban—must work together to recognize each others' legitimate needs and to seek solutions to meeting the State's future water shortages. When the Bay-Delta Accord was signed in 1994, it was hailed as a truce in, if not an end to, one of the State's longstanding water wars. The Accord, and the efforts by California agencies to negotiate a resolution to interstate and intrastate Colorado River water issues, represent a new spirit of fostering cooperation and consensus rather than competition and conflict. Such an approach will be increasingly necessary, given the magnitude of the water shortages facing California. Mutual accommodation of each others' needs is especially important in drought years, when water purveyors face the greatest water supply challenges. With continued efforts to prepare for the future, California can have safe and reliable water supplies for urban areas, adequate long-term water supplies to maintain the State's agricultural economy, and restoration and protection of fish and wildlife habitat.

5A

Regional Water Budgets with Existing Facilities and Programs

The following tables show the water budgets for each of the State's ten hydrologic regions with existing facilities and programs. Water use/supply totals and shortages may not sum due to rounding.

TABLE ES5A-1

North Coast Region Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	169	177	201	212
Agricultural	894	973	927	1,011
Environmental	19,544	9,518	19,545	9,518
Total	**20,607**	**10,668**	**20,672**	**10,740**
Supplies				
Surface Water	20,331	10,183	20,371	10,212
Groundwater	263	294	288	321
Recycled and Desalted	13	14	13	14
Total	**20,607**	**10,491**	**20,672**	**10,546**
Shortage	**0**	**177**	**0**	**194**

TABLE ES5A-2

San Francisco Bay Region Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	1,255	1,358	1,317	1,428
Agricultural	98	108	98	108
Environmental	5,762	4,294	5,762	4,294
Total	**7,115**	**5,760**	**7,176**	**5,830**
Supplies				
Surface Water	7,011	5,285	7,067	5,417
Groundwater	68	92	72	89
Recycled and Desalted	35	35	37	37
Total	**7,115**	**5,412**	**7,176**	**5,543**
Shortage	**0**	**349**	**0**	**287**

TABLE ES5A-3

Central Coast Region Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	286	294	379	391
Agricultural	1,192	1,279	1,127	1,223
Environmental	118	37	118	37
Total	**1,595**	**1,610**	**1,624**	**1,652**
Supplies				
Surface Water	318	160	368	180
Groundwater	1,045	1,142	1,041	1,159
Recycled and Desalted	18	26	42	42
Total	**1,381**	**1,328**	**1,452**	**1,381**
Shortage	**214**	**282**	**172**	**270**

TABLE ES5A-4

South Coast Region Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	4,340	4,382	5,519	5,612
Agricultural	784	820	462	484
Environmental	100	82	104	86
Total	**5,224**	**5,283**	**6,084**	**6,181**
Supplies				
Surface Water	3,839	3,196	3,625	3,130
Groundwater	1,177	1,371	1,243	1,462
Recycled and Desalted	207	207	273	273
Total	**5,224**	**4,775**	**5,141**	**4,865**
Shortage	**0**	**508**	**944**	**1,317**

TABLE ES5A-5

Sacramento River Region Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	766	830	1,139	1,236
Agricultural	8,065	9,054	7,939	8,822
Environmental	5,833	4,223	5,839	4,225
Total	**14,664**	**14,106**	**14,917**	**14,282**
Supplies				
Surface Water	11,881	10,022	12,196	10,012
Groundwater	2,672	3,218	2,636	3,281
Recycled and Desalted	0	0	0	0
Total	**14,553**	**13,239**	**14,832**	**13,293**
Shortage	**111**	**867**	**85**	**989**

TABLE ES5A-6

San Joaquin River Region Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	574	583	954	970
Agricultural	7,027	7,244	6,450	6,719
Environmental	3,396	1,904	3,411	1,919
Total	**10,996**	**9,731**	**10,815**	**9,609**
Supplies				
Surface Water	8,562	6,043	8,458	5,986
Groundwater	2,195	2,900	2,295	2,912
Recycled and Desalted	0	0	0	0
Total	**10,757**	**8,943**	**10,753**	**8,898**
Shortage	**239**	**788**	**63**	**711**

TABLE ES5A-7

Tulare Lake Region Water Budget with Existing Facilities and Programs (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	690	690	1,099	1,099
Agricultural	10,736	10,026	10,123	9,532
Environmental	1,672	809	1,676	813
Total	**13,098**	**11,525**	**12,897**	**11,443**
Supplies				
Surface Water	7,888	3,693	7,791	3,593
Groundwater	4,340	5,970	4,386	5,999
Recycled and Desalted	0	0	0	0
Total	**12,228**	**9,663**	**12,177**	**9,592**
Shortage	**870**	**1,862**	**720**	**1,851**

TABLE ES5A-8

North Lahontan Region Water Budget with Existing Facilities and Programs (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	39	40	50	51
Agricultural	530	584	536	594
Environmental	374	256	374	256
Total	**942**	**880**	**960**	**901**
Supplies				
Surface Water	777	557	759	557
Groundwater	157	187	183	208
Recycled and Desalted	8	8	8	8
Total	**942**	**752**	**950**	**773**
Shortage	**0**	**128**	**10**	**128**

TABLE ES5A-9

South Lahontan Region Water Budget with Existing Facilities and Programs (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	238	238	619	619
Agricultural	332	332	257	257
Environmental	107	81	107	81
Total	**676**	**651**	**983**	**957**
Supplies				
Surface Water	322	259	437	326
Groundwater	239	273	248	296
Recycled and Desalted	27	27	27	27
Total	**587**	**559**	**712**	**649**
Shortage	**89**	**92**	**270**	**308**

TABLE ES5A-10

Colorado River Region Water Budget with Existing Facilities and Programs (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	418	418	740	740
Agricultural	4,118	4,118	3,583	3,583
Environmental	39	38	44	43
Total	**4,575**	**4,574**	**4,367**	**4,366**
Supplies				
Surface Water	4,154	4,128	3,920	3,909
Groundwater	337	337	285	284
Recycled and Desalted	15	15	15	15
Total	**4,506**	**4,479**	**4,221**	**4,208**
Shortage	**69**	**95**	**147**	**158**

5B

Regional Water Budgets with Options Likely to be Implemented

The following tables show the water budgets for each of the State's ten hydrologic regions with options likely to be implemented. Water use/supply totals and shortages may not sum due to rounding.

TABLE ES5B-1

North Coast Region Water Budget with Options (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	169	177	201	194
Agricultural	894	973	927	1,011
Environmental	19,544	9,518	19,545	9,518
Total	**20,607**	**10,668**	**20,672**	**10,722**
Supplies				
Surface Water	20,331	10,183	20,371	10,212
Groundwater	263	294	288	321
Recycled and Desalted	13	14	13	14
Total	**20,607**	**10,491**	**20,672**	**10,546**
Shortage	**0**	**177**	**0**	**176**

TABLE ES5B-2

San Francisco Bay Region Water Budget with Options (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	1,255	1,358	1,317	1,371
Agricultural	98	108	98	108
Environmental	5,762	4,294	5,762	4,294
Total	**7,115**	**5,760**	**7,176**	**5,773**
Supplies				
Surface Water	7,011	5,285	7,067	5,607
Groundwater	68	92	72	96
Recycled and Desalted	35	35	37	70
Total	**7,115**	**5,412**	**7,176**	**5,773**
Shortage	**0**	**349**	**0**	**0**

TABLE ES5B-3

Central Coast Region Water Budget with Options (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	286	294	347	359
Agricultural	1,192	1,279	1,127	1,223
Environmental	118	37	118	37
Total	**1,595**	**1,610**	**1,592**	**1,620**
Supplies				
Surface Water	318	160	477	287
Groundwater	1,045	1,142	1,043	1,161
Recycled and Desalted	18	26	71	71
Total	**1,381**	**1,328**	**1,592**	**1,519**
Shortage	**214**	**282**	**0**	**100**

TABLE ES5B-4

South Coast Region Water Budget with Options (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	4,340	4,382	5,435	5,528
Agricultural	784	820	455	477
Environmental	100	82	104	86
Total	**5,224**	**5,283**	**5,993**	**6,090**
Supplies				
Surface Water	3,839	3,196	4,084	3,832
Groundwater	1,177	1,371	1,243	1,592
Recycled and Desalted	207	207	667	667
Total	**5,224**	**4,775**	**5,994**	**6,090**
Shortage	**0**	**508**	**0**	**0**

TABLE ES5B-5

Sacramento River Region Water Budget with Options (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	766	830	1,139	1,236
Agricultural	8,065	9,054	7,939	8,822
Environmental	5,833	4,223	5,839	4,225
Total	**14,664**	**14,106**	**14,917**	**14,282**
Supplies				
Surface Water	11,881	10,022	12,282	10,279
Groundwater	2,672	3,218	2,636	3,281
Recycled and Desalted	0	0	0	0
Total	**14,553**	**13,239**	**14,918**	**13,560**
Shortage	**111**	**867**	**0**	**722**

TABLE ES5B-6

San Joaquin River Region Water Budget with Options (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	574	583	954	970
Agricultural	7,027	7,244	6,448	6,717
Environmental	3,396	1,904	3,411	1,919
Total	**10,996**	**9,731**	**10,813**	**9,607**
Supplies				
Surface Water	8,562	6,043	8,497	6,029
Groundwater	2,195	2,900	2,317	2,920
Recycled and Desalted	0	0	0	0
Total	**10,757**	**8,943**	**10,814**	**8,949**
Shortage	**239**	**788**	**0**	**658**

TABLE ES5B-7

Tulare Lake Region Water Budget with Options (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	690	690	1,099	1,099
Agricultural	10,736	10,026	10,106	9,515
Environmental	1,672	809	1,676	813
Total	**13,098**	**11,525**	**12,880**	**11,426**
Supplies				
Surface Water	7,888	3,693	8,292	4,167
Groundwater	4,340	5,970	4,386	6,391
Recycled and Desalted	0	0	0	0
Total	**12,228**	**9,663**	**12,678**	**10,558**
Shortage	**870**	**1,862**	**202**	**868**

TABLE ES5B-8

North Lahontan Region Water Budget with Options (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	39	40	50	51
Agricultural	530	584	536	594
Environmental	374	256	374	256
Total	**942**	**880**	**960**	**901**
Supplies				
Surface Water	777	557	759	557
Groundwater	157	187	183	208
Recycled and Desalted	8	8	8	8
Total	**942**	**752**	**950**	**773**
Shortage	**0**	**128**	**10**	**128**

TABLE ES5B-9

South Lahontan Region Water Budget with Options (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	238	238	568	568
Agricultural	332	332	252	252
Environmental	107	81	107	81
Total	**676**	**651**	**927**	**901**
Supplies				
Surface Water	322	259	651	578
Groundwater	239	273	248	296
Recycled and Desalted	27	27	27	27
Total	**587**	**559**	**926**	**901**
Shortage	**89**	**92**	**0**	**0**

TABLE ES5B-10

Colorado River Region Water Budget with Options (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	418	418	715	715
Agricultural	4,118	4,118	3,393	3,393
Environmental	39	38	44	43
Total	**4,575**	**4,574**	**4,152**	**4,151**
Supplies				
Surface Water	4,154	4,128	3,852	3,852
Groundwater	337	337	285	284
Recycled and Desalted	15	15	15	15
Total	**4,506**	**4,479**	**4,152**	**4,151**
Shortage	**69**	**95**	**0**	**0**

Abbreviations and Acronyms

A

AB	Assembly Bill
AAC	All American Canal
ACID	Anderson-Cottonwood Irrigation District
ACWD	Alameda County Water District
AD	allowable depletion
ADWR	Arizona Department of Water Resources
AEWSD	Arvin-Edison Water Storage District
af	acre-foot/acre-feet
AFB	Air Force Base
AFRP	Anadromous fish restoration program (or plan)
AMD	acid mine drainage
AOP	advanced oxidation process
APCD	air pollution control district
ARP	aquifer reclamation program
ARWI	American River Watershed Investigation
ARWRI	American River Water Resources Investigation
ASR	aquifer storage and recovery
AVEK	Antelope Valley-East Kern Water Agency
AVWG	Antelope Valley Water Group

B

BARWRP	Bay Area regional water recycling program
BAT	best available technology
BBID	Byron-Bethany Irrigation District
BDAC	Bay-Delta Advisory Council
B/C	benefit-to-cost (ratio)
BLM	Bureau of Land Management
BMP	Best management practice
BVWSD	Buena Vista Water Storage District
BWD	Bard Water District
BWRDF	Brackish water reclamation demonstration facility

C

CAL-AM	California-American Water Company
Cal/EPA	California Environmental Protection Agency
CALFED	State (CAL) and federal (FED) agencies participating in Bay-Delta Accord
CAP	Central Arizona Project
CAWCD	Central Arizona Water Conservation District
CCID	Central California Irrigation District
CCMP	Comprehensive conservation and management plan
CCWD	Colusa County Water District or Contra Costa Water District
CDI	capacitive deionization
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
cfs	cubic feet per second
CII	commercial, industrial, and institutional
CIMIS	California irrigation management information system
CLWA	Castaic Lake Water Agency
CMWD	Calleguas Municipal Water District
COA	Coordinated Operation Agreement
COG	Council of Governments
CMO	crop market outlook
COP	certificate of participation
CPUC	California Public Utilities Commission
CRA	Colorado River Aqueduct
CRB	Colorado River Board
CRIT	Colorado River Indian Tribes
CSD	community services district
CSIP/SVRP	Castroville Seawater Intrusion Project/ Salinas Valley Reclamation Project
CSJWCD	Central San Joaquin Water Conservation District
CUWCC	California Urban Water Conservation Council

CVHJV	Central Valley Habitat Joint Venture
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVPM	Central Valley production model
CVWD	Coachella Valley Water District
CWA	Clean Water Act
CWD	Coastal Water District, Cawelo Water District, or county water district

D

D-1485	State Water Resources Control Board Water Right Decision 1485
DAU	detailed analysis unit
DBCP	dibromochloropropane
DBP	disinfection by-products
DCID	Deer Creek Irrigation District
D/DBP	disinfectant/disinfection by-product
DDT	dichloro diphenyl trichloroethane
DEIR	draft environmental impact report
DEIS	draft environmental impact statement
DFA	California Department of Food and Agriculture
DFG	California Department of Fish and Game
DHS	California Department of Health Services
DMC	Delta-Mendota Canal
DOE	Department of Energy
DOF	California Department of Finance
DOI	Department of the Interior
DPR	Department of Parks and Recreation or Department of Pesticide Regulation
DU	distribution uniformity
DWA	Desert Water Agency
DWB	DWR's Drought Water Bank
DWD	Diablo Water District
DWR	California Department of Water Resources
DWRSIM	DWR's operations model for SWP/CVP system

E

EBMUD	East Bay Municipal Utility District
ec	electrical conductivity
ECCID	East Contra Costa Irrigation District
ECWMA	East County Water Management Association
ED	electrodialysis
EDB	ethylene dibromide
EDCWA	El Dorado County Water Agency
EDF	Environmental Defense Fund
EDR	electrodialysis reversal
EID	El Dorado Irrigation District
EIR	environmental impact report
EIS	environmental impact statement
ENSO	El Niño Southern Oscillation cycle
EPA	U.S. Environmental Protection Agency or Energy Policy Act of 1992
ERP	ecosystem restoration program or plan
ESA	Endangered Species Act
ESP	emergency storage project
ESU	evolutionarily significant unit
ESWTR	Enhanced Surface Water Treatment Rule
ET	evapotranspiration
ET_o	reference evapotranspiration
ETAW	evapotranspiration of applied water
EWMP	efficient water management practice

F

FAIRA	Federal Agriculture Improvement and Reform Act
FC&WCD	flood control and water conservation district
FCD	flood control district
FERC	Federal Energy Regulatory Commission
FY	fiscal year

G

GAC	granular activated carbon
GBUAPCD	Great Basin Unified Air Pollution Control District
GCID	Glenn-Colusa Irrigation District
GDPUD	Georgetown Divide Public Utility District
GO	general obligation
gpcd	gallons per capita per day
gpf	gallons per flush
gpm	gallons per minute

H

HCP	habitat conservation plan
HLWA	Honey Lake Wildlife Area
HR	House Resolution
HUD	Department of Housing and Urban Development

I

IBWC	International Boundary and Water Commission
ICR	information collection rule
ID	irrigation district or improvement district
IE	irrigation efficiency
IEP	Interagency Ecological Program
IID	Imperial Irrigation District
IOT	intake opportunity time
IRP	integrated resources planning
IRWD	Irvine Ranch Water District
ISDP	Interim South Delta Program

J

JPA	joint powers authority

K

KCWA	Kern County Water Agency
KPOP	Klamath Project Operations Plan
KRCC	Klamath River Compact Commission
KWB	Kern Water Bank
KWBA	Kern Water Bank Authority
kWh	kilowatt hour

L

LAA	Los Angeles Aqueduct
LADWP	Los Angeles Department of Water and Power
LAFCO	local agency formation commission
LBG	Los Banos Grandes
LCRMSCP	Lower Colorado River Multi-Species Conservation Program
LEPA	low-energy precision application
LMMWC	Los Molinos Mutual Water Company
LTBMU	Lake Tahoe Basin Management Unit

M

m	meter
maf	million acre-feet
MCL	maximum contaminant level
MCWD	Marina Coast Water District or Mammoth Community Water District
MCWRA	Monterey County Water Resources Agency
MF	microfiltration or Middle Fork
mgd	million gallons per day
mg/L	milligrams per liter
M&I	municipal & industrial
MID	Madera Irrigation District, Maxwell Irrigation District, Merced Irrigation District, or Modesto Irrigation District
MMWC	McFarland Mutual Water Company
MMWD	Marin Municipal Water District
MOU	memorandum of understanding
MPWMD	Monterey Peninsula Water Management District
MRWPCA	Monterey Regional Water Pollution Control Agency
MTBE	methyl tertiary butyl ether
MUD	municipal utility district
mW	megawatt
MWA	Mojave Water Agency
MWD	municipal water district
MWDOC	Municipal Water District of Orange County
MWDSC	Metropolitan Water District of Southern California

N

NAWMP	North American Waterfowl Management Plan
NCFC&WCD	Napa County Flood Control and Water Conservation District
NCMWC	Natomas-Central Mutual Water Company
NED	national economic development (plan)
NEPA	National Environmental Policy Act
NF	nanofiltration or North Fork
NGO	non-governmental organization
NID	Nevada Irrigation District
NISA	National Invasive Species Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOP	notice of preparation
NPDES	national pollutant discharge elimination system
NPDWR	national primary drinking water regulations
NRCS	Natural Resources Conservation Service
NTU	Nephelometric Turbidity Unit
NWD	Northridge Water District
NWR	National Wildlife Refuge

O

OCWD	Orange County Water District
OID	Oakdale Irrigation District
O&M	operations and maintenance

P

PAC	powdered activated carbon
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	perchloroethylene
PCGID/PID	Princeton-Codora-Glenn Irrigation District/Provident Irrigation District
PCWA	Placer County Water Agency
PEIR	programmatic environmental impact report
PEIS	programmatic environmental impact statement
PG&E	Pacific Gas and Electric Company
PGVMWC	Pleasant Grove-Verona Mutual Water Company
PL	Public Law
PMWC	Pelger Mutual Water Company
ppb	parts per billion
PROSIM	USBR's operations model for the CVP/SWP
PSA	planning subarea
psi	pounds per square inch
PTA	packed-tower aeration
PUC	public utility commission
PUD	public utility district
PVID	Palo Verde Irrigation District or Pleasant Valley Irrigation District
PVWMA	Pajaro Valley Water Management Agency
PWD	Palmdale Water District

R

RBDD	Red Bluff Diversion Dam
RCD	resource conservation district
RD	reclamation district
RDI	regulated deficit irrigation
RO	reverse osmosis
RWQCB	Regional Water Quality Control Board

S

SAE	seasonal application efficiency
SAFCA	Sacramento Area Flood Control Agency
SAWPA	Santa Ana Watershed Project Authority
SB	Senate Bill
SBCFC&WCD	Santa Barbara County Flood Control and Water Conservation District
SBVMWD	San Bernardino Valley Municipal Water District
SCCWRRS	Southern California comprehensive water reclamation and reuse study
SCE	Southern California Edison
SCVWD	Santa Clara Valley Water District
SCWA	Solano County Water Agency or Sonoma County Water Agency
SDCWA	San Diego County Water Authority
SDWA	Safe Drinking Water Act or South Delta Water Agency
SEIS	supplemental environmental impact statement
SEWD	Stockton East Water District
SF	South Fork
SFBJV	San Francisco Bay Joint Venture
SFEP	San Francisco Estuary Project
SFPUC	San Francisco Public Utility Commission
SFWD	San Francisco Water Department
SGPWA	San Gorgonio Pass Water Agency
SID	Solano Irrigation District
SJBAP	San Joaquin Basin Action Plan
SJRMP	San Joaquin River Management Plan (or Program)
SLC	San Luis Canal
SLD	San Luis Drain
SLDMWA	San Luis & Delta-Mendota Water Authority
SLOCFC&WCD	San Luis Obispo County Flood Control and Water Conservation District
SMBRP	Santa Monica Bay restoration project
SMUD	Sacramento Municipal Utility District
SNWA	Southern Nevada Water Authority
SOC	synthetic organic compound
SOFAR	South Fork American River (project)
SPPC	Sierra Pacific Power Company
SRCD	Suisun Resource Conservation District
SRF	state revolving fund
SRFCP	Sacramento River Flood Control Project
SRI	Sacramento River index
SSA	Salton Sea Authority
SSJID	South San Joaquin Irrigation District
SSWD	South Sutter Water District

STPUD	South Tahoe Public Utility District
SVGMD	Sierra Valley Groundwater Management District
SVOC	semi-volatile organic compound
SVRID	Stanford Vina Ranch Irrigation District
SVRP	Salinas Valley reclamation project
SWP	State Water Project
SWPP	source water protection program or supplemental water purchase program
SWRCB	State Water Resources Control Board
SWSD	Semitropic Water Storage District

T

taf	thousand acre-feet
TCC	Tehama-Colusa Canal
TCD	temperature control device
TCE	trichloroethylene
TDPUD	Tahoe Donner Public Utility District
TDS	total dissolved solids
THM	trihalomethane
TID	Turlock Irrigation District
TID-MID	Turlock Irrigation District and Modesto Irrigation District
TOC	total organic carbon
TROA	Truckee River Operating Agreement
TRPA	Tahoe Regional Planning Agency

U

UC	University of California
UCD	University of California at Davis
UF	ultrafiltration
ULFT	ultra low flush toilet
USBR	U.S. Bureau of Reclamation
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UV	ultraviolet
UWCD	United Water Conservation District

V

VAMP	Vernalis adaptive management plan
VOC	volatile organic compound

W

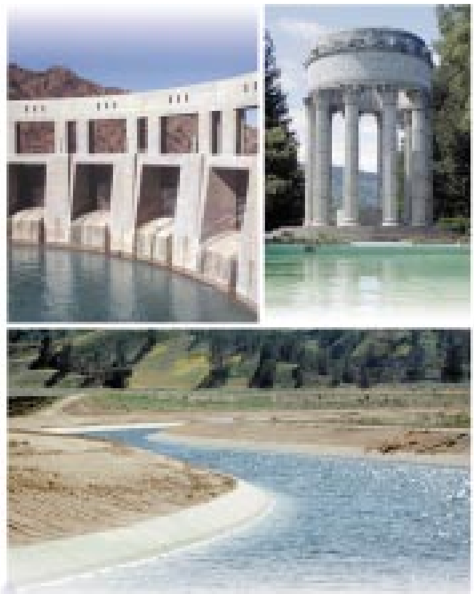
WA	water agency, water authority, or wildlife area
WCD	water conservation district
WCWD	Western Canal Water District
WD	water district
WMD	water management district
WMI	watershed management initiative
WQA	water quality authority
WQCP	water quality control plan
WR 95-6	SWRCB Order WR 95-6
WRCD	Westside Resource Conservation District
WRDA	Water Resources Development Act
WRF	water reclamation facility or water recycling facility
WRID	Walker River Irrigation District
WSD	water storage district
WTP	water treatment plant
WWD	Westlands Water District
WWTP	wastewater treatment plant

Y

YCFC&WCD	Yolo County Flood Control and Water Conservation District
YCWA	Yuba County Water Agency

Z

Z7WA	Zone 7 Water Agency



CALIFORNIA WATER PLAN UPDATE BULLETIN 160-98

Volume 1

November 1998

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Foreword

. . .

In 1957, the Department published Bulletin 3, the *California Water Plan*. Bulletin 3 was followed by the Bulletin 160 series, published six times between 1966 and 1993, updating the *California Water Plan*. A 1991 amendment to the California Water Code directed the Department to update the plan every five years. Bulletin 160-98 is the latest in the series. The Bulletin 160 series assesses California's water needs and evaluates water supplies, to quantify the gap between future water demands and water supplies. The series presents a statewide overview of current water management activities and provides water managers with a framework for making decisions.

In response to public comments on the last update, Bulletin 160-93, this 1998 update evaluates water management options that could improve California's water supply reliability. Water management options being planned by local agencies form the building blocks for evaluations performed for each of the State's ten major hydrologic regions. Local options are integrated into a statewide overview that illustrates potential progress in reducing the State's expected future water shortages.

When the previous water plan update was released, California was just emerging from a six-year drought. This update follows the largest and most extensive flood disaster in California's history, the January 1997 floods. These two hydrologic events fittingly illustrate the complexity of water management in the State.

The Department appreciates the assistance provided by the Bulletin 160-98 public advisory committee, which met with the Department over a three-year period as the Bulletin was being prepared. The Department also appreciates the assistance provided by the many local water agencies who furnished information about their planned water management activities.

David N. Kennedy
Director

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The California Water Commission serves as a policy advisory body to the Director of the Department of Water Resources on all California water resources matters. The nine-member citizen commission provides a water resources forum for the people of the State, acts as a liaison between the legislative and executive branches of State government, and coordinates federal, State, and local water resources efforts.

1

Introduction

In 1957, the Department published Bulletin 3, the *California Water Plan*. Bulletin 3 was followed by the Bulletin 160 series, published six times between 1966 and 1993, updating the *California Water Plan*. A 1991 amendment to the California Water Code directed the Department to update the plan every five years. Bulletin 160-98 is the latest in the series.

The Bulletin 160 series assesses California's agricultural, environmental, and urban water needs and evaluates water supplies, in order to quantify the gap between future water demands and the corresponding water supplies. The series presents a statewide overview of current water management activities and provides water managers with a framework for making water resources decisions.

While the basic scope of the Department's water plan updates has remained unchanged, each update has taken a distinct approach to water resources planning, reflecting issues or concerns at the time of its publication. In response to public comments on the last update, Bulletin 160-93, the 1998 update evaluates water management actions that could be implemented to improve California's water supply reliability. Bulletin 160-93 analyzed 2020 agricultural, environmental, and urban water demands in considerable detail. These demands, together with water supply information, have been updated for the 1998 Bulletin, which also uses a 2020 planning horizon. However, much of Bulletin 160-98 is devoted to identifying and analyzing options for improving water supply reliability. Water management options available to, and being considered by, local agencies form the building

The Department's Bulletin 160 series quantifies California's managed or dedicated water uses—urban, agricultural, and environmental uses. Unmanaged uses, such as the precipitation consumed by native plants, are not quantified.

blocks of evaluations prepared for each of the State's ten major hydrologic regions. (Water supplies provided by local agencies represent about 70 percent of California's developed water supplies.) These potential local options are integrated with options that are statewide in scope, such as the CALFED Bay-Delta program, to create a statewide evaluation.

The statewide evaluation represents a snapshot, at an appraisal level of detail, of how actions planned by California water managers could reduce the gap between supplies and demands. The evaluation does not present potential measures to reduce all shortages statewide to zero in 2020. Such an approach would not reflect economic realities and current planning by local agencies. Not all areas of the State and not all water users can afford to reduce drought year shortages to zero. Bulletin 160-98 focuses on compiling those options that appear to have a reasonable chance of being implemented by water suppliers, to illustrate potential progress in reducing the State's future shortages.

Bulletin 160-98 estimates that California's water shortages at a 1995 level of development are 1.6 maf in average water years, and 5.1 maf in drought years. (As described later in the Bulletin, shortages represent the difference between water supplies and water demands.) The magnitude of shortages shown for drought conditions in the base year reflects the cutbacks in supply experienced by California water users during the recent six-year drought. Bulletin 160-98 forecasts increased shortages by 2020—2.4 maf in average water years and 6.2 maf in drought years. The future water management options identified as likely to be implemented could reduce those shortages to 0.2 maf in average water years and 2.7 maf in drought years.

The accompanying sidebar summarizes key statistics developed later in the Bulletin, to provide the reader with an overview of California's water uses.

California—An Overview

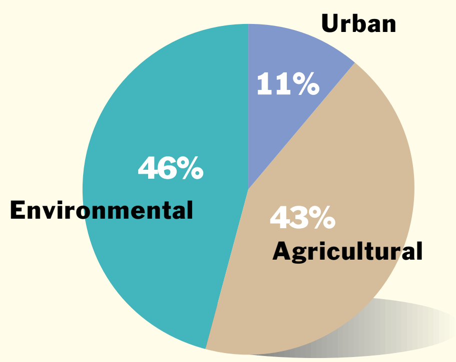
Figure 1-1 shows California's size relative to that of the contiguous 48 states. California is the nation's most populous state and is also the top-ranked state in dollar value of agricultural production. Although California's present population is over 33 million people, the State still has large areas of open space and

Summary of Key Statistics

Shown below for quick reference are some key statistics presented in Chapter 4. Water use information is based on average water year conditions. The details behind the statistics are discussed later.

	1995	*2020 Forecast*	*Change*
Population (million)	32.1	47.5	+15.4
Irrigated crops (million acres)	9.5	9.2	-0.3
Urban water use (maf)	8.8	12.0	+3.2
Agricultural water use (maf)	33.8	31.5	-2.3
Environmental water use (maf)	36.9	37.0	+0.1

1995



2020

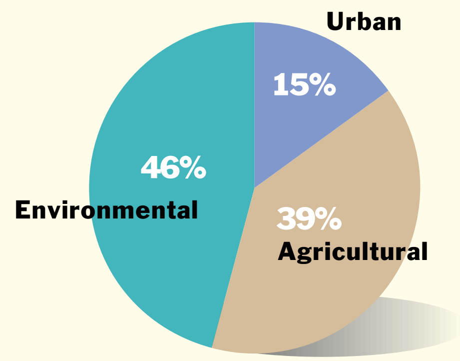


FIGURE 1-1.
California in Relation to the United States

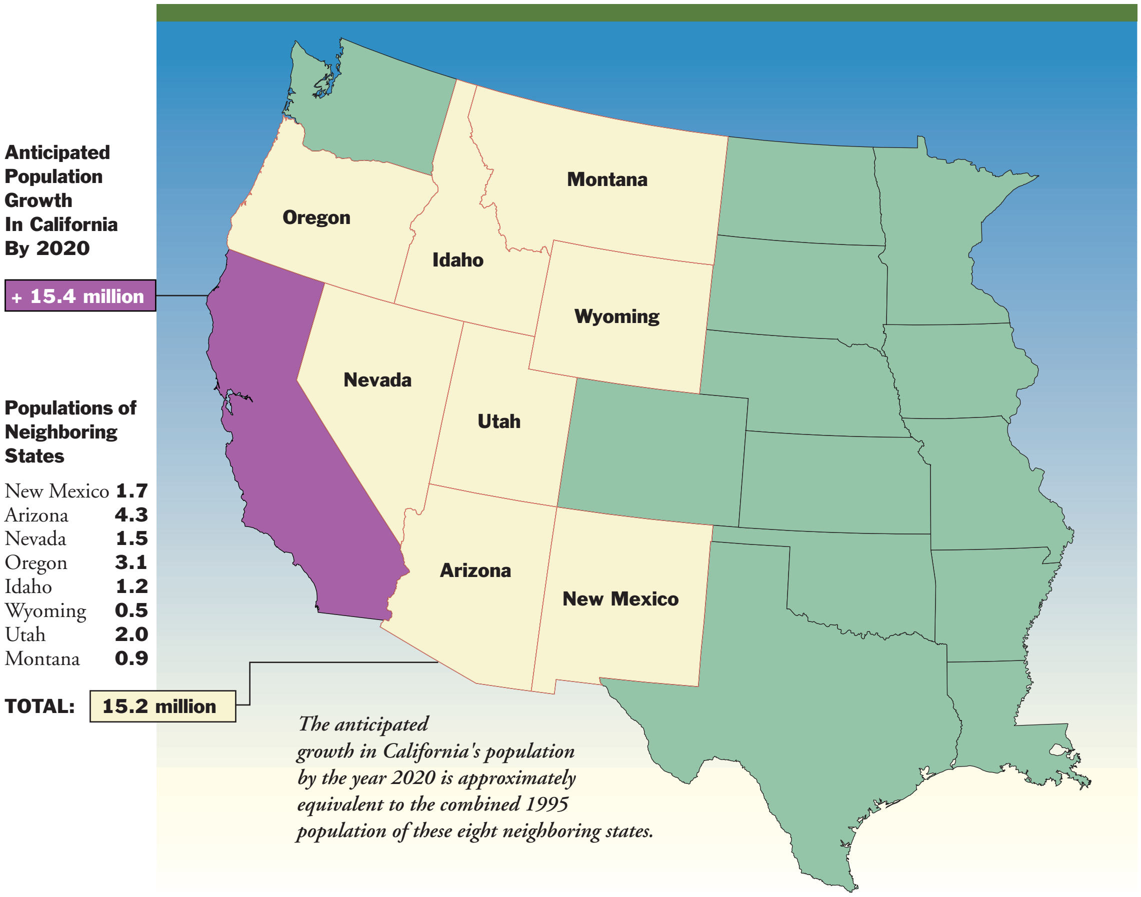
lands set aside for public use and enjoyment, including 18 national forests, 23 units of the national park system, and 355 units of the state park system. California is a state of great contrasts. Population density ranges from over 16,000 people per square mile in the City and County of San Francisco to less than 2 people per square mile in Alpine County. The highest (Mount Whitney) and lowest (Death Valley) points in the contiguous United States are located not far from each other in California. The State's average annual precipitation ranges from more than 90 inches on the North Coast to about 2 inches in Death Valley.

To put California's population into perspective, about one of every eight U.S. residents now lives in California. During the time period covered in the Bulletin (the 25 years from 1995 to 2020), California's population is forecast to increase by more than 15 million people, the equivalent of adding the present populations of Arizona, Nevada, Oregon, Idaho, Montana, Wyoming, New Mexico, and Utah to California,

Yosemite National Park is one of the U.S. Park Service's most popular facilities. Here, Half Dome is seen from the Merced River.

FIGURE 1-2.

California's Expected Population Growth Versus Neighboring States' Populations



as shown in Figure 1-2. Today, four of the nation's 15 largest cities (Los Angeles, San Diego, San Jose, and San Francisco) are located in the State.

California's population and abundant natural resources have helped create the State's trillion-dollar economy which, according to the California Trade and Commerce Agency, ranks seventh among world economic powers. California's water resources have helped it maintain its status as the nation's top agricultural state for 50 consecutive years. It is the nation's leading agricultural export state, the sixth largest agricultural exporter in the world, the nation's number one dairy state, and the producer of 55 percent of the nation's fruits, nuts, and vegetables. California is the primary U.S. producer of specialty crops such as almonds, artichokes, dates, figs, kiwifruit, olives, pistachios, and walnuts. Ten of the top 15 agricultural counties in the U.S. are in California.

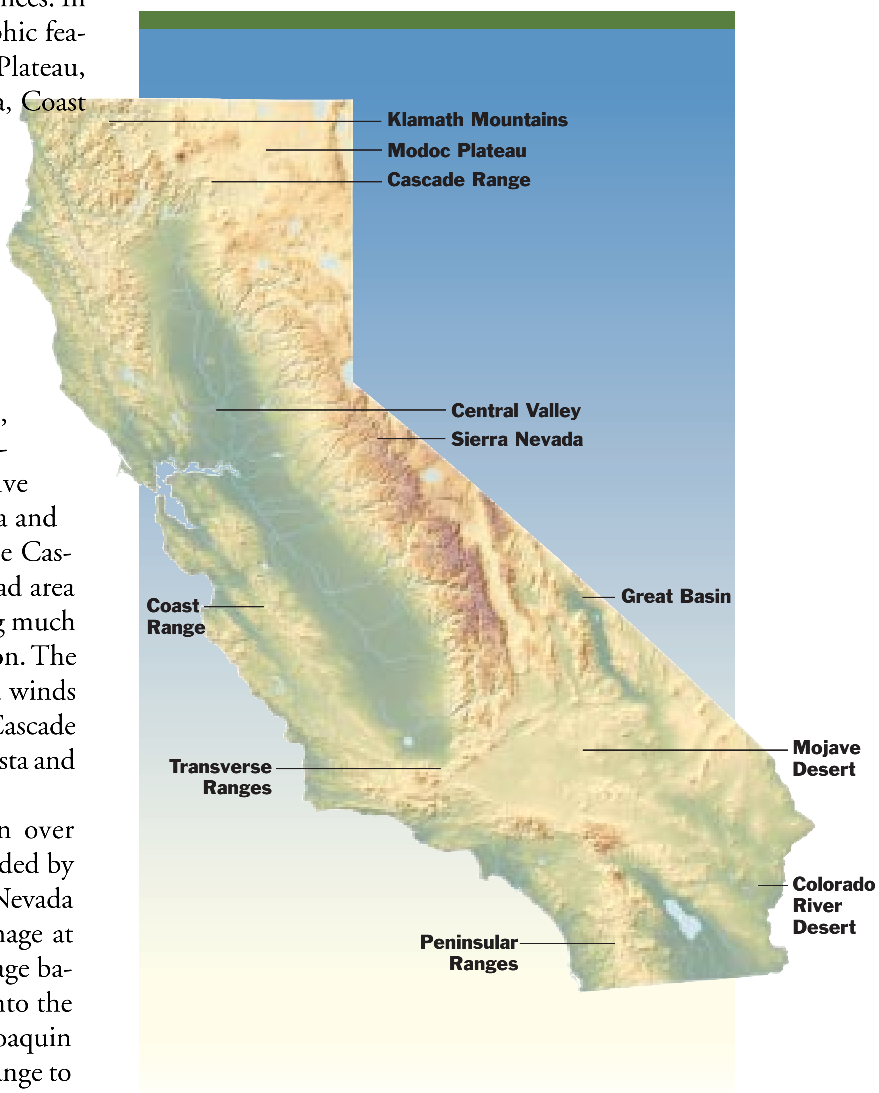
Despite the State's increasing human population, many species of wildlife still call California home. Some of the larger animal species that frequently coexist with suburban development, like this opossum, are nocturnal. Suburban residents thus may not realize how widespread these species are.

Mount Shasta, a Cascade Range volcano, dominates the horizon in the northern Sacramento Valley.

California is a state of diverse climates and landforms. Figure 1-3 is a relief map of California illustrating the State's major geomorphic provinces. In roughly north to south order, major geomorphic features are: the Klamath Mountains, Modoc Plateau, Cascade Range, Central Valley, Sierra Nevada, Coast Range, Great Basin, Transverse Ranges, Mojave Desert, Peninsular Ranges, and Colorado River Desert.

FIGURE 1-3.

Relief Map of California



The Klamath Mountains are a rugged mountain range on the California-Oregon border. To the east, the Cascade Range is a chain of volcanic cones that stretches from California into Washington. Until the 1980 eruption of Mount St. Helens in Washington, Mount Lassen (the southernmost of the Cascade volcanos) was the most recently active volcano in the United States outside of Alaska and Hawaii. The Modoc Plateau to the east of the Cascade Range is the southernmost part of a broad area of lava flows and small volcanic cones covering much of eastern Oregon and southeastern Washington. The Pit River, a major Sacramento River tributary, winds through the Modoc Plateau and crosses the Cascade Range between two of its major volcanos—Shasta and Lassen.

The Central Valley is an alluvial basin over 400 miles long by about 50 miles wide, bounded by the Coast Range on the west and the Sierra Nevada on the east. Except for the Tulare Lake drainage at the southern end of the valley (a closed drainage basin), rivers draining the Sierra Nevada flow onto the valley floor, join with the Sacramento or San Joaquin Rivers, and flow through a gap in the Coast Range to San Francisco Bay. The Central Valley provides about

80 percent of the State's agricultural production. The Sierra Nevada is a fault block mountain range whose western slopes are marked by deep river-cut canyons. Sierran rivers furnish much of California's developed surface water supplies.

The Coast Ranges are bounded on the north by the Klamath Mountains and on the south by the Transverse Ranges. The San Andreas Fault is a prominent geologic feature of the Coast Ranges; its path can readily be traced in areas where faulting has controlled the direction of watercourses such as the Gualala River on the North Coast. The San Andreas Fault extends into the San Bernardino Mountains of the Transverse Ranges geomorphic province (so called because these mountain ranges trend east-west). The Peninsular Ranges (which trend north-south) are a cluster of ranges separated by long valleys dividing, for example, the Riverside area from the Los Angeles coastal plain.

The western edge of the Mojave Desert is delineated by the Garlock Fault and by a portion of the San Andreas Fault. The Mojave is a region of interior drainage characterized by large areas of alluvium with scattered areas of recent volcanic features. The Mojave has numerous playa lakes, including Silver Lake, the terminus of the Mojave River. The Colorado River Desert to the south, also a closed drainage basin, is a lower elevation desert whose most prominent feature is the Salton Sea, which occupies a structural trough.

The Great Basin (also called the Basin and Range province) begins on the east side of California's Sierra Nevada and extends across Nevada and into Utah. Also a region of interior drainage, it is characterized by fault block mountain ranges separated by roughly north-south trending valleys, such as Owens Valley and Death Valley.

Figure 1-4 shows the location of the State's major water projects. The federal Central Valley Project is the largest water project in California and the Department's State Water Project is the second largest. (Descriptions of these, and of some of the larger local water projects, are provided in Chapter 3.) The

Looking out toward the floor of Death Valley from Zabriskie Point. Borate minerals concentrated by centuries of evaporation on the valley floor were mined here in the 1800s and hauled from the valley by mule teams.

California's Largest Water Retailers

Shown below are some of the largest annual retail water deliveries by local agencies, to illustrate the magnitude of urban and agricultural water demands. Retail delivery is the water supplied to an individual urban or agricultural customer. (Local agencies that wholesale water, such as Metropolitan Water District of Southern California or the City and County of San Francisco, have larger annual deliveries than the amounts shown here.)

Historical Maximum Annual Retail Water Deliveries

Water Agency	*Year*	*Delivery (taf)*
Agricultural		
Imperial Irrigation District	1996	2,846
Westlands Water District	1984	1,444
Glenn-Colusa Irrigation District	1984	831
Turlock Irrigation District	1976	687
Fresno Irrigation District	1995	627
Urban		
Los Angeles Department of Water and Power	1986[a]	706
City of San Diego	1989	257
East Bay Municipal Utility District	1976	249
San Jose Water Company	1987	128
City of Fresno	1996	125

[a] For fiscal year from July 1986 to June 1987.

FIGURE 1-4.

California's Major Water Projects

sidebars highlight California's largest waterbodies and provide information on historic water deliveries by California's largest water retailers, to provide a perspective on California's water resources and water use.

Bulletin 160-98 Hydrologic Regions

Figure 1-5 shows California's hydrologic regions. The Department subdivides the State into regions for planning purposes. The largest planning unit is the hydrologic region, a unit used extensively in this Bulletin. California has ten hydrologic regions, corresponding to the State's major drainage basins. The next level of delineation below hydrologic regions is the planning subarea. Some of the regional water management plans in Chapters 7-9 discuss information at the PSA level. The smallest study unit used by the Department is the detailed analysis unit. California is divided into 278 DAUs. Most of the Department's

California Water Statistics

California's Largest Lakes, Reservoirs, and Rivers

Natural (Undammed) Lakes

Lake	Storage Capacity (taf)	Comments
Salton Sea	7,500	At water surface elevation of -226 feet. This is a saline lake.
Mono Lake	2,620	At water surface elevation of 6,383.2 feet. This lake is also saline.
Eagle Lake	640	At water surface elevation of 5,107 feet. Has no outlet and is somewhat alkaline.
Goose Lake	475	At water surface elevation of 4,700 feet. Partly in Oregon. The lake is alkaline.

Reservoirs Constructed at Sites Not Previously Occupied by Pre-existing Natural Lakes

Reservoir	Capacity (taf)	Owner
Shasta	4,552	USBR
Oroville	3,538	DWR
Trinity	2,448	USBR
New Melones	2,420	USBR

Reservoirs Constructed by Damming Pre-existing Natural Lakes

Reservoir	Capacity (taf)[a]	Owner
Lake Tahoe	745	USBR
Clear Lake (Modoc County)	451	USBR
Clear Lake (Lake County)	315	YCFCWCD[b]

Rivers

Based on average annual runoff (maf)	
Sacramento River	22.4
Klamath River	11.1
San Joaquin River	6.4
Eel River	6.3

Based on watershed area (square miles)	
Sacramento River	26,548
San Joaquin River	15,946
Klamath *(California portion only)*	10,020
Amargosa River *(California portion only)*	6,442

[a] Storage capacity shown is the operable capacity of the reservoir, not the total capacity of the lake.
[b] Yolo County Flood Control and Water Conservation District

FIGURE 1-5.

California's Hydrologic Regions

California's Hydrologic Regions

North Coast	Klamath River and Lost River Basins, and all basins draining into the Pacific Ocean from the Oregon stateline southerly through the Russian River Basin.
San Francisco Bay	Basins draining into San Francisco, San Pablo, and Suisun Bays, and into Sacramento River downstream from Collinsville; western Contra Costa County; and basins directly tributary to the Pacific Ocean below the Russian River watershed to the southern boundary of the Pescadero Creek Basin.
Central Coast	Basins draining into the Pacific Ocean below the Pescadero Creek watershed to the southeastern boundary of Rincon Creek Basin in western Ventura County.
South Coast	Basins draining into the Pacific Ocean from the southeastern boundary of Rincon Creek Basin to the Mexican boundary.
Sacramento River	Basins draining into the Sacramento River system in the Central Valley (including the Pit River drainage), from the Oregon border south through the American River drainage basin.
San Joaquin River	Basins draining into the San Joaquin River system, from the Cosumnes River Basin on the north through the southern boundary of the San Joaquin River watershed.
Tulare Lake	The closed drainage basin at the south end of the San Joaquin Valley, south of the San Joaquin River watershed, encompassing basins draining to the Kern, Tulare, and Buena Vista Lakebeds.
North Lahontan	Basins east of the Sierra Nevada crest, and west of the Nevada stateline, from the Oregon border south to the southern boundary of the Walker River watershed.
South Lahontan	The closed drainage basins east of the Sierra Nevada crest, south of the Walker River watershed, northeast of the Transverse Ranges, north of the Colorado River Region. The main basins are the Owens and the Mojave River Basins.
Colorado River	Basins south and east of the South Coast and South Lahontan regions; areas that drain into the Colorado River, the Salton Sea, and other closed basins north of the Mexican border.

Bulletin 160 analyses begin at the DAU level, and the results are aggregated into hydrologic regions for presentation.

Some Trends in California Water Management Activities

Key dates in California's water history are shown in the sidebar. The late 1940s through the 1970s was a period of significant expansion of the State's infrastructure, in response to California's post-World War II population boom. During this time, the State expanded its highway system, constructed the State Water Project, and established a blueprint for a higher education system. At the federal level, many of the Central Valley Project's major facilities were constructed. There was substantial State and federal government involvement in—and funding for—water resources development, including direct financial assistance to local agencies for constructing water supply infrastructure (such as the Davis-Grunsky Act and Small Reclamation Projects Act programs).

The emergence of the environmental movement in the latter part of the 1960s began to effect a change in society's values, increasing the desire to preserve natural areas in a relatively undeveloped condition. With enactment of a number of environmental protection statutes, the State and federal governments' roles in water began to shift from development to management and regulation. In the 1970s, the "taxpayer revolt", typified by voter support for Proposition 13, reduced available funding to local agencies. (Two recent influences on funding sources for resources programs include deficit reduction goals for the federal budget and voter approval of Proposition 218, a measure to limit the ability of local governments to levy assessments.) There was a reduction in construc-

A California Water Chronology

In 2000, California will celebrate its sesquicentennial (150 years of statehood). Within this relatively short time period, the State's major water infrastructure and complex institutional framework for managing water have been developed. The following chronology highlights some key points in California's water history.

1848 Treaty of Guadalupe Hidalgo transfers California from Mexico to the U.S.
1848 Gold is discovered at Sutter's Mill on the American River.
1850 California is admitted to the Union.
1871 First reported construction of a dam on Lake Tahoe.
1884 Hydraulic mining is banned because of its impacts on navigation and contribution to flooding.
1886 Lux v. Haggin addresses competing water rights doctrines of riparianism and prior appropriation.
1887 Legislature enacts Wright Irrigation District Act, allowing creation of special districts.
1887 Turlock Irrigation District becomes first irrigation district formed under the Wright Act.
1895 World's first long-distance transmission of electric power (22 miles), from a 3,000 kW hydropower plant at Folsom to Sacramento.
1902 Congress enacts the Reclamation Act of 1902, creating the Reclamation Service, and authorizing federal construction of water projects.
1905 Salton Sea is created when the Colorado River breaches an irrigation canal and flows into the Salton Trough.
1913 First barrel of Los Angeles Aqueduct completed.
1914 California's present system of administering appropriative water rights is established by the Water Commission Act.
1922 Colorado River Compact signed.
1928 California Constitution amended to prohibit waste of water and to require reasonable beneficial use.
1928 Saint Francis Dam fails.
1929 State dam safety program goes into effect.
1929 East Bay MUD's Mokelumne River Aqueduct is completed.
1934 San Francisco's Hetch Hetchy Aqueduct is completed.
1940 All American Canal is completed.
1941 Colorado River Aqueduct is completed.
1945 Shasta Dam is completed.
1957 The Department publishes Bulletin 3, the *California Water Plan*.
1960 California voters approve the Burns-Porter Act, authorizing the sale of bonds to finance State Water Project construction.
1968 Oroville Dam is completed.
1968 Congress enacts National Wild and Scenic Rivers Act.
1969 Legislature enacts Porter-Cologne Act, the foundation of California water quality regulatory programs.
1969 Congress enacts National Environmental Policy Act.
1970 Legislature enacts California Environmental Quality Act.
1972 Legislature enacts California Wild and Scenic Rivers Act.
1973 California Aqueduct is completed.
1978 California v. U.S. held that the U.S. must obtain water rights under State law for reclamation projects, absent clear congressional direction to the contrary.
1978 SWRCB issues Decision 1485, requiring the CVP and SWP to meet specified Bay-Delta operating criteria.
1983 National Audubon Society v. Superior Court sets forth the application of public trust concepts to water rights administered by SWRCB.
1990 Congress enacts the Truckee-Carson-Pyramid Lake Water Rights Settlement Act (PL 101-618).
1992 Congress enacts the Central Valley Project Improvement Act (PL 102-575).
1994 SWRCB issues Decision 1631, requiring specified protections for Mono Lake levels.
1994 Bay-Delta Accord signed; its original three-year term was subsequently extended to a total of four years.

The founding of the San Diego Mission in 1769 is considered to mark the beginning of California's water supply development. This 1918 photo shows the ruins of the mission's dam.

Courtesy of Water Resources Center Archives, University of California, Berkeley

tion of large-scale water projects from the 1980s onward. The result of these changing circumstances was that few large-scale water management actions were able to move forward after the late 1960s. Since there is a long lead time for developing large water supply projects, the consequences were not immediately felt.

A theme now dominating much water management planning at the statewide level is ecosystem restoration (accompanied by substantial funding). Bay-Delta actions are an example of this trend—voter approval of Proposition 204 provided $460 million for State restoration actions directly associated with the Delta, and another $93 million in State matching funds for the U.S. Bureau of Reclamation's Central Valley Project Improvement Act restoration actions. USBR's annual budget for CVPIA restoration actions covered by the Restoration Fund has been in the $40 million range. Other examples of funding for environmental restoration actions are described throughout the Bulletin.

Greater local government and other stakeholder participation in statewide-level water management decision-making is an emerging trend. Formal governance structures are being employed to coordinate and manage the collective actions of local agencies. For example, CVP water users formed three joint powers authorities to contract with USBR for operation and maintenance of CVP facilities. Those JPAs have been working with USBR to develop mechanisms to allow the JPAs to finance normal operations and maintenance activities, rather than going through the congressional appropriations process. Another JPA has been formed by two county governments and two water agencies to implement Salton Sea restoration actions.

Changes Since the Last California Water Plan Update

The last *California Water Plan* update, Bulletin 160-93, was published in 1994 and used 1990-level information to represent base year water supply and demand conditions. At that time, California had recently emerged from the six-year drought and Bay-Delta issues were in a state of flux. Bulletin 160-98 uses 1995-level information to represent base year conditions, including new (interim) Bay-Delta standards.

Changes in Delta conditions are a major difference between the two bulletins. Bulletin 160-93 was based on SWRCB D-1485 regulatory conditions in the Delta, and used a range of 1 to 3 maf for unspecified future environmental water needs—a range that reflected uncertainties associated with Bay-Delta water needs and Endangered Species Act implementation. Bulletin 160-98 uses SWRCB's Order WR 95-6 as the base condition for Bay-Delta operations, and describes proposed CALFED actions for the Bay-Delta.

Bulletin 160-93 was the first *California Water Plan* update to examine the demand/supply balance for drought water years as well as for average water years, a response to water shortages experienced during the then-recent drought. Bulletin 160-98 retains the drought year analysis and also considers the other end of the hydrologic spectrum—flooding. Traditionally, water supply has been the dominant focus of the water plan updates. In response to the January 1997 flooding in Northern and Central California, Bulletin 160-98 highlights common areas in water supply and flood control planning and operations and emphasizes the benefits of multipurpose facilities.

Agreements reached in the 1994 Bay-Delta Accord were widely hailed as a truce in California's water wars. The approach taken in the Bay-Delta exemplifies some hallmarks of today's water management activities—increased participation by local governments and other stakeholders in statewide water management issues, and significant efforts to carry out ecosystem restoration actions.

Changes in Response to Bulletin 160-93 Public Comments

Other changes between the two reports resulted from public comments on Bulletin 160-93. The dominant public comment on Bulletin 160-93 was that it should show how to reduce the gap between existing supplies and future demands, in addition to making supply and demand forecasts. Bulletin 160-98 addresses that comment by presenting a compilation of local agencies' planning efforts together with potential water management options that are statewide in scope. Local agencies' plans form the base for this effort, since it is local water purveyors who have the ultimate responsibility for meeting their service areas' needs. About 70 percent of California's developed water supply is provided by local agencies.

Bulletin 160-98 excludes groundwater overdraft from the Bulletin's base year water supply estimate and is therefore the first water plan update to show an average water year shortage in its base year. (Both of the bulletins excluded future groundwater overdraft from future water supply estimates.) About 1.5 maf of the 1.6 maf base year shortage is attributable to groundwater overdraft.

Finally, Bulletin 160-98 uses applied water data, rather than the net water amounts historically used in the water plan series. This change was made in response to public comments that net water data were more difficult to understand than applied water data. This concept is explained in Chapter 4.

Changes in Future Demand/Shortage Forecasts

Bulletin 160-93 used a planning horizon of 1990-2020. Bulletin 160-98 uses a planning horizon of 1995-2020. Bulletin 160-98 uses the 2020 planning horizon because no major data changes occurred between the two reports that would justify extending the planning horizon. Urban water demands depend heavily on population forecasts—the next U.S. Census will not be conducted until 2000. Appendix 1A compares some key 2020 average year forecasts from the two bulletins.

The water plan series uses population forecasts from the Department of Finance. DOF reduced its

Flooding and threatened flooding triggered the evacuation of thousands of people in the greater Yuba City/Marysville area during the January 1997 storms.

2020 forecast for California in the period between Bulletin 160-93 and Bulletin 160-98. The reduction reflects the impacts of the economic recession in California in the early 1990s. California experienced a record negative net domestic migration then, as more people moved out of the State than moved in. This reduction in the population forecast translates to a reduction in forecasted urban water use in Bulletin 160-98.

The 2020 forecasted agricultural water demands increased from Bulletin 160-93 to Bulletin 160-98, even though the forecasted crop acreage decreased slightly. This increase resulted from elimination of the "other" category of water use shown in Bulletin 160-93, which included conveyance losses. For Bulletin 160-98, water in the "other" category was reallocated to the major water use categories to simplify information presentation. Most of the conveyance losses are associated with agricultural water use. Combining the "other" category into the major water use categories most affected the agricultural water demand forecast. As shown in Appendix 1A, when conveyance losses are factored out of the Bulletin 160-98 forecast, agricultural water use decreases between Bulletin 160-93 and Bulletin 160-98.

Bulletin 160-93 was the first water plan update to quantify environmental water use, recognizing the importance of the water that is dedicated to environmental purposes and that this water is unavailable for future development for other purposes. As illustrated earlier, the environmental sector is California's largest water using sector. Bulletin 160-98 uses the same definition and quantification procedure for environmental water use as did Bulletin 160-93.

The 2020 environmental water demand forecast increased substantially from Bulletin 160-93 to Bulletin 160-98. This increase results from implementation of the Bay-Delta Accord, inclusion of additional wild and scenic river flows, and increased instream flow requirements.

The shortage shown in Bulletin 160-98 is similar in magnitude to the low end of the shortage range reported in Bulletin 160-93. The treatment of forecasted Bay-Delta environmental water demands accounts for much of the difference. A 1 to 3 maf range of potential future environmental water demands was added to the Bulletin 160-93 base environmental water demand forecast, rather than being evaluated through operations studies, because Bay-Delta regulatory assumptions could not be determined then. This conservative approach yielded higher demands than operations studies would have provided. (Use of operations studies to calculate water supply requirements is explained in Chapter 3.)

Preparation of Bulletin 160-98

Although the water plan updates are published only every five years, the Department continuously compiles and analyzes the annual data used to prepare them. After publication of Bulletin 160-93 in 1994, the remainder of that year was devoted to finishing data evaluation deferred during the Bulletin's production. Work on Bulletin 160-98 began in 1995. A citizen's advisory committee with more than 30 members, representing a wide range of interests, was established to assist the Department in its preparation of the next water plan update. The advisory committee met with Department staff 17 times over the period of Bulletin 160-98 preparation, and in August 1997 reviewed an administrative draft that preceded release of the public review draft at the end of January 1998. The review period for the public draft extended through mid-April 1998, during which time public meetings were held and presentations were made to interested parties. The draft was also made available on the World Wide Web. Over 4,000 copies of the public review draft were distributed. Comments received on the public review draft were addressed in the final version of the Bulletin.

Public Comments on Draft

The Department received over 200 comment letters on the draft and additional comments from public meetings. A summary of the comments is provided in Appendix 1B. Many comments were provided by local agencies whose facilities and projects are described in the public draft, and dealt with edits or corrections regarding those facilities or projects. Another major class of comments dealt with policy, conceptual, or analytical subjects. Many of these comments were influenced by discussions taking place in the CALFED Bay-Delta program and reflected the commenters' positions on CALFED issues. For example, proponents of CALFED's no conveyance improvements alternative generally expressed opposition to Bulletin 160-98's exclusion of groundwater overdraft as a supply, because this approach increases overall statewide shortages. The Department received positive public comments on Bulletin 160-93 when it excluded groundwater overdraft as a supply for the first time, and also received positive comments on its treatment of overdraft for Bulletin 160-98.

Often, public comments conflicted with one another. For example, environmental organizations frequently stated that the Bulletin should include more future water conservation, while water purveyors frequently stated that levels assumed in the Bulletin were overly optimistic. Some comments suggested that the Bulletin's future water demands could be reduced by raising water prices, while others felt that the forecasted demands were too low and did not take into account future needs of California's population and agricultural economy. Likewise, some comments expressed philosophical opposition to constructing more reservoirs in California, while others emphasized the need for more storage and flood control reservoirs. The Department considered these comments in the context of the Bulletin's goal of accurately reflecting actions that water purveyors statewide would be reasonably likely to implement by year 2020.

Some comments suggested that Bulletin 160-98 (or the Department, or the State of California) advocate or express a vision on a variety of subjects—including State-funded water supply development, sustainable development, nonpoint source pollution, flood control, food production security, mandatory water pricing, and greater use of desalting (by entities other than the commenter). Such an approach is outside the scope of the Department's water plan update series. The role of the Bulletin 160 series is to evaluate present and future water supplies and demands given current social/economic policies, and to evaluate progress in meeting California's future water needs. As appropriate, the Bulletin discusses how other factors such as flood control may relate to water supply planning.

In its forecasts, the Department is making a fundamental assumption that today's conditions—facilities, programs, water use patterns, and other factors—are the basis for predicting the future. (And, as one commenter correctly pointed out, Bulletin 160-98 also assumes that California's climate will remain unchanged over the Bulletin's 25-year planning horizon.) This approach differs distinctly from the approach of establishing a desired future goal or vision, and then preparing a plan that would implement that goal or vision. Such a plan would require public acceptance that simply does not exist today.

Many of the advocacy or vision comments described above are also not within the Department's jurisdiction or the jurisdiction of other State agencies. For example, the Department's role in developing water supply for local agencies is limited to fulfilling its State Water Project contractual obligations. (The Department may provide financial assistance to local agencies for various water management programs as authorized under bond measures enacted by the Legislature and approved by the voters.) The Department has no regulatory authority to mandate how local water agencies price their water supplies, or to require that local agencies adopt one type of water management option over another. Comments such as those suggesting that the Department make plans for control of nonpoint source pollution or food production address the jurisdictional areas of other State agencies.

The subject of flood control merits special mention because of the direct relationship between operations of water supply projects and flood control projects. The purpose of the water plan update series is to evaluate water supplies, but those supplies can be affected by flood control actions such as increasing the amount of reservoir storage dedicated to flood control purposes. With memories of the disastrous January 1997 floods still fresh in peoples' minds, some commenters recommended that Bulletin 160-98 devote more attention to flood control needs, including needs such as floodplain mapping programs that are not directly related to water supply considerations. The 1997 *Final Report of the Governor's Flood Emergency Action Team* describes recommended actions to be taken based on the damages experienced in January 1997. The Department has referenced sections of that report throughout Bulletin 160-98. Bulletin 160-98 emphasizes the interaction between water supply and flood control planning, and points out the benefits associated with multipurpose water projects.

As discussed in the following section, the Department received a number of comments requesting that Bulletin 160-98 quantify future water supply uncertainties associated with ongoing programs or regulatory actions, such as the CALFED Bay-Delta program, Federal Energy Regulatory Commission hydroelectric plant relicensing, and Endangered Species Act listings. Text has been added that quantifies those actions for which data are available.

The Department also received some comments that could not be incorporated in Bulletin 160-98 because they suggested substantial changes in the scope or content of the Bulletin that could not be addressed before the Bulletin's due date to the Legislature, or suggested changes for the next update of the water plan. The scope of Bulletin 160-98 was established in coordination with the Bulletin's advisory committee in 1995, just as the scope of the next plan update (five years hence) will have to be established early in the process of preparing that update. The Department will consider these long-term comments when work begins on the next update.

Works in Progress and Uncertainties

The descriptions of major California water management activities provided in the Bulletin are generally current through July 1998. There are several pending activities that could be characterized as works in progress, including the CALFED Bay-Delta program and Colorado River water use discussions. For programs such as these, the Bulletin describes their current status and potential impacts, if known, on future water supplies. There are uncertainties associated with the outcomes of these activities, just as there are with any process that is evaluated in mid-course.

As noted at the beginning of this chapter, each water plan update focused on issues or concerns of special interest at the time of its publication. Water use for hydroelectric power generation is a good example of this focus. Bulletin 160-83 was the last water plan update to review hydropower generation use, because no major changes have occurred since the late 1970s/early 1980s, when high energy prices and favorable tax treatment for renewable energy spurred a boom in small hydropower development. Today uncertainties about water supply and water use associated with hydropower production are increasing, with the 1998 initiation of deregulation for California investor-owned utilities and the prospect of FERC relicensing of several powerplants on major Sierra Nevada rivers between 2000 and 2010. Although there is presently little information available on which to base forecasts of resultant changes in water supplies, more information is likely to be available for the next water plan update.

Colorado River interstate issues are a new addition to a statewide water picture largely dominated by Delta and CVPIA issues in the recent past. Achieving a solution to California's need to reduce its use of Colorado River water to the State's basic apportionment (a reduction of as much as 900 taf from historical uses) requires consensus among California's local agencies that use the river's water, as well as concurrence in the plan by the other basin states.

Presentation of Data in Bulletin 160-98

Water budget and related data are tabulated by hydrologic region throughout the Bulletin. The statewide totals in these tables are generally presented as rounded values. As a result, individual table entries will not sum exactly to the rounded totals.

In the water budget appendices 6A, 6E, and 10A, regional water use/supply totals and shortages are not rounded. Individual table entries may not sum exactly to the reported totals due to rounding of individual entries for presentation purposes.

Organization of Bulletin 160-98

Chapter 2 provides an overview of recent events in California water and summarizes significant changes in statutes and programs since the publication of Bulletin 160-93. An appendix for Chapter 2 summarizes some State and federal statutes affecting water management. Chapters 3 and 4 cover water supplies and water uses. Chapter 5 describes the status of technology applications relating to water supply, reflecting the continuing public interest in topics such as potential future use of seawater desalting, status of water conservation and use technologies, or fish screening technology applications.

Chapters 6-9 focus on ways to meet California's future water needs. Chapter 6 covers statewide level water management actions, including actions such as the CALFED Bay-Delta program, SWP future water supply options, and CVPIA fish and wildlife water acquisition. Chapters 7-9 evaluate regional water management options for each of the State's ten major hydrologic regions. These regional evaluations are combined in Chapter 10 into a tabulation of actions likely to be taken to meet California's future water needs. The water budget tables in Chapter 10, shown for a 2020 level of demand with future water management options, are key summaries of the Bulletin's planning process. Appendices follow at the end of the chapters in which they are referenced. Following Chapter 10 are a brief glossary and list of abbreviations and acronyms used in the text.

An executive summary of Bulletin 160-98 is available as a separate document.

1A

Comparison of 2020 Average Year Forecasts Between Bulletin 160-93 and Bulletin 160-98

Table 1A-1 compares some key 2020 average year forecasts from Bulletin 160-93 and Bulletin 160-98.

Bulletin 160-93 provided water use information as applied water, net water, and depletion. The table shows Bulletin 160-93 urban, agricultural, and environmental water use as applied water demands, to be compatible with Bulletin 160-98 applied water use data.

Bulletin 160-93 included a fourth category of water use called "other." This "other" category included major canal conveyance losses, recreation use, cooling water use, energy recovery use, and use by high water using industries. Water uses previously categorized as "other" are included in the Bulletin 160-98 urban, agricultural, and environmental water use categories according to their intended purpose. To provide a meaningful comparison with Bulletin 160-93 water use data in the table, water use previously classified as "other" was removed from the Bulletin 160-98 data.

TABLE 1A-1
2020 Average Year Forecasts

	Bulletin 160-93	*Bulletin 160-98*
Population (million)	48.9	47.5
Irrigated crop acreage (million acres)	9.3	9.2
Urban water use (maf)	12.7	11.4[a]
Agricultural water use (maf)	28.8	28.3[a]
Environmental water use (maf)	30.3-32.3	36.9[a]
Average water shortage[b] (maf)	3.7-5.7	2.4

[a] The "other" category of water use was removed to make the 160-93 and 160-98 numbers directly comparable, as described in the text.

[b] As described in the text, a major reason for the change in the shortage numbers between the two bulletins was differences in forecasted Bay-Delta environmental water demands. Shortage values are not exactly comparable, as Bulletin 160-93 presented net water shortages and Bulletin 160-98 presented applied water shortages

1B

Summary of Public Comments on Draft Bulletin 160-98

Work on Bulletin 160-98 began in 1995. A public advisory committee with more than 30 members representing a wide range of interests was established to assist the Department in preparing the water plan update. The advisory committee met with Department staff 17 times over the period of Bulletin 160-98 preparation and, in August 1997, reviewed an administrative draft that preceded the public review draft's release at the end of January 1998. Over 4,000 copies of the draft were distributed. The draft was also made available on the World Wide Web. The review period for the public draft extended through mid-April 1998, during which time eight public meetings were held and presentations were made to interested parties. The Department received about 200 letters, form letters, postcards, and other comment submissions.

Because this update of the water plan focused on local agency water management actions, the Department received many local agency comments with corrections, updates, or other changes to the draft's text on their facilities, service areas, or programs. The Department also received many comments relating to CALFED Bay-Delta program activities. CALFED's draft PEIR/PEIS was released during the Bulletin 160-98 public review period; comments on Bulletin 160-98 often reflected commenters' positions on the CALFED document. For example, proponents of CALFED's alternative one generally commented that the Bulletin's future water demand forecasts were too high.

The following sections summarize the most frequently repeated comments. Public comments often conflicted with one another. Specific comments or edits on descriptions of local agencies' facilities and programs are not included in the summary due to space limitations. Copies of comments received are available for review at the Department's office.

The Role of the State, the Department, and the Water Plan Update Series

- The Department should take the lead in planning new facilities to meet California's future needs. (Chapter 6, Chapter 10)
- The Bulletin only summarizes the actions that local agencies are taking to meet future needs. It does not acknowledge the State's responsibility for meeting California's water needs. (Chapter 6, Chapter 10)
- The State should provide financial assistance to local agencies to help them meet future water needs. Many agencies cannot afford the actions that would be required to provide reliable supplies for their service areas. (Chapter 6, Chapter 10)
- The Department should take steps to meet the future needs of water users in the area of origin. (Chapter 6, Chapter 8)
- The State should provide leadership in addressing California's serious groundwater overdraft. (Chapter 3, Chapter 4, Chapter 8, Chapter 10)
- The State should take an active role in promoting or enforcing water conservation, and should take action to reduce water waste and high water use by agriculture. (Chapter 4, Chapter 6)
- The State should require local agencies to price their water in a manner that reflects its true cost or to achieve goals such as water conservation. (Chapter 4)
- The Bulletin does not plan for the State's future—it tabulates a list of possible options. A plan should

contain a process for achieving the desired goal and should identify financing sources. (Chapter 6, Chapter 10)

- The Bulletin should prioritize the options that most urgently need to be implemented, perhaps those that would eliminate average year water shortages. (Chapter 6, Chapter 10)
- The Bulletin should plan explicitly for future flood control needs. (Chapter 3, Chapter 6, Chapter 8, Chapter 10)
- The Bulletin's scope should be expanded beyond water supply planning to include planning for nonpoint source pollution control and controlling agricultural drainage. (Chapter 6, Chapter 10)
- The Bulletin should plan for the agricultural water supply needed to maintain California's agricultural production and to grow the food that will be needed by the State's increasing population. (Chapter 4, Chapter 10)

The Bulletin in General

- The Bulletin does a good job of presenting a balanced overview of California water supplies and demands, and options for meeting future needs. (no specific chapter)
- The Bulletin has fundamental flaws in methodology and should not be used to support CALFED-related decisions. The public draft should be critiqued by an external peer review committee. (Chapter 4, Chapter 6)
- The Bulletin 160-98 switch to an applied water budget approach for presentation of information is appreciated. The applied water budget is easier to understand than the net water budgets used in previous bulletins. (Chapter 3, Chapter 4)
- The applied water budget is more confusing than the previous net water budgets. (Chapter 3, Chapter 4)
- The Bulletin should not use an applied water budget because it overstates environmental water use. (Chapter 4)
- The Bulletin should provide more detail on demand forecasting, descriptions of water management options, and cost data. Show all assumptions and background data. (Chapter 4, Chapter 6)
- Presentation of some subjects is difficult to follow. Simplify presentation. (no specific chapter)
- Status of ongoing programs/actions (CALFED, Colorado River Board 4.4 Plan negotiations, new ESA listings) should be updated. (Chapter 2, Chapter 6)
- The Bulletin should show a range of shortage outcomes to reflect uncertainties associated with new ESA listings, FERC relicensing, CVPIA supplemental water acquisition, SWRCB's Bay-Delta water rights proceedings, and CALFED. (Chapter 6, Chapter 10)

Water Supplies and Demands

- There were comments on groundwater supplies or overdraft for individual groundwater basins or hydrologic regions. There were also several comments about boundaries of specific groundwater basins or sub-basins. A general comment was that the Bulletin needs to place more emphasis on good groundwater data. (Chapter 3)
- The Bulletin's treatment of 1995 and 2020 groundwater overdraft as not available as a source of supply accurately represents dependable water supplies. Groundwater overdraft is not sustainable over the long term and should not be a long-term solution to water supply needs. (Chapter 3)
- Groundwater overdraft should not be treated as creating a shortage, but should be a source of supply. Farmers will stop overdrafting groundwater when it becomes too expensive to pump. (Chapter 3)
- The high levels of groundwater overdraft shown in the San Joaquin Valley are of concern. The Bulletin should examine means to address this overdraft through long-term basin management. (Chapter 3, Chapter 8)
- There were several questions about the source of water supply data for water recycling. It was suggested that water recycling survey results be shown in an appendix. (Chapter 3, Chapter 6)
- There were several suggestions for different terminology to distinguish among water transfers, banking, exchanges, sales, and acquisitions. (Chapter 3, Chapter 6)
- The Bulletin should recognize the reality of global warming/long-term global climate change. Future hydrologic conditions will differ from today's. Existing hydrologic forecasts are based on a limited period of historical record. (Chapter 3)
- The Bulletin should evaluate the relationship of local land use planning to water supply/water

needs. Quantify the results of enactment of SB 901 (a 1995 amendment to Section 65302 of the Government Code). (Chapter 4)

- Environmental water use should be treated on an equal basis with urban and agricultural water use. The only environmental demands forecasted in the Bulletin are those required by laws or agreements. The Bulletin forecasts urban and agricultural uses based on needs, not minimum legal requirements. (Chapter 4)
- North Coast wild and scenic rivers should not be counted as environmental water use. The magnitude of their flow is so great that it skews the rest of the environmental water uses. North Coast wild and scenic rivers should not be counted as environmental water use because no one is seriously planning to develop them. (Chapter 4)
- The Bulletin should emphasize that the environment once received 100 percent of the water and now receives much less. Environmental water supplies are needed for more uses than recognized in the Bulletin—for non-listed species of fish and wildlife, flushing flows through the Golden Gate, and other aquatic resources. (Chapter 4)
- The Bulletin puts environmental water use in proper perspective with other water uses—that the environment is California's largest water using sector. (Chapter 4)
- The Bulletin understates future environmental demands because it uses Bay-Delta Accord requirements which expire in 1998 and present ESA requirements. Water requirements for recently listed fish species will likely increase future environmental demands. (Chapter 4)
- The Bulletin should place more emphasis on environmental water conservation. Conservation is required of the urban and agricultural sectors, but not of the environmental sector. (Chapter 4, Chapter 6)
- CVPIA supplemental water needs shown in USBR's draft CVPIA PEIS should not be counted as future environmental water demands because they falsely inflate future shortages. CVPIA supplemental water needs should not be counted as future environmental water demands because water users will not sell such large quantities of water to USBR. (Chapter 4)
- The Bulletin correctly includes CVPIA supplemental water needs as future environmental water demands. (Chapter 4)
- The Bulletin should recognize environmental water needs for the Colorado River delta area in Mexico. (Chapter 4, Chapter 9)
- More attention should be given to environmental water needs at the south end of the San Francisco Bay. (Chapter 7)
- Urban water use forecasts are too high because they are based on normalized data, not on actual water data. (Chapter 4)
- Water pricing should be explicitly considered in future demand forecasts. The definition of demand should be revised to make demand a function of price. (Chapter 4)
- There were several comments stating that water demand is not price inelastic. (Chapter 4)
- Much more conservation is possible than is shown in the Bulletin. Price should be used to achieve or enforce conservation. (Chapter 4, Chapter 6)
- Increased market penetration of horizontal axis washing machines will result in greater conservation amounts than forecasted in the Bulletin. Urban landscaping changes will also result in greater conservation. (Chapter 4, Chapter 6)
- The assumption that water agencies statewide will implement BMPs should be clarified. Not all BMPs can be quantified. (Chapter 4)
- The Bulletin overstates potential demand reductions from implementing BMPs. Agencies are only obligated to implement measures that are cost-effective for their service areas. (Chapter 4)
- Water conservation should not be implemented unless it is cost effective. Water savings do not necessarily result in depletion reductions. (Chapter 4, Chapter 6)
- The Bulletin should provide more information on its conservation assumptions, and data to substantiate forecasted conservation. (Chapter 4, Chapter 6)
- The Bulletin should discuss CVPIA water conservation plans and the effects of CVPIA tiered pricing. (Chapter 4, Chapter 6)
- The Bulletin should discuss lack of data available for city/county implementation of AB 325 (model landscaping ordinance). (Chapter 4, Chapter 6)
- There were several comments that the Bulletin's forecasts of future irrigated acreage underestimated acreage for specific areas. (Chapter 4)
- Forecasts of irrigated acreage and crop mix in past water plan updates (e.g., Bulletin 160-83) do not seem to be coming true (were too high). The Bul-

letin should acknowledge uncertainties in the forecasts. (Chapter 4)

- The Bulletin should give equal treatment to forecasts of agricultural and urban water use. Urban water use is forecasted based on the needs of California's future population. Agricultural needs should be based on maintaining California agriculture's proportionate share of in-state, national, and global food and fiber production. (Chapter 4)
- The Bulletin's irrigated acreage forecast does not include the effects of proposed large-scale land use conversion from irrigated agriculture to wildlife habitat, such as that proposed in CALFED's ecosystem restoration program. (Chapter 4)
- The Bulletin provides a realistic assessment of the potential for agricultural water conservation. (Chapter 4, Chapter 6)
- The potential for agricultural water conservation is much greater than is shown in the Bulletin. The Bulletin did not consider the impacts of reducing federal crop and water subsidies on forecasted demands. (Chapter 4, Chapter 6)
- The Bulletin incorrectly characterizes shortages as the gap between forecasted supplies and demands. There is no shortage if water users are unwilling to pay the amount needed to acquire new water. It is generally not economically rational to reduce shortages to zero. (Chapter 6, Chapter 10)
- The Bulletin should shift from requirements-based planning to reliability-based planning. (Chapter 6)

Future Water Management Options

- The Bulletin places too much emphasis on structural solutions to future water needs and not enough on nonstructural solutions. (Chapter 6, Chapters 7-9)
- Pricing and marginal costs should be explicitly included in the evaluation of future water management options. Use demand and supply curves to illustrate role of cost in evaluating future supplies. (Chapter 4, Chapter 6)
- Environmental impacts from new projects must be balanced against gains in environmental water supplies. Benefits of developing additional water supplies should be weighed against benefits of protecting other natural resources. (no specific chapter)
- No new reservoirs should be constructed in California. (Chapter 6, Chapters 7-9)
- California needs additional reservoirs. (Chapter 6, Chapters 7-9)
- As a matter of policy, the Bulletin should give priority to options that use existing supplies more efficiently, or reallocate existing supplies, before considering new water development projects. (Chapter 6, Chapters 7-9)
- As a matter of policy, the Bulletin should give priority to options that create new water supplies (reservoirs). (Chapter 6, Chapters 7-9)
- The Bulletin should emphasize that implementing conjunctive use projects in some areas is constrained by the lack of surface water available for recharge. (Chapter 6)
- California's future water needs can be met through increased conservation and water marketing. A modest reallocation of agricultural water supplies would satisfy the needs of California's growing urban population. (Chapter 6, Chapter 10)
- Retirement of agricultural lands should not be considered as a future water supply option. (Chapter 6)
- Land retirement costs shown in the Bulletin are too high—economic multipliers were not used for any other water management option. (Chapter 6)
- Land retirement costs shown in the Bulletin are too low. (Chapter 6)
- More emphasis should be given to integrating water supply and flood control benefits. Flood control needs should be emphasized. (Chapter 6, Chapter 8, Chapter 10)
- Multiple benefits of water conservation and recycling should be acknowledged. Conservation and recycling should be treated as new supplies regardless of where they are implemented (e.g., in inland regions). (Chapter 4, Chapter 6)
- Multipurpose benefits of new reservoirs should be emphasized. New reservoirs are increasingly important as future options, because demand hardening due to increased water conservation efforts has removed past flexibility in responding to droughts. (Chapter 6, Chapter 10)
- The Bulletin correctly recognizes that conservation and recycling create new water only where that water would otherwise be lost to the ocean or to another unusable source. (Chapter 4, Chapter 6)
- It is unrealistic to assume further conservation beyond BMPs and EWMPs. There is no way of accurately quantifying future conservation. (Chapter 6)

- There is no evidence suggesting that the 80 percent ET_0 target for urban landscaping could be attained statewide. The urban BMPs and AB 325 have been in effect for some time and have not shown that this level is being achieved. (Chapter 4, Chapter 6)
- Distribution uniformity values assumed for the future agricultural water conservation options may be unrealistically high with present agricultural technology. (Chapter 6)
- The Bulletin should recognize that there are no accurate numbers for estimated acreage of urban landscape—either existing landscape acreage or potential future acreage. (Chapter 6)
- The Bulletin places undue reliance on conservation as a panacea for reducing future shortages. (Chapter 4, Chapter 6)
- Much more future conservation can be achieved beyond BMPs and EWMPs. Reduction of outdoor water use for landscape is not costly and can be phased in over time. More agricultural acreage can be converted from inefficient irrigation techniques to drip irrigation. (Chapter 6)
- The Bulletin does not give water transfers/water marketing equal treatment with construction of new reservoirs. The Bulletin substantially understates the future potential for water marketing. (Chapter 6)
- Water transfers do not create new water supplies—they are a reallocation of existing uses. The future market for water transfers will be much less than is shown in the Bulletin. (Chapter 6)
- There were several comments regarding treatment of potential future transfers in the water budgets—whether transfers should or should not be shown as a supply if no sellers had been identified, whether transfers should be identified as options if an environmental document had not been completed, whether transfers should be subject to a real water test. (Chapter 3, Chapter 6)
- The water budgets do not show enough water supplies from potential future transfers. (Chapter 3, Chapter 6)
- New water supplies from transfers should not be shown in the water budgets. (Chapter 3, Chapter 6)
- The Bulletin does not adequately analyze third-party impacts resulting from water transfers. (Chapter 6)
- The "real water" concept in water transfers is not valid—the Department is just trying to protect the SWP. (Chapter 6)
- The Bulletin does not take into account that competition for supplies from transfers will limit the amount of water available. Well-funded environmental restoration programs such as CVPIA's supplemental water program and the CALFED program will reduce supplies available for others. (Chapter 3, Chapter 6)
- Pending regulatory actions and additional ESA listings may further reduce the amount of water that could be available for transfer. (Chapter 6)
- Area of origin protections need to be explicitly recognized as a limitation to transfers. (Chapter 6)
- The Bulletin should recognize salinity constraints in Southern California water supplies that limit local agencies ability to implement water recycling projects. (Chapter 6, Chapter 7)
- As technology improves, there is increasing potential for desalting San Joaquin Valley agricultural drainage water as part of larger projects for urban/agricultural water transfers or exchanges. (Chapter 8)
- The Bulletin should place more emphasis on seawater desalting in the future. Additional research and development funds should be devoted to desalting. (Chapter 6)
- The State should support marine transport of freshwater (tankers or water bags). The Department should work with interested parties to develop this option. (Chapter 6)
- Forest thinning should be given serious consideration as a source of future water supply. (Chapter 6)

2

Recent Events In California Water

This chapter highlights key infrastructure and institutional changes that have occurred since the publication of Bulletin 160-93, and reviews the status of selected programs. An overview of significant legislative actions is provided, and the legislative framework for California water management is summarized in the appendix.

Infrastructure Update

A common theme in previous updates of the *California Water Plan* has been the need to respond to California's continually increasing population. Population growth brings with it the need for new or expanded infrastructure. This section provides a very brief overview of the largest infrastructure projects which are now under construction or have been recently completed. Some of these projects are described in more detail in later chapters.

California's increasing population is a driving factor in future water management planning.

Large dams under construction or recently completed are listed in Table 2-1. Large conveyance projects under construction or recently completed are listed in Table 2-2. Information about smaller-scale new water supply facilities, including water recycling and desalting plants, can be found in Chapter 5 and Chapters 7-9.

TABLE 2-1

Large Dams Under Construction or Recently Completed

Dam	*Constructing Agency*	*Estimated Capacity (taf)*	*Reservoir Purpose*	*Project Cost[a] (million $)*
Seven Oaks	USACE	146	flood control	366
Los Vaqueros	CCWD	100	offstream storage[b]	450
Eastside	MWDSC	800	offstream storage	2,000

[a] Project construction include costs for land acquisition, environmental mitigation, and associated facilities (such as pipelines and road relocations).
[b] Offstream storage for water quality and emergency service; no new water supply created.

TABLE 2-2

Major Water Conveyance Facilities Since 1992

Facility	*Constructing Agency*	*Status*	*Length (miles)*	*Maximum Capacity (cfs)*
Coastal Branch Aqueduct	DWR	completed 1997	100	100
Eastside Reservoir Pipeline	MWDSC	completed 1997	8	1,000
East Branch Enlargement	DWR	completed 1996	100	2,880
Mojave River Pipeline	MWA	started 1997	70	94
Old River Pipelines (Los Vaqueros Project)	CCWD	completed 1997	20	400
East Branch Extension	DWR	started 1998	14	104
Inland Feeder Project	MWDSC	started 1997	44	1,000
Morongo Basin Pipeline	MWA	completed 1994	71	100
New Melones Water Conveyance Project	SEWD and CSJWCD	completed 1993	21	500

TABLE 2-3

Large Structural Fishery Restoration Projects

Project	*Owner*	*Description*
Shasta Dam Temperature Control Device	USBR	An approximately $83 million modification to the dam's outlet works to allow temperature-selective releases of water through the dam's powerplant was completed in 1997.
Red Bluff Diversion Dam Research Pumping Plant	USBR	A $40 million experimental facility to evaluate fishery impacts of different types of pumps diverting Sacramento River water into the Tehama-Colusa and Corning Canals was contructed in 1995.
Butte Creek fish passage	Western Canal Water District and others	A multi-component project to improve fish passage by removing small irrigation diversion dams from the creek. By 1998, five diversion dams will have been removed.
Maxwell Irrigation District fish screen	Maxwell ID	An 80 cfs diversion on the Sacramento River was screened in 1994.
Pelger Mutual Water Company fish screen	PMWC	A 60 cfs diversion on the Sacramento River was screened in 1994.

Table 2-3 lists some of the largest examples of recently completed structural environmental restoration actions. Several more fish screening projects in the Sacramento River system are expected to begin construction or to be completed in 1998. Details on these facilities can be found in Chapters 5 and 8. Table 2-4 shows a sampling of completed smaller restoration projects.

Legislative Update

This section summarizes major changes within the last five years to State and federal statutes affecting water resources management, together with the status of ongoing efforts to reauthorize some key federal statutes. The existing statutory and regulatory framework for California water management is summarized in Appendix 2A.

State Statutes

Local Water Supply Reliability. In 1995, the Legislature enacted three bills dealing with water supply reliability and long-range planning to serve future water needs. Two of the bills (Statutes of 1995, Chapters 330 and 854) amended requirements for preparing urban water management plans by requiring that local agencies make a specified assessment of the reliability of their water supplies. (Water agencies serving more than 3,000 customers or 3 taf annually are required to prepare urban water management plans and to update the plans at least every five years.) Local water agencies are required to evaluate the reliability of their supplies for varying water year types.

The third bill (Statutes of 1995, Chapter 881) requires that cities and counties making specified land use planning decisions, such as amending a general plan, consult with local water agencies to determine if water supply is available. The bill also requires that findings by local water agencies on water supply availability be incorporated into cities' or counties' environmental documents for the proposed action. To date, there are no statewide data available on local agen-

TABLE 2-4

Sample Restoration Projects Funded in Part by the SWP's 4-Pumps Program

Location	*Description*	*Implementing Agency(ies)*	*Capital Costs*	*Completion Date*
Suisun Marsh Fish Screening Project				
Suisun Marsh	Design, construct, and install seven fish screens on diversions for managed wetlands within Suisun Marsh.	Suisun Resource Conservation District, DFG, DWR, USBR	$2,000,000	1997
Durham Mutual Fish Screens and Ladder				
Butte Creek at Durham Mutual Dam	Install two fish screens and an improved high volume fish ladder to eliminate entrainment and improve fish passage.	Durham Mutual Water Company, USBR, DWR, DFG	$930,000	1998
Parrot-Phelan Fish Ladder				
Butte Creek at Parrot-Phelan Dam	Design and construct a pool-and-chute fish ladder to provide fish passage.	DFG, USBR, DWR	$800,000	1995
Mill Creek Water Exchange Project				
Mill Creek	Fund operation of an irrigation well to replace diversions (up to 25 cfs) bypassed to provide flows for anadromous fish.	DFG, DWR	$559,000	Phase II-Summer 1994
Magneson Salmon Habitat Restoration and Predator Habitat Isolation Project, Merced River				
Merced River (River Mile 29-30)	Restore river channel and isolate abandoned gravel pit.	DFG, DWR	$336,000	1996
Stanislaus River Spawning Habitat Restoration, 3 Riffles				
Stanislaus River	Restore salmon spawning gravel at three sites.	DFG, DWR	$209,000	1994

The Department's Coastal Branch extension from Kings County to Santa Barbara County was completed in 1997.

cies' implementation of these new requirements. The statute did not require reporting on consultations or findings to the State CEQA clearinghouse or to any external agency.

Financing Water Programs and Environmental Restoration Programs (Proposition 204). California voters approved Proposition 204—the Safe, Clean, Reliable Water Supply Act—in 1996. The act authorized the issuance of $995 million in general obligation bonds to finance water and environmental restoration programs throughout the state. Approximately $600 million of these bonds would provide the State share of costs for projects to benefit the Bay-Delta and its watershed, including $390 million of this amount to implement CALFED's ecosystem restoration program for the Bay-Delta. These latter funds would be available after final federal and State environmental documents are certified and a cost-sharing agreement is executed between the federal and State governments. Table 2-5 summarizes programs authorized for Proposition 204 funding.

TABLE 2-5

Proposition 204 Funding Breakdown

Program	*Dollars (in millions)*
Delta Restoration	**193**
CVPIA State share	93
Category III State share	60
Delta levee rehabilitation	25
South Delta barriers	10
Delta recreation	2
CALFED administration	3
Clean Water and Water Recycling	**235**
State Revolving Fund Clean Water Act loans	80
Clean Water Act grants to small communities	30
Loans for water recycling projects	60
Loans for drainage treatment and management projects	30
Delta tributary watershed rehabilitation grants and loans	15
Seawater intrusion loans	10
Lake Tahoe water quality improvements	10
Water Supply Reliability	**117**
Feasibility investigations for specified programs	10
Water conservation and groundwater recharge loans	30
Small water project loans and grants, rural counties	25
Sacramento Valley water management and habitat improvement	25
River parkway program	27
CALFED Bay-Delta Ecosystem Restoration Program	**390**
Flood Control Subventions	**60**
Total	**995**

Proposition 218. Voter approval of Proposition 218 in November 1996 changed the procedure used by local government agencies for increasing fees, charges, and benefit assessments. Benefit assessments, fees, and charges that are imposed as an "incident of property ownership" are now subject to a majority public vote. Proposition 218 defines "assessments" as any levy or charge on real property for a special benefit conferred to the real property, including special assessments, benefit assessments, and maintenance assessments. Proposition 218 further defines "fee" or "charge" as any levy (other than an ad valorem tax, special tax, or assessment), which is imposed by an agency upon a parcel or upon a person as an incident of property ownership, including a user fee or charge for a property-related service.

Although there are many tests to determine if a fee or charge is subject to the provisions of Proposition 218, the most significant one is whether the agency has relied upon any parcel map for the imposition of the fee or charge. There is currently uncertainty in the interpretation of Proposition 218 requirements, especially as they relate to certain water-related fees and charges. From one point of view, Proposition 218 could be interpreted as a comprehensive approach to regulate all forms of agency revenue sources. This broad interpretation would include all fees and charges for services provided to real property. Types of water-related charges and fees that may be affected by Proposition 218's requirements include meter charges, acreage-based irrigation charges, and standby charges.

Additional legislation or judicial interpretation may be needed to clarify the application of Proposition 218 to fees and charges used by water agencies. Several water industry groups are working on proposals for clarifying legislation. To date, there has been one water-related legislative clarification of Proposition 218. A 1997 statute clarified that assessments imposed by water districts and earmarked for bond repayment are not subject to the proposition's voter approval requirements.

Municipalities and special districts are beginning to seek voter approval of assessments as required by Proposition 218. Many assessments to fund existing programs have been receiving voter approval. There has been at least one example, however, of a water agency whose proposed assessment was not approved. Monterey County Water Resources Agency did not receive voter approval for an assessment to support existing programs—groundwater quality monitoring, water conservation, and nitrate management outreach—funded by water standby charges. Examples of MCWRA's proposed assessment charges were $1.67 per irrigated acre for agricultural land use and $2.26 per parcel for single-family dwellings.

Water Recycling. In 1995, provisions of the Water Code, Fish and Game Code, Health and Safety Code, and other statutes were amended to replace terms such as wastewater "reclamation" and "reclaimed water" with "water recycling" and "recycled water." The legislation was intended to enhance public acceptance of recycled water supplies.

MTBE. Detection of methyl tertiary butyl ether in water supplies soon after it was approved for use as an air pollution-reducing additive in gasoline has raised concerns about its mobility in the environment. Legislation enacted in 1997 included several provisions dealing with MTBE regulation, monitoring, and studies. One provision required the Department of Health Services to establish a primary (health-based) drinking water standard for MTBE by July 1999, and a secondary (taste and odor) drinking water standard by July 1998. (MTBE can be detected by taste at very low concentrations, hence the early requirement for a secondary drinking water standard.)

Federal Statutes

Safe Drinking Water Act. The Safe Drinking Water Act, administered by the U.S. Environmental Protection Agency in coordination with the states, is the chief federal regulatory legislation dealing with drinking water quality. The 104th Congress reauthorized and made significant changes to the SDWA, which had last been reauthorized in 1986. Major changes included:

- Establishing a drinking water state revolving loan fund, to be administered by states in a manner similar to the existing Clean Water Act State Revolving Fund. Loans would be made available to public water systems to help them comply with national primary drinking water regulations and to upgrade water treatment systems.
- The standard-setting process for drinking water contaminants established in the 1986 amendments was changed from a requirement that EPA adopt standards for a set number of contaminants on a fixed schedule to a process based on risk assessment and cost/benefit analysis. The 1996 amendments require EPA to publish (and periodically update) a list of contaminants

not currently subject to NPDWRs and to periodically determine whether to regulate at least five contaminants from that list, based on risk and benefit considerations.

- A requirement that states conduct vulnerability assessments in priority source water areas expanded existing source water quality protection provisions. States are authorized to establish voluntary, incentive-based source protection partnerships with local agencies. This activity may be funded from the new SRF.
- As a result of the 1996 amendments, EPA adopted a more ambitious schedule for promulgating the Disinfectant/Disinfection By-Products Rule and the Enhanced Surface Water Treatment Rule. The first phase of the D/DBP Rule is proposed to take effect in late 1998, as is an interim ESWTR. More stringent versions of both rules are proposed to follow in 2002. This subject is discussed in more detail in Chapter 3.

Clean Water Act Reauthorization. The Clean Water Act, administered by EPA in coordination with the states, is the chief federal regulatory statute controlling point and nonpoint source discharges to surface water. The CWA additionally provides federal authority for wetlands protection and regulation of dredging and filling. CWA reauthorization proposals were heard in the 103rd and 104th Congresses, but no legislation was enacted. The act's broad scope complicates reauthorization.

Some of the topics covered in reauthorization proposals have included funding levels for the SRF program; changes to the water quality standard setting process (such as special recognition of environmental benefits of discharging treated wastewater to streams in arid areas); recognition of impacts of introduced aquatic species on species of concern in the water quality standard setting process; Good Samaritan liability provisions for remediation measures at abandoned mines; new programs for nonpoint source management and regulation of combined sanitary/stormwater sewers; new stormwater management requirements for municipalities; recognition of state primacy in water quantity allocation; and expanded statutory treatment of wetlands protection.

Endangered Species Act Reauthorization. As with the CWA, ESA reauthorization proposals were heard in past congresses, but no legislation has been enacted. Some proposed changes included amending the act to focus on preserving ecological communities rather than on preserving a single species or subspecies, providing for stakeholder participation and peer-reviewed science in the species listing process, addressing management of candidate species, streamlining the Section 7 consultation process, quantifying recovery plan objectives, and providing assurances and regulatory relief for nonfederal landowners.

Reclamation, Recycling, and Water Conservation Act of 1996. This act amended Title 16 of PL 102-575 by authorizing federal cost-sharing in additional wastewater recycling projects. (PL 102-575 had authorized federal cost-sharing in specified recycling projects.) The additional California projects are shown below, along with the nonfederal sponsors identified in the statute.

- North San Diego County area water recycling project (San Elijo Joint Powers Authority, Leucadia County Water District, City of Carlsbad, Olivenhain Municipal Water District)
- Calleguas Municipal Water District recycling project (CMWD)
- Watsonville area water recycling project (City of Watsonville)
- Pasadena reclaimed water project (City of Pasadena)
- Phase 1 of the Orange County regional water reclamation project (Orange County Water District and County Sanitation Districts of Orange County)
- Hi-Desert Water District wastewater collection and reuse facility (HDWD)
- Mission Basin brackish groundwater desalting demonstration project (City of Oceanside)
- Effluent treatment for the Sanitation Districts of Los Angeles County with the City of Long Beach (Water Replenishment District of Southern California, OCWD)
- San Joaquin area water recycling and reuse project (San Joaquin County, City of Tracy)

Federal cost-sharing in these projects is authorized at a maximum of 25 percent for project construction and federal contributions for each project are capped at $20 million. Funds are not to be appropriated for project construction until after a feasibility study and cost-sharing agreement are completed. Federal cost-sharing may not be used for operations and maintenance.

The act also authorizes the Department of Interior to cost-share up to 50 percent (planning and design) in a Long Beach desalination research and development project. Local sponsors are the City of Long Beach, Central Basin Municipal Water District, and MWDSC.

Water Desalination Act of 1996. This act authorizes DOI to cost-share in non-federal desalting projects at levels of 25 percent or 50 percent (for projects which are not otherwise feasible unless a federal contribution is provided). Cost-shared actions can be research, studies, demonstration projects, or development projects. The authorization provides $5 million per year for fiscal years 1997 through 2002 for research and studies, and $25 million per year for demonstration and development projects. The act requires DOI to investigate at least three different types of desalting technology and to report research findings to Congress.

National Invasive Species Act of 1996 (PL 104-332). NISA reauthorized and amended the Nonindigenous Aquatic Nuisance and Prevention and Control Act of 1990. The purpose of the legislation was to provide tools for management and control of aquatic nuisance species, such as zebra mussels. NISA reauthorized a mandatory ballast management program for the Great Lakes, an area already heavily infested with zebra mussels, and created an enforceable national ballast management program for all U.S. coastal regions. The act requires detailed reporting on ballast exchange by cargo vessels. Ship ballast water has been identified as a likely mode of introduction for many of the nonindigenous invertebrates identified in the Bay-Delta, now home to at least 150 introduced plant and animal species.

The zebra mussel has caused millions of dollars in increased operations and maintenance costs to Great Lakes water users. Preventing the mussels' spread is a priority in invasive species management.

State and Federal Programmatic Actions

SWP Monterey Agreement Contract Amendments

The Monterey Agreement among the Department and SWP water contractors was signed in December 1994. This agreement set forth principles for making changes in SWP water supply contracts, which would then be implemented by an amendment (Monterey amendment) to each contractor's SWP contract. The amendment has been offered to all SWP contractors. Those contractors that sign the amendment will receive the benefits of it, while those that do not will have their water supply contracts administered such that they will be unaffected by the amendment. As of December 1997, 26 of the 29 contractors had signed the amendment.

Changes to SWP Water Allocation Rules. The amendment states that during drought years project supplies are to be allocated proportionately on the basis of contractors' entitlements. The amendment allocates water to urban and agricultural purposes on equal basis, deleting a previous initial supply reduction to agricultural contractors.

Permanent Sales of Entitlement. The amendment provides for transfer of up to 175 taf of annual entitlement from agricultural use. The first transfer made was relinquishment of 45 taf of annual entitlement (40,670 acre-feet from Kern County Water Agency, 4,330 acre-feet from Dudley Ridge Water District) back to the SWP, as part of the transfer of the Kern Water Bank property to these agencies. This relinquishment reduces the total SWP contractual commitment. The amendment provides for an additional 130 taf/yr of existing agricultural entitlement to be sold on a permanent basis to urban contractors, on a willing buyer-willing seller basis. As of April 1997, 25 taf/yr of KCWA entitlement had been purchased by Mojave Water Agency for recharge in Mojave's groundwater basin. Other potential permanent transfers are being discussed.

Storing Water Outside a Contractor's Service Area and Transfers of Non-Project Water. While some of the amendment's benefits help the larger SWP contractors, the ability to store water outside a contractor's service area is a significant benefit to the smaller contractors. Many SWP urban contractors do not have significant water storage opportunities in their service areas. This provision of the Monterey amendment allows a contractor to store water in another agency's reservoir or groundwater basin. Examples include water storage programs with Semitropic Water Storage District (a member agency of KWCA).

Several water exchanges are moving forward following approval of the Monterey amendment. Dudley Ridge Water District has entered into an exchange agreement with San Gabriel Valley Municipal Water District. Solano County Water Agency has developed an exchange program with MWA whereby SCWA provides a portion of its entitlement in wetter years in return for a lesser amount of water in dry years. While these exchanges cannot be directly attributed to the amendment, the amendment facilitates their implementation.

Finally, the amendment provides a mechanism for using SWP facilities to transport non-project water for SWP water contractors. (The Department uses other contractual arrangements for wheeling water for the CVP and for other non-SWP water users.)

Annual Turnback Pool. Prior to the amendment, water allocated to contractors that was not used during a year would revert to the SWP at the end of the year. No compensation was provided to the contractor for this water, and no other contractors could make use of these supplies during the year. The turnback pool is an internal SWP mechanism which provides for pooling potentially unused supplies early in the year for purchase by other SWP contractors at a set price. The pool was not intended as a water market, but rather as an incentive to return unneeded water early in the year for reallocation among SWP contractors on a willing-buyer basis. The turnback pool operated successfully on a trial basis during 1996, when more than 200 taf were reallocated. If neither the SWP nor individual SWP contractors wish to use water placed into the pool, that water may then be sold to entities that are not SWP contractors.

Other Operational Changes. The amendment established a procedure to transfer ownership of the Department's KWB property to KCWA and Dudley Ridge Water District. The amendment allows contractors repaying costs of constructing the Castaic and Perris terminal reservoirs to increase their control and management of a portion of the storage capacity of each reservoir to optimize the operation of local and SWP facilities. This is expected, for example, to improve drought year supplies for MWDSC, Castaic Lake Water Agency, and Ventura County Flood Control and Water Conservation District.

CVPIA Implementation

CVPIA made significant changes to the CVP's legislative authorization, amending the project's purposes to place fish and wildlife mitigation and restoration on a par with water supply, and to place fish and wildlife enhancement on a par with power generation. Key areas of CVPIA implementation are summarized below. A more detailed summary of the act is provided in Appendix 2A. USBR and USFWS released a draft programmatic EIS on CVPIA implementation for public review in November 1997. The draft PEIS describes, among other things, estimated water supply impacts of federal implementation of the act, and illustrates the consequences of different alternatives for fish and wildlife supplemental water acquisition. A final EIS is scheduled to be released in 1999.

Renewal of CVP Water Service Contracts. CVPIA prohibited execution of new CVP water service contracts (with minor exceptions), except for fish and wildlife purposes, until all of the many environmental restoration actions specified in the statute had been completed. The act also provided that existing long-term water service contracts be renewed for 25-year terms, as opposed to their previous 40-year terms. Only interim renewals (not more than three years) are allowed until the PEIS required by the act is completed. Beginning in October 1997, most existing long term contracts are subject to a monetary hammer clause encouraging early renewal. Renewed contracts will incorporate new provisions required by CVPIA, such as tiered water pricing. Since USBR has not completed the PEIS, all contract renewals to date have been interim renewals. USBR has had more than 60 interim contract renewals from the date of enactment through 1996, representing over 1 maf/yr of supply.

Transfers of Project Water. CVPIA authorized transfer of project water outside the CVP service area, subject to many conditions, including a right of first refusal by entities within the service area. Several conditions, including right of first refusal by entities within the service area, terminate in 1999. Transfers must be consistent with State law, be approved by USBR, and be approved by the contracting water district if the transfer involves more than 20 percent of its long-term

CVPIA's Dedicated Water

Section 3406(b)(2) describes the dedicated water as follows:

Upon enactment of this title dedicate and manage annually 800,000 acre-feet of Central Valley Project yield for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes and measures authorized by this title; to assist the State of California in its efforts to protect the waters of the San Francisco Bay-San Joaquin Delta Estuary; and to help meet such obligations as may be legally imposed upon the Central Valley Project under State or Federal law following the date of enactment of this title, including but not limited to additional obligations under the federal Endangered Species Act. For the purpose of this section, the term "Central Valley Project yield" means the delivery capability of the Central Valley Project during the 1928-1934 drought period after fishery, water quality, and other flow and operational requirements imposed by terms and conditions existing in licenses, permits, and other agreements pertaining to the Central Valley Project under applicable State or Federal law existing at the time of enactment of this title have been met.

contract supply. USBR has published interim guidelines for administration of this provision, pending formal promulgation of rules and regulations. As of this writing, no out of service area transfers have been approved or implemented.

Fish and Wildlife Restoration Actions. One of the most controversial elements of CVPIA implementation has been management of the 800 taf/yr of CVP yield (see sidebar) dedicated by the act to fishery restoration purposes. This water is available for use on CVP controlled streams (river reaches downstream from the project's major storage facilities on the Sacramento, American, and Stanislaus Rivers) and in the Bay-Delta.

The ambiguity of the statutory language and the use of dedicated water in the Bay-Delta Accord have generated many questions, including whether the water may be exported from the Delta after it has been used for instream flow needs in upstream rivers, and if the water may be used for Bay-Delta purposes beyond Bay-Delta Accord requirements. Initially, USBR and USFWS attempted to develop guidelines or criteria for its management. Subsequent to CALFED's creation, the CALFED Operations Group became a forum for attempting to resolve dedicated water. In November 1997, DOI released its final administrative proposal on management of the dedicated water issues. The proposal's release was subsequently challenged in legal action filed by some CVP water contractors.

A main purpose of the dedicated water is meeting the act's goal of doubling natural production of Central Valley anadromous fish populations from their average 1967-91 levels by year 2002. Release of water to the San Joaquin River from Friant Dam is excluded from this program. CVPIA authorizes USBR and USFWS to acquire additional, supplemental water from willing sellers to help achieve the doubling goal. Details of supplemental water acquisition are presented

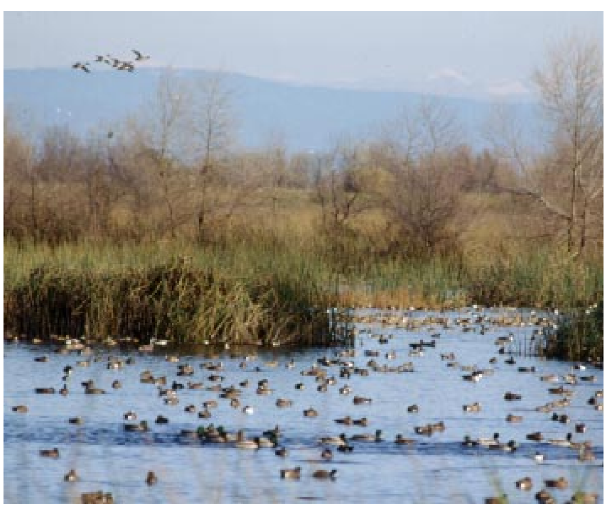
Looking at the upstream face of Shasta Dam, with the temperature control device at the center of the photo. At this high reservoir level, only a small portion of the TCD is visible. The structure is bolted to the face of the dam, covering the powerplant intakes.

CVPIA Waterfowl Habitat Provisions

Most CVPIA environmental restoration measures address fishery needs. Several provisions specifically address restoring and enhancing waterfowl habitat. The act authorizes a 10-year voluntary incentive program for farmers to flood their fields to create waterfowl habitat, and directs USBR and USFWS to prepare reports on the water supply reliability of private wildlife refuges and on water needs for 120,000 acres of additional wetlands identified in a plan by the Central Valley Habitat Joint Venture (see Chapter 4). CVPIA's major waterfowl habitat provision is a requirement that, by 2002, USBR and USFWS must provide specified levels of water supply for certain federal, State, and private refuges. Part of this water supply is to come from reallocating existing CVP supplies, and part from acquisition from willing sellers. Requirements for specific refuges are summarized in Chapter 4. The act also authorizes DOI to construct or acquire conveyance facilities or wells needed to supply water to the refuges.

in Chapter 6. CVPIA further allocates additional CVP water supply for instream use in the Trinity River, reducing the quantity of water which the project could otherwise divert, by requiring that an instream flow of 340 taf/yr be maintained through water year 1996 while USFWS finishes a long-term instream flow study. As discussed in Chapter 7, USFWS now recommends instream flows much greater than 340 taf/yr.

CVPIA enumerates specific physical restoration measures that the federal government must complete for fishery and waterfowl habitat restoration. The largest completed measures are a temperature control device at Shasta Dam and a research pumping plant at Red Bluff Diversion Dam. CVPIA allocated part of the costs of some restoration measures to the State of California; the remaining costs are being paid by federal taxpayers and by CVP water and power contractors. Some of the smaller restoration actions include individual fish-screening projects that USBR and USFWS are cost-sharing with local agencies under the anadromous fish screening program. Examples of these projects are described in Chapter 8.



Part of the CVP water supply reallocated by CVPIA to environmental purposes is used to provide a firm water supply for specified federal, State, and private wildlife refuges. The Secretary of Interior is additionally directed to acquire supplemental water supply to meet the full habitat needs of these refuges.

CVPIA required USBR to impose a surcharge on CVP water and power contracts for deposit into a Restoration Fund created by the act. Monies deposited into the fund are appropriated by Congress to help fund CVPIA environmental restoration actions. The act authorizes appropriation of up to $50 million (1992 dollars) per year for the restoration actions. Annual deposits into the fund vary with water and power sales. CVPIA environmental restoration actions can be funded from the general federal treasury, as well as from the Restoration Fund.

Land Retirement Program. CVPIA authorized DOI to carry out an agricultural land retirement program for lands receiving CVP water. The statute specified that targeted lands be lands that "are no longer suitable for sustained agricultural production because of permanent damage resulting from severe drainage or agricultural wastewater management problems, groundwater withdrawals, or other causes." The retirement of these lands would result in improved water conservation in a contracting district, or would help implement recommendations of the San Joaquin Valley Drainage Program's 1990 report. USBR published interim guidelines for administration of a pilot program, pending formal promulgation of rules and regulations. The federal guidelines were developed in coordination with a state land retirement program established in 1992 under Water Code Section 14902 et seq. The State statute limited the retirement program to drainage-impaired lands. The State land retirement program has never been funded, and thus no State acquisitions have been made. By November 1997, the federal land retirement program had made one purchase—about 600 acres of drainage-impaired land in Westlands Water District that will be managed for wildlife habitat. Recently, USBR solicited proposals from landowners wishing to participate in the retirement program and received offers to sell lands amounting to 31,000 acres.

CVP Reform Act Bill and CVPIA Administration. In 1995, the CVP Water Association sponsored introduction of HR 1906, the Central Valley Project Reform Act of 1995, a bill which would have made extensive amendments to CVPIA. That bill was opposed by the federal administration and did not pass out of the House. DOI took up CVPIA implementation issues raised by the water users in a 1996 administrative process that produced a series of concept papers outlining issues with federal implementation of CVPIA.

USBR initially prepared interim guidelines on many provisions of the act, with the intent that the guidelines would remain in place until rules and regulations were promulgated for sections of CVPIA involving discretionary actions by the federal government. In some cases, the concept papers produced in the administrative process attempt to clarify or augment the interim guidelines. USBR has not formally promulgated rules and regulations for any CVPIA provision.

Other Programs and Reports. USBR has developed criteria for evaluating water conservation plans of CVP contractors, as required by the act (see Chapter 4), and has been reviewing contractors' plans for compliance with the criteria. As of March 1998, over 70 water agencies had submitted plans pursuant to the criteria. The Department, DFG, USBR, and USFWS negotiated a master State-federal cost-sharing agreement for environmental restoration actions whose costs the act allocated in part to California. Funding for the State's share of those costs was provided by voter approval of Proposition 204.

From a water supply standpoint, certain CVPIA-mandated reports are of special interest. USFWS has prepared several draft documents relating to estimated Central Valley environmental water needs and water management actions for the AFRP. The most recent draft of the AFRP was published in May 1997. In 1995, USBR released an appraisal-level least-cost CVP yield increase plan, required by the act to identify options for replacing the water supply dedicated to environmental purposes. Although the act directed that the plan be prepared, USBR was not required to implement it.

Title Transfer of Reclamation Projects

In the 1990s, there was increasing interest in title transfer of federal water projects (or components of projects) to nonfederal ownership. Generally, transfer proposals can be divided into three broad categories—USBR's westwide program for small uncomplicated projects, general congressional action dealing with principles for transfer of certain types of projects, and water user-initiated transfers of specific projects. There was additionally a brief period of State-federal negotiations on title transfer of the CVP. Transfer of a federal project or its components to nonfederal ownership would normally require congressional authorization.

In 1995, USBR announced that it was initiating a westwide program to transfer title of uncomplicated reclamation projects. Uncomplicated projects were defined as small, single-purpose projects—typically distribution and conveyance systems (without hydropower or conservation storage components)—which could easily be transferred to project beneficiaries. The projects would have no competing interests, would not be hydrologically integrated with other projects, and would have simple financial arrangements. Transfer of a distribution system would not necessarily "defederalize" a project's service area. For example, a local agency could acquire title to a distribution system but still hold a water service contract with USBR for the water supply made available for diversion. In this instance, the service area would probably continue to be subject to existing federal requirements such as Reclamation Reform Act acreage limitations and water conservation regulations. USBR indicated that it will not entertain transfers of large projects in their entirety under this program. Transfer of isolated elements of such projects can be considered under the program. One transfer being negotiated under the administrative program is that of the Contra Costa Canal, a CVP facility, to Contra Costa Water District. If USBR and CCWD can successfully negotiate terms and conditions, they would then seek congressional authorization for the transfer. Other California reclamation facilities considered for transfer under the administrative program include the CVP's Clear Creek Community Services District distribution system. Title to the San Diego Aqueduct, a conveyance facility origi-

Negotiations have been in progress on transferring title of the Contra Costa Canal from USBR to CCWD. The transfer would include the 48-mile-long canal, two regulating reservoirs, and associated pumping plants. The canal's maximum capacity is 350 cfs, decreasing to 22 cfs at its terminus.

nally constructed under Department of Defense authorization and subsequently turned over to USBR to manage, was transferred to nonfederal entities in 1997.

Legislation was introduced in the 104th Congress that would have directed DOI to transfer title of reclamation projects whose construction costs had been repaid by the project beneficiaries. This legislation was not enacted. There were several proposals for transfers of individual projects during the 104th Congress, none of which were approved.

In 1992, California and the United States signed a memorandum of agreement on a process to transfer title of the CVP to California. The federal government subsequently declined to pursue transfer negotiations due to a change in the federal administration and 1992 enactment of CVPIA. In 1995, local agencies that operate and maintain much of the CVP system formed a joint powers authority to explore transferring title of the CVP to the local agencies. The CVP Authority proposed to introduce title transfer legislation in the 104th Congress, but legislation was not introduced. Solano Project water users also pursued transfer legislation in the 104th Congress. That effort was put on hold while an adjudication of Putah Creek water rights proceeded.

FERC Relicensing

The Federal Energy Regulatory Commission administers a program of licensing nonfederal hydroelectric power plants. FERC licenses establish conditions on the owners' operation of their plants; typical conditions include instream flow requirements and other fishery protection measures. Licenses for many California hydropower plants will be coming up for renewal in the near future. FERC has begun to schedule regulatory activities for plants with licenses expiring in 2000 to 2010 (Table 2-6). The relicensing process affords resource agencies and individuals the opportunity to seek changes in instream flow requirements, such as those suggested in CVPIA's draft AFRP. Hydropower generation is a nonconsumptive water use, but changes in the amount and timing of water diverted for power generation can affect other uses downstream. The impact of deregulation of the electric power industry on relicensing decisions is uncertain. Current owners of some generating facilities (especially smaller plants) may sell their generation assets in response to deregulation.

Water supply impacts of relicensing are difficult to quantify, in part because impacts are site-specific. Some plants subject to relicensing, for example, currently have no bypass flow requirements. It is likely that relicensing would establish bypass flows at these sites. Other plants subject to relicensing already have substantial bypass flows, and it is not clear what changes relicensing would bring.

Recent ESA Listings

Since publication of Bulletin 160-93, there has been action on federal listing of several fish species having statewide water management significance. In August 1997, the National Marine Fisheries Service listed two coastal steelhead populations as threatened (from the Russian River south to Soquel Creek, and

TABLE 2-6

California Hydropower Projects - License Years 2000 - 2010 (projects over 1,000 kW)

License Expiration Date	*Project*	*Stream*	*Licensee*	*Capacity (1,000 kW)*
June 2000	Lower Tule	Middle Fork Tule River	Southern California Edison	2.0
September 2000	Hat Creek No. 1 & 2	Hat Creek & Pit River	Pacific Gas & Electric	20.0
February 2002	El Dorado	South Fork American River	PG&E	20.0
April 2003	San Gorgonio No. 1 & 2	San Gorgonio Creek	SCE	2.3
August 2003	Vermillion Valley	Mono Creek	SCE	N/A
September 2003	Poe	North Fork Feather River	PG&E	142.8
October 2003	Pit	Pit River	PG&E	317.0
April 2004	Santa Felicia Reservoir	Piru Creek Santa Clara River	United Water Conservation District	1.4
October 2004	Upper North Fork Feather River	North Fork Feather River	PG&E	342.0
December 2004	Donnells & Beardsley	Middle Fork Stanislaus River	Oakdale & South San Joaquin Irrigation Districts	64.0
December 2004	Tulloch	Stanislaus River	OID and SSJID	17.1
December 2004	Stanislaus - Spring Gap	South Fork Stanislaus River	PG&E	175.8
February 2005	Borel	Kern River	SCE	9.2
March 2005	Portal	Rancheria Creek Big Creek	SCE	10.0
April 2005	Kern Canyon	Kern River	PG&E	11.5
February 2006	Klamath	Klamath River	Pacificorp	231.0
January 2007	Feather River	Feather River	DWR	844.0
March 2007	Kilarc & Cow Creek	Old Cow Creek & Cow Creek	PG&E	8.9
July 2007	Upper American River	South Fork American River	SMUD	722.3
July 2007	Chili Bar	South Fork American River	PG&E	7.0
November 2007	Mammoth Pool	San Joaquin River	SCE	181.0
February 2009	Big Creek No. 2A & 8	South Fork San Joaquin River	SCE	480.1
February 2009	Big Creek 3	San Joaquin River	SCE	177.5
February 2009	Big Creek No. 1 & 2	Big Creek & San Joaquin River	SCE	225.9
March 2009	South Fork	Kelly Ridge Canal	Oroville-Wyandotte Irrigation District	104.1
April 2009	Santa Ana No. 3	Santa Ana River	SCE	1.5

from the Pajaro River south to the Santa Maria River), and one population as endangered (from the Santa Maria River south to Malibu Creek). NMFS deferred listing decisions for six months for other California populations—from the Elk River in Oregon to the Trinity River in California, from Redwood Creek to the Gualala River, and in the Central Valley—due to scientific disagreement about the sufficiency and accuracy of the data available for listing determinations. In March 1998, NMFS listed the Central Valley population as threatened, and deferred listing of the two north coast populations in favor of working with California and Oregon on state conservation plans.

Also in 1997, NMFS listed the Southern Oregon/Northern California coast evolutionarily significant unit of coho salmon as threatened. In 1996, NMFS listed coho salmon in the central coast ESU (from Punta Gorda in Humboldt County south to the San Lorenzo River) as threatened.

In 1998, NMFS proposed several runs of chinook salmon for listing—the spring-run in the Central Valley ESU as endangered, the fall and late-fall runs in the Central Valley ESU as threatened, and the spring and fall runs in the Oregon/California coastal ESU as threatened. NMFS expects to make its decision on listing in 1999. The spring-run chinook salmon has been listed as a candidate species under the California ESA.

USFWS proposed in 1994 to list a resident Delta fish species, the Sacramento River splittail, but a congressional moratorium on listing of new species prevented USFWS from working on the proposal until 1996. USFWS again proposed to list splittail in 1996, but received significant public comments on new scientific information for splittail. As of July 1998, the extended public comment period is just ending. USFWS is expected to make a decision after that time.

USFWS has also listed or proposed for listing species whose limited range would result in localized water management impacts. For example, the red legged frog, found primarily in the Central Coast area, was listed as threatened in 1996. Another example is the Santa Ana sucker, found in the Santa Ana River, proposed for listing in 1998.

San Francisco Bay and Sacramento-San Joaquin River Delta

Bay-Delta Accord and CALFED

Representatives from the California Water Policy Council, created to coordinate activities related to State long-term water policy, and the Federal Ecosystem Directorate, created to coordinate actions of federal agencies involved in Delta programs, signed a Framework Agreement for the Bay-Delta estuary in June 1994. Working together, these agencies are known as CALFED. The Framework Agreement improved coordination and communication between State and federal agencies with resource management responsibilities in the estuary. It covered the water quality standards setting process; coordinated water project operations with requirements of water quality standards, endangered species laws, and CVPIA; and provided for cooperation in planning long-term solutions to problems affecting the estuary's major public values.

In December 1994 State and federal agencies, working with stakeholders, reached agreement on the "Principles for Agreement on Bay-Delta Standards Between the State of California and the Federal Government" (commonly referred to as the Bay-Delta Accord) that would remain in effect for three years. Provisions of the Bay-Delta Accord covered water quality standard setting and water project operational constraints, ESA implementation and use of real-time monitoring data, and improvement of conditions not directly related to Delta outflow. Parties to the accord committed to fund "non-flow Category III" measures at $60 million per year for the agreement's three-year term. The accord was subsequently extended for a fourth year. An Operations Group composed of representatives from the State and federal water projects and the other CALFED agencies was established to coordinate project operations. Stakeholders from water agencies and environmental and fishery groups participate in Operations Group meetings.

Water Quality Standard Setting. SWRCB adopted a water quality control plan for the Bay-Delta in May 1995, incorporating agreements reached in the accord. In June 1995, SWRCB adopted Order WR 95-6, an interim order amending terms and conditions of SWRCB's D-1485 and the SWP's and CVP's water right permits to resolve inconsistencies with D-1485 requirements and the projects' voluntary implementation of accord standards. The interim order will expire when a water right decision allocating final responsibilities for meeting the 1995 objectives is adopted, or on December 31, 1998, whichever comes first. SWRCB released a revised draft EIR for implementing the water quality control plan in 1998, and intends to issue a water right decision implementing the order by the end of 1998. The DEIR has eight flow alternatives:

(1) SWP and CVP Responsible for D-1485 Flow Objectives.
(2) SWP and CVP Responsible for 1995 Bay-Delta Water Quality Control Plan Flow Objectives.
(3) Water Right Priority Alternative (The CVP's Friant Unit is assumed to be an in-basin project.)
(4) Water Right Priority Alternative (The CVP's Friant Unit is assumed to be an export project.)
(5) Watershed Alternative–Monthly average flow requirements are established for major watersheds based on Delta outflow and Vernalis flow objectives and the watersheds' average unimpaired flow. The parties responsible for providing the required flows are water users with storage in foothill reservoirs that control downstream flow to the Delta, and water users with upstream reservoirs that have a cumulative capacity of at least 100 taf who use water primarily for consumptive uses.
(6) Recirculation Alternative–USBR is required to make releases from the Delta-Mendota Canal to meet the Vernalis flow objectives.
(7) San Joaquin Basin Negotiated Agreement–San Joaquin Basin water right holders' responsibility to meet the plan objectives is based on an agreement titled "Letter of Intent among Export Interests and San Joaquin River Interests to Resolve San Joaquin River Issues Related to Protection of Bay-Delta Environmental Resources."
(8) San Joaquin Basin Negotiated Agreement–Vernalis flow objectives are replaced by target flows contained in the agreement.

CALFED Long-Term Solution-Finding Process for Bay-Delta. The June 1994 Framework Agreement called for a State-federal process to develop long-term solutions to Bay-Delta problems related to fish and wildlife, water supply reliability, natural disasters, and water quality. The CALFED program is managed by an interagency team under the policy direction of CALFED member agencies, with public input provided by the Bay-Delta Advisory Council. BDAC is a 31-member advisory panel representing California's agricultural, environmental, urban, business, fishing, and other interests who have a stake in the long term solution to Bay-Delta problems.

The CALFED program's first phase identified problems in and goals for the Bay-Delta, and developed a range of alternatives for long-term solutions. This phase concluded with a September 1996 report identifying three broad solutions, each of which included a range of water storage options, a system for conveying water, and some programs that were common to all alternatives. The second phase consisted of preparing a programmatic EIR/EIS covering three main alternatives for conveyance of water across the Delta—an existing system alternative, a through-Delta alternative, and a dual Delta conveyance alternative. A first public review draft of the PEIR/PEIS was released in March 1998. CALFED expects to issue a second draft PEIR/PEIS by the end of 1998. The revised draft would identify CALFED's draft preferred alternative.

The third phase would involve staged implemen-

CALFED's Ecosystem Restoration Program calls for extensive creation of new habitat in the Delta. Construction of setback levees would allow restoration of riparian and riverine aquatic habitats, benefitting fish and wildlife.

tation of the preferred alternative over a time period of several decades and will require site-specific compliance with NEPA and CEQA. Current plans are for an initial implementation period of 7 to 10 years, during which only common program elements would be implemented (water conservation measures, ecosystem restoration, levee improvements). Any conveyance or storage facilities would be constructed in a later phase of implementation.

ESA Administration. The Bay-Delta Accord established several principles governing ESA administration in the Bay-Delta during the agreement's term.

- The accord is intended to improve habitat conditions in the Bay-Delta to avoid the need for additional species listings during the agreement's term. If additional listings do become necessary, the federal government will acquire any additional water supply needed for those species by buying water from willing sellers.
- There is intended to be no additional water cost to the CVP and SWP resulting from compliance with biological opinion incidental take provisions for presently listed species. The CALFED Operations Group is to develop operational flexibility by adjusting export limits.
- Real-time monitoring is to be used to the extent possible to make decisions regarding operational flexibility. CALFED commits to devote significant resources to implement real-time monitoring.

An aerial view of the Montezuma Slough salinity control structure. The structure includes three 36-foot wide radial gates, a 66-foot wide barge access, and a boat lock.

Suisun Marsh

SWRCB's D-1485 required USBR and the Department to develop a plan to protect the Suisun Marsh. The Suisun Marsh Preservation and Restoration Act of 1979 authorized the DOI to enter into an agreement with California for cost-sharing in activities to protect the marsh's fish and wildlife resources. A plan was subsequently developed and initial water supply distribution systems called for in the plan were completed in 1981.

In 1986 PL 99-546 authorized the federal government to contract with Suisun Resource Conservation District, DFG, and the Department for mitigating effects of the SWP, CVP, and other upstream diversions on marsh water quality. The agreement, approved in March 1987, described proposed facilities to be constructed, a construction schedule, cost-sharing responsibilities, water quality standards, soil salinity, water quality monitoring, and purchase of land to mitigate the impacts of the Suisun Marsh facilities themselves. As provided by the agreement, a salinity control structure on Montezuma Slough was completed in 1989. The structure has effectively reduced salinity in Montezuma Slough and eastern regions of the marsh, and to a lesser degree, in most of the western regions of the marsh.

Because of the effectiveness of the salinity control structure and the increased Delta outflows called for in SWRCB's Order WR 95-6, parties to the 1987 Suisun Marsh Preservation Agreement are amending the agreement to focus on funding water management activities instead of constructing the large-scale facilities initially planned. Activities such as improving discharge facilities, screening portable pumps, employing a water manager, and constructing joint-use water management facilities among landowners will enable landowners to effectively use water from marsh sloughs.

Delta Protection Commission

The Delta Protection Act of 1992 established the Delta Protection Commission and charged it with preparing a plan for land uses within the primary zone of the Delta, and with working with local governments to ensure that their general plans are brought into conformance with the Commission's plan. Delta counties—including Solano, Yolo, Sacramento, San Joaquin, and Contra Costa—are required to comply with findings of the plan. In February 1995, the Commission adopted the *Land Use and Resource*

Management Plan for the Primary Zone of the Delta (Delta Plan). The major goals of the Delta Plan include the following:

- Preserve and protect the natural resources of the Delta, including soils.
- Promote protection of remnants of riparian habitat.
- Promote seasonal flooding and agricultural practices to maximize wildlife use.
- Promote levee maintenance and rehabilitation to preserve land areas and channel configurations in the Delta.
- Protect the Delta from excessive construction of utilities and other infrastructure. Where construction of new infrastructure is appropriate, minimize the impacts of new construction on levees, wildlife, and agriculture.
- Protect the unique character and qualities of the primary zone by preserving its cultural heritage and strong agricultural base. Encourage residential, commercial, and industrial development in existing developed areas.
- Support long-term viability of commercial agriculture and discourage inappropriate development of agricultural lands.
- Protect long-term water quality in the Delta.
- Promote continued recreational use of the land and waters of the Delta; ensure that facilities that allow such uses are constructed and maintained; protect landowners from unauthorized recreational uses on private lands; and maximize dwindling public funds for recreation by promoting public-private partnerships and multiple use of Delta lands.
- Support the improvement and long-term maintenance of Delta levees by coordinating permit reviews and guidelines for levee maintenance; develop a long-term funding program for levee maintenance; protect levees in emergency situations; and give levee rehabilitation and maintenance priority over other uses of levee areas.

As originally authorized, the Delta Protection Commission was to expire in January 1997. Its expiration date was extended to January 1, 1999. The Commission is currently studying existing recreational uses in the Delta in conjunction with the Department of Boating and Waterways and the Department of Parks and Recreation. The Commission continues to monitor proposed land use changes in the Delta.

San Francisco Estuary Project

The San Francisco Estuary Project, begun in 1987, is a federal-State partnership established under Clean Water Act authority to develop a plan for protecting and restoring the estuary while maintaining its beneficial uses. The project, jointly sponsored by EPA and by the State, is financed by federal appropriations and matching funds from State and local agencies.

In 1993, the SFEP's Comprehensive Conservation and Management Plan was completed and signed by the State and federal governments. The CCMP contained 145 specific action items to protect and restore the estuary, classified into the following programs: aquatic resources, wildlife, wetlands management, water use, pollution prevention and reduction, dredging and waterway modification, land use, public involvement and education, and research and monitoring. Since no specific funding exists for implementing these action items, progress has continued under existing federal, State, and local programs. A 1996 SFEP progress report on CCMP implementation identified ten priorities to be implemented over the next five years:

(1) Expand, restore, and protect Bay-Delta wetlands.
(2) Integrate and improve regulatory and scientific monitoring programs.
(3) Create economic incentives that encourage local governments to implement measures to protect and enhance the estuary.
(4) Improve management and control of urban runoff.
(5) Prepare and implement watershed management plans throughout the estuary.
(6) Reduce and control introduction of exotic species.
(7) Build awareness about CCMP implementation.
(8) Increase public awareness about the estuary's natural resources and the need to protect them.
(9) Implement a regional monitoring program.
(10) Work with CALFED and others to address program priorities.

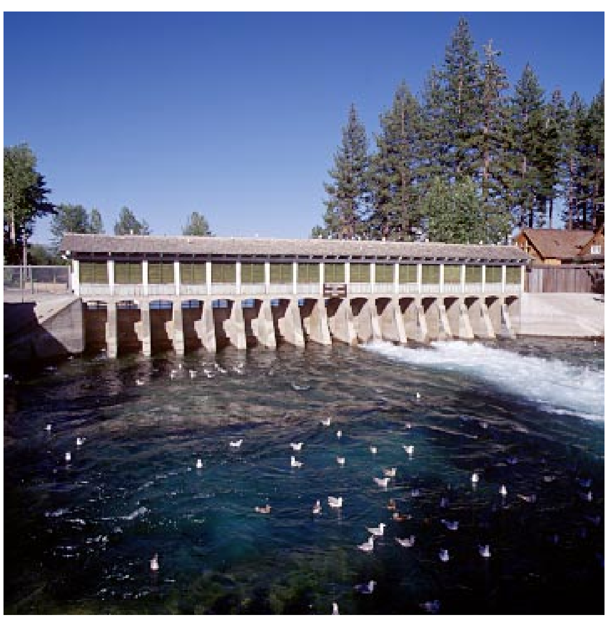
Coordinated Operation Agreement Renegotiation

In 1986, the Department and USBR signed a Coordinated Operation Agreement obligating the CVP and the SWP to coordinate their operations to meet D-1485 standards. The agreement authorizes DOI to operate the CVP in coordination with the SWP to meet State water quality standards for the Bay-Delta (unless DOI determines such operation to be inconsistent with Congressional directives), and provides a formula for sharing the obligation to provide water to meet water quality standards and other in-basin uses. It sets forth the basis for CVP and SWP operation to ensure that each project receives an equitable share of Central Valley runoff and guarantees that the two systems will operate more efficiently during periods of drought than they would if operated independently. Under the COA, the USBR also agreed to meet its share of future water quality standards established by SWRCB.

Article 14 of the COA provides for periodic review of project operation and of the COA, and for future adjustments to the sharing formula if assumed conditions used to calculate the sharing formula change. Since COA execution, biological opinions for winter-run chinook salmon and Delta smelt have imposed new operational constraints on both the CVP and the SWP. In addition, the Bay-Delta Accord has established standards which the two projects are voluntarily meeting, pending implementation of the standards through SWRCB's water rights proceedings. As a result of these changes, the Department and USBR have begun a review of the sharing formula.

Interstate Issues

California receives most of its water supply from intrastate rivers and groundwater basins. The Colorado River, shared among seven states, contributes a substantial water supply to Southern California, and other smaller interstate rivers are locally important sources. The status of apportionment actions on rivers with long-standing interstate issues is discussed below. There is currently no significant activity on interstate groundwater basins. Within the last decade, there had been concerns in California about proposed large-scale groundwater development projects in northern Nevada that could affect interstate basins, but these projects have not been implemented.



USBR's dam on Lake Tahoe regulates releases for downstream water users in Nevada.

Truckee-Carson River System

The Truckee-Carson-Pyramid Lake Water Rights Settlement Act (Title II of PL No. 101-618) settled several water rights disputes affecting the waters of Lake Tahoe, the Truckee River, and the Carson River. Of most importance to California, the act made an interstate apportionment of these waters between the States of California and Nevada. (It was the first Congressional apportionment since the Boulder Canyon Project Act of 1928.) The act addresses several other issues, including settlement of water supply disputes between the Pyramid Lake Paiute Tribe of Indians and other users of the Truckee and Carson Rivers. The act also addresses environmental concerns, such as recovery of listed fish species in Pyramid Lake.

Many of the act's provisions—including the interstate apportionment between California and Nevada—will not take effect until several conditions have been satisfied, including dismissal of specified lawsuits and negotiation and adoption of a Truckee River Operating Agreement. The act requires that a TROA be negotiated among DOI and the States of California and Nevada, after consultation with other parties as may be designated by DOI or by the two states. The TROA addresses interstate water allocation and implements an agreement between Sierra Pacific Power Company and the United States which provides for storing water in upstream reservoirs for Pyramid Lake fish and for emergency drought water supplies for the Reno-Sparks area. TROA negotiation has been ongoing since 1991. A draft TROA is being analyzed in an EIS/EIR prepared by DOI. The Department is the State lead agency for CEQA compliance. The draft EIS/EIR was released for public review in 1998 and is expected to be completed in 1999.

Walker River

There are currently no significant interstate actions pending on the Walker River. A proposed interstate allocation of the Walker River was negotiated at one time but was not implemented. The Walker

River was not included in the settlement legislation for the adjoining Truckee and Carson River Basins. In the recent past, interstate activities on the Walker River have involved water quality and fishery issues associated with river operations and not water allocation issues.

Klamath River

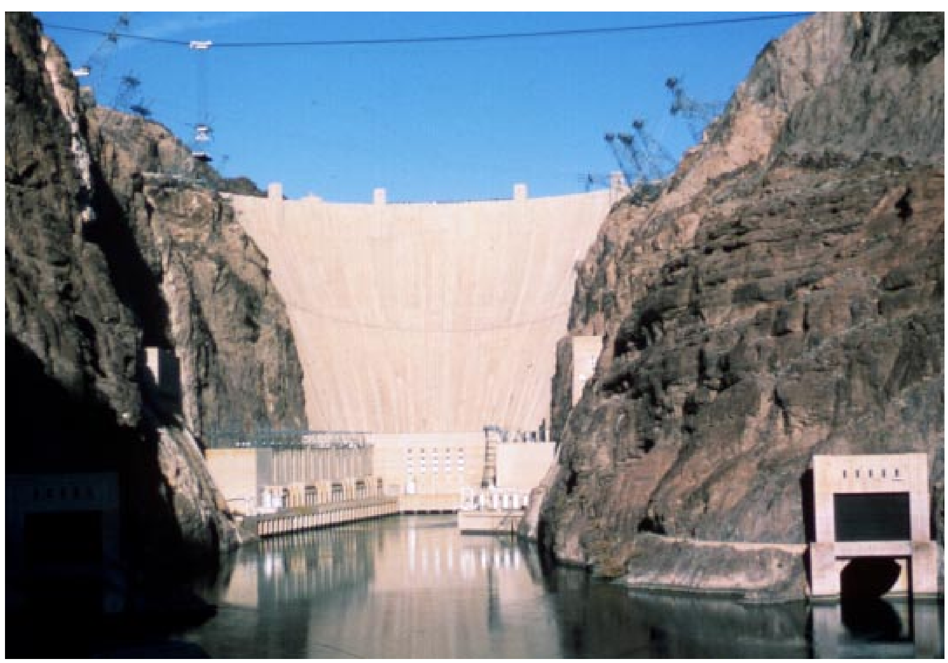
An interstate compact providing for administration of the Klamath River was adopted by California and Oregon and ratified by Congress in 1957. The compact is managed by a Commission consisting of the Director of the Oregon Water Resources Department, the Director of the California Department of Water Resources, and a non-voting federal representative who serves as chairperson.

For the Compact's first 39 years, there was little controversy concerning the upper river basin. Recent changes in operation of USBR's Klamath Project facilities to protect listed fish species have affected irrigation supplies available from the project. The State of Oregon has begun a comprehensive water rights adjudication for its portion of the basin. USBR is drafting a new operations plan for its project to formalize procedures for meeting the needs of listed fish species in Klamath Lake and listed anadromous fish downstream in the lower river. The Klamath River Compact Commission began facilitating a process in cooperation with USBR and basin water users to identify voluntary solutions to water shortages affecting the upper basin. The effort seeks to achieve agreement on ways to secure sufficient water for all needs, rather than on asserting claims to rights.

Colorado River

Colorado River water management activities are described in detail in Chapter 9. The major issue facing California is its use of Colorado River water in excess of the amount apportioned to it by the existing body of statutes, court decisions, and agreements controlling use of the water supply among the seven basin states. California's basic apportionment of river water is 4.4 maf of consumptive use per year (plus a share of surplus flows, when available), as compared to its present consumptive use of up to 5.3 maf/yr. California's use has historically exceeded the basic apportionment because California has been able to divert and use Arizona's and Nevada's unused apportionments, and to divert surplus water. With completion of the Central Arizona Project and the 1996 enactment of groundwater banking legislation, Arizona used more than its basic apportionment in 1997.

California has been meeting with the other basin states to develop a plan for California to reduce its use of Colorado River water to the State's basic apportionment. A draft plan has been developed by the Colorado River Board of California and the local agencies it represents. As described in detail in Chapter 9, the plan includes actions such as water transfers from agricultural users of river water to urban users in the South



USBR's Hoover Dam on the Colorado River was a major engineering feat at the time of its construction and provided jobs for thousands of Depression-era workers. Today, the dam is an important source of water and power for Southern California.

Coast Region, lining of portions of the All American and Coachella Canals, and groundwater banking. As presently envisioned, implementing California's plan would occur in two phases, with projects that are presently well-defined (e.g., canal lining, a San Diego/ Imperial Valley water transfer) implemented in the first phase.

Regional and Local Programs

Local Agency Groundwater Management Programs

In most western states, the rights to the use of surface water and groundwater resources are administered by the states. California administers rights to surface water at the State level, but not rights to groundwater. In California, groundwater may be managed under a variety of authorities, ranging from judicial adjudication of individual basins to several forms of local agency management. Some local agencies have specific statutory authority to manage groundwater resources in their service areas. Other local agencies may manage groundwater under authority provided by general enabling legislation, such as Water Code Section 10750 *et seq.* A few counties have adopted local ordinances dealing with groundwater management.

The 1992 enactment of AB 3030 (Water Code Section 10750 *et seq.*) provided broad general authority for local agencies to adopt groundwater management plans and to impose assessments to cover the cost of implementing the plans. To date, about 150 local agencies have adopted AB 3030 groundwater management plans. Under other groundwater management authorities, there are 7 agencies with AB 255 plans and over 50 agencies with some other form of statutory authority.

The number of agencies adopting AB 3030 plans is increasing. Quantifying the number of plans adopted is somewhat uncertain, since there is no requirement in the statute that agencies adopting plans file copies of those plans with the Department or SWRCB. A tabulation of agencies with AB 3030 plans, together with agencies managing groundwater under some other authority, can be found in the Department's 1998 report to the Legislature on local agency groundwater management.

Watershed-Based Planning

There has been increased interest in watershed-based planning, sometimes prompted by water quality regulatory programs. Watersheds and sub-watersheds are logical units for implementing SDWA source water protection programs and CWA nonpoint source pollution control programs. "Watershed planning" can have a range of meanings—some people associate watershed planning with small, community-based watershed restoration efforts, often carried out via a coordinated resources management plan. Others think of larger-scale efforts that focus on nonpoint source pollution control, such as SWRCB's watershed management initiative. Some watershed-based planning activities are reviewed below.

Nonpoint Source Pollution Control Watershed Planning. SWRCB and the nine regional water quality control boards are implementing a watershed management approach to administering water pollution control programs, addressing point and nonpoint

USBR's Spring Creek Debris Dam was constructed to control runoff reaching the Sacramento River from part of the Iron Mountain Mine site.

TABLE 2-7

Partial List of Targeted Watersheds and Watershed Activities Identified for the Watershed Management Initiative

Regional Board	*Targeted Watershed*	*Targeted Watershed Priorities/Activities*
Region 1 North Coast	Russian/Bodega	Fish restoration, erosion/sedimentation control, riparian enhancement
	Lost River and Klamath River upstream of Iron Gate Dam	Stream restoration on Clear Lake tributaries (Modoc County)
	Shasta River and tributaries	Irrigation return flows, nutrient and temperature reductions, irrigation water conservation
	Scott River and tributaries	Temperature reduction, irrigation water conservation, erosion/ sedimentation control
	Other Klamath River tributaries upstream of Scott River confluence	Fish restoration, erosion/sedimentation control
	Garcia Watershed	Fish restoration, erosion/sedimentation control, temperature reduction
	Humboldt Bay	Fish restoration, erosion/sedimentation control
Region 2 San Francisco Bay	Napa River	Riparian and wetland restoration, sedimentation control, volunteer monitoring
	Petaluma River	Riparian and wetland restoration, sedimentation control, animal waste control, volunteer monitoring
	Tomales Bay	Riparian restoration, sedimentation control, mine waste management, on-site disposal, volunteer monitoring
	San Francisquito Creek	Riparian and wetland restoration, sedimentation control, urban runoff prevention and control, volunteer monitoring
	Walnut Creek	Riparian restoration, sedimentation control, urban runoff prevention and control, volunteer monitoring
	Suisun Marsh	Riparian and wetland restoration, sedimentation control, construction and agricultural activities, volunteer monitoring and education
	Alameda Creek	Riparian and wetland restoration, sedimentation control, construction and agricultural activities, groundwater protection, volunteer monitoring and education
Region 3 Central Coast	Salinas River	Agricultural activities, erosion/sedimentation control, riparian and wetland enhancement and restoration
	Morro Bay	Erosion/sedimentation control, abandoned mines, road construction, agricultural activities, riparian and wetland enhancement and restoration
	San Lorenzo	Erosion/sedimentation control, road construction and maintenance, riparian and wetland enhancement and restoration
	Pajaro River	Nonpoint source pollution control, riparian and wetland enhancement and restoration
	Santa Maria River	Nonpoint source pollution control, riparian and wetland enhancement and restoration

TABLE 2-7

Partial List of Targeted Watersheds and Watershed Activities Identified for the Watershed Management Initiative (continued)

Regional Board	*Targeted Watershed*	*Targeted Watershed Priorities/Activities*
Region 4 Los Angeles	Calleguas Creek	Reduce nutrients, pesticides, and sediments in irrigation water; restore aquatic and riparian habitats; flood control; enhance recreational uses
	Ventura River Watershed	Restore aquatic habitats; implement flood control; enhance recreational uses
	Los Angeles River	Restore aquatic and riparian habitats; enhance recreational uses; reduce pollutants
	Santa Monica Bay	Reduce pollutants from boatyards and marinas; enhance recreational uses; restore wetlands
Region 5 Central Valley	Lower San Joaquin River Watershed	Selenium, agriculture, dairies, temperature, urban runoff
	Sacramento-San Joaquin Delta	Agriculture, sediments, bacteria, dredged material, dissolved oxygen, urban runoff
	Lower Sacramento River Watershed	Agriculture, urban runoff, mercury, heavy metals, nitrates, septic systems, fisheries
	Cache Creek Watershed and Clear Lake	Nutrients (algal blooms), mercury
	Pit River	Hydromodification, nutrients (algal blooms), dissolved oxygen, turbidity/sedimentation, temperature, agriculture, grazing, silvaculture
	Tulare Lake	Salts, pesticides, boron, chloride, molybdenum, sulfate, dissolved oxygen, bacteria, used oil
Region 6 Lahontan	Lower Truckee River	Roadside drainage, erosion control, urban runoff, fisheries habitat improvement, wetlands enhancement, stream restoration
	Upper Truckee River	Sedimentation control, nutrients from watershed disturbances; watershed education; restoration of wetland function, riparian areas, and/or river morphology and function
	Carson River	Erosion control, disposal of livestock waste, watershed education, wetland/riparian restoration
Region 7 Colorado River	Imperial Valley Watershed	Agricultural pollution control
	Coachella Valley Watershed	Agricultural pollution control, groundwater protection
Region 8 Santa Ana	Chino Basin Watershed	Agricultural runoff, dairies, salt build-up in groundwater
	Newport Bay Watershed	Toxics, nutrients, pathogens, sediments
Region 9 San Diego	San Diego Bay - all tributaries	Urban runoff, public education
	San Diego Bay	Copper leaching from boat hulls, oil spills
	Otay River Valley	Urban runoff, public education, pollutant loadings
	Sweetwater River	Heavy metals, petroleum products, public education, nutrient transport, sediment transport
	Aliso Creek	Coliform contamination
	Santa Margarita River	Nitrogen and phosphorus loading from agriculture

pollution sources. In 1997, SWRCB, RWQCBs, and EPA began a new program known as the Watershed Management Initiative. Targeted watersheds and watershed priorities or activities were identified for each of California's nine RWQCBs. Examples of targeted watersheds and watershed priorities or activities are listed in Table 2-7. Federal CWA funding administered by SWRCB may be used to work on priority programs.

Upper Sacramento River Fisheries and Riparian Habitat Plan. In 1986, State legislation (SB 1086) called for preparation of a management plan to protect, restore, and enhance the fishery, riparian habitat, and wildlife of the upper Sacramento River. The plan, published in 1989, was prepared by an advisory council working closely with a wide range of agency representatives and stakeholders. The plan recommended implementation of 20 fishery improvement actions, several of which (for example, constructing a temperature control device at Shasta Dam and improving fish passage at USBR's Red Bluff Diversion Dam) were subsequently included in CVPIA. Other actions, such as habitat restoration at Mill Creek, are being implemented largely under State authorities with the participation of local property owners and other stakeholders.

In 1992, the Upper Sacramento River Advisory Council was reconvened by the Secretary for Resources to "complete its earlier work concerning riparian habitat protection and management, including the development of a specific implementation program." The council in turn established a riparian committee to define the inner and outer zones of a proposed conservation area, provide the basic framework of the riparian plan, and evaluate and recommend a suitable organizational structure to implement the riparian plan. Detailed mapping of the riparian corridor continues, and the committee is continuing to refine mechanisms to manage the proposed conservation area.

San Joaquin River Management Program. The San Joaquin River Management Program was authorized by 1990 State legislation that established an advisory council and action team, and directed the Secretary for Resources to coordinate their activities in preparing a program to develop solutions to meet water supply, water quality, flood protection, fisheries, wildlife habitat, and recreation needs on a specified segment of the San Joaquin River. Members of the advisory council and action team included State, federal, and local agencies and stakeholders representing a variety of interests. The members developed a consensus-based plan addressing resource issues listed in the authorizing legislation; the plan was published in 1995. Subsequent State legislation extended the original 1995 termination of the program and further

USBR is evaluating the fishery impacts of different types of pump diversions to the Tehama-Colusa Canal. One alternative for improving fish passage at Red Bluff Diversion Dam would be to leave the dam's gates in the raised position and use a pumping plant to make TCC diversions. The research plant contains three pumps–one helical pump and two Archimedes screw pumps (right side of photo).

directed SJRMP to work with programs such as CVPIA and CALFED to seek funding for actions recommended in the 1995 plan.

The plan recommended implementation of specific projects and further study of other projects, such as enlargement of Friant Dam and construction of Montgomery Reservoir offstream storage reservoir for fishery water supply. Some of the recommended projects are being implemented, including a pilot program for real-time management of agricultural drainage discharge to the San Joaquin River. Other recommended projects may be implemented through CVPIA's AFRP or the CALFED Category III program.

Conservancies. Other mechanisms for watershed-based planning are conservancies created by special enabling legislation. These conservancies are usually focused on land acquisition or management activities. Two conservancies have a water-related orientation. The Tahoe Conservancy was created in 1984 to acquire and manage property in the Lake Tahoe Basin for the primary purpose of maintaining the lake's water quality. Other authorized purposes of the conservancy are to provide access to public lands, preserve wildlife habitat, and perform environmental restoration projects. The conservancy is governed by a seven-member board, with members from the City of South Lake Tahoe, El Dorado County, Placer County, the Resources Agency, Department of Finance, and two members appointed by the Legislature. A representative of the U.S. Forest Service is a non-voting board member. Since voter enactment of the 1982 Lake Tahoe Acquisitions Bond Act, the conservancy has spent about $85 million in land acquisition and erosion control projects in the basin.

The San Joaquin River Conservancy was created by 1992 legislation to acquire and manage lands along the river in Fresno and Madera Counties for recreational and wildlife habitat. As established in the enabling legislation, the conservancy is governed by a board of six voting members and seven non-voting ex-officio members.

Non-Governmental Organizations. Some watershed-based planning activities are being carried out by voluntary non-governmental organizations, often in the form of non-profit corporations. These NGOs are typically focused on resource issues in small watersheds, where they may partner with a resource conservation district to carry out specific projects. Examples of such efforts are found on Mill Creek and Deer Creek in the Sacramento Valley, where local landowners banded together to improve fishery habitat on the creeks. Actions taken or being considered include addressing fish passage problems at water diversion structures, using groundwater for irrigation instead of surface water during times critical to fish passage, and fencing riparian habitat to exclude livestock.

Implementation of Urban Water Conservation MOU

The 1991 *Memorandum of Understanding Regarding Urban Water Conservation in California* defined a set of urban best management practices and procedures for their implementation, and established a California Urban Water Conservation Council composed of MOU signatories (local water agencies, environmental groups, and other interested parties). More than 200 entities have signed the MOU. The CUWCC has monitored implementation of BMPs and reported progress annually to the SWRCB. The council developed a plan providing for ongoing review of BMPs and potential BMPs. In late 1996, the council initiated a review of the BMPs to clarify expectations for implementation and to develop an implementation evaluation methodology. Revised BMPs were adopted in 1997, as described in Chapter 4.

Implementation of Agricultural Efficient Water Management Practices MOU

The Agricultural Efficient Water Management Practices Act of 1990 (AB 3616) required the Department to establish an advisory committee to develop EWMPs for agricultural water use. Negotiations among agricultural water users, environmental interests, and governmental agencies on a MOU to implement EWMPs were completed in 1996. The MOU established an Agricultural Water Management Council to oversee EWMP implementation, much like the organizational structure that exists for urban BMPs, and also provided a mechanism for its signatories to evaluate and endorse water management plans. By May 1998, the MOU had been signed by 31 agricultural water suppliers irrigating about 3 million acres of land, as well as by over 60 other entities. More detail on the agricultural MOU is provided in Chapter 4.

2A

Institutional Framework for Allocating and Managing Water Resources in California

In California, water use and supplies are controlled and managed under an intricate system of federal and State laws. Common law principles, constitutional provisions, State and federal statutes, court decisions, and contracts or agreements all govern how water is allocated, developed, or used. All of these components constitute the institutional framework for allocation and management of water resources in California.

This appendix presents an overview of California's institutional framework, highlighting some of the more recent changes. Summarized here are major constitutional requirements, statutes, court decisions, and agreements that form the groundwork for many water resource management and planning activities. Changes since the publication of Bulletin 160-93 are covered in the Chapter 2 text.

Allocation and Management of California's Water Supplies

The following subsections condense basic water rights laws and doctrines governing allocation and use of California's water supplies.

California Constitution Article X, Section 2

The keystone of California's water law and policy, Article X, Section 2 of the California Constitution, requires that all uses of the State's water be both reasonable and beneficial. It places a significant limitation on water rights by prohibiting the waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water.

Riparian and Appropriative Rights

California operates under a dual system of water rights for surface water which recognizes both riparian rights and appropriative rights. Under the riparian doctrine, the owners of land have the right to divert, but not store, a portion of the natural flow of water flowing by their land for reasonable and beneficial use upon their land adjacent to the stream and within its watershed, subject to certain limitations. Generally, all riparian water right holders must reduce their water use in times of water shortages. Under the prior appropriation doctrine, a person may acquire a right to divert, store, and use water regardless of whether the land on which it is used is adjacent to a stream or within its watershed, provided that the water is used for reasonable and beneficial uses and is surplus to water from the same stream used by earlier appropriators. The rule of priority between appropriators is "first in time is first in right."

Water Rights Permits and Licenses

The Water Commission Act, which took effect in 1914 following a referendum, recognized the overriding interest of the people in the waters of the State, but provided that private rights to use water may be acquired in the manner provided by law. The act established a system of State-issued permits and licenses to appropriate water. Amended over the years, it now appears in Division 2 (commencing with Section 1000) of the Water Code. These provisions place responsibility for administering appropriative water rights with

SWRCB; however, the permit and license provisions do not apply to pre-1914 appropriative rights (those initiated before the act took effect in 1914). The act also provides procedures for adjudication of water rights, including court references to SWRCB and statutory adjudications of all rights to a stream system.

Groundwater Management

Generally, groundwater is available to any person who owns land overlying the groundwater basin. Groundwater management in California may be accomplished either by a judicial adjudication of the respective rights of overlying users and exporters, or by local management of rights to extract and use groundwater as authorized by statute or agreement. Statutory management may be granted to a public agency that also manages surface water, or to a groundwater management agency created expressly for that purpose by a special district act.

In 1991, the Water Code was amended by AB 255 to allow local water agencies overlying critically overdrafted groundwater basins to develop groundwater management plans. Only a few local agencies adopted plans pursuant to that authorization. In 1992, the Legislature adopted new sections authorizing another form of groundwater management, also available to any local agency that provides water service, if the groundwater was not subject to management under other provisions of law or a court decree. Plans adopted pursuant to the 1992 statute (commonly called AB 3030 plans) may include control of salt water intrusion; identification and protection of wellhead and recharge areas; regulation of the migration of contaminated water; provisions for abandonment and destruction of wells; mitigation of overdraft; replenishment; monitoring; facilitating conjunctive use; identification of well construction policies; and construction of cleanup, recharge, recycling, and extraction projects by the local agency.

Public Trust Doctrine

In the 1980s, the public trust doctrine was used by courts to limit traditional water rights. Under the equal footing doctrine of the U.S. Constitution, each state has title to tidelands and the beds of navigable lakes and streams within its borders. The public trust doctrine—recognized in some form by most states—embodies the principle that the state holds title to such properties within the state in trust for the beneficial use of the public, and that public rights of access to and use of tidelands and navigable waters are inalienable. Traditional public trust rights include navigation, commerce, and fishing. California law has expanded the traditional public trust uses to include protection of fish and wildlife, preserving trust lands in their natural condition for scientific study and scenic enjoyment, and related open-space uses.

In 1983, the California Supreme Court extended the public trust doctrine's limitation on private rights to appropriative water rights. In *National Audubon Society v. Superior Court of Alpine County,* the court held that water right licenses held by the City of Los Angeles to divert water from streams tributary to Mono Lake remain subject to ongoing State supervision under the public trust doctrine. The court held that public trust uses must be considered and balanced when rights to divert water away from navigable water bodies are considered. The court also held that California's appropriative rights system and the public trust doctrine embody important precepts which ". . . make the law more responsive to the diverse needs and interests involved in planning and allocation of water resources." Consequently, in issuing or reconsidering any rights to appropriate and divert water, the State must balance public trust needs with the needs for other beneficial uses of water. In 1994, the SWRCB issued a final decision on Mono Lake (Decision 1631) in which it balanced the various uses in determining the appropriate terms and conditions of the water rights permit for the City of Los Angeles. The public trust doctrine will also be applied by the SWRCB in its current consideration of water rights in the Bay-Delta.

Since the 1983 National Audubon decision, the public trust doctrine has been involved in several other cases. In *United States v. State Water Resources Control Board* (commonly referred to as the Racanelli Decision and discussed below), the State Court of Appeal reiterated that the public trust doctrine is a significant limitation on water rights. The public trust doctrine was also a basis for the decision in *Environmental Defense Fund v. East Bay Municipal Utility District.* In this case, EDF claimed that EBMUD should not contract with USBR for water diverted from the American River upstream from the Sacramento urban area in a manner that would harm instream uses including recreational, scenic, and fish and wildlife preservation purposes. The Superior Court upheld the validity of EBMUD's contract with USBR, but placed limitations on the timing and amounts of deliveries to EBMUD. As a result of these cases, the SWRCB now routinely implements the public trust doctrine through regulations and through terms and conditions in water rights permits and licenses.

Federal Power Act

The Federal Power Act created a federal licensing system administered by the Federal Energy Regulatory Commission and required that a license be obtained for nonfederal hydroelectric projects proposing to use navigable waters or federal lands. The act contains a clause modeled after a clause in the Reclamation Act of 1902, which disclaims any intent to affect state water rights law.

In a number of decisions dating back to the 1940s, the U.S. Supreme Court held that provisions of the Reclamation Act and the Federal Power Act preempted inconsistent provisions of law. Decisions under both acts found that these clauses were merely "saving clauses" which required the United States to follow minimal state procedural laws or to pay just compensation where vested nonfederal water rights are taken.

In *California v. United States* (1978), however, the U.S. Supreme Court disavowed dicta in a number of earlier Supreme Court decisions which stated that under the Reclamation Act the United States need not comply with state water law. It held that the Reclamation Act clause requires the USBR to comply with conditions in state water rights permits unless those conditions conflict with "clear Congressional directives." In *California v. FERC* (1990), commonly referred to as the Rock Creek Decision, the U.S. Supreme Court rejected California's argument that the Federal Power Act clause required deference to state water law, as the Reclamation Act did. The Supreme Court distinguished between the two acts, finding that the Federal Power Act envisioned a broader and more active oversight role than did the Reclamation law. The Federal District Court case of *Sayles Hydro Association v. Maughan* (1993), reinforced this view by holding that federal law prevents any state regulation of federally licensed power projects other than determining proprietary water rights.

In 1994, the U.S. Supreme Court issued a decision referred to as the Elkhorn decision or Tacoma decision (*PUD No. 1 of Jefferson County and City of Tacoma v. Washington Department of Ecology)*. The Supreme Court held that a state minimum instream flow requirement is a permissible condition of a Clean Water Act Section 401 certification, in response to a proposal to construct a hydroelectric project on the Dosewallips River. Pursuant to Section 401 of the Clean Water Act, the project proponents were required to obtain state certification for the hydroelectric project. The State of Washington set an instream flow requirement in its certification process to protect the river's designated use as fish habitat. Section 303 of the Clean Water Act requires states to establish water quality standards for intrastate waters, with the standards to include both numeric water quality criteria and designated uses.

Area of Origin Protections

During the years when California's two largest water projects, the CVP and SWP, were being planned and developed, area of origin provisions were added to the water code to protect local Northern California supplies from being depleted as a result of the projects. County of origin statutes reserve water supplies for counties in which the water originates when, in the judgment of the SWRCB, an application for the assignment or release from priority of State water right filings will deprive the county of water necessary for its present and future development. Watershed protection statutes are provisions which require that the construction and operation of elements of the CVP and the SWP not deprive the watershed, or area where water originates (or immediately adjacent areas which can be conveniently supplied with water) of the prior right to water reasonably required to supply the present or future beneficial needs of the watershed area or any of its inhabitants or property owners.

The Delta Protection Act, enacted in 1959 (not to be confused with the Delta Protection Act of 1992, which relates to land use), declares that the maintenance of an adequate water supply in the Delta—to maintain and expand agriculture, industry, urban, and recreational development in the Delta area and provide a common source of fresh water for export to areas of water deficiency—is necessary for the peace, health, safety, and welfare of the people of the State, and is subject to the County of Origin and Watershed Protection laws. The act requires the SWP and the CVP to provide salinity control in the Delta and an adequate water supply for water users in the Delta.

In 1984, additional area of origin protections were enacted covering the Sacramento, Mokelumne, Calaveras, and San Joaquin Rivers; the combined Truckee, Carson, and Walker Rivers; and Mono Lake. The protections prohibit the export of groundwater from the combined Sacramento River and Delta Basins, unless the export is in compliance with local groundwater plans.

Environmental Regulatory Statutes and Programs

Endangered Species Act

Under the federal ESA, an endangered species is one that is in danger of extinction in all or a significant part of its range, and a threatened species is one that is likely to become endangered in the near future. The ESA is designed to preserve endangered and threatened species by protecting individuals of the species and their habitat and by implementing measures that promote their recovery. The ESA sets forth a procedure for listing species as threatened or endangered. Final listing decisions are made by USFWS or NMFS.

Once a species is listed, Section 7 of the act requires that federal agencies, in consultation with the USFWS or NMFS, ensure that their actions do not jeopardize the continued existence of the species or habitat critical for the survival of that species. The federal wildlife agencies are required to provide an opinion as to whether the federal action would jeopardize the species. The opinion must include reasonable and prudent alternatives to the action that would avoid jeopardizing the species' existence. Federal actions subject to Section 7 include issuance of federal permits such as the dredge and fill permit required under Section 404 of the federal Clean Water Act, which requires that the project proponent demonstrate that there is no feasible alternative consistent with the project goals that would not affect listed species. Mitigation of the proposed project is not considered until this hurdle is passed.

State agencies and private parties also are subject to the ESA. Section 9 of the ESA prohibits the "take" of endangered species and threatened species for which protective regulations have been adopted. Take has been broadly defined to include actions that harm or harass listed species or that cause a significant loss of their habitat. State agencies and private parties are generally required to obtain a permit from the USFWS or NMFS under Section 10(a) of the ESA before carrying out activities that may incidentally result in taking listed species. The permit normally contains conditions to avoid taking listed species and to compensate for habitat adversely impacted by the activities.

California Endangered Species Act

The California Endangered Species Act is similar to the federal ESA. Listing decisions are made by the California Fish and Game Commission.

All State lead agencies are required to consult with the Department of Fish and Game about projects that impact State listed species. DFG is required to render an opinion as to whether the proposed project jeopardizes a listed species and to offer alternatives to avoid jeopardy. State agencies must adopt reasonable alternatives unless there are overriding social or economic conditions that make such alternatives infeasible. For projects causing incidental take, DFG is required to specify reasonable and prudent measures to minimize take. Any take that results from activities that are carried out in compliance with these measures is not prohibited.

Many California species are both federally listed and State listed. CESA directs DFG to coordinate with the USFWS and NMFS in the consultation process so that consistent and compatible opinions or findings can be adopted by both federal and State agencies.

Natural Community Conservation Planning

Adopted in 1991, California's Natural Community Conservation Planning Act establishes a program to identify the habitat needs of species before they become listed as threatened or endangered, and to develop appropriate voluntary conservation methods compatible with development and growth. Participants in the program develop plans to protect certain habitat and will ultimately enter into agreements with DFG to ensure that the plans will be carried out. Plans must be created so that they are consistent with endangered species laws.

Dredge and Fill Permits

Section 404 of the federal Clean Water Act regulates the discharge of dredged and fill materials into waters of the United States, including wetlands. The term "discharge of dredged and fill material" has been defined broadly to include the construction of any structure involving rock, soil, or other construction material. No discharge may occur unless a permit is obtained from the USACE. Generally, the project proponent must agree to mitigate or have plans to mitigate environmental impacts caused by the project before a permit is issued. The EPA has the authority to veto permits issued by the Corps for projects that have unacceptable adverse effects on municipal water supplies, fisheries, wildlife, or recreational areas.

Section 404 allows the issuance of a general permit on a state, regional, or nationwide basis for certain categories of activities that will cause only minimal environmental effects. Such activities are permitted without the need of an individual permit application. Installation of a stream gaging station along a river levee is one example of an activity which falls within a nationwide permit.

The USACE also administers a permitting program under Section 10 of the 1899 Rivers and Harbors Act. Section 10 generally requires a permit for obstructions to navigable water. The scope of the permit under Section 10 is narrower than under Section 404 since the term "navigable waters" is more limited than "waters of the United States."

The majority of water development projects must comply with Section 404, Section 10, or both.

Public Interest Terms and Conditions

The Water Code authorizes the SWRCB to impose public interest terms and conditions to conserve the public interest, specifically the consideration of instream beneficial uses, when it issues permits to appropriate water. It also considers environmental impacts of approving water transfers under its jurisdiction. Frequently, it reserves jurisdiction to consider new instream uses and to modify permits accordingly.

Releases of Water for Fish

Fish and Game Code Section 5937 provides protection to fisheries by requiring that the owner of any dam allow sufficient water at all times to pass through the dam to keep in good condition any fisheries that may be planted or exist below the dam. In *California Trout, Inc. v. the State Water Resources Control Board* (1989), the court determined that Fish and Game Code sections 5937 and 5946 required the SWRCB to modify the permits and licenses issued to the City of Los Angeles to appropriate water from the streams feeding Mono Lake to ensure sufficient water flows for downstream fisheries. The SWRCB reconsidered Los Angeles' permits and licenses in light of Fish and Game Code Section 5937 and the public trust doctrine. In 1994, the SWRCB adopted D-1631, which requires Los Angeles to allow sufficient flows from the streams feeding Mono Lake to reach the lake to allow it to rise to the level of 6,391 feet in approximately twenty years.

Streambed Alteration Agreements

Fish and Game Code Sections 1601 and 1603 require that any governmental entity or private party altering a river, stream, lakebed, bottom, or channel enter into an agreement with DFG. When the project may substantially impact an existing fish or wildlife resource, DFG may require that the agreement include provisions designed to protect riparian habitat, fisheries, and wildlife. New water development projects and ongoing maintenance activities are often subject to these sections.

Migratory Bird Treaty Act

This act implements various treaties for the protection of migratory birds and prohibits the "taking" (broadly defined) of birds protected by those treaties without a permit. The Secretary of the Interior determines conditions under which a taking may occur, and criminal penalties are provided for unlawfully taking or transporting protected birds. Liability imposed by this act was one of several factors leading to the decision to close the San Luis Drain and Kesterson Reservoir.

Environmental Review and Mitigation

Another set of environmental statutes compels governmental agencies and private individuals to document and consider the environmental consequences of their actions. They define the procedures through which governmental agencies consider environmental factors in their decision-making process.

National Environmental Policy Act

NEPA directs federal agencies to prepare an environmental impact statement for all major federal actions which may have a significant effect on the human environment. It states that it is the goal of the federal government to use all practicable means, consistent with other considerations of national policy, to protect and enhance the quality of the environment. It is a procedural law requiring all federal agencies to consider the environmental impacts of their proposed actions during the planning and decision-making processes.

California Environmental Quality Act

CEQA, modeled after NEPA, requires California public agency decision-makers to document and consider the environmental impacts of their actions. It requires an agency to identify ways to avoid or reduce environmental damage, and to implement those measures where feasible. CEQA applies to all levels of California government, including the State, counties, cities, and local districts.

CEQA requires that a public agency carrying out a project with significant environmental effects prepare an environmental impact report. An EIR contains a description of the project; a discussion of the project's environmental impacts, mitigation measures, and alternatives; public comments; and the agency's responses to the comments. In other instances, a notice of exemption from the application of CEQA may also be appropriate.

NEPA does not generally require federal agencies to adopt mitigation measures or alternatives provided in the EIS. CEQA imposes substantive duties on all California governmental agencies that approve projects with significant environmental impacts to adopt feasible alternatives or mitigation measures that substantially lessen these impacts, unless there are overriding reasons. When a project is subject to both CEQA and NEPA, both laws encourage the agencies to cooperate in planning the project and to prepare joint environmental documents.

Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act expresses congressional policy to protect the quality of the aquatic environment as it affects the conservation, improvement, and enjoyment of fish and wildlife resources. Under this act, any federal agency that proposes to control or modify any body of water, or to issue a permit allowing control or modification of a body of water, must first consult with the USFWS and State wildlife officials. This requires coordination early in the project planning and environmental review processes.

Protection of Wild and Natural Areas

Water use and management are also limited by several statutes designed to set aside resources or areas to preserve their natural conditions. These statutes preclude many activities, including most water development projects, within the areas set aside.

Federal Wild and Scenic Rivers System

In 1968, Congress passed the National Wild and Scenic Rivers Act to preserve, in their free-flowing condition, rivers which possess "outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values." The act also states " . . . that the established national policy of dam and other construction at appropriate sections of rivers of the United States needs to be complemented by a policy that would preserve other selected rivers or sections thereof in their free-flowing condition to protect the water quality of such rivers and to fulfill other vital national conservation purposes."

The act prohibits federal agencies from constructing, authorizing, or funding the construction of water resources projects having a direct and adverse effect on the values for which a river was designated. This restriction also applies to rivers designated for potential addition to the National Wild and Scenic Rivers System. Included in the system are most rivers protected under California's State Wild and Scenic Rivers Act; these rivers were included in the national system upon California's petition on January 19, 1981. The West Walker and East Fork Carson Rivers are not included in the federal system.

California Wild and Scenic Rivers System

In 1972, the Legislature passed the California Wild and Scenic Rivers Act, declaring that specified rivers possess extraordinary scenic, recreational, fishery, or wildlife values, and should be preserved in a free-flowing state for the benefit of the people of California. It declared that such use of the rivers would be the highest and most beneficial use within the meaning of Article X, Section 2 of the California Constitution. The act prohibits construction of any dam, reservoir, diversion, or other water impoundment on a designated river. Diversions needed to supply domestic water to residents of counties through which the river flows may be authorized, if the Secretary for Resources determines that the diversion will not adversely affect the river's free-flowing character.

The major difference between the national and State acts is that if a river is designated wild and scenic under the State act, FERC can still issue a license to build a dam on that river, thus overriding the State system. (See Federal Power Act discussion above.) This difference explains why national wild and scenic designation is often sought.

National Wilderness Act

The Wilderness Act sets up a system to protect federal land designated by Congress as a "wilderness area" and preserve it in its natural condition. Wilderness is defined as undeveloped federal land retaining its primeval character and influence without permanent improvements or human habitation. Commercial enterprise, permanent roads, motor vehicles, aircraft landings, motorized equipment, or construction of structures or installations (such as dams, diversions, conveyance facilities, and gaging stations) are prohibited within designated wilderness areas.

Water Quality Protection

Water quality is an important aspect of water resource management. The SWRCB plays a central role in determining both water rights and regulating water quality. The Department of Health Services has regulatory oversight over drinking water quality, a program administered in coordination with county environmental health agencies. Discussed below are key State and federal laws governing water quality.

Porter-Cologne Water Quality Control Act

This act is California's comprehensive water quality control law and is a complete regulatory program designed to protect water quality and beneficial uses of the State's water. The act requires the adoption of water quality control plans by the State's nine RWQCBs for areas within their regions. These plans are subject to the approval of the SWRCB, and ultimately the federal EPA. The plans are to be reviewed and updated.

The primary method of implementing the plans is to require each discharger of waste that could impact the waters of the State to meet formal waste discharge requirements. Anyone discharging waste or proposing to discharge waste into the State's waters must file a "report of waste discharge" with the regional water quality control board within whose jurisdiction the discharge lies. Dischargers are subject to a wide variety of administrative, civil, and criminal actions for failing to file a report. After the report is filed, the regional board may issue waste discharge requirements that set conditions on the discharge. The waste discharge requirements must be consistent with the water quality control plan for the body of water and protect the beneficial uses of the receiving waters. The regional boards also implement Section 402 of the federal Clean Water Act, which allows the State to issue a single discharge permit for the purposes of both State and federal law.

Clean Water Act—National Pollutant Discharge Elimination System

Section 402 of the Clean Water Act established a permit system known as the National Pollutant Discharge Elimination System to regulate point sources of discharges in navigable waters of the United States. The EPA was given the authority to implement the NPDES, although the act also authorizes states to implement the act in lieu of the EPA, provided the state has sufficient authority.

In 1972, the Legislature amended the Porter-Cologne Act to give California the authority and ability to operate the NPDES permits program. Before a permit may be issued, Section 401 of the Clean Water Act requires that the regional water quality control board certify that the discharge will comply with applicable water quality standards. After making the certification, the regional board may issue the permit, satisfying both State and federal law. In 1987, Section 402 was amended to require the regulation of storm water runoff under the NPDES.

Safe Drinking Water Act

The SDWA, enacted in 1974 and significantly amended in 1986 and 1996, directed the EPA to set national standards for drinking water quality. It required the EPA to set maximum contaminant levels for a wide variety of constituents. Local water suppliers are required to monitor their water supplies to assure that regulatory standards are not exceeded.

The 1986 amendments set a timetable for the EPA to establish standards for specific contaminants and increased the range of contaminants local water suppliers were required to monitor to include contaminants that did not yet have an MCL established. The amendments included a wellhead protection program, a grant program for designating sole-source aquifers for special protection, and grant programs and technical and financial assistance to small systems and states.

The 1996 amendments added a provision requiring states to create their own revolving funds in order to be eligible to receive federal matching funds for loans and grants to public water systems. More details of the 1996 amendments are described in Chapter 2.

California Safe Drinking Water Act

In 1976, California enacted its own Safe Drinking Water Act, requiring the Department of Health Services to regulate drinking water, including: setting and enforcing federal and State drinking water standards; administering water quality testing programs; and administering permits for public water system operations. The federal Safe Drinking Water Act allows the State to enforce its own standards in lieu of the federal standards so long as they are at least as protective as the federal standards. Significant amendments to the California act in 1989 incorporated the new federal safe drinking water act requirements into California law, gave DHS discretion to set more stringent MCLs, and recommended public health levels for contaminants. DHS was authorized to consider the technical and economic feasibility of reducing contaminants in setting MCLs. The standards established by DHS are found in the California Code of Regulations, Title 22.

Historical Background—Bay-Delta Regulatory Actions

The SWRCB issued the first water rights permits to the USBR for operation of the CVP in 1958, and to the Department for operation of the SWP in 1967. In these and all succeeding permits issued for the CVP and SWP, the SWRCB reserved jurisdiction to reformulate or revise terms and conditions relative to salinity control, effect on vested rights, and fish and wildlife protection in the Delta. SWRCB has a dual role of issuing both water rights permits and regulating water quality.

Decision 1485

In 1976, SWRCB initiated proceedings leading to the adoption of D-1485 in 1978. D-1485 set forth conditions—including water quality standards, export limitations, and minimum flow rates—for SWP and CVP operations in the Delta and superseded all previous water rights decisions for the SWP and CVP operations in the Delta. Among beneficial uses to be protected by the decision were: municipal and industrial water supply, agriculture, and fish and wildlife.

In formulating D-1485, the SWRCB asserted that Delta water quality should be at least as good as it would have been if the SWP and CVP had not been constructed. In other words, both the SWP and the CVP were to be operated to meet "without project" conditions. D-1485 standards included different levels of protection to reflect variations in hydrologic conditions during different types of water years.

To help implement these water quality standards, D-1485 mandated an extensive monitoring program. It also called for special studies to provide critical data about major concerns in the Delta and Suisun Marsh for which information was insufficient. D-1485 included water quality standards for Suisun Marsh, as well as for the Delta, requiring the Department and USBR to develop a plan for the marsh that would ensure meeting long-term standards.

Recognizing that the complexities of project operations and water quality conditions would change over time, the SWRCB also specified that the Delta water right hearings would be reopened within ten years of the date of adoption of D-1485, depending upon changing conditions in the Bay-Delta region and the availability of new evidence on beneficial uses of water.

Racanelli Decision

Lawsuits by various interests challenged D-1485 and the decision was overturned by the trial court in 1984. Unlike its predecessor, D-1379, whose standards had been judicially stayed, D-1485 remained in effect. In 1986, the appellate court in the Racanelli Decision (named after Judge Racanelli who wrote the opinion) broadly interpreted the SWRCB's authority and obligation to establish water quality objectives, and its authority to set water rights permit terms and conditions that provide reasonable protection of beneficial uses of Delta water.

The court stated that SWRCB needed to separate its water quality planning and water rights functions. SWRCB needs to maintain a "global perspective" in identifying beneficial uses to be protected (not limited to water rights) and in allocating responsibility for implementing water quality objectives (not just to the SWP and CVP, nor only through the SWRCB's own water rights processes). The court recognized the SWRCB's authority to look to all water rights holders to implement water quality standards and advised SWRCB to consider the effects of all Delta and upstream water users in setting and implementing water quality standards in the Delta, as well as those of the SWP and the CVP.

SWRCB Bay-Delta Proceedings

Hearings to adopt a water quality control plan and water rights decision for the Bay-Delta estuary began in July 1987. Their purpose was to develop a Bay-Delta water quality control plan and to consider public interest issues related to Delta water rights, including implementation of water quality objectives. During the first phase of the proceedings, testimony was heard on issues pertaining to the reasonable and beneficial uses of the estuary's water. The second phase of the Bay-Delta hearings was to come up with a water quality control plan. SWRCB adopted a final plan in May 1991. The federal EPA rejected this plan in September 1991, setting the stage for preparation of federal water quality standards for the Bay-Delta.

With the adoption of the water quality control plan, the SWRCB began the EIR scoping phase and held several workshops during 1991 to receive testimony regarding planning activities, facilities development, negotiated settlements, and flow objectives.

Concurrently, under the broad authority of the ESA, the federal regulatory process was proceeding toward development of Delta standards and upstream measures applicable to the CVP and SWP for the protection of the threatened winter-run chinook salmon. In February 1993, the NMFS issued a long-term biological opinion governing operations of the CVP and SWP with Delta environmental regulations that, in certain months, were more restrictive than SWRCB's proposed measures. In March 1993, the USFWS listed the Delta smelt as a threatened species and shortly thereafter indicated that further restrictions of CVP and SWP operations would be required. In December 1993, EPA announced its proposed standards for the estuary in place of the SWRCB water quality standards that EPA had rejected in 1991. In addition, USFWS proposed to list the Sacramento splittail as a threatened species, and NMFS announced its decision to change the status of winter-run salmon from threatened to endangered.

The impending regulatory gridlock lead to the negotiation and signing of the June 1994 Framework Agreement for the Bay-Delta estuary. The Framework Agreement and subsequent Bay-Delta activities are described in Chapter 2.

To mitigate fish losses at Delta export facilities, the Department and USBR have entered into agreements with DFG. As part of the environmental review process for installing four additional pumps at SWP's Banks Pumping Plant in the Delta in 1992, DFG and the Department negotiated an agreement to preserve fish potentially affected by the operation of the pumps. This agreement, signed by the two departments in 1986, identifies the steps needed to offset adverse impacts of the Banks Pumping Plant on fisheries. It sets up a procedure to calculate direct fishery losses annually and requires the Department to pay for mitigation projects that would offset the losses. Losses of striped bass, chinook salmon, and steelhead are to be mitigated first. Mitigation of other species is to follow as impacts are identified and appropriate mitigation measures found. In recognition of the fact that direct losses today would probably be greater if fish populations had not been depleted by past operations, the Department also provided $15 million for a program to increase the probability of quickly demonstrated results. In 1996, the Department and DFG agreed to extend the period for expending the remainder of the $15 million to the year 2001.

Following negotiation of the agreement for Banks Pumping Plant, DFG negotiated a similar agreement with USBR for its CVP Tracy Pumping Plant.

Surface Water Management

The following sections are brief descriptions of major statutes affecting surface water management in California.

CVPIA

The Central Valley Project Improvement Act (Title 34 of PL 102-575) made significant changes to the CVP's legislative authorization, amending the project's purposes to place fish and wildlife mitigation and restoration on a par with water supply, and to place fish and wildlife enhancement on a par with power generation. Major provisions of the act are summarized below.

The act prohibits execution of new CVP water supply contracts for purposes other than fish and wildlife (with a few limited exceptions) until all environmental restoration actions specified in the act have been completed. Existing long-term water supply contracts are to be renewed for a 25-year term, with the possibility of subsequent 25-year renewals thereafter. Only interim contract renewals are allowed until the programmatic EIS required by the act is completed. Renewed contracts are to incorporate CVPIA's new requirements, such as restoration fund payments.

The act allows transfers of project water to users outside of the CVP service area, under numerous specified conditions. The conditions include a right of first refusal to a proposed transfer by existing CVP water users (under the same terms and conditions specified in the proposed transfer), and a requirement that proposed transfers of more than 20 percent of a contracting agency's project water supply be subject to review and approval by the contracting agency.

The act requires DOI to develop water conservation criteria, and to review conservation plans submitted by contracting agencies pursuant to Reclamation Reform Act requirements for conformance to the CVPIA criteria. Tiered pricing is to be included in CVP water supply contracts when they are renewed. Project water supply and repayment contractors' surface water delivery systems are to be equipped with water measurement devices.

The act directs DOI to develop a program, by October 1995, to make all reasonable efforts to double, by 2002, natural production (based on 1967-91 fishery population levels) of specified anadromous fish in the Central Valley, and to implement that program. (A portion of the San Joaquin River is exempted from this provision.) The act dedicates 800 taf/yr of CVP yield to fish and wildlife purposes, and authorizes DOI to acquire supplemental water for meeting the fish doubling goal. The act further requires that DOI provide an annual Trinity River instream flow of at least 340 taf through 1996, via releases from Lewiston Dam, with subsequent instream flow requirements to be determined by a USFWS instream flow study.

The act requires DOI to provide, from CVP supplies, firm water supplies (i.e., deliver water corresponding to existing non-firm supplies such as agricultural drainage) to specified federal, State, and private wildlife refuges in the Sacramento and San Joaquin Valleys. DOI is to acquire, from willing sellers, an additional increment of water supply for the wildlife areas, corresponding to their full habitat development needs. All of the supplemental water needs are to be met by 2002.

The act requires DOI to implement numerous specified environmental restoration actions, such as constructing a temperature control device at Shasta Dam, remedying fish passage problems at Red Bluff Diversion Dam, replenishing spawning gravel, and assisting in screening non-federal diversions. Costs of some of these restoration actions are allocated in part to the State of California. DOI is required to enter into a cost-sharing agreement with California for the environmental restoration actions whose costs are allocated in part to California.

The act requires DOI to prepare specified reports and studies, to implement a Central Valley fish and wildlife monitoring program, and to develop ecosystem and water operations models. Examples of reports to be prepared include a least-cost plan to replace the 800 taf/yr of project yield dedicated to environmental purposes, and an evaluation of water supply and development requirements for 120,000 acres of wetlands identified in a Central Valley Habitat Joint Venture report. DOI is also directed to prepare, by October 1995, a programmatic EIS analyzing impacts of CVPIA implementation.

The act authorizes DOI to carry out a land retirement program, and specifies categories of land that may be acquired. San Joaquin Valley drainage-impaired lands are among the authorized categories.

The act establishes a CVPIA restoration fund within the federal treasury, and directs DOI to collect mitigation and restoration payments from project water and power users. DOI is authorized to use appropriations from the fund to carry out the environmental restoration measures required by the act. Payments are capped at $6/af for agricultural water contractors and $12/af (1992 dollars) for municipal and industrial water contractors, but the caps are subject to adjustment for inflation. (An additional restoration payment is assessed against contractors in the Friant Division, in lieu of requiring Friant Dam releases for instream flows in the San Joaquin River between Gravelly Ford and the Mendota Pool.)

Regional and Local Water Agency Formation

In general, there are two methods in California for forming special districts which develop, control, or distribute water: enactment of a general act under which the districts may be formed as set forth in the act, and enactment of a special act creating the district and prescribing its powers. There are more than 40 different statutes under which local agencies may be so organized. In addition, there are a number of special act districts, such as the Metropolitan Water District of Southern California. The Department's Bulletin 155-94, *General Comparison of Water District Acts* (March 1994), presents a comparison of various water district acts in California.

In addition to public agencies, there are other entities that may provide water supply. Mutual water companies, for example, are private corporations that perform water supply and distribution functions similar to public water districts. Investor-owned utilities may also be involved in water supply activities, sometimes as an adjunct of hydroelectric power development.

Water Use Efficiency

Article X, Section 2 of the California Constitution prohibits the waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water. It also declares that the conservation and use of water "shall be exercised with a view to the reasonable and beneficial use thereof in the public interest and for the public welfare." Although provisions and requirements of the Constitution are self executing, the Constitution states that the Legislature may enact statutes to advance its policy. Water Code Section 275 directs the Department and SWRCB to "take all appropriate proceedings or actions before executive, legislative, or judicial agencies to prevent waste or unreasonable use of water." SWRCB's Water Right Decision 1600, directing the Imperial Irrigation District to adopt a water conservation plan, is an example of an action brought under Article X, Section 2. SWRCB's authority to order preparation of such a plan was upheld in 1990 by the courts in *Imperial Irrigation District v. State Water Resources Control Board.*

Urban Water Management Planning Act

Since 1983, this act has required urban water suppliers that serve more than 3,000 customers or more than 3,000 af/yr to prepare and adopt urban water conservation plans. The act authorizes the supplier to implement the water conservation program. The plans must contain several specified elements, including estimates of water use, identification of existing conservation measures, identification of alternative conservation measures, a schedule of implementation of actions proposed by the plan, and identification of the frequency and magnitude of water shortages. In 1991, the act was amended in response to the drought to require water suppliers to estimate water supplies available at the end of one, two, and three years, and to develop contingency plans for severe shortages. The act also requires water suppliers to review and update their plans at least once every five years.

Water Conservation in Landscaping Act

The Water Conservation in Landscaping Act required the Department, with the assistance of an advisory task force, to adopt a model water-efficient landscape ordinance. The model ordinance was adopted in August 1992, and has been codified in Title 23 of the California Code of Regulations. It establishes methods of conserving water through water budgeting plans, plant use, efficient irrigation, and auditing.

Cities and counties were required to review the model ordinance and adopt a water-efficient landscape ordinance by January 1, 1993, if they had not done so already. Alternatively, cities and counties could make a finding that such an ordinance is unnecessary due to climatic, geological, or topographic conditions, or water availability. If a city or county failed to adopt a water efficient landscape ordinance or make findings by January 31, 1993, the model ordinance became effective in that jurisdiction.

Agricultural Water Management Planning Act

Under this act, agricultural water suppliers supplying more than 50 taf of water annually were required to submit a report to the Department indicating whether a significant opportunity exists to conserve water or reduce the quantity of highly saline or toxic drainage water through improved irrigation water management. The act provided that agricultural water suppliers who indicated that they had an opportunity to conserve water or reduce the quantity of highly saline or toxic water should prepare a water management plan and submit it to the Department. The Department was required to review the plans and submit a report to the Legislature by January 1993.

Agricultural Water Suppliers Efficient Management Practices Act

The Agricultural Water Suppliers Efficient Management Practices Act, adopted in 1990, required that the Department establish an advisory committee to review efficient agricultural water management practices. Under the act, the Department was required to offer assistance to agricultural water suppliers seeking to improve the efficiency of their water management practices. The committee developed a Memorandum of Understanding to implement the practices, and to establish an Agricultural Water Management Council. The advisory committee adopted the MOU in October 1996. The MOU was declared in effect in May 1997 after 15 agricultural water suppliers, representing 2 million irrigated acres, had signed. The Council was established and held its first meeting in July 1997.

Agricultural Water Conservation and Management Act of 1992

This act gives any public agency that supplies water for agricultural use authority to institute water conservation or efficient management programs. The programs can include irrigation management services, providing information about crop water use, providing irrigation consulting services, improving the supplier's delivery system, providing technical and financial assistance to farmers, encouraging conservation through pricing of water, and monitoring.

Water Recycling Act of 1991

This act describes the environmental benefits and public safety of using recycled water as a reliable and cost-effective method of helping to meet California's water supply needs. It sets a statewide goal to recycle 700 taf/yr by the year 2000 and 1 maf/yr by 2010.

3

Water Supplies

This chapter reviews existing water supplies and updates information presented in Bulletin 160-93. Beginning with a brief overview of California's climate and hydrology, this chapter describes how water supplies are calculated and summarized within a water budget framework. A description of California's existing supplies—surface water, groundwater, recycled water, and desalted water—and how a portion of these supplies are reallocated through water marketing follows. Chapter 3 concludes with a review of water quality considerations that influence how the State's water supplies are used.

Climate and Hydrology

Much of California enjoys a Mediterranean-like climate with cool, wet winters and warm, dry summers. An atmospheric high pressure belt results in fair weather for much of the year with little precipitation during the summer. The high pressure belt shifts southward during the winter, placing the State under the influence of Pacific storms, bringing rain and snow. Most of California's moisture originates in the Pacific Ocean. As moisture-laden air moves over mountain barriers such as the Sierra Nevada, the air is lifted and cooled, dropping rain or snow on the western slopes. This mountain-induced (orographic) precipitation is very important for the State's water supply.

The SWP's California Aqueduct is the only conveyance facility that moves water from the Central Valley to Southern California.

Average annual statewide precipitation is about 23 inches, corresponding to a volume of nearly 200 maf over California's land surface. About 65 percent of this precipitation is consumed through evaporation and transpiration by trees and other plants. The remaining 35 percent comprises the State's

The Colorado River Region is California's driest region; the North Coast Region is its wettest.

average annual runoff of about 71 maf. Less than half this runoff is depleted by urban or agricultural use. Most of it maintains ecosystems in California's rivers, estuaries, and wetlands. Available surface water supply totals 78 maf when out-of-state supplies from the Colorado and Klamath Rivers are added.

Distribution of the State's water supplies varies geographically and seasonally. Water supplies also vary climatically through cycles of drought and flood.

Geographic Variability

Uneven distribution of water resources is part of the State's geography. More than 70 percent of California's 71 maf average annual runoff occurs in the northern part of the State; the North Coast Region accounts for 40 percent and the Sacramento River Region accounts for 32 percent. Figure 3-1 shows average annual rainfall and runoff in California by hydrologic region. About 75 percent of the State's urban and agricultural demands for water are south of Sacramento. The largest urban water use is in the South Coast Region where roughly half of California's population resides. The largest agricultural water use is in the San Joaquin River and Tulare Lake

FIGURE 3-1

Distribution of Average Annual Precipitation and Runoff

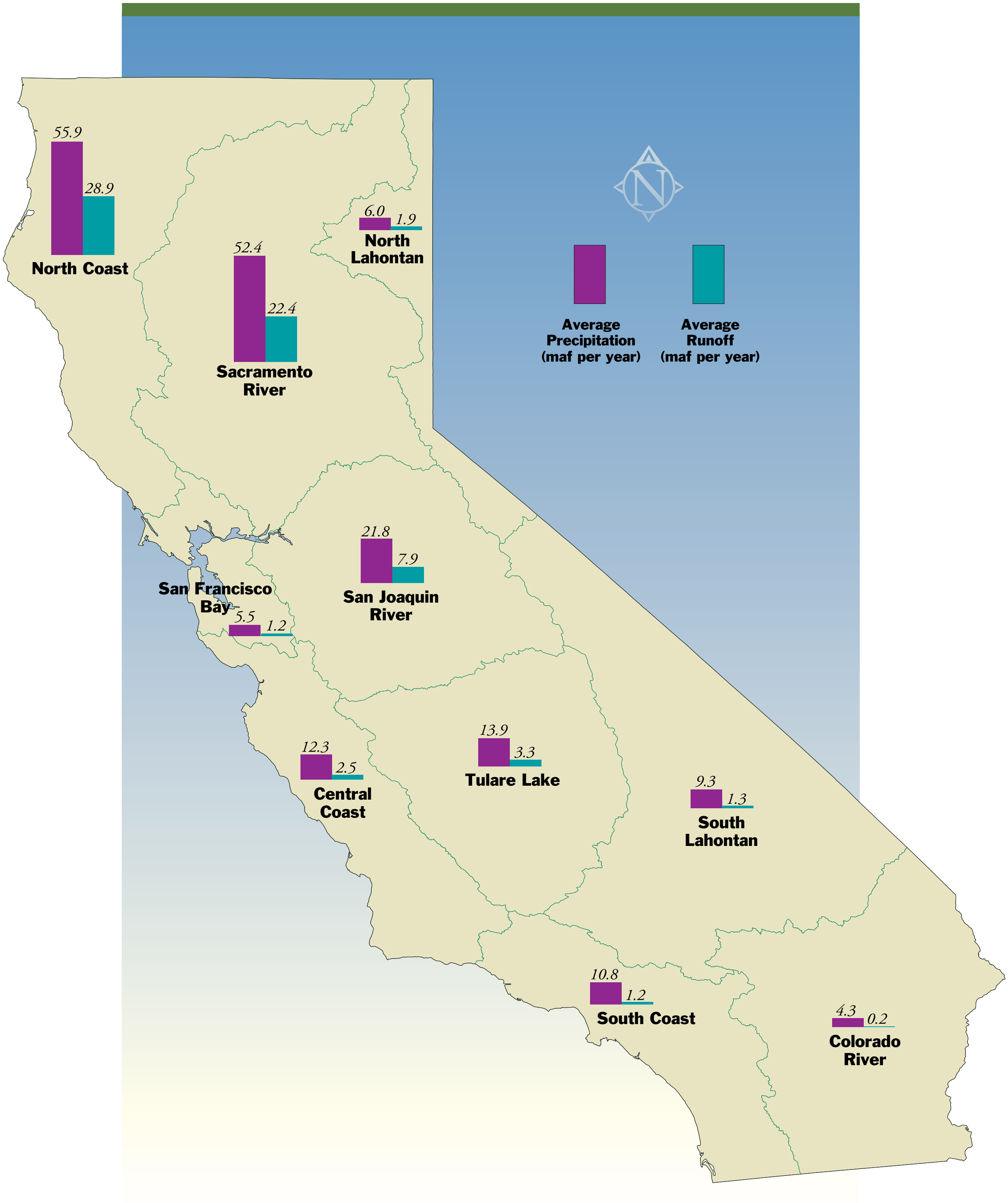
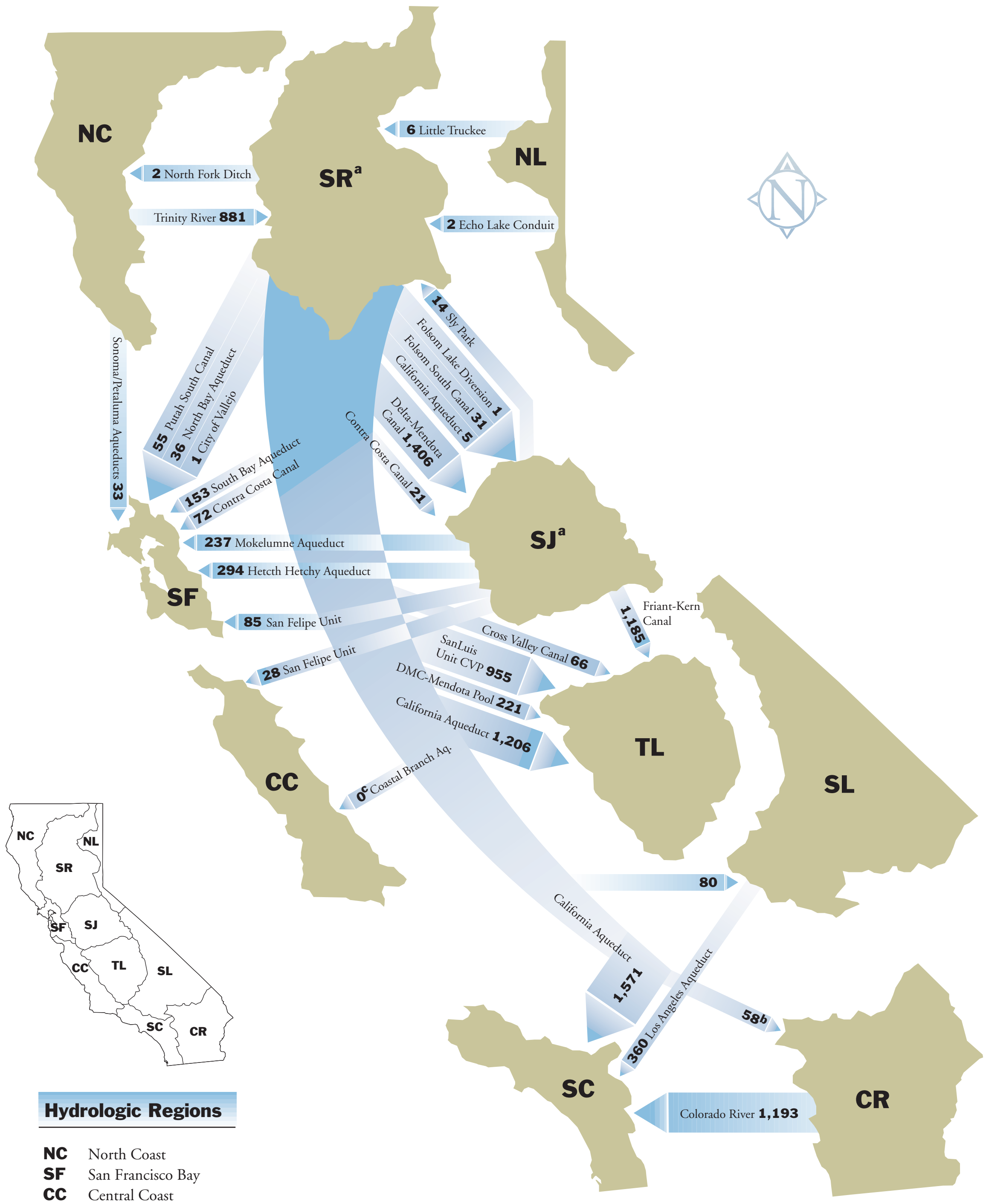


FIGURE 3-2

Regional Imports and Exports, 1995 Level of Development

1995 Level of Development (taf)



Hydrologic Regions

NC	North Coast
SF	San Francisco Bay
CC	Central Coast
SC	South Coast
SR	Sacramento River
SJ	San Joaquin River
TL	Tulare Lake
NL	North Lahontan
SL	South Lahontan
CR	Colorado River

[a] Exports from the Delta are taken from commingled waters originating in both the Sacramento and San Joaquin River Regions.

[b] Exchange

[c] Deliveries did not begin until 1997.

Spring snowmelt helps fill Sierra Nevada reservoirs. Every year, snowpack depth and water content are measured at selected sites throughout the Sierra as part of a cooperative snow surveys program. This information is used to forecast spring runoff, allowing reservoir operators to plan for the coming year.

regions. Fertile soils, a long, dry growing season, and water availability have combined to make these regions among the most agriculturally productive in the world. Wild and scenic river flows in the North Coast Region provide the largest environmental water use. Statewide water use is described in Chapter 4.

In response to the uneven geographic distribution of California's water resources, facilities have been constructed to convey water from one watershed or hydrologic region to another. Figure 3-2 shows larger exports and imports among the State's hydrologic regions.

Seasonal Variability

On average, 75 percent of the State's average annual precipitation of 23 inches falls between November and March, with half of it occurring between December and February. A shortfall of a few major storms during the winter usually results in a dry year; conversely, a few extra storms or an extended stormy period usually produces a wet year. An unusually persistent Pacific high pressure zone over California during December through February predisposes the year toward a dry year. Urban and agricultural water demands are highest during the summer and lowest during the winter, the inverse of statewide rainfall patterns. Figure 3-3 compares average monthly precipitation in the Sacramento River region with precipitation during extremely wet (1982-83) and dry (1923-24) years.

FIGURE 3-3

Northern Sierra Eight Station Precipitation Index

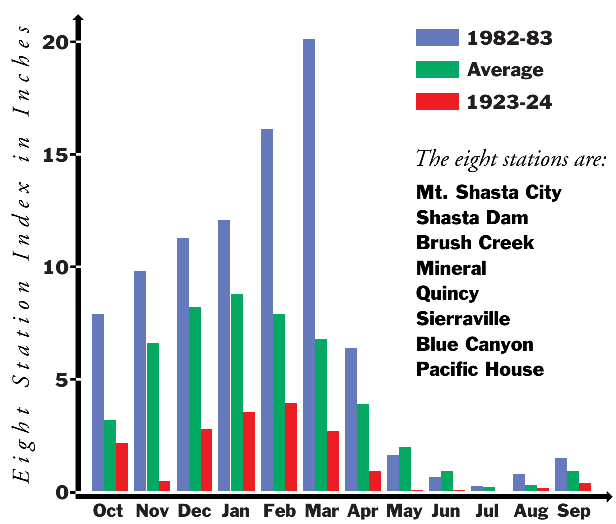
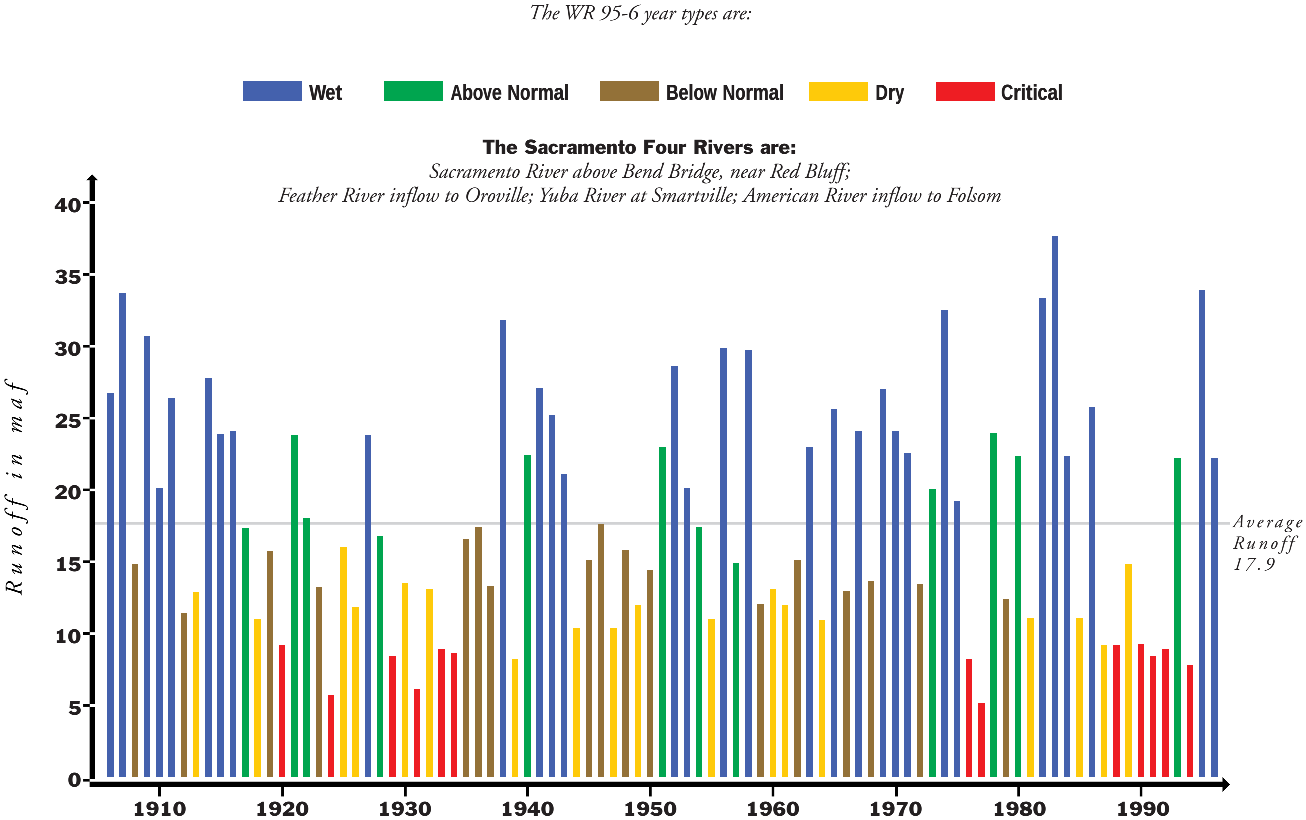


FIGURE 3-4

Sacramento Four Rivers Unimpaired Runoff



Climatic Variability

California's water development has generally been dictated by extremes of droughts and floods. The six-year drought of 1929-34 established the criteria commonly used to plan storage capacity or water yield of large Northern California reservoirs.

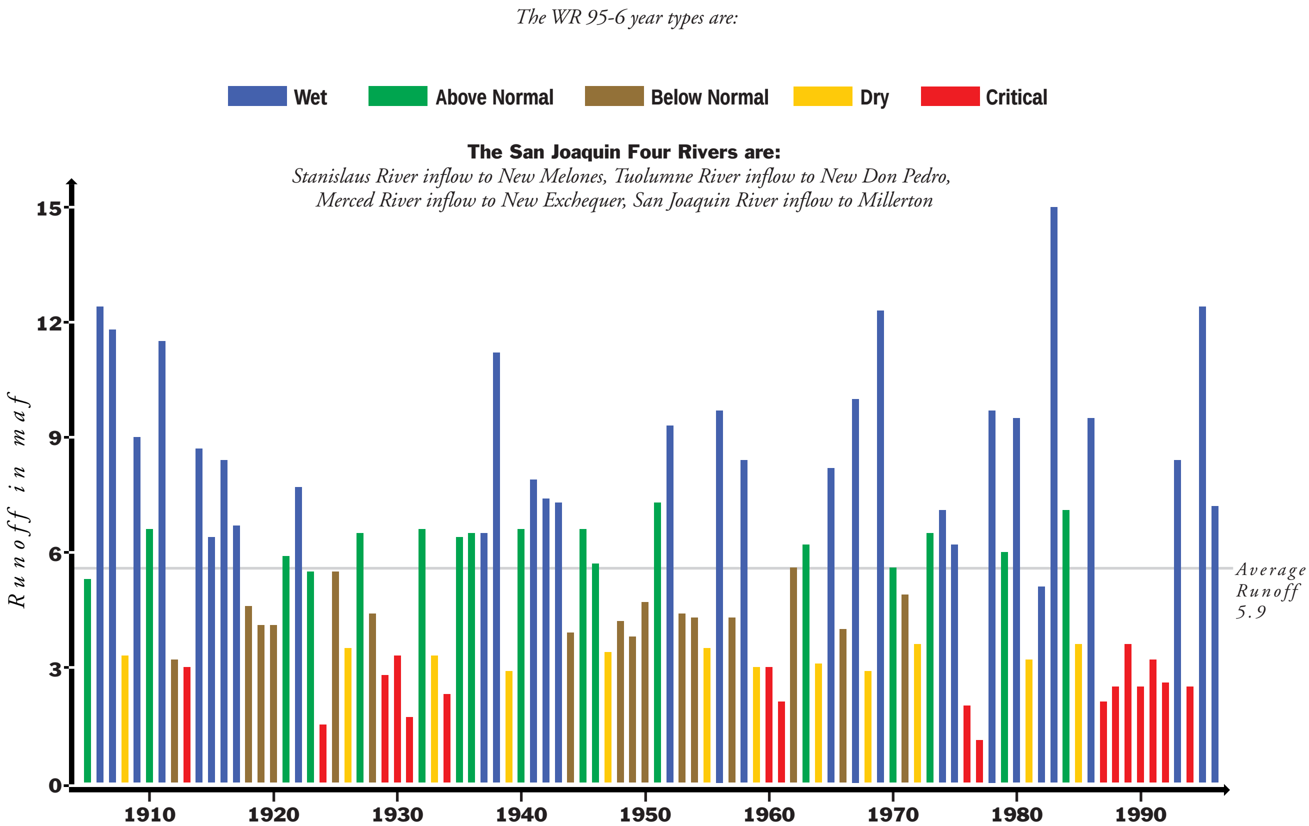
The influence of climatic variability on California's water supplies is much less predictable than the influences of geographic and seasonal variability, as evidenced by the recent historical record of precipitation and runoff. For example, the State's average annual runoff of 71 maf includes the all-time low of 15 maf in 1977 and the all-time high (exceeding 135 maf) in 1983. Floods and droughts occur often, sometimes in the same year. The January 1997 flood was followed by a record-setting dry period from February through June and the flooding of 1986 was followed by six years of drought (1987-92).

Figures 3-4 and 3-5 show the estimated annual unimpaired runoff from the Sacramento and San Joaquin River basins to illustrate climatic variability. Because these basins provide much of the State's water supply, their hydrologies are often used as indices of water year classification systems (see sidebar, page 3-8).

Droughts of Recent Record. Numerous multi-year droughts have occurred in California this century: 1912-13, 1918-20, 1922-24, 1929-34, 1947-50, 1959-61, 1976-77, and 1987-92. In order to provide water supply reliability, major reservoirs are designed to maintain and deliver carryover storage through several years of drought. The 1929-34 drought established the criteria commonly used to design the storage capacity and water yield of large Northern California reservoirs. Many reservoirs built since this drought were sized to maintain a reliable level of deliveries should a repeat of the 1929-34 hydrology occur. Even a single critical run-off year such as 1977 can be devastating to water users with limited storage reserves, who are more dependent

FIGURE 3-5

San Joaquin Four Rivers Unimpaired Runoff



on annual runoff. Table 3-1 compares the severity of recent droughts with the 1929-34 drought in the Sacramento Valley and San Joaquin Valley.

Groundwater supplies about 30 percent of California's urban and agricultural applied water use. In drought years when surface water supplies are reduced, groundwater supports an even greater percentage of use, resulting in declining groundwater levels in many areas. For example, during the first five years of the 1987-92 drought, groundwater extractions exceeded groundwater recharge by 11 maf in the San Joaquin Valley. Drawing down groundwater reserves in drought years is analogous to reservoir carryover storage operations.

TABLE 3-1

Severity of Extreme Droughts in the Sacramento and San Joaquin Valleys

Drought Period	*Sacramento Valley Runoff*		*San Joaquin Valley Runoff*	
	(maf/yr)	*(% Average 1906-96)*	*(maf/yr)*	*(% Average 1901-96)*
1929-34	9.8	55	3.3	57
1976-77	6.6	37	1.5	26
1987-92	10.0	56	2.8	47

An Example of Water Year Classifications

Water year classification systems provide a means to assess the amount of water originating in a basin. Because water year classification systems are useful in water planning and management, they have been developed for several hydrologic basins in California. The Sacramento Valley 40-30-30 Index and the San Joaquin Valley 60-20-20 Index were developed by SWRCB for the Sacramento and San Joaquin River hydrologic basins as part of SWRCB's Bay-Delta regulatory activities. Both systems define one "wet" classification, two "normal" classifications (above and below normal), and two "dry" classifications (dry and critical), for a total of five water year types.

The Sacramento Valley 40-30-30 Index is computed as a weighted average of the current water year's April-July unimpaired runoff forecast (40 percent), the current water year's October-March unimpaired runoff forecast (30 percent), and the previous water year's index (30 percent). A cap of 10 maf is put on the previous year's index to account for required flood control reservoir releases during wet years. Unimpaired runoff (calculated in the 40-30-30 Index as the sum of Sacramento River flow above Bend Bridge near Red Bluff, Feather River inflow to Oroville, Yuba River flow at Smartville, and American River inflow to Folsom) is the river production unaltered by water diversions, storage, exports, or imports. A water year with a 40-30-30 index equal to or greater than 9.2 maf is classified as "wet." A water year with an index equal to or less than 5.4 maf is classified as "critical." Unimpaired runoff from the Sacramento Valley, often referred to as the Sacramento River Index or the Four River Index, was the dominant water supply index used in SWRCB's 1978 Delta Plan and in D-1485. The SRI, while still used in SWRCB's Order WR 95-6 as a water supply index, is no longer employed to classify water years. By considering water availability from storage facilities as well as from seasonal runoff, the 40-30-30 Index provides a more representative characterization of water year types than does the SRI.

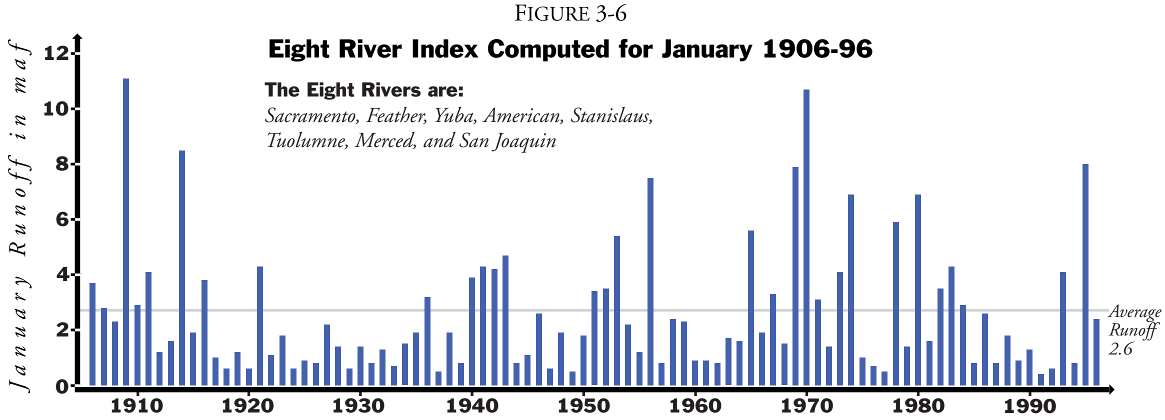
The San Joaquin Valley 60-20-20 Index is computed as a weighted average of the current water year's April-July unimpaired runoff forecast (60 percent), the current water year's October-March unimpaired runoff forecast (20 percent), and the previous water year's index (20 percent). A cap of 4.5 maf is placed on the previous year's index to account for required flood control reservoir releases during wet years. San Joaquin Valley unimpaired runoff is defined as the sum of inflows to New Melones Reservoir (from the Stanislaus River), Don Pedro Reservoir (from the Tuolumne River), New Exchequer Reservoir (from the Merced River), and Millerton Lake (from the San Joaquin River). A water year with a 60-20-20 index equal to or greater than 3.8 maf is classified as "wet." A water year with an index equal to or less than 2.1 maf is classified as "critical."

Although not used to classify water years, the Eight River Index is another important water supply index employed in Order WR 95-6. The Eight River Index, defined as the sum of the unimpaired runoff from the four Sacramento Valley Index rivers and the four San Joaquin Valley Index rivers, is used to define Delta outflow requirements and export restrictions. Key index months for triggering Delta requirements are December, January, and February. Figure 3-6 shows the Eight River Index computed for January from 1906-96.

Existing water year classification systems have been useful in planning and managing water supplies; however, they have also shown shortcomings during unusual hydrologic periods. The 1997 water year is one such example. Because of wet antecedent conditions and unusually high precipitation runoff in December and January, the water year was classified as "wet" in spite of a string of dry months that followed this unusually wet period. Water project operators were compelled to meet stringent instream flow and Delta requirements during the subsequent dry months to comply with the "wet" water year classification. Compliance was met through reservoir storage releases, as spring and summer runoff was significantly lower than is typical in wet years. Reservoir levels benefitted only marginally from the wet December and January, as flood control criteria limited the amount of water that could be stored.

FIGURE 3-6

Eight River Index Computed for January 1906-96



The Sacramento metropolitan area has one of the lowest flood protection levels in the nation, for a community of its size. Without interim reoperation of Folsom Dam, the community is estimated to have only a 1-in-60 year level of protection. (With reoperation, the level of protection is 1-in-77 years). This photo shows the American River in January 1997, and the high-density urban development adjacent to the levee.

Floods of Recent Record. Wet water years are not necessarily indicative of flood conditions. Although water year 1983 was the wettest in California this century, major flooding did not occur then. Table 3-2 shows estimated unimpaired runoff from a few of the State's larger floods since the 1950s. In January 1997, California confronted one of the largest and most extensive flood disasters in its history. Rivers across the State from the Oregon border to the southern Sierra reached flood stages. Flood volumes of some rivers exceeded channel capacities by as much as 700 percent. In many major river systems, flood control dams reduced peak flows by one-half or more. Even so, leveed flood control systems were overwhelmed in some areas. Flood damage costs are nearing $2 billion.

Pre-Nineteenth Century Climatic Variability. Precipitation and runoff records for some locations in California date back to the mid to late 1800s. Data for many other areas are sparse into the early 1900s. These data provide only a glimpse of the range of variability that has occurred. One approach to supplementing the existing climate record is to statistically reconstruct data through the study of tree rings. By properly selecting trees, data on the thickness of annual growth rings can be used to infer the wetness of the season. A 420-year reconstruction of Sacramento River runoff data from tree ring data was made for the Department in 1986 by the Laboratory for Tree Ring Research at the University of Arizona. The tree ring data suggested that the 1929-34 drought was the most severe in the 420-year reconstructed record from 1560 to 1980. The data also suggested that a few droughts prior to 1900 exceeded three years, and none lasted over six years, except for one eight-year period of less than average runoff from 1839-46. John Bidwell, an early pioneer who arrived in California in 1841, confirmed that 1841, 1843, and 1844 were extremely dry years in the Sacramento area. Similar tree ring studies, covering the period between 1550 and 1977, were also conducted for the Colorado and Santa Ynez Rivers. According to these studies, the most severe drought on the Colorado River occurred during 1580-1600, while the most severe drought on the Santa Ynez River occurred during 1621-37. Below average periods, very long wet periods, and

TABLE 3-2

Major Floods Since the 1950s

			Unimpaired Runoff	
River	*Location*	*Date*	*Max 1-Day (cfs)*	*3-day Volume (taf)*
Sacramento	Shasta Dam	Jan 1974	196,000	779
		Feb 1986	126,000	681
		Jan 1997	216,000	1,000
Feather	Oroville Dam	Dec 1964	179,000	984
		Feb 1986	217,000	1,113
		Jan 1997	298,000	1,392
Yuba	Marysville	Dec 1964	144,000	703
		Feb 1986	142,000	729
		Jan 1997	161,000	736
American	Folsom Dam	Dec 1964	183,000	835
		Feb 1986	171,000	988
		Jan 1997	249,000	977
Mokelumne	Camanche Dam	Dec 1964	36,000	171
		Feb 1986	28,000	149
		Jan 1997	76,000	233
Stanislaus	New Melones Dam	Dec 1964	44,000	198
		Feb 1986	40,000	246
		Jan 1997	73,000	298
Tuolumne	New Don Pedro Dam	Dec 1964	73,000	306
		Feb 1986	53,000	294
		Jan 1997	120,000	548
Merced	New Exchequer Dam	Dec 1964	33,000	136
		Feb 1986	30,000	164
		Jan 1997	67,000	262
San Joaquin	Friant Dam	Feb 1986	33,000	176
		Mar 1995	39,000	156
		Jan 1997	77,000	313
Truckee	Reno	Oct 1963	25,000	79
		Feb 1986	22,000	112
		Jan 1997	37,000	148
Cosumnes	Michigan Bar	Dec 1964	29,000	115
		Feb 1986	34,000	196
		Jan 1997	60,000	N/A
Eel	Scotia	Dec 1964	648,000	2,936
		Feb 1986	304,000	1,515
Santa Ynez	Lompoc[a]	Jan 1969	38,000	175
Salinas	Spreckles[a]	Feb 1969	65,000	252
		Mar 1983	60,000	314
		Mar 1995	64,000	241
Santa Clara	Saticoy	Feb 1969	92,000	270

[a] Impaired flows

short severe drought periods were also reconstructed in the studies.

A 1994 study of relict tree stumps rooted in present-day lakes, rivers, and marshes suggested that California sustained two “epic drought” periods, extending over more than three centuries. The first epic drought lasted more than two centuries before the year 1112; the second drought lasted more than 140 years before 1350. In this study, the researcher used drowned tree stumps rooted in Mono Lake, Tenaya Lake, West Walker River, and Osgood Swamp in the central Sierra. One conclusion that can be drawn from this study is that California is subject to droughts far more severe and far more prolonged than anything witnessed in the last 150 years of weather recording.

Future Climate Change. Much concern has been expressed about possible future climate change caused by burning fossil fuel and other modern human activities that increase carbon dioxide and other trace greenhouse gases in the atmosphere. World weather records indicate an overall warming trend during the last century, with a surge of warming prior to 1940 (which cannot be attributed to greenhouse gases) and a more recent rise during the 1980s. The extent to which this latest rise is real or an artifact of instrument location (heat island effect of growing cities) or a temporary anomaly is debated among climatologists. For now, most projections of climate change are derived from computer simulation studies and generally indicate a global average temperature rise of about 2 to 5°C over the next century, for a doubling of carbon dioxide content in the atmosphere. Figures for regional changes are less dependable because of regional weather influences not accounted for in the global models.

For California, if global warming occurs, the most likely impact would be a shift in runoff patterns. Warmer temperatures would mean higher snow levels during winter storms, more winter runoff, and less carryover storage into late spring and summer (assuming precipitation remains the same). There would be some loss in water supply yield if the shift in snowmelt runoff occurs.

When the climate was drier in the past, trees were growing in areas now submerged by alpine lakes such as Lake Tenaya. Dating these submerged stumps by radiocarbon and other techniques provides information about the dates and durations of previous drought periods.

Water Supply Calculation

Bulletin 160-98 calculates existing water supplies and demands, then balances forecasted future demand against supplies and future water management options. The balance, or water budget, with existing supply is presented on a statewide basis in Chapter 6 and on a regional basis in Chapters 7-9. The water budget with future water management options is presented in Chapter 10.

The following section defines and classifies water supplies, describes the method for calculating water supplies within the Bulletin 160 water budget framework, and quantifies statewide water supplies with existing facilities and programs. Two water supply scenarios—an average year and a drought year—are presented for a base year (1995) and a forecast year (2020) to illustrate existing and future water supply reliability.

Definition of Bulletin 160-98 Water Supplies

The Bulletin's water budgets do not account for the State's entire water supply and use. In fact, less than one-third of the State's precipitation is quantified in the water budgets.

As discussed in the previous section on climate and hydrology, precipitation provides California with about 200 maf of total water supply in average years. Of this renewable supply, about 65 percent is depleted through evaporation and transpiration by trees and other plants. This large volume of water (approximately 130 maf) is excluded from the Bulletin's water supply and water use calculations. The remaining 35 percent stays in the State's hydrologic system as runoff.

Over 30 percent of the State's runoff is not explicitly designated for urban, agricultural, or environmental uses. This water is depleted from the State's hydrologic system as outflow to the Pacific Ocean or other salt sinks. (Some of this non-designated runoff is captured by reservoirs, but is later released for flood control.) Similar to precipitation depletions by vegetation, non-designated runoff is excluded from the Bulletin 160 water supply and water use calculations.

The State's remaining runoff is available as renewable water supply for urban, agricultural, and environmental uses in the Bulletin's water budgets (Figure 3-7). In addition to this supply, water budgets include supplies not generated by intrastate precipitation. These supplies include imports from the Colorado and Klamath Rivers and new supplies generated by water recycling and desalting.

Classification of Water Supplies. Water supplies are classified into three broad groups to develop the

Key Water Supply and Water Use Definitions

Chapters 3 and 4 introduce California's water supplies and urban, agricultural and environmental water uses. Certain key concepts, defined below, provide a foundation for analyzing water supplies and water use.

Applied Water: The amount of water from any source needed to meet the demand of the user. It is the quantity of water delivered to any of the following locations:

- The intake to a city water system or factory.
- The farm headgate or other point of measurement.
- A managed wetland, either directly or by drainage flows.

For instream use, applied water is the quantity of stream flow dedicated to instream use (or reserved under the federal or State wild and scenic rivers acts) or to maintaining flow and water quality in the Bay-Delta pursuant to the SWRCB's Order WR 95-6.

Net Water: The amount of water needed in a water service area to meet all demands. It is the sum of evapotranspiration of applied water in an area, the irrecoverable losses from the distribution system, and agricultural return flow or treated urban wastewater leaving the area.

Irrecoverable Losses: The amount of water lost to a salt sink, lost by evapotranspiration, or lost by evaporation from a conveyance facility, drainage canal, or fringe area.

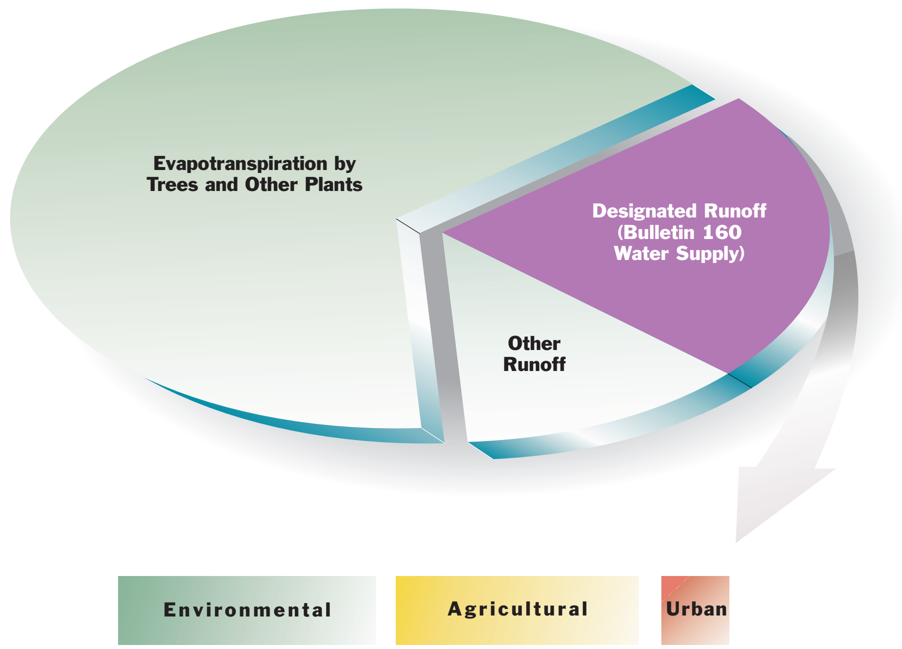
Evapotranspiration: ET is the amount of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces.

Evapotranspiration of Applied Water: ETAW is the portion of the total ET which is provided by applied irrigation water.

Depletion: The amount of water consumed within a service area that is no longer available as a source of supply. For agricultural and certain environmental (i.e., wetlands) water use, depletion is the sum of irrecoverable losses and the ETAW due to crops, wetland vegetation, and flooded water surfaces. For urban water use, depletion is the ETAW due to landscaping and gardens, wastewater effluent that flows to a salt sink, and incidental ET losses. For environmental instream use, depletion is the amount of dedicated flow that proceeds to a salt sink.

FIGURE 3-7

Disposition of California's Average Annual Precipitation



Bulletin's water budgets: surface water, groundwater, and recycled/desalted water. Surface water includes developed supplies from the CVP, the SWP, the Colorado River, other federal projects, and local projects. Surface water also includes the supplies for required environmental flows. Required environmental flows are comprised of undeveloped supplies designated for wild and scenic rivers, supplies used for instream flow requirements, and supplies used for Bay-Delta water quality and outflow requirements. (Bulletin 160-98 assumes Bay-Delta requirements are in accordance with the SWRCB's Order WR 95-6.) Finally, surface water includes supplies available for reapplication downstream. Urban wastewater discharges and agricultural return flows, if beneficially used downstream, are examples of reapplied surface water.

Groundwater includes developed subsurface supplies and water reapplied through deep percolation. Bulletin 160-98 excludes long-term basin extractions in excess of long-term basin inflows in its definition of groundwater supply. This long-term average annual difference between extractions and recharge, defined in the Bulletin as overdraft, is not a sustainable source of water and is thus excluded from the base year and forecast year groundwater supply estimates. (In response to public comments on the Bulletin 160-93, Bulletin 160-98 is the first water plan update to exclude overdraft from the base year groundwater supply estimate.)

The Bulletin 160 definition of water supply from recycling and desalting does not include all water that is reclaimed and reused through treatment technologies. The recycled/desalted classification is limited to supplies that, if not recycled or desalted, would otherwise be depleted to a saline water body, such as the Pacific Ocean. This classification is limited to "new" supply that was previously unavailable for downstream reapplication. In California, this condition exists primarily in the Colorado River Region (which drains to the Salton Sea), parts of the coastal regions, and the westside of the San Joaquin Valley. In the Sacramento River, San Joaquin River, and Tulare Lake regions, almost all urban wastewater becomes available downstream for reapplication through river discharge or groundwater percolation. In these regions, recycling reduces applied water demand and provides water supply reliability and water quality benefits. However, recycling in these regions does not generate a "new" water supply.

Applied Water Methodology. Bulletin 160-98 water supplies are computed using applied water data. As defined in the sidebar on page 3-12, applied water refers to the amount of water from any source employed to meet the demand of the user. Previous editions of Bulletin 160 computed water supplies using net water data. Bulletin 160-98 switched from a net water methodology to an applied water methodology in response to public comments on Bulletin 160-93. Because applied water data are analogous to agency water delivery data, water supply data based on an applied water methodology are easier for local water agencies to review. Net water supply values are smaller than applied water supply values because they exclude that portion of demand met by reapplication of surface and groundwater supplies. Figures 3-8 through 3-10 illustrate applied water and net water methodologies for three different cases. Figure 3-8 shows how outflow in an inland area can be reapplied downstream; Figure 3-9 shows how outflow to a salt sink cannot be reapplied downstream. Figure 3-10 is similar to Figure 3-8 except that agricultural water use is more efficient. In addition to providing another example of applied and net water methodologies, Figure 3-10 also illustrates that, unless depletions are reduced, water conservation in an inland area does not generate new water.

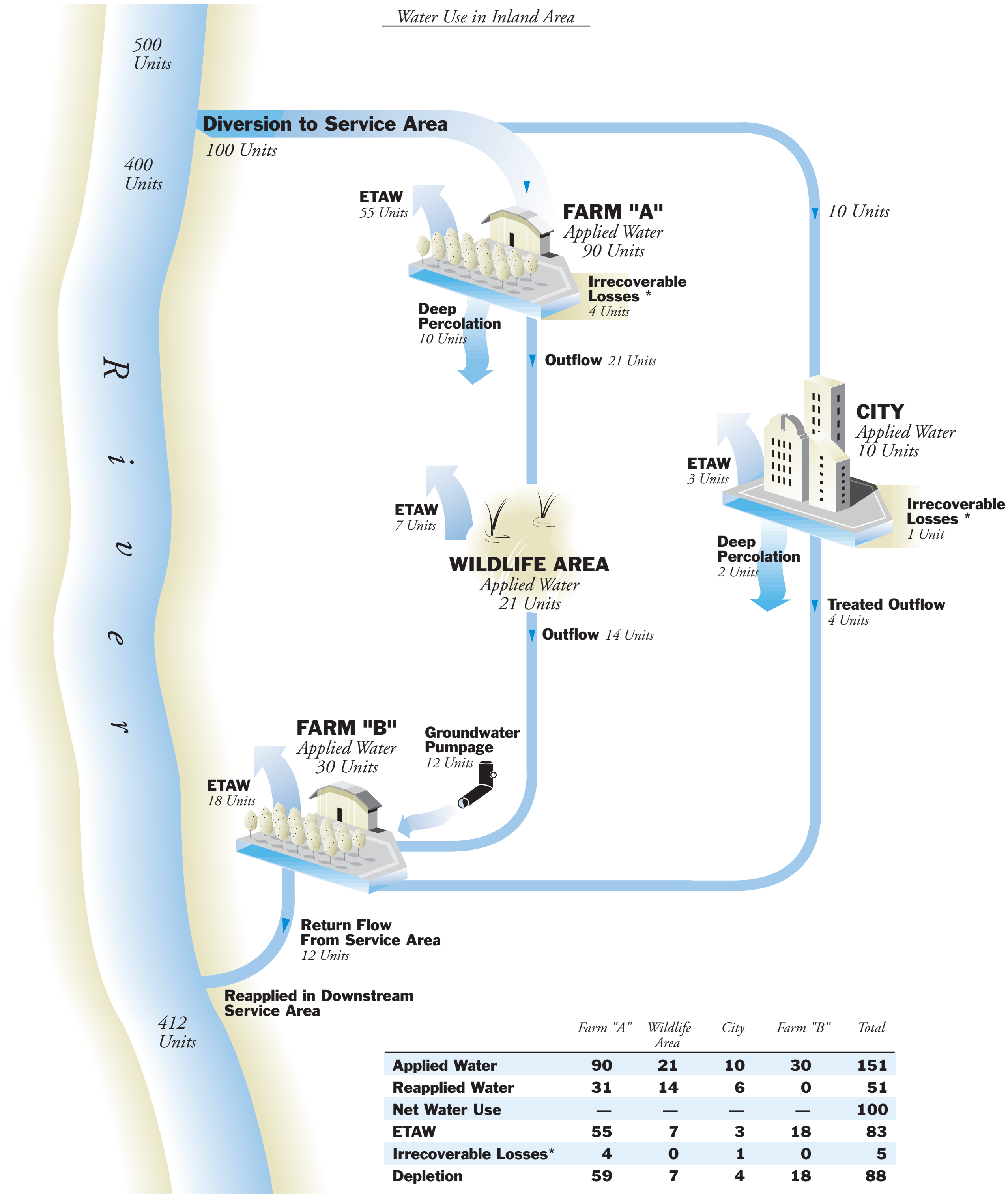
As suggested by Figures 3-8 through 3-10, reapplication can be a significant source of water in many hydrologic regions of California. An applied water budget explicitly accounts for this source. However, because of reapplication, applied water budgets do not translate directly into the supply of water needed to meet future demands. The approach used to compute the new water needed to meet future demands with applied water budgets is presented in Chapter 6.

Normalized Data. Water budget data used to represent the base planning year do not necessarily match the historical conditions observed in 1995.

Over 30 percent of the State's runoff is not explicitly designated for urban, agricultural, or environmental uses. This runoff flows to the Pacific Ocean or to inland drainage sinks.

FIGURE 3-8

Illustration of Applied and Net Water Methodologies: Inland Area



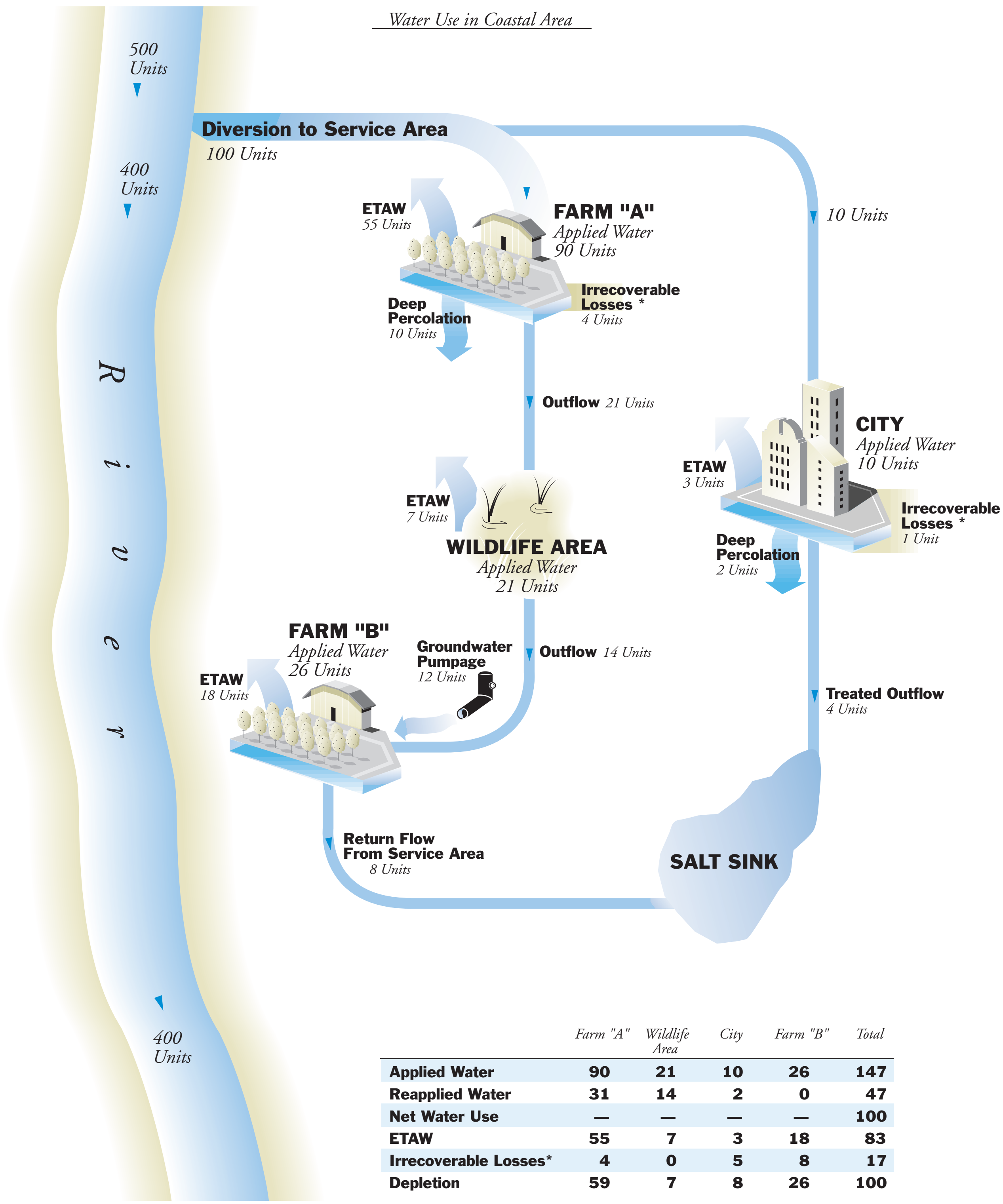
	Farm "A"	Wildlife Area	City	Farm "B"	Total
Applied Water	90	21	10	30	151
Reapplied Water	31	14	6	0	51
Net Water Use	—	—	—	—	100
ETAW	55	7	3	18	83
Irrecoverable Losses*	4	0	1	0	5
Depletion	59	7	4	18	88

ETAW = Evapotranspiration of Applied Water

* *Irrecoverable losses are losses from conveyance facilities due to evaporation, evapotranspiration, or deep percolation to a salt sink.*

FIGURE 3-9

Illustration of Applied and Net Water Methodologies: Coastal Area



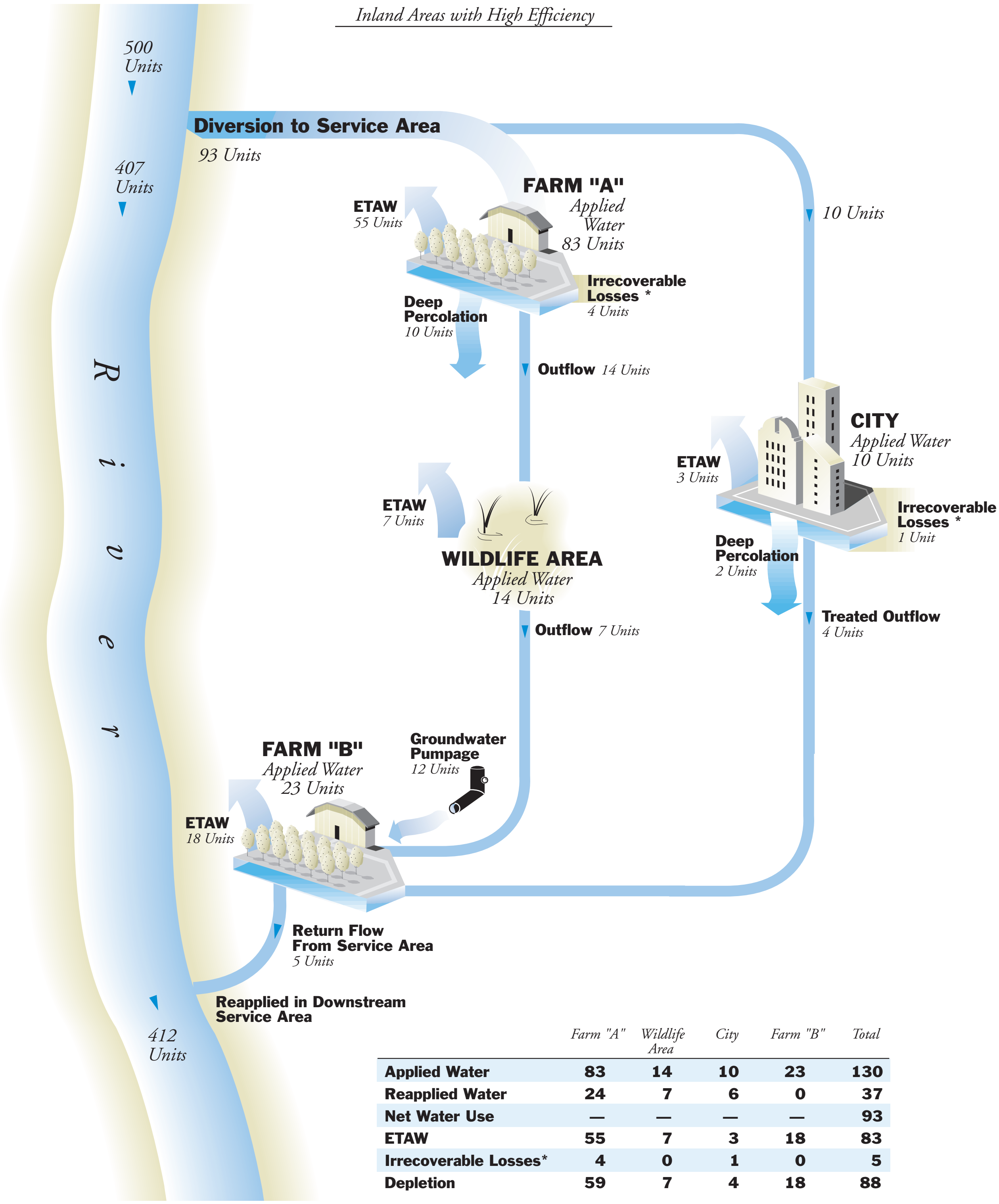
	Farm "A"	Wildlife Area	City	Farm "B"	Total
Applied Water	**90**	**21**	**10**	**26**	**147**
Reapplied Water	**31**	**14**	**2**	**0**	**47**
Net Water Use	**—**	**—**	**—**	**—**	**100**
ETAW	**55**	**7**	**3**	**18**	**83**
Irrecoverable Losses*	**4**	**0**	**5**	**8**	**17**
Depletion	**59**	**7**	**8**	**26**	**100**

ETAW = Evapotranspiration of Applied Water

* *Irrecoverable losses are losses from conveyance facilities due to evaporation, evapotranspiration, or deep percolation to a salt sink.*

FIGURE 3-10

Illustration of Applied and Net Water Methodologies: Inland Area with High Efficiency



	Farm "A"	Wildlife Area	City	Farm "B"	Total
Applied Water	83	14	10	23	130
Reapplied Water	24	7	6	0	37
Net Water Use	—	—	—	—	93
ETAW	55	7	3	18	83
Irrecoverable Losses*	4	0	1	0	5
Depletion	59	7	4	18	88

ETAW = Evapotranspiration of Applied Water

* *Irrecoverable losses are losses from conveyance facilities due to evaporation, evapotranspiration, or deep percolation to a salt sink.*

Instead, Bulletin 160-98's base year applied water budget data are developed from "normalized" water supply, land use, and water use data. Through the normalizing process, year-to-year fluctuations caused by weather and market abnormalities are removed from the data. For example, water year 1998 would greatly underestimate average annual water use, as rainfall through May and early June provided the necessary moisture needed to meet crop and landscape water demands. In most years, much of California would require applied water supplies during May and early June.

On the supply side, normalized water project delivery values are computed by averaging historical delivery data. Normalized "average year" project supplies are typically computed from 3 to 5 recent non-deficient water years. Normalized "drought year" project supplies are computed by averaging historical delivery data from 1990 and 1991. A notable exception to the above procedure is the development of normalized CVP and SWP project deliveries. Supplies from these projects are developed from operations studies rather than from historical data (See sidebar). Operations studies provide an average project delivery capability over a multi-year sequence of hydrology under SWRCB's WR 95-6 Bay-Delta standards. The following section on water supply scenarios describes how other water supply data are normalized.

On the demand side, base year urban per capita water use data are normalized to account for factors such as residual effects of the 1987-92 drought. In any given year, urban landscape and agricultural irrigation requirements will vary with precipitation, temperature, and other factors. Base year water use data are normalized to represent ETAW requirements under average and drought year water supply conditions. Land use data are also normalized. The Department collects land use data through periodic surveys; however, the entire State is not surveyed in any given year (such as 1995). To arrive at an estimate of historical statewide land use for a specific year, additional sources of data are consulted to interpolate between surveys. After a statewide historical land use base is constructed, it is evaluated to determine if it was influenced by abnormal weather or crop market conditions and is normalized to remove such influences. (See Chapter 4 for further discussion on the development of Bulletin 160-98 water and land use data.)

Normalizing allows Bulletin 160-98 to define an existing level of development (i.e., the 1995 base year) that is compatible with a forecasted level of development (i.e., the 2020 forecast year). Future year shortage calculations implicitly rely on a comparison between future water use and existing water supply, as water supplies do not change significantly (without implementation of new facilities and programs) over the planning horizon. Therefore, the normalizing procedure is necessary to provide an appropriate future year shortage calculation. Normalizing also permits more than one water supply condition to be evaluated for a given level of development. If historical data were used to define the base year, only one specific hydrologic condition would be represented. (Historical data for 1995 would represent a wet year.) But through normalizing, a base level of development can be evaluated under a range of hydrologic conditions. The following section discusses how Bulletin 160-98 develops average and drought year water supply scenarios for its water budget analysis.

Water Supply Scenarios

California is subject to a wide range of hydrologic conditions and water supply variability. Knowledge of water supplies under a range of hydrologic conditions is necessary to evaluate reliability needs that water managers must meet. Two water supply scenarios–average year conditions and drought year conditions–were selected from among a spectrum of possible water supply conditions to represent variability in the regional and statewide water budgets.

Average Year Scenario. The average year supply scenario represents the average annual supply of a system over a long planning horizon. As discussed in the sidebar, average year supplies from the CVP and SWP are defined by operations studies for a base (1995) level of development and for a future (2020) level of development. Project delivery capabilities are defined over a 73-year hydrologic sequence. For other water supply projects, historical data are normalized to represent average year conditions. For required environmental flows, average year supply is estimated for each of its components. Wild and scenic river flow is calculated from long-term average unimpaired flow data. Instream flow requirements are defined for an average year under specific agreements, water rights, court decisions, and congressional directives. Bay-Delta outflow requirements are estimated from operations studies.

Drought Year Scenario. For many local water agencies, and especially urban agencies, drought year water supply is the critical factor in planning for water

Operations Studies

Computer simulations, also known as operations studies, are performed to estimate the delivery capabilities of the CVP and SWP under average year and drought year conditions. Two widely used computer models for conducting CVP/SWP operations studies are the Department's DWRSIM and USBR's PROSIM. Most Bulletin 160-98 studies were performed with DWRSIM.

DWRSIM is designed to simulate the monthly operation of the CVP and SWP system of reservoirs and conveyance facilities under different hydrologic sequences. These hydrologic sequences are typically based on a 73-year record of historical hydrology from 1922 through 1994. DWRSIM simulates the availability, storage, release, use, and export of water in the Sacramento and San Joaquin River systems, the Delta, and the aqueduct and reservoir systems south of the Delta. The model provides numerical output on parameters such as reservoir storage and releases, Delta inflows, exports, and outflows. The model operates the CVP and SWP system to provide the maximum water withdrawal from the Delta allowed by regulatory constraints, up to the total water demand. Additional system operational objectives (e.g., reservoir carryover storage), physical constraints (e.g., reservoir and pumping plant capacities), and institutional agreements (e.g., Coordinated Operation Agreement) also affect the simulated operation.

In considering the results of a project operations study, it is important to note that conditions in a specific model year do not match those observed in the actual year. Simulated hydrology deviates from historical hydrology because the 73-year sequence is normalized to reflect existing or forecasted future land development and consumptive use conditions. Project deliveries and reservoir operations deviate from historical conditions because they are optimized for a specific level of demand over the entire hydrologic sequence. The results should be interpreted as average project delivery capability over a 73-year sequence of hydrology rather than in water years 1922 through 1994. Project deliveries over this long sequence of hydrology provide an indication of the system's average performance, as well as the performance over a wide range of wet and dry years.

An example of the use of operations studies is provided later in this chapter to describe how operations studies evaluated CVP/SWP delivery impacts associated with the SWRCB's Order WR 95-6 Delta standards.

supply reliability. Traditional drought planning often uses a design drought hydrology to characterize project operations under future conditions. For a planning region with the size and hydrologic complexity of California, selecting an appropriate statewide design drought presents a challenge. The 1990-91 water years were selected to represent the drought year supply scenario for Bulletin 160-98. (The 1990-91 water years were also used to represent the drought year scenario in Bulletin 160-93.)

The 1990-91 drought year scenario has a recurrence interval of about 20 years, or a 5 percent probability of occurring in any given year. This is typical of the drought level used by many local agencies for routine water supply planning. For extreme events such as the 1976-77 drought, many agencies would implement shortage contingency measures such as mandatory rationing. Another important consideration in selecting water years 1990-91 was that, because of their recent occurrence, local agency water demand and supply data were readily available.

The statewide occurrence of dry conditions during the 1990-91 water years was another key consideration in selecting them as a representative drought. Because of the size of California, droughts may or may not occur simultaneously throughout the entire State. Figure 3-11 illustrates the statewide occurrence of dry conditions in water year 1990. The figure also shows that, two years later, dry conditions persisted in Northern California, but not in Southern California.

Defining a representative drought in Southern California is complicated by the region's access to imported supplies from the Colorado River. The Colorado River watershed is large (about 244,000 square miles, or roughly 10 times the size of the Sacramento River watershed) and experiences hydrologic conditions different than California's. As a result, Southern California's water supply may be buffered from the effects of severe drought in Northern California. Figure 3-12 presents Colorado River unimpaired flow at the Lee Ferry interstate compact measurement point to illustrate the river basin's hydrology.

Other Drought-Related Considerations. During low runoff years such as 1990 and 1991, carryover storage in surface water reservoirs is an important source of water supply. At the beginning of an extended dry period, the drought's duration is unknown. Therefore, to manage deficiencies imposed on water users, water may be released from storage based upon a predetermined risk analysis procedure. As the drought continues, the procedure may impose progressively larger deficiencies.

Carryover storage was used to supplement water

FIGURE 3-11

Statewide Distribution of Precipitation for Water Years 1990 and 1992

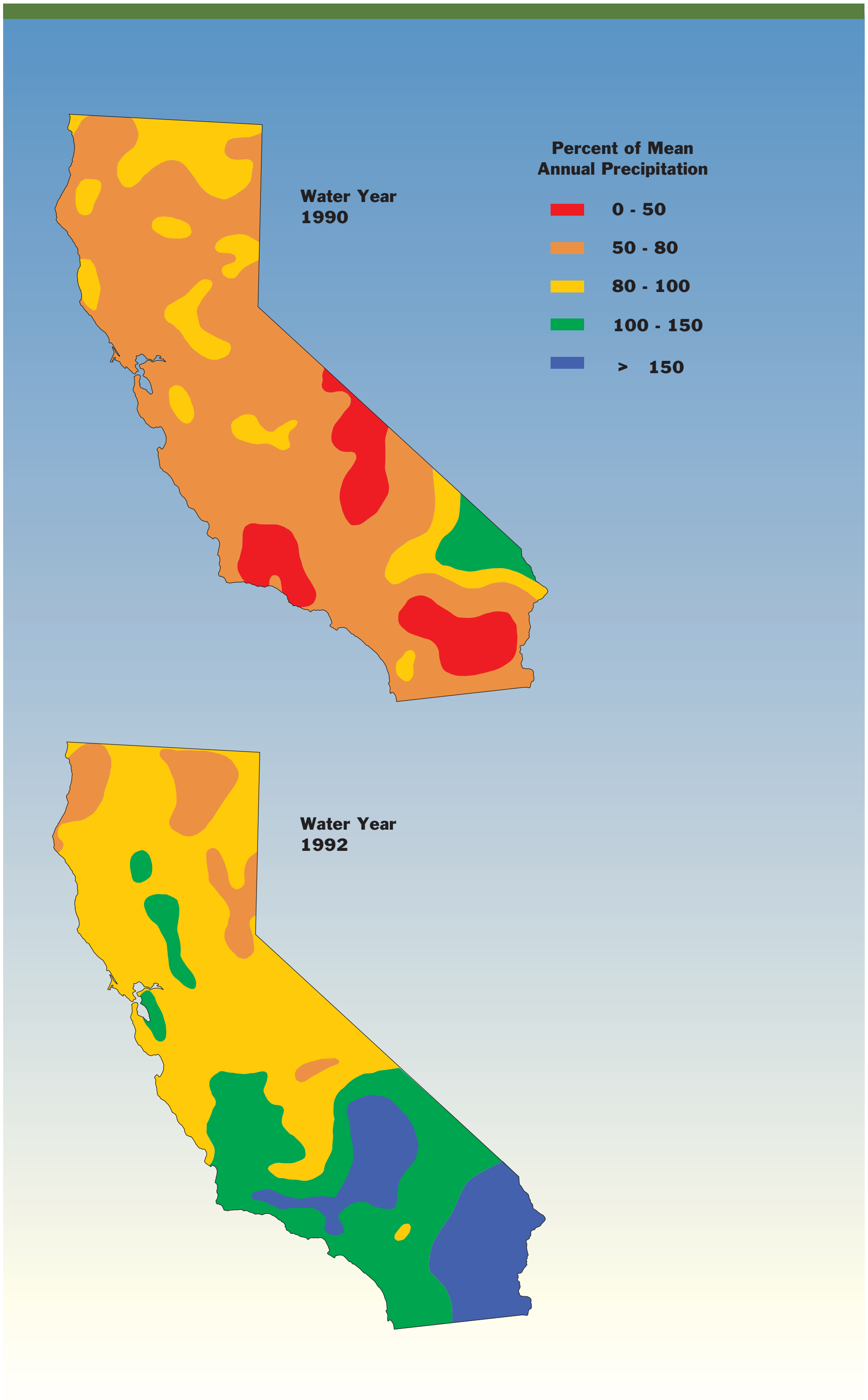
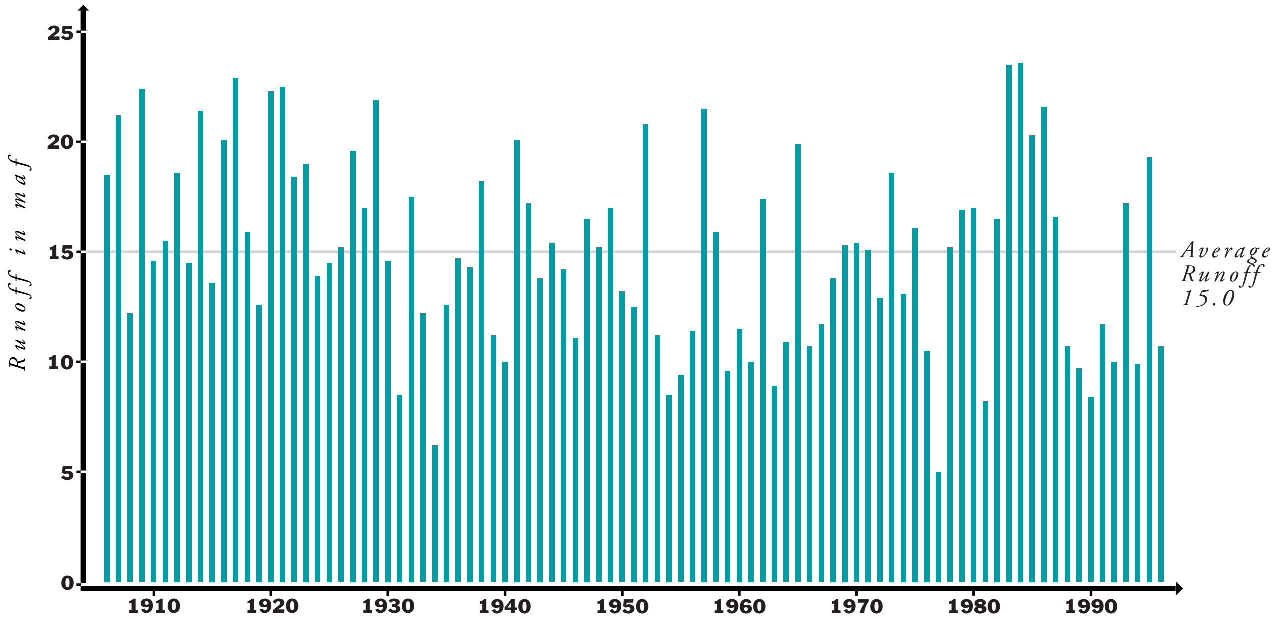


FIGURE 3-12

Colorado River Unimpaired Runoff at Lee Ferry Compact Point



deliveries during the low runoff years of the 1987-92 drought, minimizing the initial impacts of the drought on many water users. To illustrate the use of carryover storage for supplementing water project deliveries, actual CVP and SWP deliveries during the 1987-92 drought are shown in Figure 3-13. (The Bulletin's drought year water supplies from these projects are based on normalized operations studies data, not the actual delivery data shown in Figure 3-13.) Although the drought lasted six years, neither project imposed delivery deficiencies during the first three years of the drought. During the final three years, however, both projects imposed significant deficiencies.

Figure 3-14 shows how Shasta, Oroville, New Melones, and Cachuma Reservoirs were actually operated during the 1987-92 drought. Data for Cachuma

FIGURE 3-13

CVP and SWP Deliveries During 1987-92 Drought

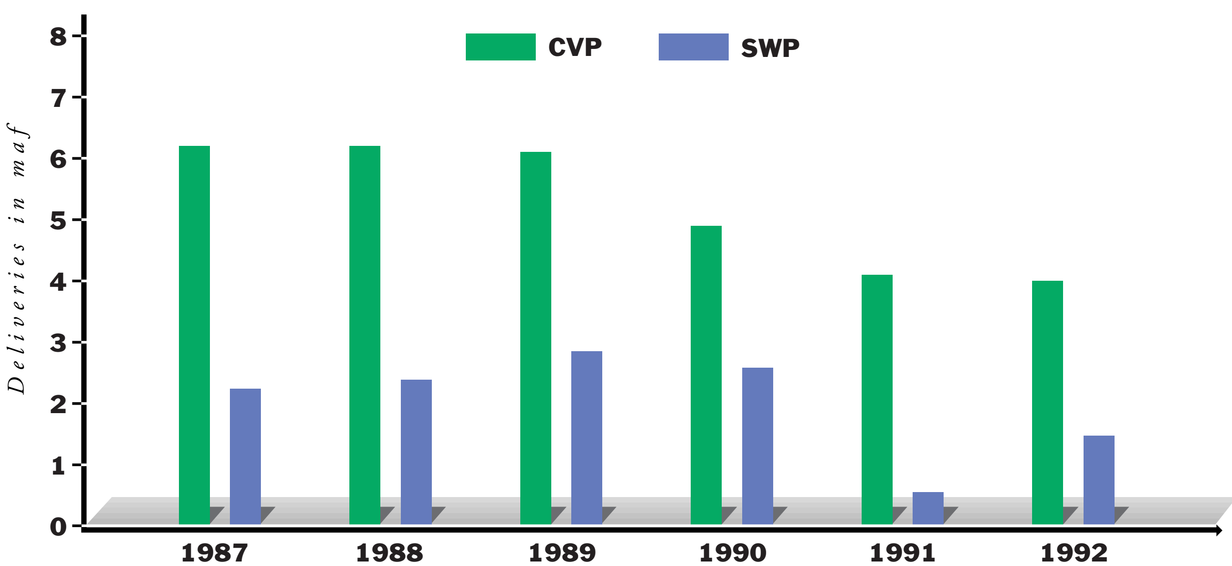
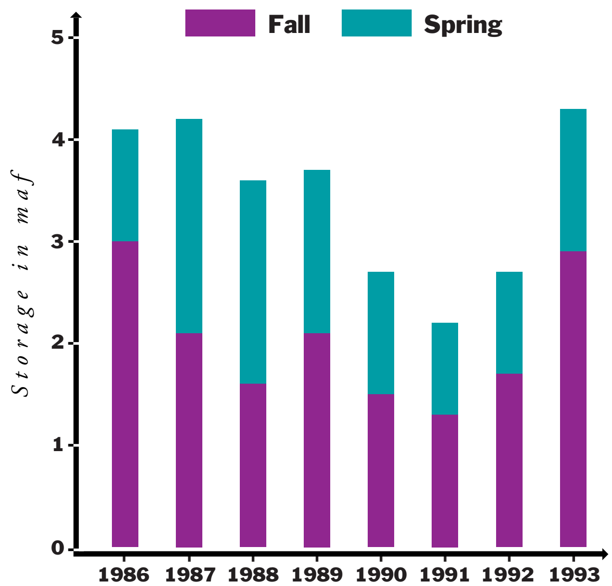


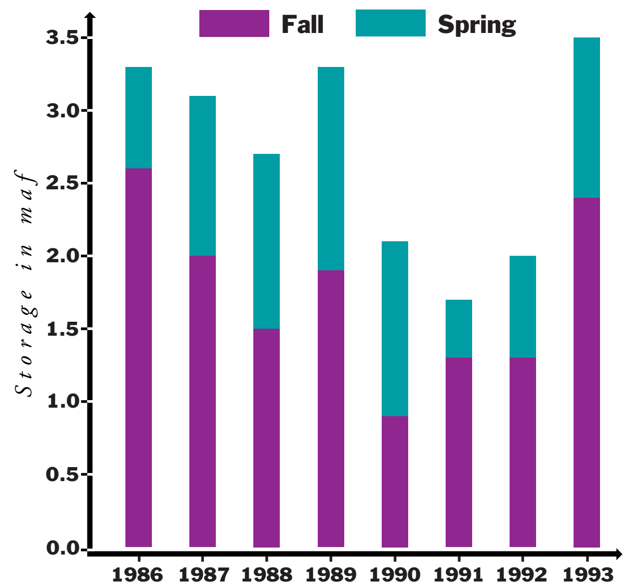
FIGURE 3-14

Selected Reservoir Storage During 1987-92 Drought

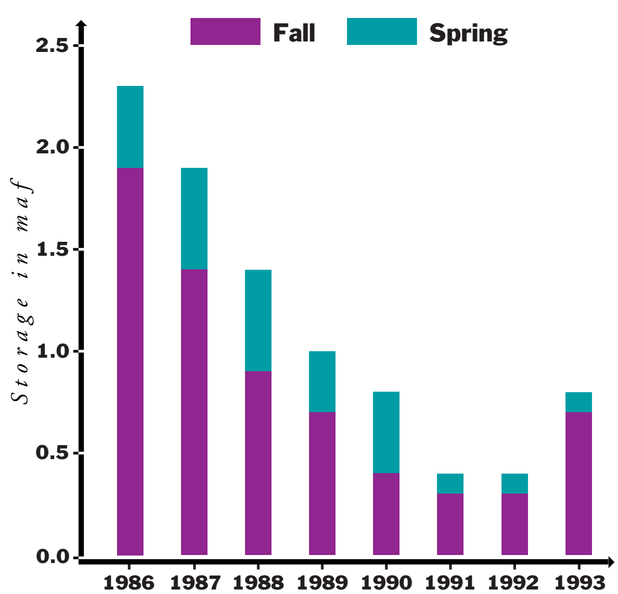
SHASTA



OROVILLE



NEW MELONES



CACHUMA

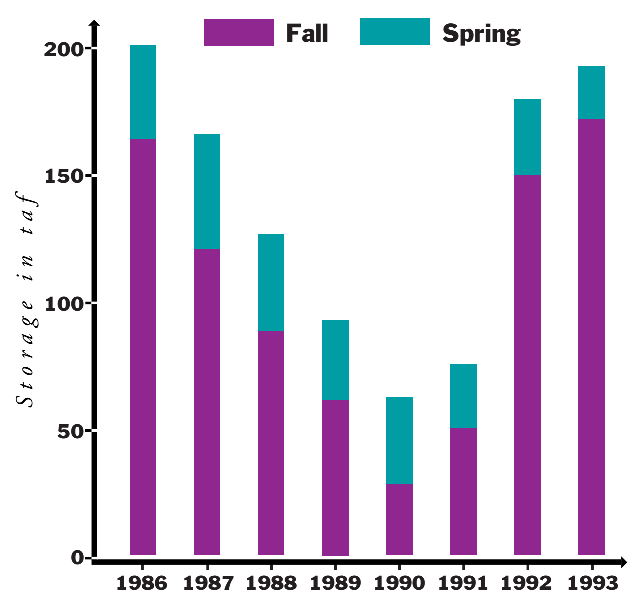


TABLE 3-3

California Water Supplies with Existing Facilities and Programs[a] (taf)

Supply	*1995*		*2020*	
	Average	*Drought*	*Average*	*Drought*
Surface				
CVP	7,004	4,821	7,347	4,889
SWP	3,126	2,060	3,439	2,394
Other Federal Projects	910	694	912	683
Colorado River	5,176	5,227	4,400	4,400
Local	11,054	8,484	11,073	8,739
Required Environmental Flow	31,372	16,643	31,372	16,643
Reapplied	6,441	5,596	6,449	5,575
Groundwater[b]	12,493	15,784	12,678	16,010
Recycled and Desalted	323	333	415	416
Total (rounded)	**77,900**	**59,640**	**78,080**	**59,750**

[a] Bulletin 160-98 presents water supply data as applied water, rather than net water. This distinction is explained in a previous section. Past editions of Bulletin 160 presented water supply data in terms of net supplies.

[b] Excludes groundwater overdraft

are shown to illustrate drought impacts to a Southern California reservoir not hydrologically connected to Central Valley supplies.

California Water Supplies with Existing Facilities and Programs

Table 3-3 shows California's estimated water supply, for average and drought years under 1995 and 2020 levels of development, with existing facilities and programs. Facility operations in the Delta are assumed to be in accordance with SWRCB's Order WR 95-6.

The State's 1995-level average year water supply is about 77.9 maf, including about 31.4 maf of dedicated flows for environmental uses. As previously discussed, this supply is based on an applied water methodology and therefore includes considerable amounts of reapplication within hydrologic regions. Even with a reduction in Colorado River supplies to California's 4.4 maf basic apportionment, annual average statewide supply is projected to increase about 0.2 maf by 2020 without implementation of new water supply options. While the expected increase in average year water supplies is due mainly to higher CVP and SWP deliveries (in response to higher 2020-level demands), new water production will also result from groundwater and recycling facilities currently under construction.

The State's 1995-level drought year water supply is about 59.6 maf, of which about 16.6 maf is dedicated for environmental uses. Annual drought year supply is expected to increase slightly by 2020 without implementation of new water supply options. The expected increase comes from higher CVP and SWP deliveries and new production from surface, groundwater, and recycling facilities currently under construction.

The following section describes the State's major surface water development projects. In response to public comments on Bulletin 160-93, the description of surface water projects was expanded to provide more detail on the larger local agency projects. A discussion on reservoir and river operations follows. The section

O'Neill Forebay with San Luis Reservoir in the background. These are joint facilities of the CVP and SWP.

concludes by addressing surface water supply impacts associated with recent events and the effects of changes in reservoir operations on supplies.

Surface Water Supplies

Surface Water Development Projects

This section describes California's largest surface water development projects, including the CVP, SWP, Colorado River facilities, and Los Angeles Aqueduct. Descriptions of smaller surface water development projects are provided in Chapters 7-9. See Chapter 1 for a location map of these larger facilities.

Central Valley Project. In 1921, California began planning a water project to serve the Central Valley. The Legislature authorized the State Central Valley Project in 1933. Because California was unable to sell the bonds needed to finance the project during the

Auburn Dam—Planned, But Not Constructed

Auburn Dam was authorized as a CVP facility by Congress in 1965 to provide greater flood control and water supply on the American River. Foundation preparation and related earthwork for a dam to impound 2.3 maf were halted by seismic safety concerns after a 1975 Oroville earthquake. The dam's design was changed in 1980 from a concrete arch to a gravity structure. The proposed dam has been a source of controversy between proponents of downstream flood control and water supply benefits and those who wish to preserve the American River Canyon. As originally planned, a multipurpose Auburn Reservoir could have provided more than 300 taf/yr of new water supply to the CVP, as well as substantial flood control and power benefits. Recent reviews of American River hydrology have emphasized the flood control potential of a dam at Auburn.

Much of the Sacramento metropolitan area is threatened by flooding from the American and Sacramento Rivers. The 100-year floodplain covers over 100,000 acres and contains over 400,000 residents, 160,000 homes and structures, and over $37 billion in developed property. When Folsom Dam was completed in 1955, the facility was estimated to provide Sacramento with 250-year level of flood protection. This estimate was revised downward to a 60-year level of protection (77-year level with Folsom reoperation for additional flood control space) after the storms of 1986 and 1997.

Given the area's low level of flood protection (one of the lowest in the nation for a metropolitan area of its size), USACE has evaluated many alternatives to providing additional flood protection. Three recent alternatives include the Folsom modification plan, the Folsom stepped release plan, and the detention dam plan. The Folsom modification plan would increase maximum flood storage in Folsom from 400 taf to 720 taf, lower the main spillway by 15 feet, enlarge 8 river outlets, and make levee improvements along the American and Sacramento Rivers. The Folsom stepped release plan would increase Folsom's flood storage to 670 taf, lower the main spillway by 15 feet, enlarge 8 river outlets, and make levee improvements to increase maximum reservoir releases to 180,000 cfs. The detention dam plan would construct a 508-foot-high flood detention facility on the North Fork of the American River near Auburn, make levee improvements along the American and Sacramento Rivers, and return the maximum flood storage in Folsom Reservoir to 400 taf.

USACE completed an EIR/EIS in 1992 and a supplemental EIR/EIS in March 1996, addressing flood control alternatives for the Sacramento area. Both identified the detention dam as the national economic development plan, i.e., the plan that would maximize net national economic benefit. In 1995, the Reclamation Board voted for a preferred plan from among the three alternatives and endorsed the detention dam plan. The Sacramento Area Flood Control Agency also voted for the detention dam as the locally preferred plan.

In its Resolution No. 95-17, the Reclamation Board stated that it " . . . believes the Folsom Modification Plan provides an inadequate level of flood protection for the Sacramento area, and would reduce water-supply capacity and hydropower benefits at Folsom Reservoir . . ." and that " . . .the Board believes the Stepped Release Plan would place undue reliance on the levees of the lower American River, would reduce water supply capacity and hydropower benefits at Folsom Reservoir, and . . . would be significantly more expensive for State and local interests . . . ." Regarding the detention dam plan, the resolution states " . . . the Board believes that the Detention Dam Plan . . . represents the NED Plan for the American River flood plain. The Board recommends that the Corps pursue Congressional authorization of this plan." In spite of support from USACE, the Reclamation Board and SAFCA, the detention dam was not authorized in the Water Resources Development Act of 1996.

In 1998, the Reclamation Board reaffirmed its support for an Auburn Dam, stating in Resolution No. 98-04 that "the best long-term engineering solution to reliably provide greater than 1-in-200 year flood protection is to develop additional flood detention storage at Auburn which, with a capacity of 894,000 acre-feet would provide a 1-in-400 year level of protection".

As Bulletin 160-98 is being written, competing proposals for American River flood control measures are being heard by congressional authorizing committees.

TABLE 3-4

Major Central Valley Project Reservoirs

Reservoir	*Capacity (taf)*	*Year Completed*	*Stream*
Shasta	4,552	1945	Sacramento River
Trinity	2,448	1962	Trinity River
New Melones	2,420	1979	Stanislaus River
Folsom	977	1956	American River
San Luis (Federal Share)	966	1967	Offstream
Millerton	520	1947	San Joaquin River
Whiskeytown	241	1963	Clear Creek

Great Depression, USBR stepped in to begin project construction. Initial congressional authorization for the CVP covered facilities such as Shasta and Friant Dams, Tracy Pumping Plant, and the Contra Costa, Delta-Mendota, and Friant-Kern Canals. Later authorizations included Folsom Dam (1949), Trinity River Division (1955), Sacramento Valley Canals (1959), San Luis Unit (1960), New Melones Dam (1962), Auburn Dam (1965), and the San Felipe Division (1967).

The USBR's CVP is the largest water storage and delivery system in California, covering 29 of the State's 58 counties. The project's features include 18 federal reservoirs and 4 additional reservoirs jointly owned with the SWP. The keystone of the CVP is the 4.55 maf Lake Shasta, the largest reservoir in California. CVP reservoirs provide a total storage capacity of over 12 maf, nearly 30 percent of the total surface storage in California, and deliver about 7 maf annually for agricultural (6.2 maf), urban (0.5 maf), and wildlife refuge use (0.3 maf). Table 3-4 shows major CVP reservoirs.

Shasta and Keswick Reservoirs regulate CVP releases into the Sacramento River. Red Bluff Diversion Dam on the Sacramento River diverts water to the Tehama-Colusa and Corning Canals. At the Delta, CVP water is exported at Rock Slough into the Contra Costa Canal and at Tracy Pumping Plant on Old River to the Delta-Mendota Canal. During the winter, water is conveyed via the Delta-Mendota Canal to San Luis

Floodflows on the American River in 1986 breached the cofferdam that USBR had constructed when it began its initial work at the Auburn damsite. This flood event produced record flows in the American River through metropolitan Sacramento.

FIGURE 3-15

Major Central Valley Project Facilities

Reservoir for later delivery to the San Luis and San Felipe Units of the project. A portion of the Delta-Mendota Canal export is placed back into the San Joaquin River at Mendota Pool to serve, by exchange, water users with long-standing historical rights to the use of San Joaquin River flow. This exchange enabled the CVP to build Friant Dam (Millerton Lake), northeast of Fresno, which diverts a major portion of San Joaquin River flows through the Friant-Kern and Madera Canals. Figure 3-15 is a map of CVP facilities.

The CVP supplies water to more than 250 long-term water contractors in the service areas shown in Figure 3-16. The majority of CVP water goes to agricultural water users. Large urban centers receiving CVP water include Redding, Sacramento, Folsom, Tracy, most of Santa Clara County, northeastern Contra Costa County, and Fresno. Collectively, the contracts call for a maximum annual delivery of 9.3 maf, including delivery of 1.7 maf of Friant Division supply when available in wet years. Of the 9.3 maf total annual contractual delivery, 4.8 maf is classified as project water and 4.5 maf is classified as water right settlement (also called base supply or prior rights) water. About 90 percent of south-of-Delta contractual delivery is for agricultural and urban uses; the remaining 10 percent is for wildlife refuges. Figure 3-17 shows actual CVP water deliveries since 1960. (The Bulletin's CVP supplies are based on normalized data, not the actual delivery data shown in Figure 3-17.)

Water right settlement water is water covered in agreements with water rights holders whose diversions existed before the project was constructed. Project reservoirs altered natural river flow upon which these pre-project diverters had relied, so contracts were negotiated to agree on the quantities of diversions that could be made without any payment to the United States. CVP base supply and settlement contractors on the upper Sacramento River receive their supply (about 2.3 maf/yr) from natural flow and storage regulated at Shasta Dam. Settlement contractors on the San Joaquin River (called exchange contractors) receive Delta water from Northern California which is diverted at Tracy Pumping Plant, stored in San Luis Reservoir and/or pumped directly via the Delta-Mendota Canal.

Courtesy of USBR

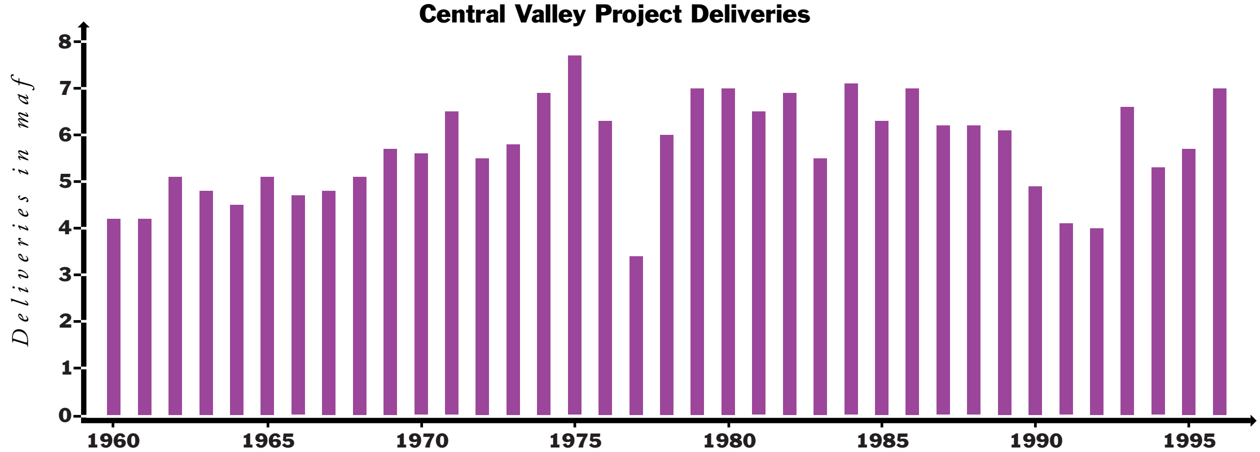
Friant Dam, a 319-foot high concrete gravity dam, controls runoff from about 1,630 square miles of the San Joaquin River's drainage basin. The Friant-Kern Canal is in the foreground.

FIGURE 3-16

Central Valley Project Service Areas

FIGURE 3-17

Central Valley Project Deliveries



The capability of the CVP to meet full water supply requests by its south-of-Delta contractors in a given year depends on rainfall, snowpack, runoff, carryover storage, pumping capacity from the Delta, and regulatory constraints on CVP operation. Figure 3-18 shows existing (1995 level) and future (2020 level) CVP south-of-Delta delivery capability, as estimated by operations studies, under SWRCB Order WR 95-6. The figure shows that existing CVP facilities have a 20 percent chance of making full deliveries under both demand levels.

State Water Project. It was evident soon after World War II that local and federal water development could not keep pace with California's rapidly growing population. Planning for the multipurpose SWP began in the late 1940s, and accelerated in the early 1950s. Voters authorized SWP construction in 1960 by ratifying the Burns-Porter Act. The majority of existing project facilities were constructed in the 1960s and 1970s. Future SWP facilities were to be added as water demands increased, to meet the project's initial contractual entitlement of 4.2 maf/yr.

SWP facilities include 20 dams, 662 miles of aqueduct, and 26 power and pumping plants. SWP reservoirs are listed in Table 3-5. Major facilities include the multipurpose Oroville Dam and Reservoir on the Feather River, the Edmund G. Brown California

FIGURE 3-18

1995 and 2020 Level Central Valley Project Delivery Capability South of Delta with Existing Facilities

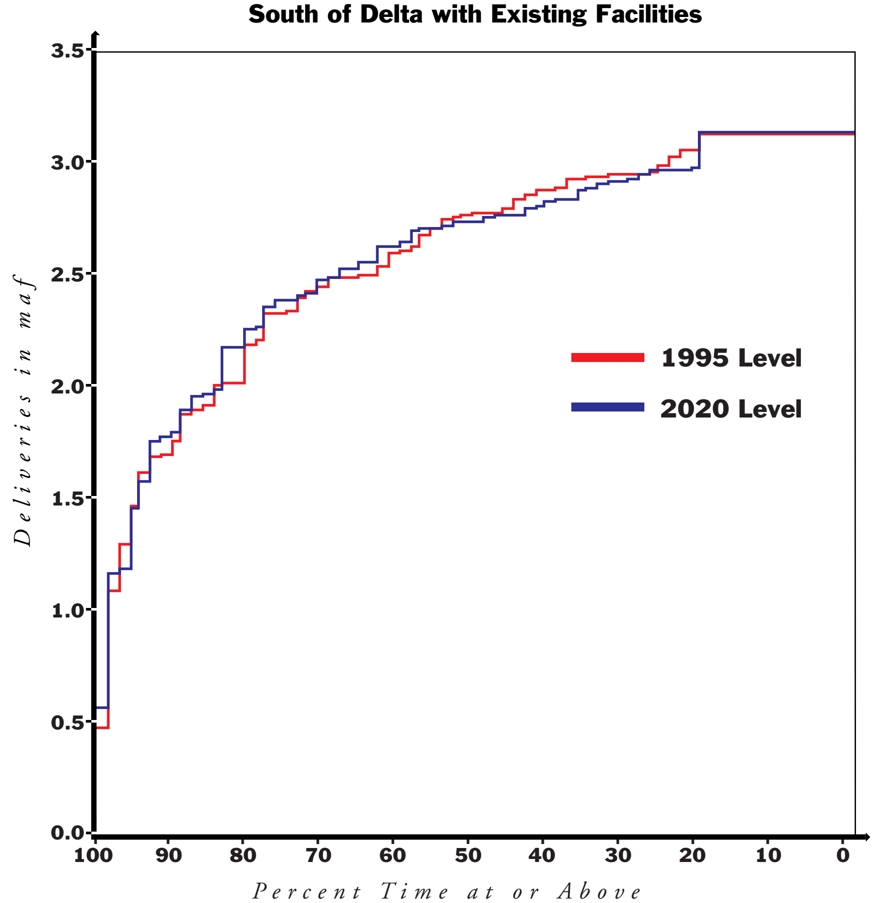


TABLE 3-5

Major State Water Project Reservoirs

Reservoir	*Capacity (taf)*	*Year Completed*	*Stream*
Oroville	3,538	1968	Feather River
San Luis (State share)	1,062	1967	Offstream
Castaic	324	1973	Offstream
Pyramid	171	1973	Offstream
Perris	131	1973	Offstream
Davis	84	1966	Big Grizzly Creek
Del Valle	77	1968	Arroyo Valle Creek
Silverwood	75	1971	Offstream
Frenchman	55	1961	Last Chance Creek
Antelope	23	1964	Indian Creek

Aqueduct, South Bay Aqueduct, North Bay Aqueduct, and a share of the State-federal San Luis Reservoir. With a storage capacity of 3.5 maf, Lake Oroville is the second largest reservoir in California after Lake Shasta. Lake Oroville stores winter and spring flows of the upper Feather River. Water released from Lake Oroville travels down the Feather and Sacramento Rivers to the Delta. There, some of the water flows to the ocean to meet mandated Delta water quality criteria, and some of the water is delivered through project facilities to the Bay Area, Central Coast, San Joaquin Valley and Southern California.

Water is diverted from the California Aqueduct into the South Bay Aqueduct, which extends into Santa Clara County. A separate Delta diversion supplies the North Bay Aqueduct, which serves areas in Napa and Solano Counties. Maximum capacity of the California Aqueduct is 10,300 cfs at the Delta and 4,480 cfs over the Tehachapis to the South Coast Region. The Department has just completed construction of the extension of the Coastal Branch of the California Aqueduct, which extends about 115 miles from the main aqueduct to serve parts of San Luis Obispo and Santa Barbara Counties. Figure 3-19 is a map of major SWP facilities.

The service area of the 29 SWP contracting agencies is shown in Figure 3-20. Initial project contracts were signed for an eventual annual delivery of 4.2 maf. Of this annual entitlement, about 2.5 maf was to serve Southern California and about 1.3 maf was to serve

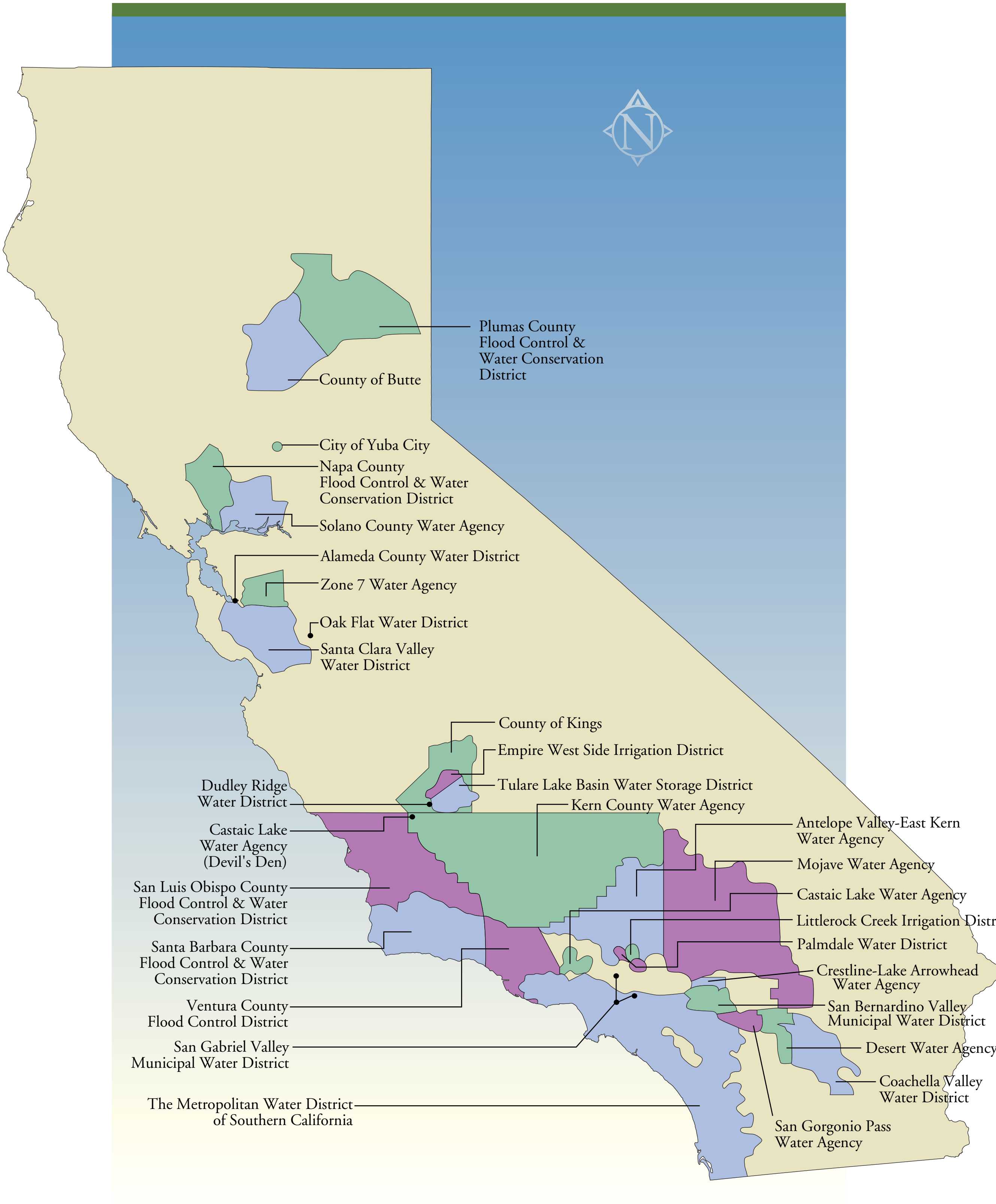
The Department's expansion of the Coastal Branch included construction of new pumping plants, such as the Bluestone Pumping Plant.

FIGURE 3-19

Major State Water Project Facilities

FIGURE 3-20

State Water Project Service Areas

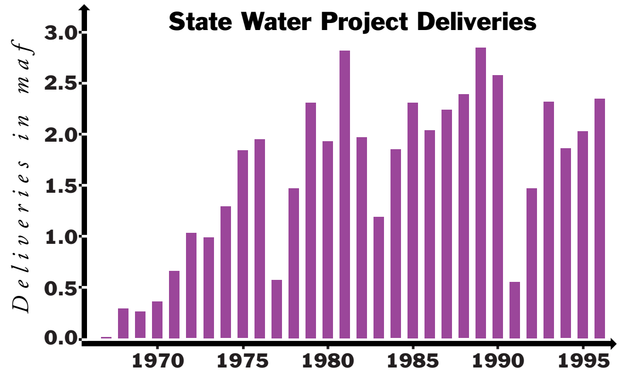


the San Joaquin Valley. The remaining 0.4 maf annual entitlement was to serve the Feather River area and the San Francisco Bay and Central Coast regions. (As discussed in Chapter 2, 45 taf of annual entitlement belonging to two project contractors in the San Joaquin Valley was subsequently retired as part of the Monterey Agreement.) Figure 3-21 shows actual SWP water deliveries since the beginning of entitlement deliveries in 1967. (The Bulletin's SWP supplies are based on normalized data, not the actual delivery data shown in Figure 3-21.) Except during very wet years and during drought years, San Joaquin Valley use of SWP supply has been near full contract amounts since about 1980. Southern California use of SWP supply has reached about 60 percent of full entitlement.

The ability of the SWP to deliver full water supply requests by its contractors in a given year depends on rainfall, snowpack, runoff, carryover storage, pumping capacity from the Delta, and regulatory constraints on SWP operation. The calculated average annual delivery during a repeat of the 1929-34 drought is about

FIGURE 3-21

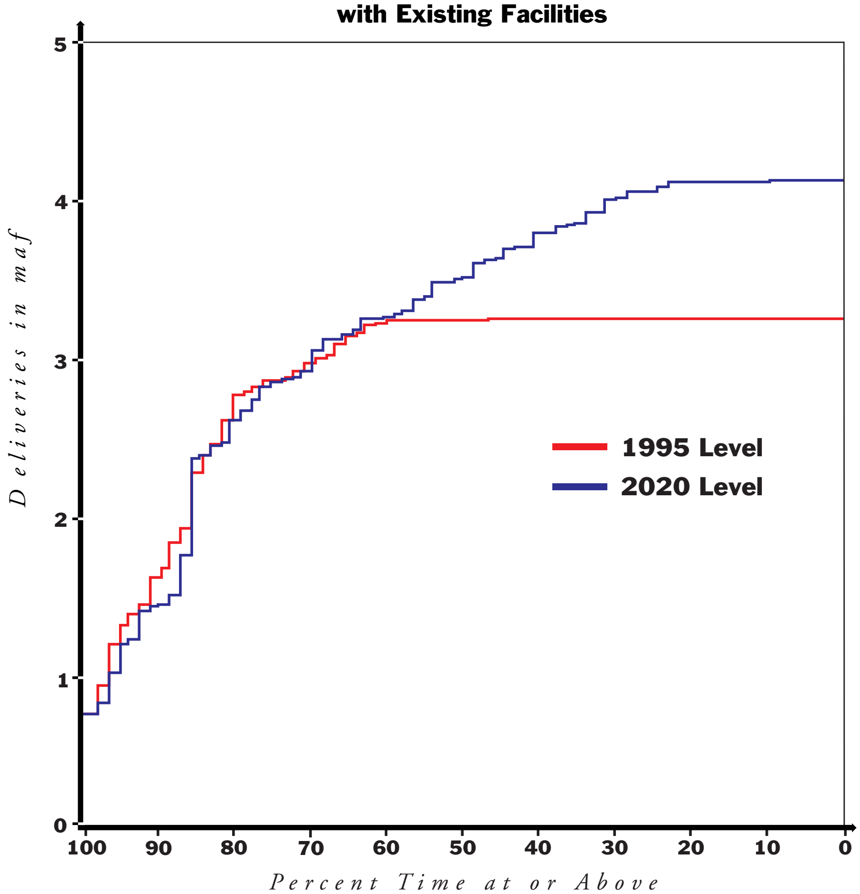
State Water Project Deliveries



2.1 maf. About half of this water would come from Lake Oroville and the rest from surplus flow in the Delta, some of which is stored in San Luis Reservoir. Figure 3-22 shows existing (1995 level) and future (2020 level) SWP delivery capability, as estimated by operations studies, under SWRCB Order WR 95-6. The figure shows that existing SWP facilities have a 65 percent chance of making full deliveries under 1995 level demands and have an 85 percent chance of delivering 2.0 maf to project contractors in any given year. The figure also shows that under a 2020 level demand scenario, existing SWP facilities have less than a 25 percent chance of making full deliveries.

FIGURE 3-22

1995 and 2020 State Water Project Delivery Capability with Existing Facilities



Colorado River. The Colorado River is an interstate and international river. Its mean annual unimpaired flow is about 15 maf. The river, which has is headwaters in Wyoming's Green River Basin, crosses through parts of seven states before flowing into Mexico and terminating at the Gulf of California. The Colorado River watershed is depicted in Figure 3-23.

Nearly 60 maf of surface water storage has been developed on the river and its tributaries, resulting in a ratio of storage to average annual river flow of about 4 to 1—comparable to the ratio found on Putah Creek at Lake Berryessa—but much higher than the ratio found on

FIGURE 3-23

Colorado River Watershed in United States

most of California's rivers. The two largest reservoirs are the 24 maf Lake Powell (impounded by Glen Canyon Dam) and the 26 maf Lake Mead (impounded by Hoover Dam). Three major structures divert water from the Colorado River to California. Parker Dam impounds Lake Havasu, which supplies water for MWDSC's Colorado River Aqueduct on the California side of the stateline and for the Central Arizona Project on the Arizona side of the stateline. Palo Verde Diversion Dam supplies water to Palo Verde Irrigation District's canal system. Imperial Dam diverts water to the All American Canal (and to California users of USBR's Yuma Project) on the California side of the stateline and to Arizona Yuma Project users on the Arizona side of the stateline. An off-stream storage reservoir, Senator Wash Reservoir, is used to adjust releases from Parker Dam and to meet downstream demands. The Colorado River service area is shown in Figure 3-24.

Three major facilities—USBR's All American Canal, MWDSC's Colorado River Aqueduct, and Palo Verde Irrigation District's main canal—convey water from the Colorado River to California users. Construction of the All American Canal was authorized in the

The 82-mile All American Canal transports water from Imperial Dam on the Colorado River to Imperial Irrigation District's service area. In an outstanding engineering feat, the canal system and district distribution system operate entirely on gravity flow.

FIGURE 3-24

Colorado River Service Areas

Colorado River Reservoir Operations

Operation of lower Colorado River reservoirs is controlled by USBR, which serves as the watermaster for the river. USBR is responsible for maintaining an accounting of consumptive use of the basin states' allocations, and for ensuring that Mexican treaty requirements are met with respect to the quantity of flows and salinity concentration of water delivered to Mexico.

The 1968 Colorado River Basin Project Act directed DOI to develop criteria for long-range operation of the major federal reservoirs on the river and its tributaries. USBR conducts a formal review of the long-range operating criteria every five years. The act further requires DOI to prepare an annual operating plan for the river, in consultation with representatives from the basin states. Some river operating criteria have already been established in the statutes comprising the law of the river (see Chapter 9 for more detail). For example, USBR is required to equalize, to the extent practicable, storage in Lake Mead and Lake Powell. (Lake Powell in essence serves as the bank account that guarantees annual delivery of 7.5 maf from the Upper Basin to the Lower Basin, plus water to satisfy Mexican treaty obligations. The actual statutory guarantee is 75 maf every 10 years, plus one-half of the Mexican treaty water requirements.)

Current federal operating criteria for the reservoirs have focused on balancing the conservation of water and avoiding downstream flood damage. As consumptive use of water in the Lower Basin has reached the annual 7.5 maf basic apportionment, there has been increasing interest in operating the river more efficiently from a water supply standpoint. Proposals discussed among Colorado River water users have included a variety of surplus and shortage operating criteria, banking programs, and augmentation of the river's base flow. In order to be implemented, any changes in operating criteria formally recommended by the Colorado River Board would have to be acceptable to the other basin states and to the federal government.

Based on the amount of water in the reservoir system, USBR declared a surplus condition on the river in 1996, 1997, and 1998, allowing California to continue diverting more than its basic apportionment. In 1997 and 1998, flood control releases were made from Lake Mead.

1928 Boulder Canyon Project Act. Work on the canal began in the 1930s, with water deliveries beginning in 1940. Colorado River water diverted at Imperial Dam flows by gravity through the All American Canal and the Coachella Canal to the Imperial and Coachella Valleys. The All American Canal has a maximum capacity of 15,200 cfs in the reach immediately downstream from Imperial Dam. The main branch of the All American Canal extends 82 miles from Imperial Dam to the western portion of Imperial Irrigation District's distribution system. The Coachella Canal branches off from the main canal and extends 121 miles northward, to terminate in Coachella Valley Water District's Lake Cahuilla.

In 1933, MWDSC started constructing its Colorado River Aqueduct to divert Colorado River water from Lake Havasu to the South Coast Region. Completed in 1941, the 242-mile long aqueduct had a design capacity of 1.2 maf/yr, although MWDSC has been able to deliver as much as 1.3 maf/yr. Facilities associated with the aqueduct include five major pumping plants and Lake Mathews, the aqueduct's terminal reservoir in Riverside County. The San Diego Aqueduct, constructed by the federal government, interconnects with the Colorado River Aqueduct in Riverside County. Delivery of Colorado River Aqueduct water to San Diego County began in 1947. Colorado River operations are described in the sidebar.

California's basic apportionment of Colorado River supplies is a consumptive use of 4.4 maf/yr, plus half of any excess or surplus water. Apportionment of Colorado River supplies is discussed in detail in Chapter 9. California has been able to use as much as 5.4 maf of Colorado River supplies annually because neither the Upper Basin states nor Arizona and Nevada were using their full apportionments, and because of wet hydrologic conditions.

Klamath Project. The USBR's Klamath Project straddles the California-Oregon stateline near Klamath Falls, Oregon, and provides water supplies to users in both states. The project, authorized in 1905 by the Reclamation Act of 1902, transfers water between the Lost River (which naturally flowed into Tule Lake and occasionally into the Klamath River) and the Klamath River. Project works were constructed to drain and reclaim lakebed lands of Lower Klamath and Tule Lakes and to provide irrigation supplies to lands within the project area totaling about 230,000 acres. Major storage facilities of the Klamath Project are given in Table 3-6.

The Klamath Project includes 185 miles of main canal, 532 miles of laterals, 37 pumping plants, and 728 miles of drains. Project agricultural water use has historically averaged about 400 taf/yr. The project also serves water to adjacent national wildlife refuges.

Other Federal Projects. In addition to the CVP,

TABLE 3-6

Major Reservoirs of USBR's Klamath Project

Reservoir	*Capacity (taf)*	*Year Completed*	*Stream*
Upper Klamath	873	1921	Klamath River
Clear	527	1910	Lost River
Gerber	94	1925	Miller Creek

Colorado River facilities, and the Klamath Project, USBR has constructed several other reclamation projects in California (Table 3-7). These reclamation projects and other facilities constructed by USACE provide important flood control and recreation benefits.

Los Angeles Aqueduct. In 1913, the City of Los Angeles began importing water from the Owens Valley through the first pipeline of the Los Angeles Aqueduct. The original aqueduct reach was 233 miles long, had 142 tunnels, and crossed 9 major canyons to deliver water to Los Angeles using only gravity. In 1940, the aqueduct was extended north to tap Mono Basin water at Lee Vining Creek, increasing its length to 338 miles. The extension included an 11-mile tunnel drilled through the Mono Craters.

To keep pace with the city's growing population, a second pipeline of the LAA was completed in 1970 to import additional water from the southern Owens Valley at Haiwee Reservoir. The second pipeline increased the aqueduct's annual delivery capacity from 330 taf to 550 taf. In dry years, the aqueduct was to be maintained at full capacity through groundwater pumping in the Owens Valley. Pumped groundwater is also used to meet in-valley uses. In addition to the two aqueduct pipelines, the system includes eight reservoirs and eleven powerplants. The largest reservoirs are shown in Table 3-8.

The delivery capability of LADWP's aqueduct system has been affected by judicial and regulatory actions intended to restore environmental resources in the Mono Lake Basin and in the Owens River Valley. In 1979, the National Audubon Society, the Mono Lake Committee, and others filed the first in a series of lawsuits which challenged the project's water diversions from the Mono Basin. In 1989 and 1990, the El Dorado County Superior Court entered preliminary injunctions which required the project to reduce diversions to restore and maintain the water level of Mono Lake at 6,377 feet. The injunctions also established minimum fishery flows in all four Mono Basin streams from which project diversions are made.

In 1994, SWRCB's Decision 1631 specified minimum fishery flows on the four Mono Basin streams. The order also established water diversion criteria to protect wildlife and other environmental resources in the Mono Basin. The water diversion criteria prohibited export of water from the Mono Basin until the water level of Mono Lake reached 6,377 feet, and restricted Basin exports until the water level of Mono Lake rose to an elevation of 6,391 feet (estimated to take approximately 20 years). Once the water level of 6,391 feet is reached, the

TABLE 3-7

Other USBR Projects in California[a]

Reservoir	*Project*	*Capacity (taf)*	*Year Completed*	*Stream*
Berryessa	Solano	1,600	1957	Putah Creek
Tahoe[b,c]	Newlands	745	1913	Truckee River
Casitas	Ventura River	254	1959	Ventura River
Twitchell	Santa Maria	240	1958	Cuyama River
Stampede[b]	Washoe	227	1970	Little Truckee River
Cachuma	Cachuma	190	1953	Santa Ynez River
East Park	Orland	51	1910	Stony Creek
Stony Gorge	Orland	50	1928	Stony Creek
Boca[b]	Truckee Storage	41	1937	Little Truckee River
Prosser Creek[b]	Washoe	30	1962	Prosser Creek

[a] Does not include CVP or Colorado River projects.

[b] Lands served by this reservoir are located in Nevada.

[c] USBR controls the dam under easement from Sierra Pacific Power Company.

LAA will be able to export approximately 31 taf/yr from the Mono Basin.

Longstanding litigation between Inyo County and the City of Los Angeles over environmental effects of Owens Valley groundwater pumping ended in June 1997, allowing implementation of water management and environmental mitigation actions. (See Chapter 9 for additional details.) A key environmental restoration effort is rewatering the lower Owens River in a 60-mile stretch from the aqueduct intake south of Big Pine to just north of Owens Dry Lake. The effort calls for providing continuous river flows of about 40 cfs (with seasonal habitat flows up to about 200 cfs), establishing 1,825 acres of wetlands, and establishing and maintaining off-river lakes and ponds. (Most of the instream flows will be pumped back out of the river and into the LAA from a point just north of Owens Dry Lake. Between 6 and 9 cfs will be allowed to flow past the pumpback station to sustain a 325 acre wetland in the Owens Lake delta.) Providing the base flow of 40 cfs and river channel restoration must begin no later than 2003.

As discussed in Chapter 9, the Great Basin Unified Air Pollution Control District issued an order to LADWP in July 1997 requiring 50 taf of water per year to control dust from the Owens Dry Lake. Two potential sources of water identified by the GBUAPCD include aquifers under the lakebed and the Los Angeles Aqueduct. As described in Chapter 9, LADWP and GBUAPCD have developed a draft agreement for dust control measures.

As Mono Lake's level rises as a result of SWRCB's Decision 1631, some of the lakeshore tufa formations will be submerged.

Tuolumne River Development. The Tuolumne River, which begins at Lyell Glacier in Yosemite National Park and extends 163 miles to its confluence with the San Joaquin River west of Modesto, is the largest of the San Joaquin River tributaries. It produces an average annual runoff of about 1.9 maf of which 1.2 maf comes from snowmelt between April and July. Total reservoir capacity on the river is 2.8 maf, almost 1.5 times its average annual runoff. Of this total, over 0.34 maf is reserved for flood control. Table 3-9 lists major reservoirs on the Tuolumne River system.

The oldest dam on the Tuolumne River is La Grange Dam, about 2.5 miles downstream of New

TABLE 3-8

Major Reservoirs in the Los Angeles Aqueduct System

Reservoir	*Capacity (taf)*	*Year Completed*	*Stream*
Crowley	183	1941	Owens River
Grant	47	1940	Rush Creek
Haiwee	39	1913	Rose Valley Creek
Bouquet	34	1934	Bouquet Creek
Tinemaha	6	1929	Owens River

TABLE 3-9

Major Reservoirs in the Tuolumne River Basin

Reservoir	*Capacity (taf)*	*Year Completed*	*Owner*	*Stream*
New Don Pedro	2,030	1971	Modesto ID/Turlock ID	Tuolumne River
Hetch Hetchy	360	1923	San Francisco PUC	Tuolumne River
Lake Lloyd	268	1956	San Francisco PUC	Cherry Creek
Turlock	49	1915	Turlock ID	Offstream
Modesto	29	1911	Modesto ID	Offstream
Eleanor	26	1918	San Francisco PUC	Eleanor Creek

Don Pedro Dam. The 131-foot high La Grange Dam was completed in 1894; it serves as a diversion dam to divert river flows into Modesto ID's and Turlock ID's canals. In 1923, Modesto and Turlock Irrigation Districts completed the old Don Pedro concrete dam with a capacity of about 290 taf. The New Don Pedro Dam, capacity 2.03 maf, was completed in 1971 as a joint project of the two irrigation districts and the City and County of San Francisco.

In its early years, the City of San Francisco's water supply came from local creeks and springs. This was soon inadequate and, in 1862, water from the peninsula was drawn from Pilarcitos Creek (in San Mateo County) via a tunnel and redwood flume. In the 1870s, San Andreas and Crystal Springs Reservoirs were added and, with later improvements, increased the city's water supply greatly. About the turn of the century, the Spring Valley Water Company, the city's main water purveyor, turned its attention to the East Bay area and

San Francisco's Pulgas Water Temple marks the original terminus of the Hetch Hetchy Aqueduct at Upper Crystal Springs Reservoir.

Alameda Creek. It constructed the Sunol Aqueduct in 1900 and completed Calaveras Dam in 1925. (The 215-foot high dam was the highest earth-fill dam in the world at the time.)

Concern about adequate water supply led to a series of studies and the choice in 1901 of the Tuolumne River as the city's next major source of supply. The centerpiece was to be a dam at Hetch Hetchy Valley in northern Yosemite Park. Authorization was secured in the 1913 Raker Act and work soon began on the construction of O'Shaughnessy Dam and the Hetch Hetchy Aqueduct. A dam at Lake Eleanor was built in 1918 to supply hydroelectric power for Hetch Hetchy construction. O'Shaughnessy Dam was completed in 1923 and the San Joaquin Valley pipeline and Coast Range tunnel were finished to deliver the first water to the San Francisco peninsula in 1934. Cherry Valley Dam (Lake Lloyd) was completed in 1956, which added further regulated storage to help satisfy irrigation district prior water rights below Hetch Hetchy.

The capacity of the current Hetch Hetchy Aqueduct system's San Joaquin pipeline is about 330 taf/yr. Average and drought year delivery capability of the system is 294 taf and 270 taf, respectively.

Two major San Joaquin Valley water agencies, Turlock and Modesto Irrigation Districts, have water rights on the Tuolumne River that are senior to those of San Francisco. Annual diversions by these irrigation districts average between 0.9 maf and 1.1 maf. As shown in Table 3-9, each of the irrigation districts uses an offstream regulatory reservoir to manage the distribution of the water diverted from the river.

Mokelumne Aqueduct. The Mokelumne River, one of the smaller Sierra Nevada rivers, has an average annual runoff of 740 taf. It is a snowmelt stream, with over 60 percent of its runoff occurring during April through July. The Mokelumne River has about 840 taf of storage capacity, approximately 1.1 times its average annual runoff. The largest reservoir is Camanche,

TABLE 3-10

Mokelumne Aqueduct System Reservoirs

Reservoir	*Capacity (taf)*	*Year Completed*	*Stream*
Camanche	417	1963	Mokelumne River
Pardee	198	1929	Mokelumne River

Hydraulic mining in the 1860s in the Michigan Bar District. Hydraulic mining was widely blamed for worsening flooding in Sacramento Valley towns because sediments washed into streams and rivers, raising their beds and reducing their capacity.

Courtesy of California State Library

which can hold 417 taf. Total flood control space on the Mokelumne River system is 200 taf. In addition to EBMUD's facilities on the river (Table 3-10), there is 220 taf of storage (owned by PG&E) and diversion works for two irrigation districts—Jackson Valley and Woodbridge Irrigation Districts.

In the 1920s, as the Hetch Hetchy Project for the San Francisco peninsula was under way, East Bay cities also turned to the Sierra Nevada for more water, specifically to the Mokelumne River. EBMUD completed Pardee Dam and the Mokelumne Aqueduct from Pardee Reservoir to the East Bay in 1929. The downstream Camanche Reservoir was completed in 1963. With the addition of a third pipeline in 1965, Mokelumne Aqueduct capacity was increased from 224 taf/yr to 364 taf/yr. Drought year supplies are not always adequate to sustain full aqueduct capacity diversions.

Yuba and Bear Rivers Development. The Yuba and Bear Rivers drain the west slope of the Sierra Nevada between the Feather River Basin on the north and the American River Basin on the south. The Yuba and Bear River Basins include portions of Yuba, Sutter, Placer, Nevada, Sierra, Butte, and Plumas Counties. Elevations range from 60 feet near Marysville to over 9,000 feet along the Sierra Nevada crest. The basins produce an average annual runoff of about 2.4 maf, 45 percent of which is derived from snowmelt from April through July. Runoff from the 1,700 square mile area drains westerly to the confluence with the Feather River, south of Marysville. Total reservoir capacity on the rivers is more than 1.6 maf, or approximately two-thirds of the average annual runoff. Surface water development provides municipal, irrigation, power generation, and environmental supplies to more than one dozen water purveyors, and serves the Cities of Marysville, Grass Valley, Nevada City, and many smaller communities.

The basins contain numerous lakes and reservoirs, including many small mountain lakes in the headwaters area. The larger reservoirs are listed in Table 3-11. New Bullards Bar, a concrete arch dam 645 feet high impounding a 966 taf reservoir, is located on the North Fork Yuba River about 30 miles northeast of Marysville. The facility was built for irrigation, power generation, recreation, fish and wildlife enhancement, and flood control. Seasonal flood control storage capacity is 170 taf. Englebright Dam (which impounds Englebright Reservoir) was constructed in 1941 by the California Debris Commission as a debris storage project. The dam, along with Daguerre Point Dam and channel training walls farther downstream, was designed to control movement of hydraulic mining debris along the lower Yuba River. Up to that time, mining debris was filling the downstream channels, creating flooding and navigation problems. Currently, PG&E and YCWA pay the federal government to use Englebright's storage to generate hydroelectric power at two powerplants.

Water from the Yuba and Bear Rivers is exported to the Feather and American River Basins via diversion works. Water is transferred to the Feather River basin (from Slate Creek to Sly Creek Reservoir) by Oroville-Wyandotte Irrigation District. Water is transferred to

TABLE 3-11

Major Reservoirs on the Yuba and Bear River Systems

Reservoir	*Capacity (taf)*	*Year Completed*	*Owner*	*Stream*
New Bullards Bar	966	1970	YCWA	NF Yuba River
Camp Far West	103	1963	South Sutter WD	Bear River
Lake Spaulding	75	1913	PG&E	SF Yuba River
Englebright	70	1941	USACE	Yuba River
Bowman	69	1927	Nevada ID	Canyon Creek
Jackson Meadows	69	1965	Nevada ID	MF Yuba River
Rollins	66	1965	Nevada ID	Bear River
Collins	57	1963	Browns Valley ID	Dry Creek
Scotts Flat	49	1948	Nevada ID	Deer Creek

the American River Basin (from Rollins Reservoir to Folsom Lake) by PG&E and Nevada Irrigation District. PG&E also diverts water for power generation from the American River Basin to the Bear River, which is subsequently returned to the North Fork American River and Folsom Lake.

Reservoir and River Operations

Most large reservoirs in California are multipurpose impoundments designed to provide water supply storage, electric power, flood control, recreation, water quality, and downstream fishery needs. Often, large reservoirs would not be economically feasible as single purpose projects. Multipurpose designs maximize the beneficial uses of large reservoir sites and provide regional water supply benefits.

Water Supply Operations. Water supply needs dictate many operating criteria of multipurpose reservoirs. Sufficient water must be provided for existing water rights, instream requirements for fish and water quality (including temperature control), downstream water demands, and, in the case of Shasta Reservoir, minimum flows or depths in the Sacramento River for navigation. The generation of hydroelectric power is, for the most part, an ancillary purpose. However, where there is capacity and an afterbay to re-regulate flow, reservoirs may be operated to meet peaking power needs. Lake recreation is an important element of the local economy at many reservoirs. High reservoir levels often are maintained into the summer to maximize local recreation.

Urban and agricultural water demands are highest during the summer and lowest during the winter, the inverse of natural runoff patterns. Environmental water demands can follow a different pattern. Water needs for flooding refuge and duck club lands tend to peak in the late fall. Anadromous fishery (primarily salmon) demands are highest in the fall to attract spawning fish and again in the spring to move the newly hatched smolts and fry downstream to the ocean. Demands for groundwater recharge can be scheduled any time of the year when water spreading capacity is available. Reservoir operators must balance these varying water demands against other considerations that affect reservoir and river use, such as flood control operating criteria and fishery temperature needs.

Flood Control Operations. Multipurpose reservoirs incorporating formal flood control functions are common on California's major rivers. Table 3-12 shows the principal Central Valley storage facilities that incorporate flood control. Most of the reservoirs shown were constructed by federal agencies under authorizations that allowed a large share of costs allocated to flood control to be treated as non-reimbursable and be absorbed by the federal government. Table 3-12 also includes several non-federal projects where part of the costs allocated to flood control were paid by the federal government under federal flood control law (or specific legislation). The share of flood control costs that must be borne by non-federal interests has gradually increased in recent years. Under the Water Resources Development Act of 1996, that non-federal share is now up to 35 percent.

Typically, flood control operations are integrated with those for other project purposes through the concept of "joint use" sharing of a portion of a reservoir's storage capacity. The usual climate patterns in California result in flood control needs being greatest in midwinter and least in the summer. Through joint use, substantial reservoir storage space is maintained empty to help control floods during the period of highest risk. As the year progresses and flooding risk diminishes,

TABLE 3-12

Federal Flood Control Storage in Major Central Valley Reservoirs

Reservoir	*Stream*	*Storage (taf)*	*Maximum Flood Control Space (taf)*	*Owner*
Shasta	Sacramento River	4,552	1,300	USBR
Oroville	Feather River	3,538	750	DWR
New Melones	Stanislaus River	2,420	450	USBR
New Don Pedro	Tuolumne River	2,030	340	Modesto ID/Turlock ID
McClure	Merced River	1,025	350[a]	Merced ID
Pine Flat	Kings River	1,000	475[a]	USACE
Folsom	American River	977	400[b]	USBR
New Bullards Bar	Yuba River	966	170	YCWA
Isabella	Kern River	568	398[a]	USACE
Millerton	San Joaquin River	520	170[a]	USBR
Camanche	Mokelumne River	417	200[a]	EBMUD
New Hogan	Calaveras River	317	165	USACE
Indian Valley	Cache Creek	301	40	YCFCWCD
Eastman	Chowchilla River	150	45	USACE
Black Butte	Stony Creek	144	137[a]	USACE
Kaweah	Kaweah River	143	142	USACE
Hensley	Fresno River	90	65	USACE
Success	Tule River	82	75	USACE
Farmington	Littlejohns Creek	52	52	USACE

[a] Maximum flood control space may vary depending on transferable upstream storage space and/or snowpack

[b] Does not include 270 taf reoperation for SAFCA

the flood reservation is reduced, allowing the storage to be used for water supply or other project purposes. The allocation of joint use storage is controlled by formal operating procedures, as discussed in the sidebar.

Flood control operating criteria are individually crafted to reflect the specific conditions at each reservoir. For example, reservoirs on the east side of the San Joaquin Valley are subject to high late spring snowmelt runoff from the high Sierra; their flood reservations must be maintained longer than those for areas where late spring snowmelt is not a factor.

Temperature Control Operations. Downstream water temperature has become an important criterion in establishing river and reservoir operations for the protection of salmon and other anadromous fish. For example, in 1990 and 1991 SWRCB established temperature standards in portions of the Sacramento and Trinity Rivers through its Orders WR 90-5 and 91-01. On the Sacramento River below Keswick Dam, these orders include a daily average water temperature objective of 56^0 F during critical periods when high temperatures could be detrimental to survival of eggs and pre-emergent fry. Through reservoir releases, the CVP attempts to maintain this temperature within the winter-run chinook salmon spawning grounds below Keswick Dam from April through September.

As another example of temperature control operations, NMFS issued a long-term winter-run chinook salmon biological opinion in 1993 that required the CVP to maintain a minimum Shasta Lake September storage of at least 1.9 maf, except in the driest years. Higher storage levels are required in Shasta Reservoir to ensure that cold water is available for reservoir releases. Before USBR constructed the temperature control device, water of sufficiently low temperature could be provided during critical periods only by bypassing Shasta Dam's powerplant, causing an annual revenue loss to the CVP of $10 to $20 million. The TCD, constructed at a cost of about $83 million, has multi-level intakes, allowing temperature- selective reservoir releases without having to bypass the powerplant. Some dams, such as the Department's Oroville Dam, were constructed with the ability to make temperature-selective reservoir releases, as shown in the photo.

In certain cases, temperature control capability can be provided by a temperature control curtain. This technology has been used successfully to provide selective withdrawal and to control reservoir mixing

Federal Flood Control Operating Criteria

For federal projects, or as a condition of federal cost sharing on other projects, USACE prescribes rules for operating reservoir space dedicated to flood control. Figure 3-25, a flood control operating diagram for Lake Oroville, illustrates the nature of those operating criteria.

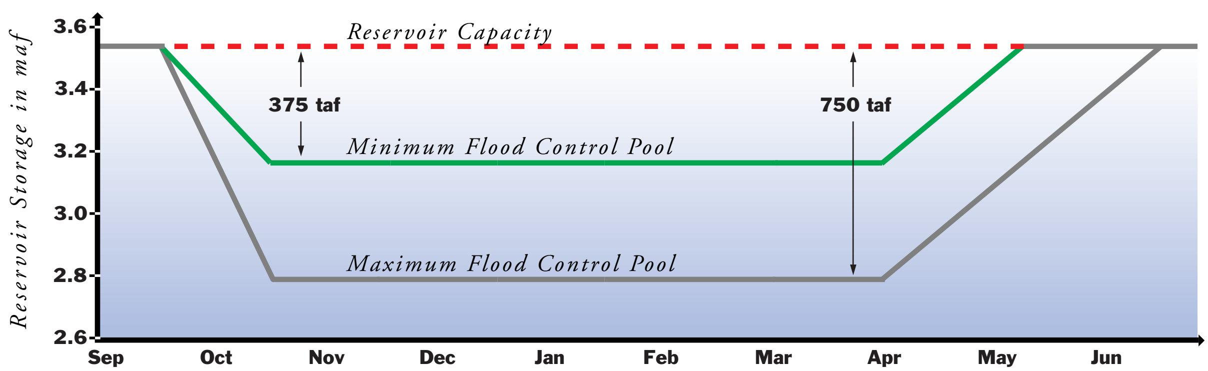
By mid-October each year, Lake Oroville storage must be reduced to a specified level within the range shown, creating an initial flood control reservation of at least 375 taf. The allowable level within the range is recalculated each day, using an index that reflects the wetness of the watershed and the likelihood of heavy runoff from any incoming storms. As a wet season such as 1997-98 progresses, the allowable storage tends to coincide with the "maximum flood control pool" line at the bottom of the flood diagram, which represents a flood reservation of 750 taf.

When high inflows occur, water is temporarily held in the flood reservation as necessary to maintain reservoir releases within prescribed limits that are designed to prevent downstream damage. The downstream flow limits set by the USACE for Lake Oroville are 150,000 cfs north of Honcut Creek, 180,000 cfs above the mouth of the Yuba River, and 320,000 cfs south of the Bear River.

While water is being stored to maintain releases within target levels, reservoir storage may exceed the level allowable under the flood operating criteria, a condition known as "encroachment" into the required flood reservation. The USACE criteria recognize that such encroachment will occur and establish release criteria for such conditions. Reservoir operators must balance the conflicting objectives of controlling the current flood event and preparing for a possible future one; the encroachment will be eliminated when downstream conditions permit.

FIGURE 3-25

Lake Oroville Flood Control Operating Diagram



at USBR's Lewiston and Whiskeytown Reservoirs. The four curtains constructed at the two reservoirs have reduced the temperature of Trinity River diversions into the upper Sacramento River by about 5^0 F. See Chapter 5 for more detailed discussion of temperature control technology.

Delta Operations. Because both the CVP and SWP export water from the Delta, a need for coordinated project operations exists. The Coordinated Operation Agreement between the Department and USBR differentiates between storage withdrawals and unstored flows in the Delta. Storage withdrawals belong to the project that makes the reservoir release. Unstored flows that are available for export are shared between the projects—55 percent to the CVP and 45 percent to the SWP. The COA also specifies how the projects are to share the responsibility of satisfying Sacramento River in-basin demands and Delta requirements

This sloping intake structure at Oroville Reservoir allows for temperature-selective releases of water through Hyatt Pump Generating Plant. Shutters underneath the trashrack structure are lowered into position with the gantry crane shown.

when there are no surplus flows. Under "balanced" conditions when storage withdrawals are being made, responsibility is allocated 75 percent to the CVP and 25 percent to the SWP. The sharing of responsibility for satisfying new Delta export restrictions under Order WR 95-6 is not specified under the present COA.

Environmental needs in the Delta, especially for threatened and endangered fisheries, exert a strong influence on export pumping and other water project operations. Starting in the 1970s, project exports were reduced during May and June to improve juvenile striped bass survival in the Delta. In the last decade, requirements to protect ESA listed fish species have led to new Delta environmental criteria and more export constraints. Travel time to the Delta is a consideration in operating SWP and CVP reservoirs to meet regulatory requirements. Sometimes, a rapid change in salinity conditions calls for additional release of water. Of the major Sacramento River region reservoirs, Folsom gives the quickest response (about a day), while it takes 3 days for Oroville releases and 5 days for water at Keswick Dam (from Shasta releases or Trinity River imports) to reach the Delta. Reservoir releases from New Melones on the San Joaquin River reach the Delta in about 1.5 days.

Stanislaus River releases from USBR's New Melones Reservoir must meet prior water rights and provide CVP water supply. Also, some water is dedicated to maintaining dissolved oxygen levels in the Stanislaus River and to diluting salts in the lower San Joaquin River. New Melones must make spring pulse flow releases to meet Delta fishery requirements. Except during flood control operations, releases are maintained below 1,500 cfs to avoid seepage effects on adjacent orchard lands.

Impacts of Recent Events on Surface Water Supplies

As discussed in Chapter 2, several key events in California water have occurred since the last update of Bulletin 160. Events of particular importance to surface water supply availability include CVPIA implementation, the 1993 winter-run chinook salmon biological opinion, the Monterey Agreement, and the Bay-Delta Accord. The Department's DWRSIM computer model was used to evaluate the Bay-Delta Accord's impact on CVP and SWP operations under base year (1995) and future year (2020) conditions. A similar operations study, assuming D-1485 Delta standards and base year conditions, was conducted to compare delivery capability of the projects with the new Delta criteria. The 73-year simulations (1922-94) show how the CVP and SWP would operate at current and future levels of demand and upstream development if the historical hydrology sequence were to repeat.

Based on these operations studies, Figures 3-26 and 3-27 show that delivery capabilities of the CVP (south

FIGURE 3-26

1995 Level Central Valley Project Delivery Capability South of Delta Under D-1485 and WR 95-6

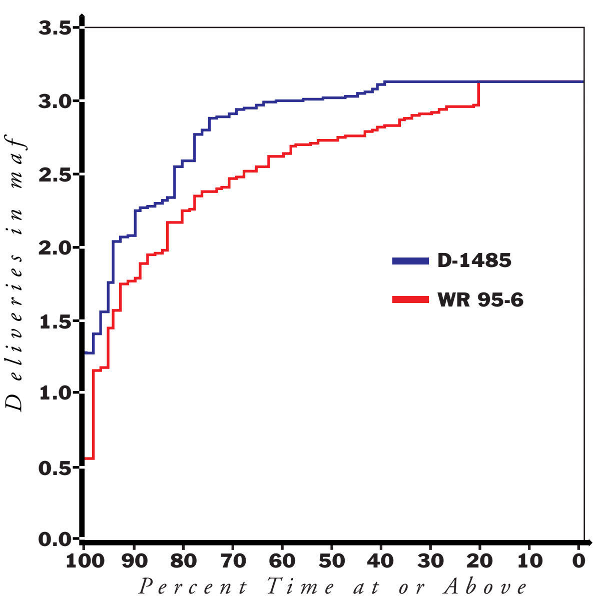
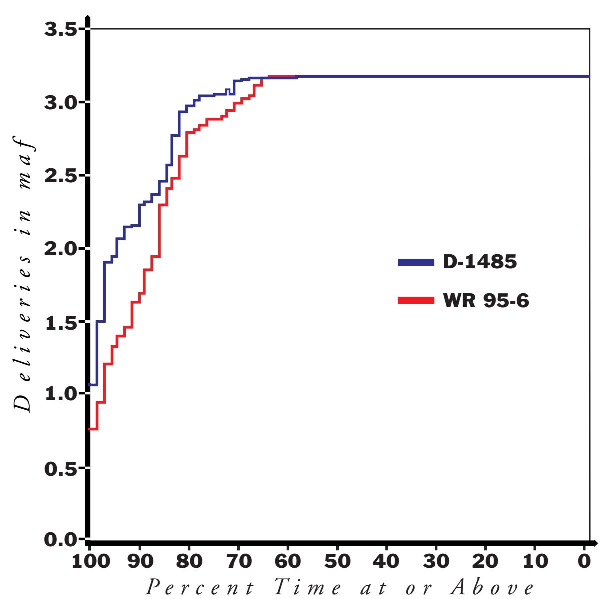


FIGURE 3-27

1995 Level State Water Project Delivery Capability Under D-1485 and WR 95-6



of the Delta) and SWP were significantly reduced from the prior Delta operating criteria to the current criteria. Under D-1485 and 1995 level demands, the CVP had a 40 percent chance of making full deliveries and a 95 percent chance of delivering 2.0 maf in any given year. Under WR 95-6 with identical demands, the CVP has a 20 percent chance of making full deliveries and an 80 percent chance of delivering 2.0 maf in any given year. Under D-1485 and 1995 level demands, the SWP had a 70 percent chance of making full deliveries and a 95 percent chance of delivering 2.0 maf in any given year. Under WR 95-6 with identical demands, the SWP has a 65 percent chance of making full deliveries and an 85 percent chance of delivering 2.0 maf in any given year.

The gated inlet structure to the SWP's Clifton Court Forebay in the Southern Delta.

Together, the operations studies indicate the combined 1995 level export capability of the CVP and SWP declined by about 300 taf/yr on average and by about 850 taf/yr during 1929-34 drought conditions. (These operations studies do not account for Delta export curtailments due to concerns for authorized take of ESA listed species. Reduction in exports due to take limits could be significant, especially during drought periods, when the projects are unable to export significant unstored flows or reservoir releases providing required instream flows.) Table 3-13 summarizes key changes in Delta standards, as modeled in operations studies, from Bulletin 160-93 to Bulletin 160-98.

Impacts of Reservoir Reoperation on Surface Water Supplies

California's large multipurpose reservoirs have been constructed to provide a certain mix of project benefits established during their planning periods. A change in a reservoir's operation rules (to increase one type of benefit) requires careful analysis of how the change may affect the project's ability to accomplish other purposes.

Providing additional winter flood control in a reservoir, for example, reduces the probability that it will refill after the flood season. Temporary increases in winter flood control space have been suggested at some of the San Joaquin River region foothill reservoirs in the wake of the 1997 flood. However, the value of water supply in this region is high, and these proposals would have significant costs and water supply impacts. At USBR's Folsom Reservoir, the local flood control agency has negotiated an agreement with USBR for an additional 270 taf of winter flood control space. The agreement requires the flood control agency to provide a substitute water supply, under specified conditions, if the flood control reservation results in a loss of supply to USBR. The payback provision of this agreement was triggered by the 1997 flood. See Chapter 8 for details.

Conversely, Chapters 7-9 discuss several flood control reservoirs being studied for reoperation to provide some water supply benefits. Many of these reservoirs are smaller, single-purpose flood detention impoundments on streams with relatively low average annual runoff. In many cases, physical changes to the existing dams, such as raising their spillways, would be needed as part of a reoperation for water supply. Often, the goal at existing detention dams is to operate the reservoir to enhance groundwater recharge, because maintaining year-round conservation storage on a stream with relatively low average runoff would not be economical.

Providing higher reservoir minimum storage requirements, another example of reservoir reoperation, results in lower delivery potential during dry periods. The increase in required Shasta Reservoir storage to maintain cool water for the winter-run salmon has reduced CVP water supply potential during drought periods. Current minimum storage target levels are about 1.9 maf, except in critical years when the target is allowed to drop to 1.2 maf. (Shasta storage dropped under 0.6 maf in the 1976-77 drought and dropped to 1.3 maf during the 1987-92 drought.) Providing higher reservoir carryover also reduces electrical energy generation, which is often replaced with electricity generated from fossil fuel burning generation plants.

TABLE 3-13

Major Changes in Delta Criteria from D-1485 to WR 95-6

Criteria	*Change*
Water Year Classification	from SRI to 40-30-30 Index
Sacramento River Flows	higher Sept.-Dec. Rio Vista flows
San Joaquin River Flows	new minimum flows and pulse flows
Vernalis Salinity Requirement	more restrictive during irrigation season, less restrictive other months
Delta Outflow	outflow required to maintain 2 ppt salinity during Feb.-June
Export Limits	35%-65% export-to-Delta inflow ratio, Apr.-May export-to-SJR inflow ratio
Delta Cross Channel Operations	additional closures required

Groundwater Supplies

In an average year, about 30 percent of California's urban and agricultural applied water is provided by groundwater extraction. In drought years when surface supplies are reduced, groundwater supports an even larger percentage of use. The amount of water stored in California's aquifers is far greater than that stored in the State's surface water reservoirs, although only a portion of California's groundwater resources can be economically and practically extracted for use.

In evaluating California water supplies, an important difference between surface water and groundwater must be accounted for—the availability of data quantifying the resource. Surface water reservoirs are constructed to provide known storage capacities, reservoir inflows and releases can be measured, and stream gages provide direct measurements of flows in surface water systems. Groundwater basins have relatively indeterminate dimensions, inflow (e.g., recharge) to an entire basin cannot be directly measured, and total basin extractions and natural outflow are seldom directly measured. In addition to physical differences between surface water and groundwater systems, statutory differences in the administration of the resources also affect data availability. Entities who construct surface water reservoirs must have State water rights for the facility, and all but the smallest dams are regulated by the State's dam safety program. These requirements help define and quantify the resource. In contrast, groundwater may be managed by local agencies (as described later in this section), but there are no statewide requirements that require quantification of the resource. Much of California's groundwater production is self-supplied, and is not managed or quantified by local agencies.

Groundwater is often the only local source of supply for desert communities.

The following description of groundwater supplies is presented in a more general manner than was used for surface water supplies, reflecting the difference in data availability. Much of the groundwater information in this section is based on calculations, rather than on direct measurement. Estimating overdraft in a basin, for example, relies on interpretation of measured data (water levels in wells) and interpretation of calculated information (extractions from the basin). The ability to assess statewide groundwater resources would benefit greatly from additional data collection and better access to existing data.

Base Year Supplies

Table 3-14 summarizes estimated 1995 level groundwater supplies. The data represent current levels of groundwater production, and not necessarily the maximum potential of statewide groundwater supplies. The data include water reapplied through deep percolation and exclude groundwater overdraft.

To help put this information in perspective, the sidebar illustrates typical groundwater production conditions in three hydrologic regions that rely heavily on groundwater because their local surface water supplies do not fully support existing development. These regions—the San Joaquin, Tulare Lake, and Central Coast regions—all have alluvial aquifer systems that support significant groundwater development, as

TABLE 3-14

Estimated 1995 Level Groundwater Supplies by Hydrologic Region (taf)

Region	*Average*	*Drought*
North Coast	263	294
San Francisco Bay	68	92
Central Coast	1,045	1,142
South Coast	1,177	1,371
Sacramento River	2,672	3,218
San Joaquin River	2,195	2,900
Tulare Lake	4,340	5,970
North Lahontan	157	187
South Lahontan	239	273
Colorado River	337	337
Total (rounded)	**12,490**	**15,780**

suggested by the information presented in the sidebar. (The data shown are typical of wells used for agricultural or municipal production. A well used to supply an individual residence would have a much smaller capacity. Over 90 percent of the groundwater use in each of these regions is for agricultural use.) In contrast, aquifer systems in fractured rock, such as those used to supply small communities in the Sierra Nevada foothills, can generally support only limited groundwater development.

In these hydrologic regions water users frequently take advantage of surface water available in wet years to recharge groundwater basins. In drought years when surface water is not available, water users increase groundwater pumping. For example, Friant-Kern CVP contractors maximize groundwater recharge with less expensive Class II supplies (wet weather water) when they are available. Member agencies of KCWA have developed extensive recharge facilities along the Kern River channel to take advantage of wet year flows.

Groundwater Basin Yield

Historically, the term safe yield has been used in an attempt to describe the available supply from a groundwater basin. Safe yield is defined in the Department's Bulletin 118-80, *Groundwater Basins in California*, as "the maximum quantity of water that can be continuously withdrawn from a groundwater basin without adverse effect." Adverse effect in this context can include depletion of the groundwater reserves (groundwater level decline), intrusion of water of undesirable quality, impacts to existing water rights, higher extraction costs, subsidence, depletion of streamflow, and environmental impacts. Historically, additional extraction from a groundwater basin above the safe yield value has been called overdraft. Overdraft is defined in Bulletin 118-80 as "the condition of a groundwater basin where the amount of water withdrawn exceeds the amount of water replenishing the basin over a period of time."

Typical Groundwater Production Conditions

The Department collects data from a statewide network of wells to monitor long-term changes in groundwater levels. The network includes local agency wells and privately-owned wells. These data were combined with Bulletin 160 water use information to prepare the tabulation on typical groundwater production conditions shown below. Long-term water level data can show the effects of increased groundwater extraction in drought years; it can also show the effects of changing water management practices in a basin.

Local conditions within the tabulated basins may deviate greatly from the typical conditions shown below. In the Tulare Lake Region, for example, some groundwater production is occurring from wells with pumping lifts of over 800 feet.

Basin	*Extraction (taf/yr)*	*Well Yields (gpm)*	*Pumping Lifts (feet)*
San Joaquin River Region			
Madera	570	750-2,000	160
Merced	560	1,500-1,900	110
Delta Mendota	510	800-2,000	35-150
Turlock	450	1,000-2,000	90
Chowchilla	260	1,500-1,900	110
Modesto	230	1,000-2,000	90
Tulare Lake Region			
Kings	1,790	500-1,500	150
Kern	1,400	1,500-2,500	200-250
Kaweah	760	1,000-2,000	125-250
Tulare Lake	670	300-1,000	270
Tule	660	NA	150-200
Westside	210	800-1,500	200-800
Pleasant Valley	100	NA	350
Central Coast Region			
Salinas Valley	550	1,000-4,000	180
Pajaro Valley	60	500	10-300

Quantifying either overdraft or safe yield is inherently complex. For example, estimates of safe yield of a basin often change over time, as more development occurs in a basin and extractions increase. The observed effects of these extractions can cause water managers to revise—either upward or downward—safe yield estimates based on an earlier level of development. The safe yield definition is limited because it tends to imply a fixed quantity of water that can be extracted on an annual basis without regard to how the overall supply might be enhanced through basin management. This update of the *California Water Plan* uses perennial yield rather than safe yield to define long-term groundwater basin yield.

Perennial Yield. Perennial yield is the amount of groundwater that can be extracted without lowering groundwater levels over the long-term. Perennial yield in basins where there is hydraulic connection between surface water and groundwater depends, in part, on the amount of extraction that occurs. Perennial yield can increase as extraction increases, as long as the annual amount of recharge equals or exceeds the amount of extraction. Extraction at a level that exceeds the perennial yield for a short period may not result in an overdraft condition. In basins with an adequate groundwater supply, increased extraction may establish a new hydrologic equilibrium with a new perennial yield. The establishment of a new and higher perennial yield requires that adequate recharge from some surface supply be induced, which may impact downstream users of that supply.

In Bulletin 160-98, perennial yield is estimated as the amount of groundwater extraction that has taken place, or could take place, over a long period of time under average hydrologic conditions without lowering groundwater levels. Existing basin water management programs (1995 level of development) were evaluated in the development of perennial yield estimates.

Overdraft. Additional annual extraction from a groundwater basin over a long period of time above the annual perennial yield is defined as overdraft in Bulletin 160-98. In wet years, recharge in developed groundwater basins tends to exceed extractions. Conversely, in dry years, groundwater basin recharge tends to be less than groundwater basin extraction. By definition, overdraft is not a measure of these annual fluctuations in groundwater storage volume. Instead, overdraft is a measure of the long-term trend associated with these annual fluctuations. The period of record used to evaluate overdraft must be long enough to produce data that, when averaged, approximate long-term average hydrologic conditions for the basin. Table 3-15

TABLE 3-15

1995 and 2020 Level Overdraft by Hydrologic Region (taf)

	1995		*2020*	
Region	***Average***	***Drought***	***Average***	***Drought***
North Coast	0	0	0	0
San Francisco Bay	0	0	0	0
Central Coast	214	214	102	102
South Coast	0	0	0	0
Sacramento River	33	33	85	85
San Joaquin River	239	239	63	63
Tulare Lake	820	820	670	670
North Lahontan	0	0	0	0
South Lahontan	89	89	89	89
Colorado River	69	69	61	61
Total (rounded)	**1,460**	**1,460**	**1,070**	**1,070**

shows the Department's estimates of 1995 and 2020-level groundwater overdraft by hydrologic region. Within some regions overdraft occurs in well-defined subareas, while additional groundwater development potential may exist in other subareas.

For the 1995 base year, Bulletin 160-98 estimates a statewide increase in groundwater overdraft (160 taf) above the 1990 base year reported in Bulletin 160-93. Most of the statewide increase in overdraft occurred in the San Joaquin and Tulare Lake regions, two regions where surface water supplies have been reduced in recent years by Delta export restrictions, CVPIA implementation, and ESA requirements. CVP contractors who rely on Delta exports for their surface water supply have experienced supply deficiencies of up to 50 percent subsequent to implementation of export limitations and CVPIA requirements. Many of these contractors have turned to groundwater pumping for additional water supplies. This long-term increase in groundwater extractions exacerbated a short-term decline in water levels as a result of the 1987-92 drought.

As shown in Table 3-15, groundwater overdraft is expected to decline from 1.5 maf to 1.1 maf statewide by 2020. Overdraft in the Central Coast Region is expected to decline as demand shifts from groundwater to imported SWP supplies, provided through the recently completed Coastal Branch of the California Aqueduct. The reduction in irrigated acreage in drainage problem areas on the west side of the San Joaquin Valley, as described in the 1990 report of the San Joaquin Valley Interagency Drainage Program, is expected to reduce groundwater demands in the San Joaquin River and Tulare Lake regions by 2020. (A discussion on the San Joaquin Valley Interagency Drainage Program is provided in Chapter 4.) Some increases in groundwater overdraft are expected in Sacramento, Placer and El Dorado Counties of the Sacramento River Region.

The Central Coast hydrologic region includes, in addition to the Salinas and Pajaro Valley Basins, several small basins with limited storage capacity. During drought periods, water levels in these basins may decline to a point where groundwater is not usable. However, during wet periods, most of these basins recover, thus making application of overdraft or perennial yield concepts difficult. The Department is currently evaluating Central Coast Region groundwater use to better estimate overdraft, but this evaluation will not be completed in time for Bulletin 160-98. Parts of the Central Coast have received CVP water through the San Felipe Tunnel since 1986; other parts are now able to receive SWP water through the Coastal Branch of the California Aqueduct. These imported supplies should help reduce overdraft in the region.

Groundwater Management Programs

Groundwater basin management may be implemented to achieve a variety of objectives, including limiting groundwater overdraft or well interference, preventing seawater intrusion, controlling land subsidence, or managing migration of contaminants of concern. Because no two groundwater basins are identical, local agency groundwater basin management programs differ in purpose and scope. Typical local groundwater management strategies include monitoring groundwater levels and extractions; cooperative arrangements among pumpers to minimize or eliminate problem conditions; and, where applicable, conjunctive use. Groundwater management options include AB 3030 plans (Water Code Section 10750, et seq.), local ordinances, and legislative authorization for individual special districts. Rights to use groundwater also may be adjudicated by court action.

Reasons for Basin Management. Overdraft in a basin, or intensive local pumping in one part of a basin, can cause problems in addition to those associated with insufficient water quantity. Some of the most common undesirable impacts are land subsidence and seawater intrusion (or migration of poorer quality water).

Land subsidence caused by groundwater withdrawal has occurred in parts of the Central and Santa Clara Valleys and in localized areas of the south coastal plain. An important groundwater management goal in developed areas is the prevention or reduction of land subsidence. Land subsidence can impact infrastructure, roads, buildings, wells, canals, stream channels, flood control structures (such as levees), and low-lying coastal or floodplain areas. Actions to monitor and manage subsidence may include monitoring changes in groundwater levels, precisely surveying land surface elevations at periodic intervals to detect changes, installing extensometers to measure the change in thickness of sediments between the land surface and fixed points below the surface, recording the amount of groundwater extracted, recharging the aquifer to control subsidence, and determining when extraction must be decreased or stopped. These management actions could be coordinated with groundwater/land subsidence modeling to predict future land subsidence under various water management scenarios.

Land Subsidence in the San Joaquin Valley

San Joaquin Valley land subsidence was observed as early as the 1920s. The rate of subsidence increased significantly in the post-WWII era as groundwater extraction increased. Subsidence was especially noticeable along parts of the west side of the valley, where land that had been used for grazing or dry farming was converted to irrigated agriculture. By 1970, 5,200 square miles in the valley had subsided more than 1 foot. Between 1920 and 1970, a maximum of 28 feet of subsidence was measured at one location southwest of Mendota. In the years since 1970, the rate of subsidence has declined because surface water was imported to the area. An increase in subsidence occurred during the 1976-77 and 1987-92 droughts, when groundwater extraction increased due to reductions in SWP and CVP supplies. Recent increases in subsidence are the result of increased groundwater extractions to compensate for water supply deficiencies caused by Bay-Delta export restrictions, ESA requirements, and CVPIA.

The Department monitors subsidence along the California Aqueduct, maintaining seven compaction recorders and performing periodic precise leveling along the aqueduct. The data indicate, for example, that a 68-mile reach of the aqueduct near Mendota subsided 2 feet between 1970 and 1994. Over the same time period, the aqueduct subsided approximately 2 feet along a 29-mile reach near Lost Hills, and up to 1 foot in a 9-mile reach near the Kern Lake Bed. At the time of the aqueduct's design, the potential for San Joaquin Valley subsidence was recognized, and measures were taken to compensate for some of its impacts. Canal sections in subsidence-prone areas were designed with extra freeboard, and structures crossing the canal (such as bridges) were designed to allow them to be raised later. Even so, continued subsidence along the aqueduct alignment creates the need for canal lining repairs and reduces the canal's capacity in places.

One area of particular concern is the west side of the San Joaquin Valley, where infrastructure affected by subsidence includes state highways, county roads, and water conveyance and distribution facilities. The sidebar provides an overview of subsidence in the area.

Seawater intrusion was recognized as a water management problem in California's coastal areas as early as the 1950s (see sidebar), affecting both urban and agricultural water agencies. Overextraction from basins near the coast induces seawater intrusion into the aquifer where the extraction occurred and leads to the expansion of areas of degraded water quality, as pumpers relocate wells to take advantage of better quality water in deeper aquifers or in aquifers farther inland. Typically, seawater intrusion in larger basins occurs in areas where surface water supplies are limited, relative to the extent of water demands. In this case, a new supply of surface water must be provided to the area as part of controlling seawater intrusion, if existing land use patterns (either urban or irrigated agriculture) are to continue. Examples of areas which have experienced seawater intrusion problems include some of the managed basins in the highly urbanized South Coast Region, small basins serving individual communities in the Central Coast Region, and the Salinas Valley (a highly productive agricultural area). Imported supplies from the SWP have helped local agencies manage seawater intrusion in the South Coast Region; local agencies are also increasingly turning to recycled water supplies to help manage intrusion. Examples of local agency efforts to control seawater intrusion are described in Chapter 7.

Local Agency Groundwater Management Programs. The 1992 enactment of AB 3030 (Water Code Section 10750, et seq.) provided broad general authority for local agencies to adopt groundwater management plans pursuant to specified procedures, and to impose assessments to cover the cost of implementing the plans. To date, about 150 local agencies have adopted AB 3030 groundwater management plans. Under other groundwater management authorities, there are 7 agencies with AB 255 plans and over 50 agencies with some other form of statutory authority.

While the number of agencies adopting AB 3030 plans increases every year, quantifying the statewide number of adopted plans is somewhat uncertain; there is no requirement in the statute that agencies adopting plans file copies of those plans with the Department or SWRCB. A tabulation of agencies with AB 3030 plans, together with agencies managing groundwater under some other authority, can be found in the Department's 1998 report to the Legislature on the number of local agencies having some form of management authority.

Special Powers Agencies and Local Ordinances. The California Legislature may create special powers agencies, such as the Fox Canyon Groundwater Management District, or may amend the statutory authority of an existing agency to allow it to manage groundwater. Generally, these agencies are governed by a board of directors that may be appointed or elected.

The *Baldwin v. County of Tehama* decision

Seawater Intrusion in Orange County

Orange County Water District was formed in 1933 to protect and manage the groundwater basin that underlies the northwest half of the county. Groundwater supplies about 75 percent of OCWD's total water demand. As the county developed, increased groundwater extractions resulted in a gradual lowering of the water table. By 1956, years of heavy pumping to sustain the region's agricultural economy had lowered the water table below sea level, and saltwater from the ocean had encroached as far as 5 miles inland. The area of seawater intrusion is primarily along 4 miles of coast between Newport Beach and Huntington Beach known as the Talbert Gap.

To prevent further seawater intrusion, OCWD operates a hydraulic barrier. A series of 23 multi-point injection wells 4 miles inland delivers fresh water into the underground aquifer to form a water mound, blocking further passage of seawater. Water supply for the Talbert Barrier is produced at OCWD's Water Factory 21. The supply is a blend of recycled water and groundwater pumped from a deep aquifer zone that is not subject to seawater intrusion. The first blended recycled water from the plant was injected into the barrier in October 1976.

Water Factory 21 recycles about 10 mgd and, with the deep well water used for blending, produces about 15 mgd. OCWD has applied for and has received a permit to modify the treatment process to allow for injection of 100 percent recycled water, eliminating the use of deep well water for blending. The plant's current treatment includes chemical clarification, recarbonation, multi-media filtration, granular activated carbon, reverse osmosis, chlorination, and blending. The blended injection water has a total dissolved solids content of 500 mg/L or lower, and meets DHS primary and secondary drinking water standards.

confirmed the right of cities and counties to adopt local regulations concerning groundwater. Moreover, the *Baldwin* decision confirmed that Tehama County has general police power to regulate groundwater and water transfers, and that counties are free to adopt local ordinances that do not conflict with State legislative mandates. The following counties have ordinances regulating groundwater: Butte, Glenn, Imperial, San Benito, San Joaquin, Tuolumne, and Tehama. At least three other counties (Shasta, Sutter, and Yolo) have developed ordinances, or are in the process of developing ordinances, to regulate indirect transfers of groundwater resulting from groundwater substitution programs.

Basin Adjudication. In California's adjudicated groundwater basins, groundwater extraction is regulated or administered by a court-appointed watermaster. The court retains jurisdiction over the judgment, so parties can appeal to the court to resolve disputes related to their adjudicated rights. The groundwater that each well owner may extract is determined by the court decision as administered by the watermaster. While each court decision may be different, the common goal is to avoid groundwater overdraft. Table 3-16 shows a list of adjudicated basins. Also see Figure 3-28.

While not listed in Table 3-16, groundwater and surface water have also been adjudicated in the Santa Margarita River Watershed in Riverside and San Diego Counties. Water users are required by the court decision to report to the court-appointed watermaster the amount of groundwater they extract from the aquifer and the amount of surface water they divert from the river, canals, or ditches. However, groundwater extraction is not limited by the decision.

Water Marketing

In recent years, water marketing has received increasing attention as a tool for addressing statewide imbalances between water supply and water use. Experience with water markets during and since the 1987-92 drought bolstered interest in utilizing marketing as a local and statewide water supply augmentation option. While water marketing does allow water agencies to purchase additional water supply reliability during both average and drought years, water marketing does not create new water. Therefore, water markets alone cannot meet California's long-term water supply needs. A discussion on the use of marketing to meet future statewide water needs is provided in Chapter 6.

Definition of Water Marketing

In this update of the *California Water Plan,* water marketing may include:

- A permanent sale of a water right by the water right holder.
- A lease from the water right holder (who retains the water right), allowing the lessee to use the water under specified conditions over a specified period of time.
- A sale or lease of a contractual right to water supply. Under this arrangement, the ability of the holder to transfer a contractual water right is usually con-

FIGURE 3-28

Adjudicated Groundwater Basins

TABLE 3-16

California Adjudicated Groundwater Basins and Watermasters

County	*Basin*	*Watermaster*
Los Angeles	Central West Coast Upper Los Angeles River Area Raymond Main San Gabriel[a] Puente	DWR DWR Superior Court appointee Raymond Basin Management Board Nine-member board Three appointees
Kern	Cummings Tehachapi	Tehachapi-Cummings Water District Tehachapi-Cummings Water District
San Bernardino	Warren Valley San Bernardino Basin Area Cucamonga Mojave Basin Area	Hi-Desert Water District One representative each from Western Municipal Water District of Riverside County and San Bernardino Valley Municipal Water District Cucamonga County Water District and San Antonio Water Company Mojave Water Agency
Riverside and San Bernardino	Chino	Nine-member board
Riverside and San Diego	Santa Margarita River Watershed	District Court appointee
Siskiyou	Scott River Stream System	Two irrigation districts
Ventura	Santa Paula	Three-person Technical Advisory Committee

[a] The watermaster for Main San Gabriel Basin has returned to court and obtained approval of regulations to control extraction for protecting groundwater quality.

tingent upon receiving approval from the supplier. An example of this type of arrangement is a sale or lease by a water agency that receives its supply from the CVP, SWP, or other water wholesaler.

Water marketing is not an actual statewide source of water, but rather is a means to reallocate existing supplies. Therefore, marketing is not explicitly itemized as a source of water supply from existing facilities and programs in the Bulletin 160 water budgets. (Water marketing agreements in place by 1995 are considered to be existing programs and are implicitly part of the water budgets.) Water marketing is identified as a potential water supply augmentation option in the Bulletin 160 water budgets (see Chapter 6). Potential water marketing options have several characteristics that must be captured in the water budgets incorporating supplies from future management options. For example, through changes in place of use, water marketing options can reallocate supplies from one hydrologic region to another. And through changes in type of use, water marketing options can reallocate supplies from one water use sector to another. Finally, for a given place and type of use, water marketing options can reallocate supplies between average years and drought years.

A transfer of water through a local exchange is not defined as water marketing in this update of Bulletin 160. Water exchanges between individual water users within a water district are common in drought years, and such transfers are becoming increasingly common, even in average years. Water exchanges between users within a district normally do not require approval from the SWRCB because a change in the place of use, purpose of use, or point of diversion does not occur.

Water banking, where water is physically banked or stored without a change in ownership, is also not defined as water marketing in this Bulletin. For example, Warren Act contracts, where local agencies contract with USBR for storage or conveyance of non-project water in federal facilities, only involve the rental of facilities for storage or conveyance. On the other hand, if a water banking agreement does involve a change in ownership, it is defined as water marketing in this Bulletin. For example, an agreement between MWDSC and Semitropic Water Storage District allows MWDSC access to 35 percent of SWSD's groundwater storage capacity. According to the agreement, MWDSC may store a portion of its SWP entitlement water for later withdrawal and delivery to its service area. Alternatively, SWSD could exchange a portion of its SWP entitlement water for MWDSC's stored water.

Short-Term Agreements

Short-term agreements have made up the majority of water marketing arrangements in recent years. Short-term agreements (less than one year) can be an effective means of alleviating the most severe drought year impacts. Short-term agreements can be executed on the spot market; however, water purveyors are increasingly interested in negotiating longer-term agreements for drought year transfers. In such future agreements, specific water supply conditions may be the triggers to determine whether water would be transferred in a specific year.

Two examples of programs for acquiring water through short-term agreements are the Drought Water Bank and the CVPIA interim water acquisition program. These programs are discussed below. Beyond these programs, data on short-term water marketing arrangements are difficult to locate and verify. Agreements executed for less than one year do not need SWRCB approval (unless there is a change in place of use or point of diversion) and thus are not tracked by outside entities. Data are also difficult to evaluate, as it is often difficult to distinguish between exchanges and marketing arrangements.

Drought Water Bank. In 1991, after four consecutive years of drought, the Governor signed an executive order establishing a Drought Action Team. The first emergency drought water bank was created in response to the team's recommendations. The Department operated the DWB in coordination with other agencies, including USBR, SWRCB, DFG, and local governments. DWB's primary role was to purchase water from willing sellers and sell it to entities with critical needs. Sellers made water available to DWB by fallowing farmland, releasing surplus reservoir storage, and by substituting groundwater for surface supplies.

During 1991, the DWB purchased about 820 taf of water under more than 300 short-term agreements. About half of that water came from fallowing agreements. About 30 percent came from groundwater substitution arrangements made with participating farmers and water districts. The remainder of the water came from reservoir storage.

The 1991 DWB experience and contracts provided a basis for administration of the 1992 DWB. In 1992, the Department purchased about 190 taf of water, with 80 percent from groundwater substitution contracts and 20 percent from reservoir storage. No land fallowing contracts were executed. These conditions allowed the 1992 DWB to operate at a significantly reduced cost for water. As with the 1991 DWB, the 1992 DWB was able to acquire sufficient water to meet the critical needs of all participants.

Drawing on the 1991 and 1992 DWB experiences, the Department completed a programmatic environmental impact report that evaluated different types of water marketing. The final EIR, released in 1993, covered future drought water bank programs intended to meet water demands during drought periods over the next 5 to 10 years, on an as-needed basis. The program is a water purchase and allocation program whereby the Department will purchase water from willing sellers and market the water to buyers under specific critical needs allocation guidelines.

The DWB program would be implemented as needed for a particular year upon an executive order of the Governor, a decision by the Secretary for Resources, or upon a finding by the Department's Director that drought or other unanticipated conditions exist that would significantly curtail water deliveries. The program would continue to operate until water supplies returned to noncritical levels.

In 1994, the Department reactivated the DWB and also initiated a short-term water purchase program for SWP contractors. More than 170 taf of water was delivered to cities and farms throughout the State. About 115 taf was delivered from the DWB and 58 taf was delivered from the short-term water purchase program. A comparison of the three DWBs is shown in Table 3-17.

The Department began to organize a 1995 DWB in September 1994, anticipating another drought year. By mid-November, water agencies had signed contracts with the Department to purchase water from DWB for critical needs. The Department established DWB in an inactive status, with the intent of activating it if 1995 precipitation was below normal. While in inactive

TABLE 3-17

Drought Water Bank Purchases and Allocations (taf)

	1991	*1992*	*1994*[a]
Supply			
Purchases	821	193	222
Delta and instream fish requirements	(165)	(34)	(48)
Net supply	**656**	**159**	**174**
Allocation			
Urban	307	39	24
Agricultural	83	95	150
Environmental	—	25	—
SWP Carryover	266	—	—
Total Allocation	**656**	**159**	**174**
Selling Price ($/af)[b]	**175**	**72**	**68**

[a] Includes deliveries for the SWP.

[b] Price to buyers south of the Delta at Banks Pumping Plant. Includes the cost of the water, adjustments for carriage losses and administrative charges. Does not include transportation charges which have ranged from $15 to $200 /af, depending on the point of delivery and other factors.

status, DWB purchased options on 29 taf of water from five willing sellers. As a result of an abundance of precipitation and snowpack throughout California in 1995, the DWB was not activated and the Department did not exercise the acquired options.

Despite the success of the DWB, it is a contingency or drought management supply option. The program does not provide a permanent water supply. Based upon past experience, future State-operated DWBs might be able to reallocate about 250 taf/yr of supplies during droughts. Future ESA listings and other actions that would reduce the ability to convey water through the Delta could reduce the amount of water available from the DWB.

CVP Interim Water Acquisition Program. Short-term water marketing arrangements have provided supplies to meet CVPIA fish and wildlife water requirements. An interim water acquisition program was established to acquire water while long-term planning for supplemental fishery water acquisition and refuge water supply acquisition continued. The program, a joint effort by USBR and USFWS, was to be in place from October 1995 through February 1998, as initially envisioned in its environmental documentation. A 1995 environmental assessment and finding of no significant impact for the interim program addressed the regional impacts associated with four categories of water acquisition. The four categories were:

- Acquisition of up to 13.1 taf/yr of water for wildlife refuges in the Sacramento Valley;
- Acquisition of up to 45 cfs of water on Battle Creek for spawning and migration of winter- and spring-run chinook salmon and steelhead trout;
- Acquisition of up to 52.4 taf/yr of water for wildlife refuges within the San Joaquin Valley; and
- Acquisition of up to 100 taf/yr of water on each of the Stanislaus, Tuolumne, and Merced Rivers to meet instream flows for anadromous fish and to help meet Bay-Delta flow and water quality requirements on the San Joaquin River.

Table 3-18 summarizes water purchases made under the program.

Long-Term Agreements

Table 3-19 presents several long-term agreements completed in recent years. Long-term agreements currently being negotiated are presented as future water management options and are discussed in Chapter 6.

One of the terms in the SWP's Monterey Agreement was that agricultural contractors would make 130 taf of SWP annual entitlement available through permanent sale to urban contractors (on a willing buyer-willing seller basis). In 1997, KCWA concluded sale of 25 taf to MWA. KCWA is also in the process of selling up to 7 taf of annual entitlement to Zone 7 WA. Entitlement transfers among CVP contractors are also taking place. In 1997, USBR completed an environmental assessment for a proposed long-term, 25-year transfer of 25 taf/yr of water from

TABLE 3-18

CVP Interim Water Acquisition Program Purchases

Seller	Water Purchases (taf) 1995	1996	1997	Purpose
Pacific Gas and Electric	8.4	12.3	9.2	Battle Creek instream flow
Oakdale & South San Joaquin IDs	—	—	50.0	Stanislaus and lower San Joaquin River instream flows
Modesto ID	—	—	5.0	Tuolumne and lower San Joaquin River instream flows
Merced ID	—	16.2	45.3	Merced and lower San Joaquin River instream flows
SJR Exchange Contractors	25.0	30.3	40.0	Level 4 refuge supply; lower San Joaquin River instream flows
Semitropic WSD	5.2	4.3	—	Level 4 refuge supply
Yuba County WA	—	—	25.0	Level 4 refuge supply
Corning, Proberta, & Thomes Creek WDs	—	—	4.8	Level 4 refuge supply
Total	**38.6**	**63.1**	**179.3**	

Westside Water District to the CCWD.

Banking project water outside of an SWP contractor's service area for later use within its service area is also provided for in the Monterey Agreement. Semitropic WSD has developed a groundwater storage program with 1 maf of storage capacity. Under this program, an SWP contractor may negotiate an agreement with SWSD to deliver SWP water to SWSD for in-lieu groundwater recharge. At the contractor's request, groundwater would be extracted and delivered to the California Aqueduct, or otherwise exchanged for entitlement. Currently, MWDSC and SCVWD each have long-term agreements with SWSD for 350 taf of storage, Alameda County Water District has an agreement for 50 taf and Z7WA has an agreement for 43 taf.

In addition to the MWDSC-IID water conservation agreement shown in Table 3-19 (described in Chapter 9), MWDSC has executed an agreement for groundwater banking in Arizona. Under an existing agreement between MWDSC and the Central Arizona Water Conservation District, MWDSC can store a limited amount of unused Colorado River water in Arizona for future use. The Southern Nevada Water Authority is also participating in the program. The agreement stipulates that MWDSC and SNWA can store up to 300 taf in central Arizona any time before 2001. To date, MWDSC has placed 89 taf of water in storage and SNWA has placed 50 taf of water in storage for a total of 139 taf. About 90 percent of the stored water can be recovered, contingent upon the declaration of surplus conditions on the Colorado River. When

TABLE 3-19

Recently Completed Long-Term Water Marketing Agreements

Participants	Region(s)
Westside Water District, Colusa County Water District	Sacramento River
Semitropic Water Storage District, Santa Clara Valley Water District	Tulare Lake, San Francisco Bay
Semitropic Water Storage District, Alameda County Water District	Tulare Lake, San Francisco Bay
Semitropic Water Storage District, Zone 7 Water Agency	Tulare Lake, San Francisco Bay
Semitropic Water Storage District, Metropolitan Water District of Southern California	Tulare Lake, South Coast
Kern County Water Agency, Mojave Water Agency	Tulare Lake, South Lahontan
Arvin-Edison Water Storage District, Metropolitan Water District of Southern California	Tulare Lake, South Coast
Mojave Water Agency, Solano County Water Agency	South Lahontan, San Francisco Bay
Imperial Irrigation District, Metropolitan Water District of Southern California	Colorado River, South Coast

MWDSC is able to draw on this source, it can divert up to a maximum of 15 taf in any one month. The stored water would be made available to MWDSC by Arizona foregoing the use of part of its normal supply from the Central Arizona Project. MWDSC plans to recover the stored water at times in the future when its Colorado River Aqueduct diversions may be limited.

Water Recycling and Desalting Supplies

Water recycling is the intentional treatment and management of wastewater to produce water suitable for reuse. Several factors affect the amount of wastewater treatment plant effluent that local agencies are able to recycle, including the size of the available market and the seasonality of demands. Local agencies must plan their facilities based on the amount of treatment plant effluent available and the range of expected service area demands. In areas where irrigation uses constitute the majority of recycled water demands, winter and summer demands may vary greatly. (Where recycled water is used for groundwater recharge, seasonal demands are more constant throughout the year.) Also, since water recycling projects are often planned to supply certain types of customers, the proximity of these customers to each other and to available pipeline distribution systems affects the economic viability of potential recycling projects.

Technology available today allows many municipal wastewater treatment systems to produce water supplies at competitive costs. More stringent treatment requirements for disposal of municipal and industrial wastewater have reduced the incremental cost for higher levels of treatment required for recycled water. The degree of additional treatment depends on the intended use. Recycled water is used for agricultural and landscape irrigation, groundwater recharge, and industrial and environmental uses. Some uses are required to meet more stringent standards for public health protection. An example is the City of San Diego's planned 18 mgd wastewater repurification facility. This project (described in Chapter 5) would produce about 16 taf/yr of repurified water to augment local municipal supplies. If implemented, the project would be California's first indirect potable reuse project that discharges treated water directly into a surface reservoir without percolation or injection into a groundwater basin.

The use of recycled water can lessen the demand for new water supply. However, not all water recycling produces new water supply. Bulletin 160 counts water that would otherwise be lost to the State's hydrologic system (i.e., water discharged directly to the ocean or to another salt sink) as recycled water supply. If water recycling creates a new demand which would not otherwise exist, or if it treats water that would have otherwise been reapplied by downstream entities or recharged to usable groundwater, it is not considered new water supply. Water recycling also provides multiple benefits such as reduced wastewater discharge and improved water quality and may be implemented for these purposes in addition to water supply.

Water Recycling Status

The Department, in coordination with the WateReuse Association of California, conducted a survey of 1995 water recycling to update the association's 1993 survey of local agencies' planned water recycling. The 1993 survey was used in Bulletin 160-93 to estimate recycling potential. Bulletin 160-98 uses 1995 data. The 1993 survey had 111 respondents. The 1995 survey had 230 respondents. Survey data are provided in Appendix 3A.

The survey analyzed three levels of project development—base, planned, and conceptual. Projects in the conceptual stage are not yet defined and are deferred in this Bulletin from further evaluation. Total water recycling in 1995 is estimated to be 485 taf/yr,

Water supplied by the City of San Luis Obispo's water reclamation plant is used to provide instream flows in San Luis Obispo Creek.

with 323 taf/yr being new water supply. (The survey reported 450 taf/yr of base water recycling. While most agencies responded, not all water recycling was reported and data from the survey were augmented by additional data where available.) As shown in Table 3-20, recycling projects do not generate new water supply in the State's interior regions. In these regions, treated water from recycling projects would otherwise be used by downstream entities or would be recharged to usable groundwater.

The 1993 survey respondents reported plans to recycle more than 650 taf/yr of water by 1995. This level of recycling did not materialize. The most obvious reason for the shortfall between 1993 projections for 1995 and the actual 1995 recycling was because the 1993 survey was administered when the memory of the 1987-92 drought was vivid. When asked about factors that influence water recycling decisions, respondents reported that "memory of the last drought" and "concern over long-term supply" were most likely to influence recycling decisions. Financial problems and the recession were identified as least likely to affect recycling decisions in the 1995 survey. Existing use of recycled water is shown by category in Table 3-21.

Water Recycling Potential

By 2020, total water recycling is expected to increase from 485 taf/yr to 577 taf/yr, due to greater production at existing treatment plants and new production at plants currently under construction. This base production is expected to increase new water supplies from 323 taf/yr to 407 taf/yr. All new recycled water is expected to be produced in the San Francisco Bay, Central Coast, and South Coast regions. Table 3-22 shows projections of potential water recycling options and resulting new water supply based on the 1995 survey.

By 2020, water recycling options could bring total water recycling potential to over 1.4 maf/yr and could generate as much as 1.1 maf/yr of new supply, if water agencies implemented all projects identified in the survey. Future water recycling options are discussed in Chapter 6 and in the regional chapters.

Seawater Desalting

Total seawater desalting capacity is currently about 8 taf/yr statewide. Most existing plants are small (less than 1 taf/yr) and have been constructed in coastal communities with limited water supplies. The Santa Barbara desalting plant, with capacity of 7.5 taf/yr, is currently the only large seawater desalting plant. The plant was constructed during the 1987-92 drought and is now on long-term standby. In the 1995-level water budget, 8 taf of seawater desalting is included as a drought year supply. In the 2020-level water budget, 8 taf of seawater desalting is included as average and drought year supplies.

Water Quality

A critical factor in determining the usability and reliability of any particular water source is water quality. Water has many potential uses and the water quality requirements for each use vary. The quality

TABLE 3-20

1995 and 2020 Level Water Recycling by Hydrologic Region (taf)
With Existing Facilities and Programs

	1995		*2020*	
Region	*Total Water Recycling*	*New Water Supply*	*Total Water Recycling*	*New Water Supply*
North Coast	13	13	13	13
San Francisco Bay	40	35	42	37
Central Coast	19	18	36	34
South Coast	263	207	331	273
Sacramento River	12	0	15	0
San Joaquin River	37	0	39	0
Tulare Lake	51	0	51	0
North Lahontan	8	8	8	8
South Lahontan	27	27	27	27
Colorado River	15	15	15	15
Total	**485**	**323**	**577**	**407**

San Francisco's Hetch Hetchy Aqueduct system develops its water supply from the Sierra Nevada at Yosemite National Park. High elevation Sierra sources typically have low levels of mineralization. Hetch Hetchy water may be stored in Crystal Springs Reservoir on the San Francisco Peninsula where public access and land use are managed to protect water quality.

TABLE 3-21

1995 Level Total Water Recycling by Category

Category	*Amount (taf)*	*Percent of Total*
Agricultural Irrigation	155	32
Groundwater Recharge	131	27
Landscape Irrigation	82	17
Industrial Uses	34	7
Environmental Uses	15	3
Seawater Intrusion Barrier	5	1
Other[a]	63	13
Total	**485**	**100**

[a] Includes snow making, dust suppression, fire fighting and recreational ponds.

TABLE 3-22

2020 Level Total Water Recycling and New Water Supply (taf)

Projects	*Total Water Recycling*	*New Water Supply*
Base	577	407
Options	835	655
Total	**1,412**	**1,062**

needed to irrigate landscaping, for example, is lower than that required for human consumption or for making computer chips. Sometimes, different water uses may have conflicting water quality requirements. Water temperatures ideal for crop irrigation may be unsuitable for fish spawning.

Overview of Pollutants and Stressors Causing Water Quality Impairment

Mineralization. When water passes over and through soils, it picks up soluble minerals (salts) that are the result of natural processes such as geologic weathering. As the water passes through a watershed and is used for various purposes, concentrations of dissolved minerals and salts in the water increase, a process called mineralization. For example, Sierra Nevada streams typically pick up 20 to 50 mg/L of dissolved minerals from the valley floors on their way to the Pacific Ocean, which is equivalent to about 50 to 140 pounds of salts per acre-foot. An acre-foot of water with total dissolved solids of 736 mg/L (a concentration typical of water in the lower Colorado River) contains one ton of salt. Increased concentrations of minerals can result from both urban and agricultural water uses.

In the Delta, the export location for much of California's water supply, sea water intrusion is a major source of mineralization. Sea water intrusion in the Delta elevates the salinity (particularly the concentrations of sodium, chloride, and bromide) of fresher river water entering the Delta. Bromides are of particular concern because they contribute to formation of disinfection by-products when the water is treated for drinking. The impact of sea water intrusion is especially significant during periods of low river flows. For example during the 1987-92 drought, the average TDS concentration in the lower Sacramento River was 108 mg/L. In the lower San Joaquin River, the average was 519 mg/L, and at Banks Pumping Plant, the southern Delta export location of the SWP, the average was 310 mg/L. During the wetter years from 1993 to 1995, the average TDS concentration in the lower Sacramento River was 98 mg/L, while the average TDS was 342 mg/L in the lower San Joaquin River and 236 mg/L at Banks Pumping Plant.

Some water agencies south of the Delta blend Delta water supplies with other more saline water. Elevated TDS levels limit agencies' ability to recycle water. Agencies must meet customer objectives for TDS and comply with discharge requirements. Increased TDS levels may limit their ability to do so. Agencies' ability to store water for future use through groundwater recharge or conjunctive use programs depends on the TDS of the source water. RWQCB basin plans generally require that water used for recharge not degrade existing groundwater quality. Increased TDS levels increase salt loadings to groundwater basins and may ultimately limit the use of the existing groundwater.

Eutrophication. Eutrophication results when nutrients such as nitrogen and phosphorus are added to surface waters. In the presence of sunlight, algae and other microscopic organisms use the available nutrients to increase their populations. Slightly or moderately eutrophic water can support a complex web of plant and animal life. However, water containing high concentrations of microorganisms is undesirable for drinking water and other needs. Some microorganisms can produce compounds that, while not directly harmful to human health, may cause taste and odor problems in drinking water.

Eutrophication is of great concern at Lake Tahoe, where stringent regulatory controls have been imposed to maintain the lake's unique clarity or halt its decline. The lake is in the early stages of eutrophication and, if it continues, the lake's clarity will be significantly reduced in 20 to 40 years. Development of the basin's erodible land, as well as construction of highways, streets, and logging roads, mobilizes phosphorous and nitrogen compounds deposited in the lake, spurring algae growth. Algae and suspended sediments cloud the lake and reduce its transparency. The combination of the lake's large volume and the low inflow relative to volume aggravates the impacts of phosphorous and nitrogen loading because there is virtually no flushing action.

Temperature and Turbidity. Temperature is important to aquatic organisms and has been especially of concern for salmonid spawning in rivers such as the Sacramento River. Turbidity also affects aquatic organisms and water treatment plant operations. Significant turbidity increases are observed in rivers and streams during periods of high storm runoff. Phytoplankton abundance is affected by increased turbidity, and increased turbidity requires increased chemical addition or changes in operation of water treatment plants.

Abandoned Mines. Runoff from abandoned mines is a major source of heavy metals such as nickel, silver, chromium, lead, copper, zinc, cadmium, mercury, and arsenic in surface waters. Iron Mountain Mine on Spring Creek above Keswick Reservoir on the Sacramento River and Penn Mine above Camanche Reservoir on the Mokelumne River are examples of abandoned mines that drain into major watersheds. Historically, periodic fish kills occurred at these sites when acidic mine drainage with elevated levels of heavy metals flowed into surface waters. Remedial actions have been in various stages of progress at these sites for many years. Concentration of heavy metals well below levels of concern for humans can be acutely toxic to aquatic species. Much of the heavy metals loading in the Sacramento River is thought to come from abandoned mines in the upper watershed. In the drought years of 1991 and 1992, the CVP contributed 125 taf of water to dilute this metals loading.

Pathogens. *Cryptosporidium parvum* outbreaks have been documented in many places throughout the world. Table 3-23 lists some of the most significant outbreaks documented in recent years. In 1993, approximately 403,000 persons in Milwaukee, Wisconsin, became ill from cryptosporidiosis (the disease caused by *Cryptosporidium*) in their water supply. Approximately 100 deaths resulted from this

TABLE 3-23

Significant *Cryptosporidium* Outbreaks

Year	*Location*	*Reported Cases*	*Reported Deaths*
1984	Braun Station, Texas	2,000	—
1987	Carrollton, Georgia	13,000	—
1989	Thames River area, England	100,000	—
1992	Jackson County, Oregon	15,000	—
1993	Milwaukee, Wisconsin	403,000	100
1994	Las Vegas, Nevada	78	16

outbreak. The suspected sources of *Cryptosporidium* were cattle wastes, slaughterhouse wastes, and sewage carried by rivers tributary to Lake Michigan, the drinking water source. This outbreak was associated with operational deficiencies in the water treatment plant and presents a compelling example of the importance of maintaining the quality of source waters.

More significantly, the 1994 *Cryptosporidium* outbreak in Las Vegas, Nevada was the first documented epidemiologically-confirmed waterborne outbreak from a water system with no associated treatment deficiencies or breakdowns. During this outbreak, 78 immunocompromised persons became ill of cryptosporidiosis, even when no *Cryptosporidium* was detected in the treated drinking water.

State and federal surface water treatment rules require that all surface water supplied for drinking receive filtration, high level disinfection, or both, to inactivate or remove viruses and protozoan cysts such as *Giardia lamblia.* However, if a water supply meets certain source water quality criteria and a watershed management program exists to provide protection against these pathogens, the public water purveyor may receive an exemption from filtration requirements. The City and County of San Francisco is currently the only California water retailer exempted from filtration requirements.

Besides *Giardia* and *Cryptosporidium*, there are many other disease-causing viruses, bacteria, and protozoans. Table 3-24 lists some waterborne diseases of concern in the United States.

Disinfection By-Products. As water passes over and through soils, it also dissolves organic compounds (including humic and fulvic acids) present in the soil as a result of plant decay. High levels of these compounds can be present in drainage from wooded or heavily vegetated areas and from soils high in organic content. Chlorine, when used as a disinfectant in drinking water treatment, reacts with these organic compounds to form DBPs such as trihalomethanes and haloacetic acids. Where present, bromide enters the reaction to produce bromine-containing DBPs. Table 3-25 lists some potential DBPs, or chemical classes of DBPs, which may be produced during disinfection of drinking water. A maximum contaminant level for total THMs for drinking water has been established by EPA and by DHS, in accordance with the federal and State Safe Drinking Water Acts. The current MCL for total THMs in drinking water is 0.10 mg/L; no MCL for haloacetic acids is currently in effect. Under EPA's proposed

TABLE 3-24

Some Waterborne Diseases of Concern in the United States

Disease	*Microbial Agent*
Amebiasis	Protozoan (*Entamoeba histolytica*)
Campylobacteriosis	Bacterium (*Campylobacter jejuni*)
Cholera	Bacterium (*Vibrio cholerae*)
Cryptosporidiosis	Protozoan (*Cryptosporidium parvum*)
Giardiasis	Protozoan (*Giardia lamblia*)
Hepatitis	Virus (*hepatitis A*)
Shigellosis	Bacterium (*Shigella species*)
Typhoid Fever	Bacterium (*Salmonella typhi*)
Viral Gastroenteritis	Viruses (N*orwalk, rotavirus, and other types*)

TABLE 3-25

Disinfectants and Disinfection By-Products

Disinfectant	*Potential DBPs or Classes of DBPs*
Chlorine	Trihalomethanes Halogenated acids Haloacetonitriles Halogenated aldehydes Halogenated ketones Chloropicrin Chlorinated phenols
Chloramine	Trihalomethanes Halogenated acids Haloacetonitriles Halogenated aldehydes Halogenated ketones Chloropicrin Chlorinated phenols Cyanogen chloride
Ozone	Bromate Brominated acids Formaldehyde Acetaldehyde Other aldehydes Carboxylic acids Hydrogen peroxide
Chlorine dioxide	Chlorite

Disinfectant/Disinfection By-Product Rule, the maximum contaminant level for THMs will be lowered from 0.1 to 0.08 mg/L in Stage 1 and to 0.04 mg/L in Stage 2. Stage 1 and Stage 2 of the rule are to be promulgated in November 1998 and May 2002, respectively. Stage 1 of the rule also requires conventional surface water treatment systems to remove a percentage of the DBP precursors in the influent (as measured by TOC). A new MCL of 0.06 mg/L for haloacetic acids is also expected to become effective in late 1998.

Ozone is a powerful oxidant widely used for drinking water disinfection. Its advantages are that it efficiently kills pathogens such as *Giardia* and *Cryptosporidium*, destroys tastes and odors, and minimizes production of THMs and most other unwanted DBPs. However, bromate is formed during ozone disinfection of waters containing bromide. EPA estimates that bromate may be a more potent carcinogen than THMs and haloacetic acids. A new MCL of 0.01 mg/L for bromate is expected to be effective in late 1998.

Agricultural Pollutants. Pollutants from agricultural areas are generally of the nonpoint variety, meaning their sources are usually diffuse and are not readily subject to control. Agricultural runoff may contain chemical residues, trace elements, salts, nutrients, and elevated concentrations of organic compounds which may be converted to DBPs in drinking water. Pathogens from dairies and livestock operations can enter waterways through agricultural runoff. Sediments from land tillage and forestry activities can enter waterways, obstructing water flow and affecting the survival and reproduction of fish and other aquatic organisms.

Drainage from some agricultural lands in the San Joaquin Valley contains high concentrations of salts and sometimes concentrations of pesticides and trace elements. This water quality problem is exacerbated when salts are recirculated as Delta water is delivered to the San Joaquin Valley to irrigate agricultural lands, and then is returned to the Delta through the San Joaquin River.

The TOC level of water is generally a good indication of its propensity to form DBPs during water treatment. Rivers passing through the Delta pick up organic matter, due to the contribution of agricultural drainage from peat soils. As Sacramento River water passes through the Delta, its THM formation potential increases almost threefold by the time it reaches Banks Pumping Plant.

Urban Pollutants. Urban pollutants can come from both point and nonpoint sources. Nonpoint sources of pollution include recreational activities, drainage from industrial sites, runoff from streets and highways, discharges from other land surfaces, and aerial deposition. In California, storm water runoff, a major source of nonpoint source pollution, is regulated by SWRCB on behalf of EPA.

Municipal and industrial wastewater discharges are point sources of urban pollution. Most industries in California discharge to a publicly-owned wastewater treatment plant and only indirectly to the environment. These industries are required to pretreat their industrial waste prior to its discharge to municipal wastewater treatment plants. Like municipal discharges, industrial discharges are subject to regulation through the National Pollutant Discharge Elimination System. Industries discharging directly into the environment are also required to have NPDES permits. California's nine RWQCBs are responsible for enforcing compliance with NPDES, including pretreatment regulations. It is, however, the responsibility of the publicly-owned wastewater treatment plants accepting industrial wastes to ensure that industries are complying with pretreatment requirements. RWQCBs conduct regular inspections on permitted discharges and respond to public complaints on illegal discharges.

Wastewater treatment facilities operated under NPDES have, in general, been successful in maintaining the quality of California's water bodies. However, the discharge permits do not regulate all constituents that may cause adverse impacts. For example, the discharge of organic materials that contribute to the formation of DBPs in drinking water is not regulated. NPDES does not guarantee elimination of pathogens such as *Giardia* and *Cryptosporidium*, which are harder to inactivate (disinfect) than most other waterborne pathogens. In addition, permitted discharges can include nitrogen compounds that can be harmful to aquatic life, cause algae growth in surface water bodies, and force downstream drinking water facilities to increase their use of chlorine or to switch to alternative disinfection processes. Some wastewater treatment plant processes do not completely remove all synthetic chemicals that can be present in the water.

Many municipal wastewater treatment plants discharge to surface waters which are subsequently diverted for urban use. For example, the larger wastewater treatment plants discharging to the Sacramento and San Joaquin river systems above the Delta contribute an average daily discharge volume of almost 250 mgd (280 taf/yr) to the system.

Recently, there has been increasing concern about contamination of drinking water sources by methyl tertiary butyl ether. MTBE is a compound added to gasoline to promote more complete combustion and reduce exhaust emissions. In California, MTBE is used to reduce exhaust emissions and to meet federal Clean Air Act requirements for oxygenated gasoline. MTBE is now being found in wells and reservoirs used for municipal water supply.

In drinking water, MTBE causes taste and odor problems at low concentrations. The EPA drinking water advisory of 20 to 40 *u*g/L or below to protect consumer acceptance of drinking water (taste and odor) would also provide a large margin of protection from MTBE's carcinogenic effects and noncancer toxicity. In California, an action level of 35 *u*g/L in drinking water has been issued.

To evaluate the presence of MTBE in California's drinking water supplies, voluntary testing for MTBE was implemented in 1996 by water suppliers in response to a DHS request. In February 1997, a regulation was adopted requiring public drinking water systems to monitor their drinking water sources for MTBE as an unregulated chemical (a chemical for which there is no established regulatory or enforceable drinking water level or maximum contaminant level). Because MTBE is an unregulated chemical, water suppliers will be monitoring and reporting MTBE in sources of drinking water at least once every three years.

The most extensive MTBE contamination of drinking water sources in California was at two well fields (Charnock and Arcadia) in Santa Monica. This contamination was discovered in February 1996, not long after DHS' request for voluntary testing for MTBE. These well fields supplied 80 percent of Santa Monica's municipal water. MTBE concentrations as high as 610 mg/L were observed in the Charnock well field and seven wells in the field were closed. In the Arcadia well field, two wells were closed due to contamination from an underground storage tank at a nearby gasoline station.

As noted in Chapter 2, legislation enacted in 1997 required DHS to begin adopting primary and secondary drinking water standards for MTBE. The secondary drinking water standard for MTBE was to be established by July 1, 1998, and the primary drinking water standard was to be established by July 1, 1999.

The Office of Environmental Health Hazard Assessment released a draft technical document entitled *Public Health Goal for Methyl Tertiary Butyl Ether (MTBE) in Drinking Water* in April 1998. This draft document provided a review of toxicological studies and other reported data related to the adverse effects of exposures to MTBE. Based on the comprehensive review, OEHHA proposed to adopt a drinking water public health goal of 14 *u*g/L.

PHGs adopted by OEHHA are used by DHS in establishing State MCLs. PHGs are based solely on scientific and public health considerations without regard to economic cost considerations. Drinking water standards adopted by DHS also take into consideration factors related to economic and technical feasibility. PHGs established by OEHHA are not regulatory levels and represent only non-mandatory goals. Federal law requires that MCLs established by DHS must be at least as stringent as the federal MCL (if one exists).

Establishing and Meeting Water Quality Standards

The establishment and enforcement of water quality standards for water bodies in California falls under the authority of SWRCB and the nine RWQCBs. The RWQCBs protect water quality through adoption of region-specific water quality control plans, commonly known as basin plans. In general, water quality control plans designate beneficial uses of water and establish water quality objectives designed to protect them. The designated beneficial uses of water may vary between individual water bodies; some are listed in Table 3-26.

Water quality objectives are the limits or levels of water quality constituents or characteristics which are established to protect beneficial uses. Because a particular water body may have several beneficial uses, the water quality objectives established must be protective of all designated uses. When setting water quality objectives, several sources of existing water quality limits are used (Table 3-27), depending on the uses designated in a water quality control plan. When more than one water quality limit exists for a water quality constituent or characteristic (e.g., human health limit vs. aquatic life limit), the more restrictive limit is used as the water quality objective. Table 3-28 lists some typical water quality constituents or characteristics for which water quality objectives may be established in water quality control plans.

TABLE 3-26

A Partial List of Potential Beneficial Uses of Water

- Municipal and Domestic Supply
- Agricultural Supply
- Industrial Supply
- Groundwater Recharge
- Freshwater Replenishment
- Navigation
- Hydropower Generation
- Recreation
- Commercial and Sport Fishing
- Aquaculture
- Freshwater Habitat
- Estuarine Habitat
- Wildlife Habitat
- Preservation of Biological Habitats of Special Significance
- Preservation of Rare, Threatened, or Endangered Species
- Migration of Aquatic Organisms
- Spawning, Reproduction, and/or Early Development
- Shellfish Harvesting

Drinking Water Standards

Drinking water standards for a total of 81 individual drinking water constituents (Table 3-29) are in place under the mandates of the 1986 SDWA amendments. Using the new SDWA standard setting process established in the 1996 amendments, EPA will select at least five new constituents from the candidate list published in March 1998 and will determine whether to regulate them by August 2001. EPA will publish a contaminant candidate list and select constituents for regulation every five years thereafter. The agency may promulgate an interim national primary drinking water regulation for a contaminant without making the required determination or analysis to address an urgent threat to public health. Selection of the new constituents for regulation must be geared toward contaminants posing the greatest health risks.

Occasionally, drinking water regulatory goals may conflict. For example, concern over pathogens such as *Cryptosporidium* spurred a proposed rule requiring more rigorous disinfection. At the same time, there was considerable regulatory concern over THMs and other DBPs resulting from disinfecting drinking water with chlorine. If disinfection is made more rigorous,

TABLE 3-27

A Partial List of Existing Water Quality Limits

- Drinking Water Maximum Contaminant Levels
- Drinking Water Maximum Contaminant Level Goals
- State Action Levels and Recommended Public Health Levels for Drinking Water
- EPA Health Advisories and Water Quality Advisories
- National Academy of Sciences Suggested No-Adverse-Response Levels
- Proposition 65 Regulatory Levels
- EPA National Ambient Water Quality Criteria

TABLE 3-28

A Partial List of Water Quality Constituents or Characteristics for Which Water Quality Objectives May Be Established

Chemical Constituents	Pesticides
Tastes and Odors	pH
Human Health and Ecological Toxicity	Radioactivity
Bacteria	Salinity
Biostimulatory Substances	Sediment
Color	Settleable Material
Dissolved Oxygen	Suspended Material
Floating Material	Temperature
Oil and Grease	Turbidity

TABLE 3-29

Constituents Regulated Under the Federal Safe Drinking Water Act[a]

1,1-Dichloroethylene	Chromium	Methoxychlor
1,1,1-Trichloroethane	cis-1,2-Dichloroethylene	Nickel
1,1,2-Trichloroethane	Copper	Nitrate
1,2-Dibromo-3-chloropropane (DBCP)	Cyanide	Nitrite
1,2-Dichlorobenzene	Dalapon	Oxamyl
1,2-Dichloroethane	Dichloromethane	Pentachlorophenol
1,2-Dichloropropane	Dinoseb	Phthalates
1,2,4-Trichlorobenzene	Diquat	Picloram
1,4-Dichlorobenzene	Endothall	Polychlorinated biphenyls (PCBs)
2,3,7,8-TCDD (Dioxin)	Endrin	Polynuclear Aromatic Hydrocarbons (PAHs)
2,4-Dichlorophenoxyacetic acid (2,4-D)	Epichlorohydrin	Radium 226
2,4,5-TP (Silvex)	Ethylbenzene	Radium 228
Acrylamide	Ethylene dibromide (EDB)	Selenium
Adipates	Fluoride	Simazine
Alachlor	*Giardia lamblia*	Styrene
Antimony	Glyphosate	Tetrachloroethylene
Arsenic	Gross alpha particle activity	Thallium
Asbestos	Gross beta particle activity	Toluene
Atrazine	Heptachlor	Total coliforms
Barium	Heptachlor epoxide	Total trihalomethane
Benzene	Heterotrophic bacteria	Toxaphene
Beryllium	Hexachlorobenzene	trans-1,2-Dichloroethylene
Cadmium	Hexachlorocyclopentadiene	Trichloroethylene
Carbofuran	Lead	Turbidity
Carbon tetrachloride	*Legionella*	Vinyl chloride
Chlordane	Lindane	Viruses
Chlorobenzene	Mercury	Xylenes (total)

[a] As of February 1997.

DBP formation is increased. Poor quality source waters with elevated concentrations of organic precursors or bromides complicate the problem of reliably meeting standards for disinfection while meeting standards for DBPs. The regulatory community must balance benefits and risks associated with efficient disinfection and against higher DBP levels.

EPA promulgated its Information Collection Rule in 1996 to obtain data on the tradeoff posed by simultaneous control of DBPs and pathogens in drinking water. The ICR requires all large public water systems to collect and report data on the occurrence of DBPs and pathogens (including bacteria, viruses, *Giardia*, and *Cryptosporidium*) in drinking water over an 18-month period. With this information, an assessment of health risks due to the presence of DBPs and pathogens in drinking water can be made. EPA can then determine the need to revise current drinking water filtration and disinfection requirements, and the need for more stringent regulations for disinfectants and DBPs.

Source Water Protection/Watershed Management Activities

The 1996 reauthorization of the federal SDWA requires states to conduct source water assessments and encourages states to establish watershed protection programs. In response to this amendment, DHS, in cooperation with SWRCB, is preparing a drinking water source assessment and protection program. Key elements of this program include delineation of the area surrounding the water source, an inventory of possible contaminating activities, and an analysis of the vulnerability of the drinking water source to contamination. The program draft must be submitted to EPA for approval by February 1999. The assessments must be completed in 2003.

California's DWSAP program will cover both groundwater and surface water sources. Since California has not developed a wellhead protection program as required by the 1986 SDWA amendment, the groundwater portion of the DWSAP will serve as the State's wellhead protection program. DHS is responsible for conducting drinking water source assessments, although any public water agency may perform its own assessment, provided it conforms to DHS procedures. When a public water agency has completed an evaluation through another program, that information may be submitted for the drinking water source assessment. For example, drinking water utilities that utilize surface water sources are required under California law to perform watershed sanitary surveys every 5 years. Many of the watershed sanitary surveys completed prior to the DWSAP program will likely satisfy most requirements of the assessment process. Local agencies that choose to conduct their own assessments and implement source protection may receive financial assistance through the drinking water state revolving fund loan program.

The potential sources and causes of water quality impairment vary from watershed to watershed. Table 3-30 lists potential sources and causes of water quality impairment in a watershed.

A Source Water Protection Example. DHS requested that the Department perform a sanitary survey of the SWP. The Department's 1990 initial survey and 1996 update provide an example of factors considered in source protection studies. Table 3-31 lists some recommendations for action resulting from the sanitary survey.

The 1996 sanitary survey identified the need to address pathogens such as *Giardia* and *Cryptosporidium* in SWP waters. The survey recommended investigating each watershed tributary to the SWP to evaluate the potential sources of pathogens and to develop a coordinated microbiological monitoring and reporting system for municipal SWP contractors and agencies. The Department and MWDSC have implemented a pathogen monitoring program. Under this program, regularly scheduled and storm event sampling for *Giardia*, *Cryptosporidium*, and bacteria which serve as general indicators of microbiological contamination (such as *Clostridium perfringens*, *Escherichia coli*, and total and fecal coliforms) is conducted at sites throughout the SWP.

CALFED Bay-Delta Program Water Quality Planning. CALFED's goal for water quality is to provide good water quality for environmental, agricultural, drinking water, industrial, and recreational beneficial uses. To achieve this goal, CALFED is developing water quality actions to address impairments of beneficial uses in the Bay-Delta, Sacramento River, and San Joaquin River Watersheds, and in streams and rivers within SWP and CVP service areas outside of the Central Valley. Some water quality actions being considered by CALFED include:

- Reducing concentrations of heavy metals from mine drainage entering the Delta and its tributaries.
- Reducing pollutant concentrations entering the Delta from the San Joaquin River.
- Reducing vulnerability of Delta water quality to salinity intrusion by implementing a Delta long-term protection plan.
- Improving water circulation in the Delta by constructing seasonally operated barriers in south Delta channels.
- Promoting and supporting efforts of local watershed programs that improve water quality within the Delta and its tributaries.
- Reducing urban and industrial pollutants entering the Delta and its tributaries by controlling urban and industrial runoff.
- Controlling discharge of domestic wastes from boats within the Delta and its tributaries.
- Identifying and implementing actions to address pollution problems in water and sediment within the Delta and its tributaries.
- Reducing pollutants entering the Delta and its tributaries from agricultural runoff.

CALFED identified water quality parameters of concern to beneficial uses and set numerical or narrative water quality targets for each. These targets represent desirable instream concentrations of parameters of concern and would be used as indicators of success to determine the effectiveness of the water quality actions. However, the degree to which these targets are realized will depend upon overall CALFED solutions. Targets may not be fully realized because of competing CALFED solution requirements or because attainment of a target is technically infeasible.

Colorado River Water Quality. The Colorado River is a major source of water supply to Southern California. The river is subject to various water quality influences because its watershed is so large. Much of the watershed is open space and agricultural lands, and municipal and industrial discharges are not a significant source of water quality degradation.

Perchlorate has been detected in the Colorado River. Concentrations ranging from 5 to 9 *u*g/L have been found in Lake Havasu. The contamination source has been traced to manufacturing facilities in the Las Vegas/Henderson, Nevada, area. Several federal Superfund sites contribute to uranium contamination

TABLE 3-30

Potential Sources and Causes of Water Quality Impairment

Source of Contamination	*Pollutant or Stressor*	*Possible Sources*
General	Dissolved minerals	Mineral deposits, mineralized waters, hot springs, seawater intrusion
	Asbestos	Mine tailings, serpentinite formations
	Hydrogen sulfide	Subsurface organic deposits, such as peat soils in Delta islands
	Metals	Mine tailings
	Microbial agents	Wildlife
	Radon	Geologic formations
	Sediment	Forestry activities, stream banks, construction activities, roads, mining operations, gullies
	Altered flow or habitat modification	Impoundments, storm water runoff, artificial drainage, bank erosion, riparian corridor modification
Commercial Businesses	Gasoline	Service stations' underground storage tanks
	Solvents	Dry cleaners, machine shops
	Metals	Photo processors, laboratories, metal plating works
Municipal	Microbial agents	Sewage discharges, storm water runoff
	Pesticides	Storm water runoff, golf courses
	Nutrients	Storm water runoff
	Miscellaneous liquid wastes	Industrial discharge, household waste, septic tanks
Industrial	SOCs, industrial solvents, metals, acids	Electronics manufacturing, metal fabricating and plating, transformers, storage facilities, hazardous waste disposal
	Pesticides	Chemical formulating plants
	Wood preservatives	Plants that pressure treat power poles, wood pilings, railroad ties
Solid Waste Disposal	Solvents, pesticides, metals, organics, petroleum wastes, microbial agents household waste	Disposal sites receive waste from a variety of industries, municipal solid wastes, petroleum products
Agricultural	Pesticides, fertilizers, concentrated mineral salts, microbial agents, sediment, nutrients	Tailwater runoff, agricultural chemical applications, fertilizer usage, chemical storage at farms and applicators' air strips, packing sheds and processing plants, dairies, feed lots, pastures
Disasters	Solvents, petroleum products, microbial agents, other hazardous materials	Earthquake-caused pipeline and storage tank failures and damage to sewage treatment and containment facilities, major spills of hazardous materials, floodwater contamination of storage reservoirs and groundwater sources

TABLE 3-31

SWP Sanitary Survey Update Recommendations

Water Quality Problem	*Recommendation*
Pathogens	Implement pathogen monitoring program
Disinfection By-Product Precursors (Organic Carbon)	Investigate possible means of reducing organic carbon levels in the Delta and North Bay Aqueduct
Disinfection By-Product Precursors (Bromide)	Investigate possible means of controlling bromide concentrations in SWP waters
Dissolved Solids and Turbidity in the California Aqueduct	Investigate measures to reduce salts and turbidity in the Aqueduct
Hazardous Waste Facilities	Inventory hazardous waste facilities and volume of hazardous materials
Hazardous Materials Releases	Review emergency responses to hazardous materials releases to determine types/amounts of materials released and potential for contamination in watershed
Urban Runoff	Review storm water discharges from cities and urbanized areas
Barker Slough/North Bay Aqueduct	Study watershed to determine sources and extent of contamination
Solid Waste Landfills	Review solid waste landfills in SWP watersheds
Underground Storage Tanks	Evaluate status of leaking underground storage tanks within SWP watersheds
Petroleum Product Pipelines	Review pipeline failures resulting in petroleum releases to determine potential for SWP contamination
Emergency Action Plan	Review SWP emergency action plan to ensure document is up-to-date and functionally adequate

in the Colorado River watershed. Uranium mining occurs in the Colorado River Basin above Lake Mead. As uranium decays, alpha-emitting particles are released. Although gross alpha levels in Colorado River water remain under current federal and State MCLs, a slight upward trend in the levels has been observed.

Salts and turbidity from natural geologic formations and from agricultural operations are the primary forms of water quality degradation in the Colorado River. Unlike Delta soils, Colorado River watershed soils are low in organic content. As a result, water from the Colorado River typically has only about one-half the capacity to produce DBPs during drinking water treatment as does water from the Delta.

Mineral concentrations in the Colorado River are usually much higher than those found in water taken from the Delta. For example, from 1993 to 1995 the average TDS of Colorado River Aqueduct water was 691 mg/L, while the average concentration in the California Aqueduct was 236 mg/L. When possible, MWDSC blends Colorado River water with SWP water or other sources to reduce salt concentrations in the water delivered to customers. MWDSC's interim policy is to blend SWP water with Colorado River water to obtain a target TDS level between 500 and 550 mg/L, during April through September. The agency will adopt a long-term blending policy following completion of a salinity management study in 1998 (see Chapter 7).

The federal Colorado River Basin Salinity Control Act of 1974 authorized and directed the Secretary of the Interior to construct facilities to control Colorado River salinity to meet salinity requirements expressed in Minute 242 of the U.S. - Mexican Treaty. The act also directed the Secretary to expedite investigation, planning, and implementation of a salinity control program in the United States upstream of Imperial Dam. Currently, salinity control activities are removing over

600,000 tons of salt per year from the river system. To maintain the 1975 federally approved salinity standards for the basin it is estimated that by 2010 approximately 1.5 million tons of salt will have to be removed each year.

An example of a salinity control measure in the basin is USBR's Yuma desalting plant, constructed to treat agricultural drainage from Arizona's Wellton-Mohawk Irrigation and Drainage District. The plant, said to be the world's largest reverse osmosis desalter, has a capacity of 73 mgd. Plant construction was completed in 1992, and USBR began operating the plant at one-third capacity. A flood event in the Gila River along with above normal runoff in the Colorado River watershed in years since then has reduced the salinity of Colorado River water, permitting the plant to be taken off-line. Currently, agricultural drainage is bypassed through a concrete-lined canal to the Cienega de Santa Clara in Mexico, as long as Minute 242 water quality requirements are being met. Other salinity control measures implemented in Wyoming, Utah, Colorado, and Nevada have included lining or piping irrigation delivery systems, deep well injection of brines, plugging of flowing brine wells, erosion control on saline lands, and irrigation improvements.

Groundwater Quality

Groundwater pollution presents a serious challenge in California. A variety of contaminants have been found in groundwater; most have been introduced by human activities. Prominent among these are nitrates and chemicals such as pesticides and solvents. Most groundwater contamination sites are small and seldom affect water supplies on a regional basis. These sites may require cessation of pumping from one or two water supply wells, or the installation of wellhead treatment. Of greater water supply concern from a statewide perspective are areas of regional groundwater contamination—such as organics in the San Gabriel Valley or nitrates in parts of the San Joaquin Valley—which require a significant reconfiguration of local agency water supply systems. Another important consideration in evaluating larger-scale groundwater contamination problems is the treatment preference now accorded to groundwater sources under the SDWA. Because the SDWA is imposing more stringent requirements on treatment of drinking water from surface sources, many communities are planning to meet their future municipal needs by turning to groundwater.

In California, nitrates in groundwater are widespread (see Chapter 5). Nitrates may enter the soil as a result of fertilizer application, animal waste, septic tanks, industrial disposal, wastewater treatment plant sludge application, or other sources. Certain organisms have the capacity to take nitrogen from the air and convert it to nitrates. In California, the most significant source of nitrates in soils is from agricultural practices, primarily farming operations and animal husbandry. Nitrates can move through the soil into groundwater and, once there, may seriously degrade its usability. Nitrate removal is expensive; therefore, it is often not cost effective to treat nitrate-contaminated waters.

There has been growing concern over the potential human health threat of pathogens in groundwater used as drinking water. This concern stems from pathogens such as *Giardia*, *Cryptosporidium*, bacteria, and viruses being found in well water. Several waterborne-disease outbreaks associated with groundwater have been reported outside California. Some of these outbreaks are listed in Table 3-32.

Concern about pathogens in groundwater has led

TABLE 3-32

Waterborne-Disease Outbreaks Associated with Groundwater Used as a Drinking Water Source, 1993-94

State	*Date*	*Pathogen*	*Organism Type*	*No. of Cases*
Minnesota	November 1993	*Campylobacter jejuni*	Bacterium	32
Missouri	November 1993	*Salmonella serotype Typhimurium*	Bacterium	625
New York	June 1993	*Campylobacter jejuni*	Bacterium	172
Pennsylvania	January 1993	*Giardia lamblia*	Protozoan	20
South Dakota	September 1993	*Giardia lamblia*	Protozoan	7
Washington	April 1993	*Cryptosporidium parvum*	Protozoan	7
Idaho	June 1994	*Shigella flexneri*	Bacterium	33
Minnesota	June 1994	*Campylobacter jejuni*	Bacterium	19
New York	June 1994	*Shigella sonnei*	Bacterium	230
Washington	August 1994	*Cryptosporidium parvum*	Protozoan	134

to regulatory discussions on disinfection requirements for groundwater. EPA is currently developing a Groundwater Disinfection Rule proposal for release in March 1999, with a final rule by November 2000. Data obtained through the ICR will provide information to assess the extent and severity of risk.

The SDWA requires states to implement wellhead protection programs designed to prevent the contamination of groundwater supplying public drinking water wells. Wellhead protection programs rely heavily on local efforts to be effective, because communities have primary access to information on potential contamination sources and can adopt locally-based measures to manage these potential contamination sources. EPA has recommended five steps that communities can take to implement wellhead protection:

- Form a community planning organization.
- Define the land area around the well to be protected.
- Identify potential sources of contamination within the area.
- Develop and implement a management plan to protect the area.
- Plan for emergencies and future water supply needs.

Water Supply Summary by Hydrologic Region

This chapter described how the State's water supplies are affected by climate and hydrology, how water supplies are calculated, and how water supplies are reallocated through storage and conveyance facilities and through water transfers. Also, this chapter discussed water quality considerations that affect beneficial uses of California's water supplies.

Table 3-33 summarizes average year water supplies by hydrologic region assuming 1995 and 2020 levels of development and existing facilities and programs. Similarly, Table 3-34 summarizes drought year water supplies by hydrologic region for existing and future levels of development. Regional water supplies, along with water demands presented in the following chapter, provide the basis for the statewide water budget developed in Chapter 6 and regional water budgets developed in Chapters 7-9.

TABLE 3-33

California Average Year Water Supplies by Hydrologic Region (with existing facilities and programs, in taf)

Region	1995				2020			
	Surface	*Groundwater*[a]	*Recycled & Desalted*	*Total (rounded)*	*Surface*	*Groundwater*[a]	*Recycled & Desalted*	*Total (rounded)*
North Coast	20,331	263	13	20,610	20,371	288	13	20,670
San Francisco Bay	7,011	68	35	7,110	7,067	72	37	7,180
Central Coast	318	1,045	18	1,380	368	1,041	42	1,450
South Coast	3,839	1,177	207	5,220	3,625	1,243	273	5,140
Sacramento River	11,881	2,672	0	14,550	12,196	2,636	0	14,830
San Joaquin River	8,562	2,195	0	10,760	8,458	2,295	0	10,750
Tulare Lake	7,888	4,340	0	12,230	7,791	4,386	0	12,180
North Lahontan	777	157	8	940	759	183	8	950
South Lahontan	322	239	27	590	437	248	27	710
Colorado River	4,154	337	15	4,510	3,920	285	15	4,220
Total (rounded)	**65,090**	**12,490**	**320**	**77,900**	**64,990**	**12,680**	**410**	**78,080**

[a] Excludes groundwater overdraft.

TABLE 3-34

California Drought Year Water Supplies by Hydrologic Region (with existing facilities and programs, in taf)

Region	1995				2020			
	Surface	*Groundwater*[a]	*Recycled & Desalted*	*Total (rounded)*	*Surface*	*Groundwater*[a]	*Recycled & Desalted*	*Total (rounded)*
North Coast	10,183	294	14	10,490	10,212	321	14	10,550
San Francisco Bay	5,285	92	35	5,410	5,417	89	37	5,540
Central Coast	160	1,142	26	1,330	180	1,159	42	1,380
South Coast	3,196	1,371	207	4,780	3,130	1,462	273	4,870
Sacramento River	10,022	3,218	0	13,240	10,012	3,281	0	13,290
San Joaquin River	6,043	2,900	0	8,940	5,986	2,912	0	8,900
Tulare Lake	3,693	5,970	0	9,660	3,593	5,999	0	9,590
North Lahontan	557	187	8	750	557	208	8	770
South Lahontan	259	273	27	560	326	296	27	650
Colorado River	4,128	337	15	4,480	3,909	284	15	4,210
Total (rounded)	**43,530**	**15,780**	**330**	**59,640**	**43,320**	**16,010**	**420**	**59,750**

[a] Excludes groundwater overdraft.

3A

Survey of Planned Water Recycling

The Department, in coordination with the WateReuse Association of California, conducted a 1995 survey to update the Association's 1993 survey of local agencies' planned water recycling. The following tables show survey results for each of the State's ten hydrologic regions.

Data presented in the tables represent survey respondents' maximum estimates of potential recycling. Often, agencies reported multiple projects that may be alternatives to one another. Some reported projects have multiple local agency sponsors. Their supplies are shown as reported by each sponsor.

TABLE 3A-1

Planned Water Recycling for North Coast Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Lourenco Dairy Irrigation	McKinleyville Community Services District	Planned	400	0	Agriculture	Preliminary Design
Santa Rosa Long-Term Wastewater Project	Santa Rosa, City of	Planned	15,000	0	Agriculture	Preliminary Design
Total			**15,400**	**0**		
Weaverville Water Reclamation Plant	Weaverville Community Services District	Conceptual	90	0	Industrial	
	Weaverville Community Services District	Conceptual	250	0	Landscape	
Total			**340**	**0**		

TABLE 3A-2

Planned Water Recycling for San Francisco Bay Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Phase 1 Water Reclamation Program	Alameda County Water District	Planned	1,628	1,628	Landscape	Feasibility Study
Phase 2 Water Reclamation Program	Alameda County Water District	Planned	1,045	1,045	Landscape	Feasibility Study
Industrial Use	Central Contra Costa Sanitary District	Planned	20,000	20,000	Industrial	Feasibility Study
Lamorinda	Central Contra Costa Sanitary District	Planned	1,300	1,300	Landscape	Preliminary Design
Zone 1	Central Contra Costa Sanitary District	Planned	1,200	1,200	Landscape	Final Design
San Ramon Valley Recycled Water Program	DSRSD/EBMUD Recycled Water Authority	Planned	6,870	6,870	Landscape	Feasibility Study
Hercules/Franklin Canyon WRP-Phase 2	East Bay Municipal Utilities District	Planned	1,300	1,300	Industrial	Feasibility Study
Hercules/Franklin Canyon WRP-Phase 2	East Bay Municipal Utilities District	Planned	950	950	Landscape	Feasibility Study
Lamorinda Water Recycling Project	East Bay Municipal Utilities District	Planned	1,200	0	Landscape	Feasibility Study
San Ramon Valley Water Recycling Project	East Bay Municipal Utilities District	Planned	3,100	3,100	Landscape	Feasibility Study
Central Fairfield-Phase 1	Fairfield-Suisun Sewer District	Planned	342	0	Industrial	Preliminary Design
Central Fairfield-Phase 1	Fairfield-Suisun Sewer District	Planned	281	0	Landscape	Preliminary Design
Central Fairfield-Phase 2	Fairfield-Suisun Sewer District	Planned	599	0	Landscape	Feasibility Study
Lower Suisun Valley Project	Fairfield-Suisun Sewer District	Planned	630	0	Landscape	Feasibility Study
Suisun City/Tolenas	Fairfield-Suisun Sewer District	Planned	22	0	Industrial	Feasibility Study
Suisun City/Tolenas	Fairfield-Suisun Sewer District	Planned	1,066	0	Landscape	Feasibility Study
Central Marin Water Recycling Project	Marin Municipal Water District	Planned	55	55	Industrial	Feasibility Study
Central Marin Water Recycling Project	Marin Municipal Water District	Planned	800	800	Landscape	Feasibility Study
Bel Marin Keys Golf Course	North Marin Water District	Planned	382	382	Landscape	Feasibility Study
Black Point Golf Links	North Marin Water District	Planned	382	382	Landscape	Feasibility Study
Golf Course Irrigation, City Park Irrigation	North San Mateo County San. District	Planned	1,120	1,120	Industrial	Preliminary Design
Golf Course Irrigation, City Park Irrigation	North San Mateo County San. District	Planned	3,300	3,300	Landscape	Preliminary Design
Water Reclamation	Petaluma, City of	Planned	5,750	0	Agriculture	Feasibility Study
Water Reclamation	Petaluma, City of	Planned	500	0	Landscape	Feasibility Study
S.F. Water Recycling Master Plan	San Francisco Department of Public Works	Planned	920	920	Industrial	Preliminary Design
S.F. Water Recycling Master Plan	San Francisco Department of Public Works	Planned	8,280	8,280	Landscape	Preliminary Design
S.F. Water Recycling Master Plan	San Francisco Department of Public Works	Planned	2,300	2,300	Other	Preliminary Design
South Bay Water Recycling Project	Santa Clara, City of	Planned	840	840	Landscape	Final Design
South Bay Water Recycling Project	South Bay Water Recycling-San Jose	Planned	1,000	1,000	Agriculture	Feasibility Study

TABLE 3A-2

Planned Water Recycling for San Francisco Bay Region (continued)

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
South Bay Water Recycling Project	South Bay Water Recycling-San Jose	Planned	10,000	10,000	Environmental	Feasibility Study
South Bay Water Recycling Project	South Bay Water Recycling-San Jose	Planned	10,000	10,000	Industrial	Feasibility Study
South Bay Water Recycling Project	South Bay Water Recycling-San Jose	Planned	10,000	10,000	Landscape	Feasibility Study
Nonpotable Wastewater Reuse Master Plan	Union Sanitation District	Planned	4,031	4,031	Landscape	Feasibility Study
Total			**101,193**	**90,803**		
Exxon Refinery	Benicia, City of	Conceptual	2,800	2,800	Industrial	
Future Irrigation	Central Contra Costa Sanitary District	Conceptual	2,000	2,000	Landscape	
Delta Diablo Primary Treatment Plant Phase 1	Delta Diablo Sanitation District	Conceptual	1,120	1,120	Landscape	
Oakland/Berkeley/I-80 Water Reclamation Project	East Bay Municipal Utilities District	Conceptual	100	100	Industrial	
Oakland/Berkeley/I-80 Water Reclamation Project	East Bay Municipal Utilities District	Conceptual	1,250	1,250	Landscape	
San Leandro Reclamation Facility-Phase 2	East Bay Municipal Utilities District	Conceptual	900	900	Landscape	
Carneros	Napa Sanitation District	Conceptual	1,000	0	Agriculture	
Kennedy Golf Course	Napa Sanitation District	Conceptual	460	0	Landscape	
Imola Recycled Water Pipeline Installation	Napa, City of	Conceptual	400	0	Landscape	
South County Water Reclamation	Santa Clara Valley Water District	Conceptual	200	0	Agriculture	
South County Water Reclamation	Santa Clara Valley Water District	Conceptual	4,300	0	Landscape	
South County Water Reclamation	Santa Clara Valley Water District	Conceptual	1,350	0	Other	
Total			**15,880**	**8,170**		

TABLE 3A-3

Planned Water Recycling for Central Coast Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
SSLOCSD Reclamation Project	Arroyo Grande, City of	Planned	200	200	Agriculture	Preliminary Design
SSLOCSD Reclamation Project	Arroyo Grande, City of	Planned	700	700	Groundwater Recharge	Preliminary Design
SSLOCSD Reclamation Project	Arroyo Grande, City of	Planned	600	600	Landscape	Preliminary Design
Aquifer Storage/Recovery	Monterey County Regional Water Agency	Planned	10,000	10,000		
Castroville Seawater Intrusion Project	Monterey County Water Resources Agency	Planned	3,700	3,700	Agriculture	Construction
Urban Reuse Project	Monterey Regional Water Pollution Control Agency	Planned	3,000	3,000	Landscape	Feasibility Study
Santa Cruz Water Reuse Project	Pajaro Valley Water Management Agency	Planned	6,000	6,000		
Watsonville Water Reuse Project	Pajaro Valley Water Management Agency	Planned	12,000	12,000		
Water Reuse Project	San Luis Obispo, City of	Planned	300	0	Agriculture	Feasibility Study
Water Reuse Project	San Luis Obispo, City of	Planned	1,200	0	Environmental	Feasibility Study
Water Reuse Project	San Luis Obispo, City of	Planned	900	0	Landscape	Feasibility Study
SVWD Recycled Water Plant	Scotts Valley Water District	Planned	450	450	Landscape	Preliminary Design
Total			**39,050**	**36,650**		
City of Buellton	Buellton, City of	Conceptual	375	0	Groundwater Recharge	
City of Morro Bay WWTP	Morro Bay, City of	Conceptual	625	0	Agriculture	
Envest Water Initiative/Landfill Groundwater Recharge	Vandenberg Air Force Base	Conceptual	20	0	Agriculture	
Total			**1,020**	**0**		

TABLE 3A-4

Planned Water Recycling for South Coast Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Reclaimed Water Wholesale Transmission System	Calleguas Municipal Water District	Planned	617	0	Other	Preliminary Design
Non-domestic Irrigation System	Capistrano Valley Water District	Planned	200	200	Agriculture	Feasibility Study
Non-domestic Irrigation System	Capistrano Valley Water District	Planned	3,100	3,100	Landscape	Feasibility Study
Carlsbad Water Reclamation Plan-Encina Basin-P2	Carlsbad Municipal Water District	Planned	500	500	Agriculture	Preliminary Design
Carlsbad Water Reclamation Plan-Encina Basin-P2	Carlsbad Municipal Water District	Planned	11,000	11,000	Landscape	Preliminary Design
Reclaimed Water System	Castaic Lake Water Agency	Planned	1,300	0	Industrial	Preliminary Design
Reclaimed Water System	Castaic Lake Water Agency	Planned	8,000	0	Landscape	Preliminary Design
Esteban Torres Water Recycling Project	Central Basin Municipal Water District	Planned	4,400	4,400	Industrial	Preliminary Design
Esteban Torres Water Recycling Project	Central Basin Municipal Water District	Planned	4,600	4,600	Landscape	Preliminary Design
Carbon Canyon Reclamation Project-Phase 1	Chino Basin Municipal Water District	Planned	800	0	Industrial	Final Design
Carbon Canyon Reclamation Project-Phase 1	Chino Basin Municipal Water District	Planned	1,090	0	Landscape	Final Design
Carbon Canyon Reclamation Project-Phase 1	Chino Basin Municipal Water District	Planned	10,000	0	Other	Final Design
Expanded Carbon Canyon Reclamation Project	Chino Basin Municipal Water District	Planned	6,000	0	Agriculture	Feasibility Study
Expanded Carbon Canyon Reclamation Project	Chino Basin Municipal Water District	Planned	1,620	0	Industrial	Feasibility Study
Expanded Carbon Canyon Reclamation Project	Chino Basin Municipal Water District	Planned	7,598	0	Landscape	Feasibility Study
Expanded Carbon Canyon Reclamation Project	Chino Basin Municipal Water District	Planned	10,000	0	Other	Feasibility Study
Regional Plant No. 4 Outfall Project	Chino Basin Municipal Water District	Planned	4,670	0	Industrial	Final Design
Regional Plant No. 4 Outfall Project	Chino Basin Municipal Water District	Planned	4,090	0	Landscape	Final Design
Carbon Canyon Water Reclamation Facility	Chino, City of	Planned	90	0	Industrial	Construction
Carbon Canyon Water Reclamation Facility	Chino, City of	Planned	80	0	Landscape	Construction
Reclamation Project 1	Corona, City of	Planned	2,200	0	Landscape	Feasibility Study
T-Plant Filter Washwater Recycling Project	Covina Irrigating Company	Planned	500	0	Other	Preliminary Design
E. Thornton Ibbetson Century Recycled Water Project	Downey, City of	Planned	1,180	1,180	Landscape	Feasibility Study
El Toro Water District Reclamation	El Toro Water District	Planned	432	432	Landscape	Feasibility Study
City of Escondido Regional Water Recycling Program	Escondido, City of	Planned	8,000	8,000	Groundwater Recharge	Final Design

TABLE 3A-4

Planned Water Recycling for South Coast Region (continued)

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
City of Escondido Regional Water Recycling Program	Escondido, City of	Planned	600	600	Industrial	Final Design
City of Escondido Regional Water Recycling Program	Escondido, City of	Planned	3,000	3,000	Landscape	Final Design
Verdugo-Schol-Brand Project	Glendale, City of	Planned	418	418	Landscape	Construction
Irvine Ranch Water District	Irvine Ranch Water District	Planned	75	75	Agriculture	Feasibility Study
Irvine Ranch Water District	Irvine Ranch Water District	Planned	825	825	Industrial	Feasibility Study
Irvine Ranch Water District	Irvine Ranch Water District	Planned	26,500	26,500	Landscape	Feasibility Study
North San Diego County Reclamation Project Phase 2	Leucadia County Water District	Planned	8,000	8,000	Landscape	Feasibility Study
Alamitos Barrier	Los Angeles County Sanitation Districts	Planned	10,000	10,000	Seawater Intrusion Barrier	Preliminary Design
Castaic Lake Water Agency Reclaimed Water Master Plan	Los Angeles County Sanitation Districts	Planned	10,360	10,360	Landscape	Preliminary Design
City of West Covina	Los Angeles County Sanitation Districts	Planned	2,800	2,800	Landscape	Final Design
Northlake	Los Angeles County Sanitation Districts	Planned	2,800	0	Groundwater Recharge	Preliminary Design
Northlake	Los Angeles County Sanitation Districts	Planned	1,680	0	Landscape	Preliminary Design
Puente Hills/Rose Hills Reclaimed Water District System	Los Angeles County Sanitation Districts	Planned	1,500	1,500	Landscape	Construction
San Gabriel Valley Groundwater Recharge Demonstration	Los Angeles County Sanitation Districts	Planned	25,000	25,000	Groundwater Recharge	Preliminary Design
Whittier Narrows Recreation Area	Los Angeles County Sanitation Districts	Planned	4,000	4,000	Landscape	Preliminary Design
Central City/Elysian Park Water Recycling Project	Los Angeles, City of (DWP)	Planned	2,000	2,000	Industrial	Feasibility Study
Central City/Elysian Park Water Recycling Project	Los Angeles, City of (DWP)	Planned	2,000	2,000	Landscape	Feasibility Study
East Valley Water Recycling Project	Los Angeles, City of (DWP)	Planned	22,000	22,000	Groundwater Recharge	Construction
East Valley Water Recycling Project	Los Angeles, City of (DWP)	Planned	6,500	6,500	Landscape	Construction
Headworks Water Recycling Project	Los Angeles, City of (DWP)	Planned	10,000	10,000	Groundwater Recharge	Feasibility Study

TABLE 3A-4

Planned Water Recycling for South Coast Region (continued)

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Los Angeles Harbor Water Recycling Project	Los Angeles, City of (DWP)	Planned	9,000	9,000	Industrial	Preliminary Design
Los Angeles Harbor Water Recycling Project	Los Angeles, City of (DWP)	Planned	3,000	3,000	Landscape	Preliminary Design
Los Angeles Harbor Water Recycling Project	Los Angeles, City of (DWP)	Planned	5,000	5,000	Seawater Intrusion Barrier	Preliminary Design
Sepulveda Basin Water Recycling Project	Los Angeles, City of (DWP)	Planned	3,000	3,000	Landscape	Preliminary Design
Westside Water Recycling Project	Los Angeles, City of (DWP)	Planned	900	900	Industrial	Construction
Westside Water Recycling Project	Los Angeles, City of (DWP)	Planned	250	250	Landscape	Construction
Olivenhain/Kelwood Reclamation Project	Olivenhain Municipal Water District	Planned	100	0	Agriculture	Feasibility Study
Olivenhain/Kelwood Reclamation Project	Olivenhain Municipal Water District	Planned	1,800	0	Landscape	Feasibility Study
OCR Project-CSDOC	Orange County Sanitation Districts	Planned	100,000	100,000	Groundwater Recharge	Feasibility Study
Green Acres-Phase 2	Orange County Water District	Planned	1,900	1,900	Landscape	Final Design
Orange County Reclamation Project	Orange County Water District	Planned	75,000	75,000	Groundwater Recharge	Feasibility Study
Upgrade-Padre Dam W.R. Facilities	Padre Dam Municipal Water District	Planned	200	0	Industrial	Construction
Upgrade-Padre Dam W.R. Facilities	Padre Dam Municipal Water District	Planned	1,000	0	Landscape	Construction
Upgrade-Padre Dam W.R. Facilities	Padre Dam Municipal Water District	Planned	10,000	0	Other	Construction
City of Poway-Escondido	Poway, City of	Planned	500	500	Agriculture	Construction
City of Poway-Escondido	Poway, City of	Planned	1,500	1,500	Landscape	Construction
City of Poway-S.D.	Poway, City of	Planned	500	500	Agriculture	Construction
City of Poway-S.D.	Poway, City of	Planned	500	500	Agriculture	Construction
City of Poway-S.D.	Poway, City of	Planned	1,500	1,500	Landscape	Construction
North City Reclamation Plant-Poway Resources	Poway, City of	Planned	1,000	1,000	Landscape	Construction
Bonsall Basin Desalter	Rainbow Municipal Water Disrict	Planned	3,000	0	Agriculture	Feasibility Study
Santa Margarita Live Stream Discharge	Rancho California Water District	Planned	15,000	0	Groundwater Recharge	Feasibility Study
Irrigation & Industrial Projects	Riverside , City of	Planned	606	0	Industrial	Final Design
Irrigation & Industrial Projects	Riverside , City of	Planned	3,322	0	Landscape	Final Design
San Pasqual Groundwater Management Program	San Diego, City of	Planned	8,000	8,000	Groundwater Recharge	Feasibility Study

TABLE 3A-4

Planned Water Recycling for South Coast Region (continued)

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
South Bay Water Reclamation Project	San Diego, City of	Planned	2,500	2,500	Agriculture	Final Design
South Bay Water Reclamation Project	San Diego, City of	Planned	5,500	5,500	Landscape	Final Design
Water Repurification Project	San Diego, City of	Planned	13,000	13,000	Other	Feasibility Study
San Elijo Joint Powers Authority WRF	San Elijo Joint Powers Authority	Planned	580	580	Agriculture	Final Design
San Elijo Joint Powers Authority WRF	San Elijo Joint Powers Authority	Planned	2,200	2,200	Landscape	Final Design
San Elijo Joint Powers Authority	Santa Fe Irrigation District	Planned	100	100	Agriculture	Final Design
San Elijo Joint Powers Authority	Santa Fe Irrigation District	Planned	700	700	Landscape	Final Design
Lower Sweetwater River Demineralization Project	Sweetwater Authority	Planned	4,000	0	Seawater Intrusion Barrier	Final Design
Dove Canyon Weather Recovery System	Trabuco Canyon Water District	Planned	100	0	Landscape	Feasibility Study
Central Valley Water Reclamation Facility	Valley Center Municipal Water District	Planned	700	0	Agriculture	Final Design
Central Valley Water Reclamation Facility	Valley Center Municipal Water District	Planned	250	0	Landscape	Final Design
Lower Moosa Canyon W.R.F.-Expansion	Valley Center Municipal Water District	Planned	820	0	Groundwater Recharge	Construction
Reclamation Distribution System	Ventura County Waterworks District #1	Planned	2,234	0	Agriculture	Preliminary Design
Reclamation Distribution System	Ventura County Waterworks District #1	Planned	3,351	0	Landscape	Preliminary Design
Alamitos Barrier Recycled Water Project	Water Replenishment District	Planned	6,000	6,000	Seawater Intrusion Barrier	Preliminary Design
Dominguez Gap Barrier Recycled Water Project	Water Replenishment District	Planned	2,600	2,600	Industrial	Preliminary Design
Dominguez Gap Barrier Recycled Water Project	Water Replenishment District	Planned	6,000	6,000	Seawater Intrusion Barrier	Preliminary Design
Montebello Forebay Advanced Treatment Plant	Water Replenishment District	Planned	10,000	10,000	Groundwater Recharge	Feasibility Study
West Basin Recycling Project-Phase 2	West Basin Municipal Water District	Planned	48,000	48,000	Industrial	Final Design
West Basin Recycling Project-Phase 2	West Basin Municipal Water District	Planned	27,000	27,000	Landscape	Final Design
West Basin Recycling Project-Phase 2	West Basin Municipal Water District	Planned	20,000	20,000	Seawater Intrusion Barrier	Final Design
West Los Angeles Extension	West Basin Municipal Water District	Planned	1,240	1,240	Industrial	Construction
West Los Angeles Extension	West Basin Municipal Water District	Planned	1,400	1,400	Landscape	Construction
March Air Force Base	Western Municipal Water District	Planned	200	0	Landscape	Construction

TABLE 3A-4

Planned Water Recycling for South Coast Region (continued)

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Vogel Property	Yucaipa Valley Water District	Planned	500	0	Agriculture	Feasibility Study
Vogel Property	Yucaipa Valley Water District	Planned	1,700	0	Landscape	Feasibility Study
Total			**639,378**	**527,360**		
Regional Groundwater Recharge Project	Chino Basin Municipal Water District	Conceptual	1,000	0	Groundwater Recharge	
Reclaimed Water Distribution System-Phase 2	Lakewood, City of	Conceptual	107	0	Landscape	
City of Escondido	Rincon del Diablo Municipal Water District	Conceptual	450	0	Landscape	
West Basin Municipal Water Recycling Plant	Torrance, City of Municipal Water District	Conceptual	10,000	0	Industrial	
West Basin Municipal Water Recycling Plant	Torrance, City of Municipal Water District	Conceptual	1,500	0	Landscape	
Walnut Valley WD R.W. Expansion Project	Walnut Valley Water District	Conceptual	800	0	Industrial	
Walnut Valley WD R.W. Expansion Project	Walnut Valley Water District	Conceptual	2,500	0	Landscape	
Shadow Ridge Reclamation-Phase 2	Buena Sanitation District	Conceptual	600	600	Landscape	
Los Alisos Water District Tertiary Upgrade Plant	Los Alisos Water District	Conceptual	3,000	3,000	Landscape	
Eastside Greenbelt	Los Angeles, City of (DWP)	Conceptual	1,500	1,500	Industrial	
West Valley Water Recycling Project	Los Angeles, City of (DWP)	Conceptual	2,400	2,400	Landscape	
SCRWTP-5MGD	Oceanside, City of	Conceptual	5,603	5,603	Landscape	
Water Reclamation Project-Phase 2	Otay Water District	Conceptual	4,550	4,550	Landscape	
Santa Monica Dry-Weather Runoff Reclamation Project	Santa Monica, City of	Conceptual	450	450	Landscape	
Connejo Creek Diversion Project	Thousand Oaks, City of	Conceptual	5,000	5,000	Seawater Intrusion Barrier	
Total			**39,460**	**23,103**		

TABLE 3A-5

Planned Water Recycling for Sacramento River Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Land Based Discharge	Beale Air Force Base	Planned	400	0	Other	Feasibility Study
Plumas Lake Wastewater Treatment & Reclamation	Olivehurst Public Utilities District	Planned	300	0	Environmental	Final Design
Plumas Lake Wastewater Treatment & Reclamation	Olivehurst Public Utilities District	Planned	300	0	Landscape	Final Design
Water Reclamation Plant-Phase 1	Sacramento Regional County Sanitation District	Planned	3,500	0	Landscape	Final Design
Water Reclamation Plant-Phase 1	Sacramento Regional County Sanitation District	Planned	1,500	0	Other	Final Design
Total			**6,000**	**0**		
BEAY-94-1002 Golf Course Expansion	Beale Air Force Base	Conceptual	150	0	Landscape	
Laundry Dept. Water Reuse	California State Prison-Solano	Conceptual	19	0	Industrial	
City of Lakeport Municipal Sewer District	Lakeport, City of	Conceptual	1,500	0	Agriculture	
City of Live Oak	Live Oak, City of	Conceptual	1	0	Landscape	
Total			**1,670**	**0**		

TABLE 3A-6

Planned Water Recycling for San Joaquin River Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Forest Meadows	Calaveras County Water District	Planned	170	0	Landscape	Preliminary Design
City of Ceres WWRF Expansion Project	Ceres, City of	Planned	4,480	0	Agriculture	Preliminary Design
Turlock Irrigation District Almond Power Plant	Ceres, City of	Planned	448	0	Other	Construction
Wastewater Reclamation Project	Groveland Community Services District	Planned	425	0	Agriculture	Preliminary Design
California Youth Soccer Association	Lodi, City of	Planned	1,100	0	Landscape	Preliminary Design
Effluent Pipeline	Sierra Conservation Center	Planned	170	0	Agriculture	Preliminary Design
Effluent Pipeline	Sierra Conservation Center	Planned	100	0	Landscape	Preliminary Design
Total			**6,893**	**0**		
Title 22 Plant	Angels Camp, City of	Conceptual	50	0	Agriculture	
Title 22 Plant	Angels Camp, City of	Conceptual	150	0	Environmental	
Title 22 Plant	Angels Camp, City of	Conceptual	400	0	Landscape	
Copper Cove	Calaveras County Water District	Conceptual	300	0	Landscape	
City of Galt WWTP	Galt, City of	Conceptual	340	0	Agriculture	
Modesto Reclamation Project	Modesto, City of	Conceptual	5	0	Landscape	
Modesto Reclamation Project	Modesto, City of	Conceptual	15	0	Other	
Uncertain	Stockton, City of	Conceptual	60,000	0	Groundwater Recharge	
Ag Reuse	Turlock, City of	Conceptual	5,000	0	Agriculture	
Total			**66,260**	**0**		

TABLE 3A-7

Planned Water Recycling for Tulare Lake Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Wastewater Reclamation Phase 1	Dinuba, City of	Planned	11,202	0	Groundwater Recharge	Preliminary Design
Filtration/Disinfection Conjuctive Use Project	Malaga Community Water District	Planned	392	0	Other	Preliminary Design
Airport Golf Course/Open Areas Rec.	Porterville, City of	Planned	6,017	0	Agriculture	Preliminary Design
Airport Golf Course/Open Areas Rec.	Porterville, City of	Planned	2,580	0	Groundwater Recharge	Preliminary Design
Airport Golf Course/Open Areas Rec.	Porterville, City of	Planned	365	0	Landscape	Preliminary Design
Reclaimed Waste Water	U.S. Navy	Planned	4,000	0	Agriculture	Final Design
Total			**24,556**	**0**		

TABLE 3A-8

Planned Water Recycling for North Lahontan Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
No projects reported.	-	-	-	-	-	-

TABLE 3A-9

Planned Water Recycling for South Lahontan Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
MCWD Recycled Water District	Mammoth Comm. Water District	Planned	1,000	0	Environmental	Preliminary Design
MCWD Recycled Water District	Mammoth Comm. Water District	Planned	500	0	Groundwater Recharge	Preliminary Design
MCWD Recycled Water District	Mammoth Comm. Water District	Planned	100	0	Industrial	Preliminary Design
MCWD Recycled Water District	Mammoth Comm. Water District	Planned	600	0	Landscape	Preliminary Design
MCWD Recycled Water District	Mammoth Comm. Water District	Planned	300	0	Other	Preliminary Design
Effluent Re-use	Running Springs Water District	Planned	250	0	Other	Preliminary Design
Total			**2,750**	**0**		
Golf Course	Barstow, City of	Conceptual	5,289	0	Landscape	
Total			**5,289**	**0**		

TABLE 3A-10

Planned Water Recycling for Colorado River Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Hi-Desert W.D. W.W. Collection & Treatment Plant	Hi-Desert Water District	Conceptual	975	0	Groundwater Recharge	
Hi-Desert W.D. W.W. Collection & Treatment Plant	Hi-Desert Water District	Conceptual	350	0	Landscape	
Total			**1,325**	**0**		

4

Urban, Agricultural, and Environmental Water Use

This chapter describes present and forecasted urban, agricultural, and environmental water use. The chapter is organized into three major sections, one for each category of water use.

Water use information is presented at the hydrologic region level of detail under normalized hydrologic conditions. Forecasted 2020-level urban and agricultural water use have not changed greatly since publication of Bulletin 160-93. Forecasted urban water use depends heavily on population forecasts. Although the DOF has updated its California population projections since the last Bulletin, U.S. census data are an important foundation for the projections, and a new census will not be performed until 2000. The Department's forecasts of agricultural water use change relatively slowly in the short-term because the corresponding changes in forecasted agricultural acreage are a small percentage of the State's total irrigated acreage. Changes in base year and forecasted environmental water use from the last Bulletin reflect implementation of SWRCB's Order WR 95-6 for the Bay-Delta.

Nursery products are California's third largest farm product in gross value. The nursery industry is affected by the availability of both agricultural and urban water supplies.

Summary of Key Statistics

Shown below for quick reference are some key statistics presented in this chapter. Water use information values shown are for applied water use in average water year conditions. The details behind the statistics are discussed later.

	1995	*2020*	*Change*
Population (million)	32.1	47.5	+15.4
Irrigated crops (million acres)	9.5	9.2	-0.3
Urban water use (maf)	8.8	12.0	+3.2
Agricultural water use (maf)	33.8	31.5	-2.3
Environmental water use (maf)	36.9	37.0	+0.1
Percent of total			
Urban water use (%)	11	15	+4
Agricultural water use (%)	43	39	-4
Environmental water use (%)	46	46	0

Water Use Calculation

The urban, agricultural, and environmental water uses calculated in this chapter are combined with water supply information (Chapter 3) to form statewide balances (Chapter 6) and regional balances (Chapters 7-9). As noted in the Chapter 3 discussion of water supplies, Bulletin 160-98 water balances are computed with applied water data, instead of the net water data used in previous editions of the Bulletin.

Figure 4-1 shows statewide water use in terms of applied water and depletions. The two methods provide similar results at a statewide level. (The large depletion associated with environmental water use reflects the magnitude of wild and scenic river outflow to the Pacific Ocean, as discussed later in the chapter.)

For purposes of presentation in the Bulletin, urban, agricultural, and environmental water uses are treated separately. In reality, these uses are usually linked by California's hydrologic system. As discussed in Chapter 3, the return flow from one water user often becomes the supply for a downstream user. The applied water budgets used in Bulletin 160-98 reflect the multiple uses of water in a river basin. Water supplies in a river basin may count toward meeting wild and scenic river use in the Sierra Nevada foothills, count toward urban and/or agricultural uses on the Central Valley floor, and count toward meeting Bay-Delta outflow farther downstream.

Another change from Bulletin 160-93 was eliminating the "other" water use category to simplify information presentation. This category included major canal conveyance losses, recreation use, cooling water use, energy recovery use, and use by high water using industries. Water uses previously categorized as "other" are now included in urban, agricultural, or environmental water use, according to their intended purpose. At a statewide level, the magnitude of these other uses is small in comparison to that of the major categories.

Land Use Considerations

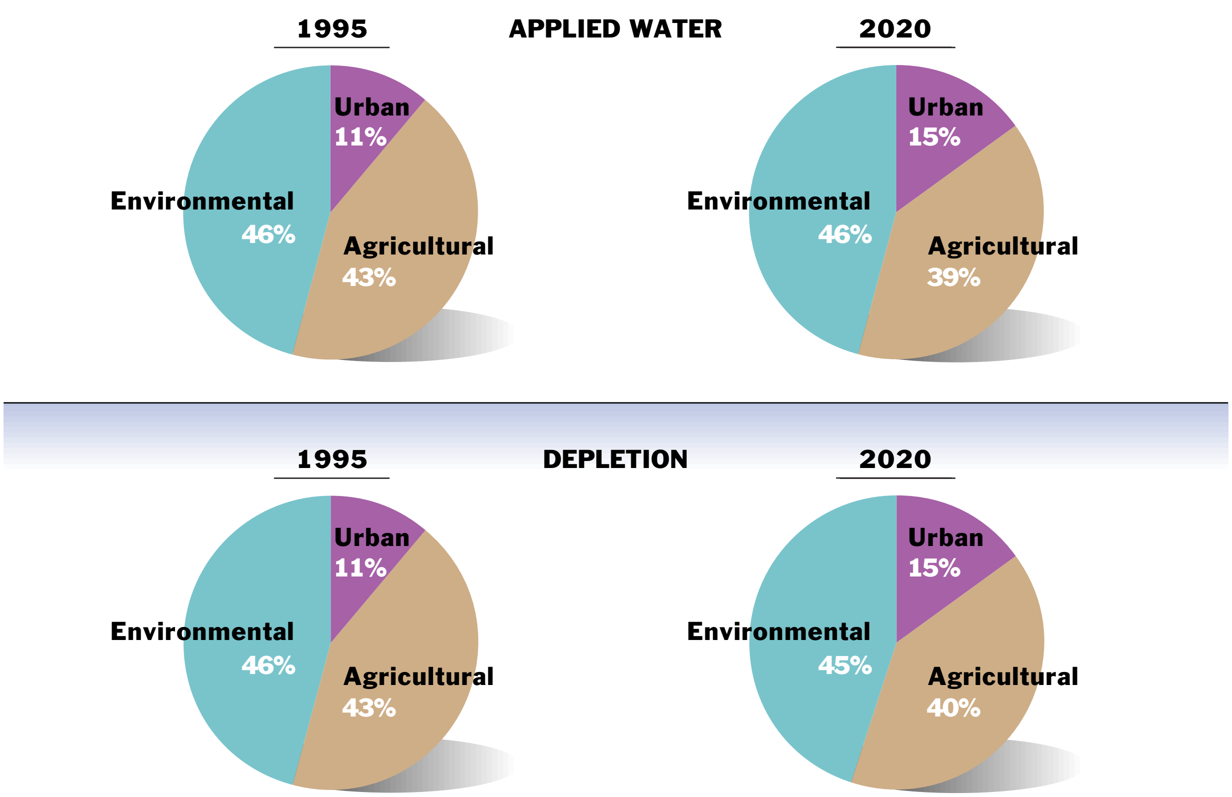
It is important to understand how urban, agricultural, and environmental water use are shaped by land use patterns and land use planning. Patterns of future development and water use trends are dictated by city and county land use planning decisions. Urbanization of agricultural lands, open space preservation, habitat creation, and wetlands preservation policies are examples of land use-related decisions that have water use implications.

DOF forecasts that California's population will increase by more than 15 million people by 2020. Where these additional people live affects statewide urban water use. For example, in terms of percent population increase, DOF forecasts that the City and County of San Francisco will have one of the slowest growth rates statewide. Adjoining Bay Area counties are also forecasted to grow slowly, reflecting the region's intensive urbanization and relatively small amounts of remaining undeveloped land. Areas expected to experience high growth rates include some San Joaquin Valley counties and the Inland Empire region in South-

Future land use patterns are important in forecasting future water use. How and where presently undeveloped lands are developed—or are preserved from development—affects water use calculations.

FIGURE 4-1

California Applied Water Use and Depletion



ern California. This population shift to warmer, drier inland areas where urban outdoor water use is higher affects future statewide water demands.

The location of urban development also affects agricultural water use. For example, subdivisions constructed on non-irrigated grazing lands do not directly displace agricultural use (although they may compete with existing agricultural water users for a supply). Subdivisions constructed on irrigated farmland result in direct conversion of water use from agricultural to urban. Bulletin 160-98 forecasts a statewide decline in irrigated acreage by 2020. Most of that decline is the result of expected urbanization of irrigated agricultural lands, especially in the San Joaquin Valley and South Coast areas. (To some extent, urbanization may shift agricultural development to presently undeveloped lands, but such lands are usually of lower quality and can economically support only limited crop types.) Local open space preservation goals can affect the extent of land use conversion. Williamson Act contracts are a commonly used means of encouraging preservation of agricultural land use, especially for agricultural lands near urban areas. Not all open space preservation goals affect water use. For example, some land use planning agencies in urban areas have set aside ridgetop areas as lands to be managed for recreation or open space to preserve viewsheds. If the areas set aside are non-irrigated grazing lands, water use impacts are minimal.

Policies to preserve and enhance wetlands can entail creating new wetlands or providing increased water supplies to existing wetlands, thus increasing environmental water use, often by conversion of agricultural water supplies. Programs creating new wildlife habitat areas would entail conversion of agricultural lands and water supplies to environmental uses.

Urban Water Use

Forecasts of urban water use for the Bulletin are based on population information and per capita water use estimates, as described later in this section. Factors influencing per capita water use include expected demand reduction due to implementation of water conservation programs. The Department has modeled effects of conservation measures and socioeconomic changes on per capita use in 20 major water service areas to estimate future changes in per capita use by hydrologic region.

The Department's Bulletin 160 series makes per capita water use estimates at a statewide level of detail. An urban water agency making estimates for its own service area would be able to incorporate more complexity in its forecasting because the scope of its effort is narrow. For this reason, and because DOF population projections seldom exactly match population projections prepared by cities and counties, the Bulletin's water use forecasts are expected to be representative of, rather than identical to, those of local water agencies.

Population Growth

Data about California's population—its geographic distribution and projections of future population and their distribution—come from several sources. The Department works with base year and projected year population information developed by DOF for each county in the State. The decadal census is a major benchmark for population projections. DOF works from census data to calculate the State's population in noncensus years, and to project future populations. Figure 4-2 shows DOF's projected growth rates by county for year 2020. (State policy requires that all State agencies use DOF population projections for planning, funding, and policy making activities.)

DOF uses as its starting population the 1990 census, modified by the Bureau of the Census for known misreporting. (These counts represent a modification to the age distribution of the census count and not an adjustment for undercount to the total.) Between 1950 and 1980 the birthrate in California mirrored the nation's. A sharp divergence began during the 1980s; the nation's birthrate was flat while the birthrate in California rose sharply.

California's annual growth rate was 2 to 3 percent throughout the 1980s. After 1990, the rate slowed to 1.3 percent and the State's population grew by only 2 million, for a 1995 population of 32.1 million. California's growth since 1992 has also been affected by lower than projected natural increase (births minus deaths) and net migration. Domestic migration patterns tend to parallel the unemployment differential rate between California and other states. Between 1990 and 1994, California lost more than 700,000 jobs due to the economic recession. This job loss resulted in a new demographic phenomenon for California—a net migration of California residents to other states. By 1996, California had replaced the jobs lost during the recession.

Migration is the most volatile component of

FIGURE 4-2

Projected Growth Rates by County, 1995-2020

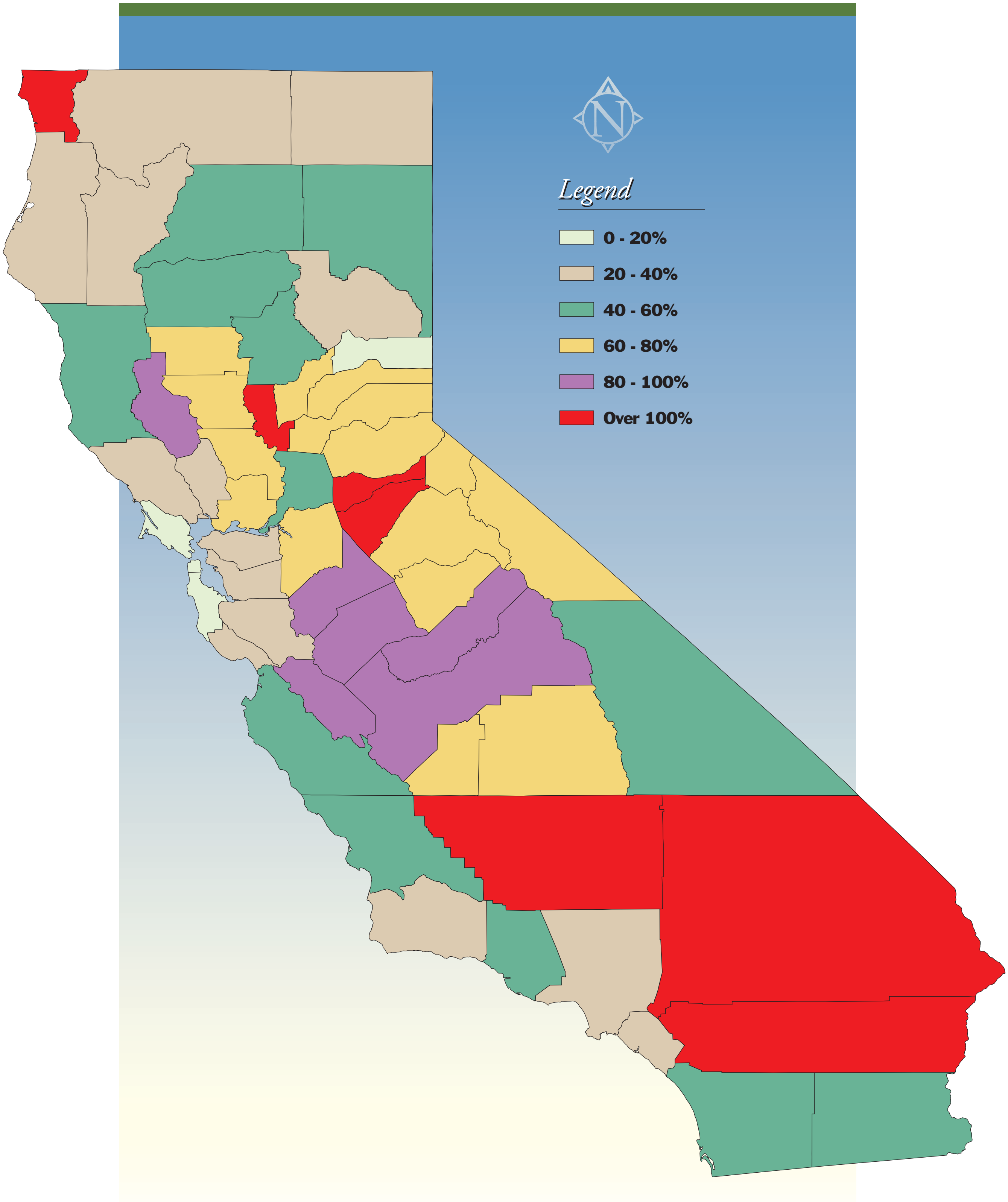
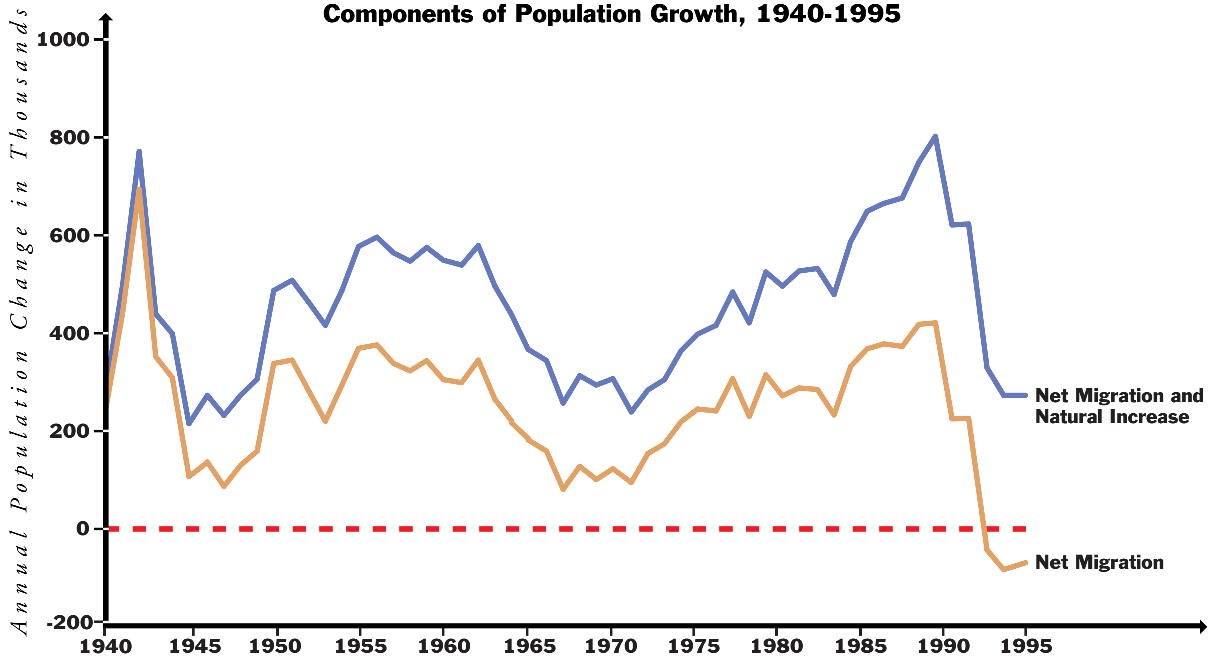


FIGURE 4-3

Components of Population Growth, 1940-1995



Urban water demand forecasts are driven by the expected increase in California's population—more than 15 million new residents by 2020. Multipurpose reservoirs help meet needs for water-based recreational opportunities, especially in arid Southern California.

population change. Migrants are separated into two categories: domestic (from other states) or foreign (from other countries). Since 1980, approximately 30 percent of net migration has been domestic and 70 percent foreign. DOF attributes fluctuations in migration primarily to domestic migration, since undocumented migration has been fairly constant and legal foreign migration has slowly increased. Figure 4-3 shows natural increase and net migration for the years 1940-95.

DOF uses a baseline cohort-component method to project population by gender, race/ethnicity, and age. A baseline projection assumes people have the right to migrate where they choose and no major natural catastrophes or wars will occur. A cohort-component method traces people born in a given year throughout their lives. As each year passes, cohorts change due to mortality and migration assumptions. New cohorts are formed by applying birthrate assumptions to women of childbearing age. Special populations display different demographic behavior and other characteristics and must be projected separately. The primary sources of special populations are prisons, colleges, and military installations.

Population projections used in Bulletin 160-98 are based on DOF's *Interim County Population Projections (April 1997)*. Table 4-1 shows the 1995 through 2020 population figures for Bulletin 160-98 by hydrologic

TABLE 4-1

California Population by Hydrologic Region (in thousands)

Region	*1995*	*2020*
North Coast	606	835
San Francisco Bay	5,780	7,025
Central Coast	1,347	1,946
South Coast	17,299	24,327
Sacramento River	2,372	3,813
San Joaquin River	1,592	3,025
Tulare Lake	1,738	3,296
North Lahontan	84	125
South Lahontan	713	2,019
Colorado River	533	1,096
Total (rounded)	**32,060**	**47,510**

region. DOF periodically updates its population forecasts to respond to changing conditions. Its 2020 population forecast used for Bulletin 160-93 was 1.4 million higher than the 2020 forecast used in Bulletin 160-98. The latter forecast incorporated the effects of the recession of the early 1990s. Small fluctuations in the forecast do not obscure the overall trend—an increase in population on the order of 50 percent.

The Department apportioned county population data to Bulletin 160 study areas based on watershed or water district boundaries. Factors considered in distributing the data to Bulletin 160 study areas included population projections prepared by cities, counties, and local councils of governments, which typically incorporate expected future development from city and county general plans. The local agency projections indicate which areas within a county are expected to experience growth and provide guidance in allocating DOF's projection for an entire county into smaller Bulletin 160 study areas. Table 4-2 compares DOF interim projections with councils of governments projections.

Factors Affecting Urban Per Capita Water Use

Urban per capita water use includes residential, commercial, industrial, and institutional uses of water. Each of these categories can be examined at a greater level of detail. Residential water use, for example, includes interior and exterior (e.g., landscaping) water use. Forecasts of urban water use for an individual community may be separated into components and forecasted individually. It is not possible to use this level of detail for each community in the State in Bulletin 160-98. Bulletin 160-98 modeled components of urban use for representative urban water agencies in each of the State's ten hydrologic regions and extrapolated those results to the remainder of each hydrologic region, as described later in the chapter.

Demand reduction achieved by implementing water conservation measures is important in forecasting per capita water use. Bulletin 160-98 incorporates demand reductions from implementation of urban best management practices contained in the 1991 *Memorandum of Understanding Regarding Urban Water Conservation in California.* Bulletin 160-98 assumes implementation of the urban MOU's BMPs by 2020, resulting in a demand reduction of about 1.5 maf over the year 2020 demand forecast without BMP implementation. The following subsections detail existing urban water conservation programs and estimated demand reductions. For simplicity of presentation, conservation plans required of USBR water contractors are described in the agricultural water conservation section, since agricultural water supply comprises the majority of CVP water contracts. USBR's urban water contractors are also required to comply with these requirements.

The relationship of water pricing to water consumption, and the role of pricing in achieving water conservation, has been a subject of discussion in recent years. Elected board members of public water

TABLE 4-2

Comparison Between Department of Finance and Councils of Governments Population Projections (in thousands)

	1990 Census	*2010 Projections*[a]	
		DOF	*COG*
Southern California Counties	17,139	23,352	24,038
Bay Area Counties	6,020	7,489	7,540
Central Coast Counties	1,172	1,508	1,518
Greater Sacramento Counties	1,684	2,542	2,586
San Joaquin Valley Counties	2,742	4,608	4,641

[a] COG data were only available for 2010, thus 2010 COG forecasts are compared with DOF 2010 forecasts.

Landscape Water Use

The Model Water Efficient Landscape Ordinance was added to Title 23 of the California Code of Regulations in response to requirements of the 1990 Water Conservation in Landscaping Act. Local agencies that did not adopt their own ordinances by January 1993 were required to begin enforcement of the model ordinance as of that date.

The model ordinance applies to all new and rehabilitated landscaping (more than 2,500 square feet in size) for public agency projects and private development projects that require a local agency permit, and to developer-installed landscaping for single-family and multifamily residential projects. The purpose of the ordinance was to promote water efficient landscape design, installation, and maintenance. The general approach of the ordinance was to use 0.8 ET_0 as a water use goal for new and renovated landscapes. (ET_0 is a reference evapotranspiration, established according to specific criteria.) Tools to help meet that goal include proper landscape and irrigation system design.

To date, there has been no statewide-level review of how cities and counties are implementing this requirement; thus, its water savings potential remains to be quantified.

agencies ultimately have the responsibility for balancing desires to achieve demand reduction through water pricing with desires to provide affordable water rates to consumers. Urban water rates in California vary widely and are affected by factors such as geographic location, source of supply, and type of water treatment provided. Water rates are set by local agencies to recover costs of providing water service and are highly site-specific. Appendix 4A provides background information on urban water pricing. As described in the appendix's summary of price elasticity studies for urban water use, residential water demand is inelastic in most cases—water users were relatively insensitive to changes in price, for the price ranges evaluated. Water price plays a small role in relation to other factors affecting water use, such as public education and plumbing retrofit programs.

Urban Water Conservation Actions. State and federal legislation imposed standards to improve the water use efficiency of plumbing fixtures, requiring that fixtures manufactured, sold, or installed after specified dates meet the targets shown in Table 4-3. These requirements apply to new construction or to retrofitting existing plumbing fixtures, but do not require removal and replacement of existing fixtures. One water conservation action being taken by urban water agencies is to sponsor programs for voluntary retrofitting of fixtures, to accelerate demand reductions. (This action is one of the BMPs included in the urban MOU.) Some water purveyors, such as the City and County of San Francisco, have regulations requiring retrofit when homes are sold.

More than 200 urban water suppliers have signed the urban MOU and are now members of the California Urban Water Conservation Council. Some key points from the MOU are highlighted in the sidebar. Water suppliers signing the urban MOU committed to implement BMPs unless a cost-benefit analysis conducted according to CUWCC guidelines showed individual BMPs not to be cost-effective, or unless there was a legal barrier to implementation. The MOU also committed CUWCC to study measures that could be added as new BMPs, such as establishing efficiency standards for water-using appliances.

The urban use forecasts in Bulletin 160-98 assume that water users statewide will implement BMPs by 2020, as set forth in Exhibit 1 of the MOU, whether or not the BMPs are cost-effective from a water supply standpoint. In making this assumption, the Bulletin recognizes that water conservation measures have potential benefits in addition to water supply, such as reduced water and wastewater treatment costs, other water quality improvements, reduced entrainment of fish at urban points of diversion, and greater control of temperature and timing of wastewater discharges. The Department believes this assumption is reasonable, given that funding sources for non-water supply benefits could help support BMP implementation, and that the planning horizon over which the Bulletin assumes that BMPs would be implemented (from 1995 to 2020) provides more time for implementation than does the MOU. The widespread acceptance that the existing BMPs have achieved, as evidenced by the number of MOU signatories, indicates that the BMPs are generally considered to be technologically feasible, so technology should not be a limiting factor in implementation.

Quantifying demand reduction from implementation of some BMPs is difficult (for example, public information programs and water education in schools). These actions contribute to implementation of other BMPs, such as demand reduction from installing water meters, but do not by themselves save quantifiable amounts of water. CUWCC reviewed implementation

TABLE 4-3

Summary of California and Federal Plumbing Fixture Requirements

Plumbing Device	*California (covers sale and installation)*	*Effective Date*	*Energy Policy Act of 1992 (covers only manufacture)*
Showerheads	2.5 gpm	CA 3/20/92 US 1/1/94	 2.5 gpm
Lavatory Faucets[a]	2.75 gpm 2.2 gpm	CA 12/22/78 CA 3/20/92 US 1/1/94	 2.5 gpm
Sink Faucets[a]	2.2 gpm	CA 3/20/92 US 1/1/94	 2.5 gpm
Metering (self-closing) Faucets[b] (public restrooms)	hot water maximum flow rates range from 0.25 to 0.75 gallons/ cycle and/or from 0.5 gpm to 2.5 gpm, depending on controls and hot water system	CA 7/1/92 US 1/1/94	 0.25 gallons/cycle (maximum water delivery per cycle)
Tub Spout Diverter[a]	0.1 (new), to 0.3 gpm (after 15,000 cycles of diverting)	CA 3/20/92	(does not appear to be included in EPA)
Toilets (residential)	1.6 gpf	CA 1/1/92 (new construction) CA 1/1/94 (all toilets for sale or installation) US 1/1/94 (non-commercial)	 1.6 gpf
Flushometer valves[a]	1.6 gpf	CA 1/1/92 (new construction) CA 1/1/94 (all toilets) US 1/1/94 (commercial) US 1/1/97 (commercial)	 3.5 gpf 1.6 gpf
Toilets (Commercial)[a]	1.6 gpf	CA 1/1/94 (all toilets for sale or installation) US 1/1/97	 1.6 gpf
Urinals	1.0 gpf	CA 1/1/92 (new) CA 1/1/94 (all) US 1/1/94	 1.0 gpf

[a] California requirements are preexisting and more stringent than federal law; therefore California requirements prevail in California.
[b] Federal law is more stringent than California requirements.

Local agencies were required by the 1990 Water Conservation in Landscaping Act to enforce ordinances intended to promote water-efficient designs. The act's requirements apply to landscapes greater than 2,500 sq. ft. in size.

and quantification of the initial BMPs, and developed a strategic plan in 1996 that included evaluating the BMPs and revising them to make them easier to quantify. The revised BMPs (see sidebar) were adopted by CUWCC in September 1997. The revisions included restructuring the original 16 BMPs to 14 BMPs (new BMPs were also added—rebate programs for high efficiency washing machines and wholesale water agency assistance to retail water agencies), revising implementation schedules and coverage requirements, and adding new evaluation criteria. Implementation of some BMPs was extended beyond the original 10-year term of the existing MOU. Appendix 4B presents a synopsis of the revisions.

Urban Best Management Practices (1997 Revision)

BMP 1	Water Audit Programs for Single-Family Residential and Multifamily Residential Customers
BMP 2	Residential Plumbing Retrofit
BMP 3	System Water Audits, Leak Detection and Repair
BMP 4	Metering With Commodity Rates for All New Connections and Retrofit of Existing Connections
BMP 5	Large Landscape Conservation Programs and Incentives
BMP 6	High-Efficiency Washing Machine Rebate Programs (New)
BMP 7	Public Information Programs
BMP 8	School Education Programs
BMP 9	Conservation Programs for Commercial, Industrial, and Institutional Accounts
BMP 10	Wholesale Agency Assistance Programs (New)
BMP 11	Conservation Pricing
BMP 12	Conservation Coordinator (Formerly BMP 14)
BMP 13	Water Waste Prohibition
BMP 14	Residential ULFT Replacement Programs (Formerly BMP 16)

Highlights of the Urban MOU

Shown below are several excerpts from the urban MOU that are relevant to the water conservation measures discussed in Chapters 4 and 6.

Recital F *It is the intent of this MOU that individual signatory water suppliers (1) develop comprehensive conservation BMP programs using sound economic criteria and (2) consider water conservation on an equal basis with other water management options.*

Recital G *It is recognized that present urban water use throughout the State varies according to many factors including, but not limited to, climate, types of housing and landscaping, amounts and kinds of commercial, industrial and recreational development, and the extent to which conservation measures have already been implemented. It is further recognized that many of the BMPs identified in Exhibit 1 to this MOU have already been implemented in some areas and that even with broader employment of BMPs, future urban water use will continue to vary from area to area. Therefore, this MOU is not intended to establish uniform per capita water use allotments throughout the urban areas of the State. This MOU is also not intended to limit the amount or types of conservation a water supplier can pursue or to limit a water supplier's more rapid implementation of BMPs.*

Section 4.1 (c) *Assumptions for use in developing estimates of reliable savings from the implementation of BMPs. Estimates of reliable savings are the water conservation savings which can be achieved with a high degree of confidence in a given service area. The estimate of reliable savings for each BMP depends upon the nature of the BMP and upon the amount of data available to evaluate potential savings. For some BMPs (e.g., public information) estimates of reliable savings may never be generated. For others, additional data may lead to significant changes in the estimate of reliable savings. It is probable that average savings achieved by water suppliers will exceed the estimates of reliable savings.*

Section 4.5 *Exemptions. A signatory water supplier will be exempt from the implementation of specific BMPs for as long as the supplier substantiates each reporting period that, based upon then prevailing local conditions, one or more of the following findings applies: (a) A full cost-benefit analysis, performed in accordance with the principles set forth in Exhibit 3, demonstrates that either the program (i) would not be cost-effective overall when total program benefits and costs are considered; OR (ii) would not be cost-effective to the individual water supplier even after the water supplier has made a good faith effort to share costs with other program beneficiaries.*

(b) Adequate funds are not and cannot reasonably be made available from sources accessible to the water supplier including funds from other entities. However, this exemption cannot be used if a new, less cost-effective water management option would be implemented instead of the BMP for which the water supplier is seeking this exemption.

(c) Implementation of the BMP is (i) not within the legal authority of the water supplier; and (ii) the water supplier has made a good faith effort to work with other entities that have the legal authority to carry out the BMP; and (iii) the water supplier has made a good faith effort to work with other relevant entities to encourage the removal of institutional barriers to the implementation of BMPs within its service area.

Bulletin 160-98 estimates water savings due to BMP implementation based on the assumptions set forth in Exhibit 1 of the urban MOU, and assumes that California will achieve a level of water conservation equivalent to that expected from full BMP implementation by 2020. The MOU specifies implementation schedules, water use reduction factors, and installation and/or compliance rates that allow quantification of water savings for 7 of the 14 BMPs. The MOU identifies the remaining BMPs as not having quantifiable water savings. The Bulletin's estimated water savings (Appendix 4B) are based on evaluation of the following BMPs in accordance with the Exhibit 1 provisions: residential water use surveys, residential plumbing retrofits, distribution system water audits/leak detection/repairs, metering with commodity rates, programs for commercial/industrial/institutional accounts, and residential ultra-low flush toilet replacement. Water savings for the BMP on large landscape water conservation (3 acres or greater) could not be evaluated due to lack of data on existing irrigated landscape acreage.

BMP implementation is estimated to result in a statewide 2020 demand reduction of 1.5 maf statewide. As discussed in Chapter 6, this demand reduction is not the same as creating new water supply. Only conservation actions that reduce irrecoverable losses or reduce depletions actually create new water supply from a statewide perspective. Table 4-4 shows applied water and depletion reductions due to BMP implementation by hydrologic region.

As more water conservation measures are implemented, especially structural changes such as plumbing retrofits, it will become increasingly difficult for urban water agencies and their customers to achieve drought year demand reductions. Demand hardening is discussed in more detail in Chapter 6. The urban MOU acknowledges that demand hardening will be a

TABLE 4-4

Annual Reductions in Applied Water and Depletions Due to BMP Implementation by 2020 (taf)

Region	*Applied Water*	*Depletion*
North Coast	20	11
San Francisco Bay	176	172
Central Coast	48	30
South Coast	768	500
Sacramento River	91	0
San Joaquin River	111	30
Tulare Lake	125	50
North Lahontan	5	2
South Lahontan	59	21
Colorado River	111	52
Total	**1,514**	**868**

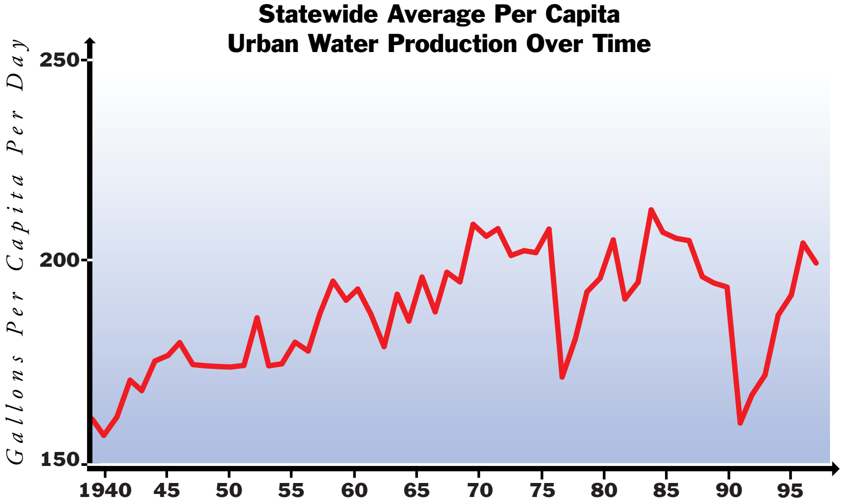
consequence of BMP implementation.

Although there are other urban water conservation programs besides those associated with the urban MOU, only the MOU presently addresses quantification of water savings. EPA has started developing water conservation guidelines pursuant to Section 1455 of the 1996 SDWA. USBR has developed guidelines for Reclamation Reform Act water conservation plans and for the more detailed conservation plans required by CVPIA. The USBR conservation plans apply to both urban and agricultural contractors, and are described in more detail in a later section on agricultural water conservation.

Effects of Droughts on Urban Water Production. To illustrate the effects of droughts, Figure 4-4 shows statewide per capita urban water production over time. (Per capita production is the water provided by urban suppliers, divided by population. Urban water production is not the same as total urban water use; total use includes self-produced supplies, water for recreation and energy production uses, and losses from major conveyance facilities.) After the severe, but brief, 1976-77 drought, statewide urban per capita water production rates returned to pre-drought levels within 3 to 4 years. During the longer 1987-92 drought, urban per capita water production rates declined by about 19 percent on the average statewide. (Most requirements for water-conserving plumbing fixtures did not take effect until after the 1987-92 drought.) The Department's data show increases in per capita water production following the drought, due to removal of mandatory water rationing and other short-term restrictions. When viewed at a statewide level, the data show a strong response to hydrologic conditions.

FIGURE 4-4

Statewide Average Per Capita Urban Water Production Over Time



Urban Water Use Planning Activities

The Department has surveyed retail water agencies and analyzed their water production data for more than 35 years, publishing the data in the Bulletin 166 series, *Urban Water Use in California.* Bulletin 166-4, published in 1994, summarized monthly urban water production data from 1980-90 for nearly 300 retail water purveyors throughout the State. This water use information, updated in the Department's annual surveys, is a primary data source for water use estimates made for Bulletin 160. The Department also conducted a statewide survey of industrial water use by water-using sector in 1994. Industrial water use information is periodically published in the Department's Bulletin 124 series, *Industrial Water Use in California.*

The Urban Water Management Planning Act requires that urban water suppliers with 3,000 or more connections, or that deliver over 3 taf of water per year, prepare urban water management plans and submit them to the Department. The initial set of plans was due in 1985; plans are to be updated every five years. Table 4-5 shows the number of agencies affected by the law and those submitting their 1995 plans as of March 1997. The 1995 plans received were from agencies representing almost 90 percent of all urban water deliveries. These plans have multiple purposes, including demonstrating how local agencies

TABLE 4-5
1995 Urban Water Management Plans by Hydrologic Region

Region	*Expected*	*Filed*
North Coast	13	10
San Francisco Bay	60	46
Central Coast	28	17
South Coast	187	152
Sacramento River	35	33
San Joaquin River	29	12
Tulare Lake	22	13
North Lahontan	5	2
South Lahontan	12	11
Colorado River	13	6
Total	**404**	**302**

propose to implement water conservation measures and how the agencies plan to meet drought year water supply reliability goals.

The CALFED Bay-Delta program includes water use efficiency—urban, agricultural, and environmental—as one of the common elements required for all proposed Delta alternatives. As described in the water use efficiency technical appendix for the March 1998 draft programmatic EIR/EIS, potential elements of an urban water use efficiency program include:

- Requirements that urban water management plans be implemented more vigorously and that the Department review and certify those plans.
- Revisions to the BMPs to make them more quantifiable.
- Requirements that CUWCC certify BMP implementation.
- Provision of financial and technical assistance to water agencies to encourage program implementation.

CALFED is also examining ways to require that the urban water use efficiency program be implemented vigorously. For example, urban water agencies that choose not to implement the program could be excluded from participation in water transfers requiring approval by a CALFED agency, from use of facilities operated by a CALFED agency, from new supplies made available by a CALFED actions, or from participating in certain loan and grant programs. In addition, CALFED has suggested that SWRCB could be asked to pursue its obligations to investigate waste and unreasonable use more vigorously. Methods to achieve assurances remain under discussion. Depending on the methods chosen, amendments to existing statutes or execution of new agreements would be needed. Quantification of CALFED's future water use efficiency program is discussed in Chapter 6.

Urban Water Use Forecasting

Urban water use forecasting relates future use to changes in factors influencing water use. Early forecasting methods were relatively simple and relied only on service area population to explain water use, assuming a direct relationship between population growth and applied water demand. These methods can provide acceptable results over the short term, especially during periods of abundant water supply and steady economic growth. However, mid- to long-term forecast accuracy may decrease sharply due to changes in other variables influencing water use. Among these factors are changes in the ratio of single to multifamily dwellings, commercial and industrial growth, income, future water conservation actions, and water pricing. The price of water currently plays a small role in water use; it could become more important if water prices increased substantially. The water price elasticity section in Appendix 4A provides more detail on this subject. New urban water supplies will be relatively expensive, so understanding interactions between price and water use is important for forecasting urban use. As described in the appendix, the Department's forecast used single family residential price elasticities of -0.1 for winter months and -0.2 for summer months.

The Department forecasted change in per capita water use in each hydrologic region to estimate 2020 urban applied water by hydrologic region. Variables included population, income, economic activity, water price, and conservation measures (implementation of urban BMPs and changes to State and federal plumbing fixture standards). The general forecasting procedure was to determine 1995 base per capita water use, estimate the effects of conservation measures and socioeconomic change on future use for 20 major representative water service areas in California, and calculate 2020 base per capita water use by hydrologic region from the results of service area forecasts.

1995 Base Per Capita Water Use. The 1995 base per capita water use includes water supplied by public water systems for municipal and industrial purposes and self-produced (not delivered by a water purveyor) surface water and groundwater. Per capita water use is not the same as the applied water use shown in Bulletin 160 water budgets. Per capita use does not include recreation water use, energy production water use, and losses from major conveyance facilities (the urban share of the "other" water demand category used in Bulletin 160-93). In most hydrologic regions, 1995 base per capita water use was calculated for each of the Department's DAUs. In the South Lahontan and Colorado River regions, analyses were done at the PSA level due to the relatively sparse populations in those regions.

The 1995 base per capita water use was computed from normalized water use data to account for variation in annual weather patterns, water supply, and residual effects of the 1987-92 drought. Appendix 4C discusses the relationship between normalized data and actual urban water production data. Actual urban water use during 1995 was less than the Bulletin 160-98 base level in many areas, largely due to wet hydrologic conditions that decreased landscape irrigation requirements. (Likewise, urban water use during a dry year would likely exceed base year use due to higher landscape irrigation water use, assuming no constraints on water supplies). Base per capita 1995 water use was developed from historical water use during recent years with normal water supply and water use patterns. Data for years during and immediately following the drought were removed from consideration due to the effects of water shortages of unprecedented severity and duration, mandatory and voluntary rationing programs, and a multi-year post-drought rebound in per capita water use on water use patterns. The 1995 base was computed from the 1990 per capita use in Bulletin 160-93, adjusted to account for permanent effects of urban BMPs and post-1990 changes to federal and State plumbing fixture standards. The most significant post-1990 change to the plumbing fixture standards was that all toilets for sale or installation in California must use no more than 1.6 gallons per flush, compared to 3.5 gallons or more per flush for older toilets. Plumbing code effects were quantified based on the proportion of total housing stock subject to the new code. ULFT retrofit water savings were estimated based on information on toilet retrofit programs from local water agencies. The final 1995 base value for each DAU was weighted by population to yield 1995 base per capita water use by hydrologic region.

2020 Per Capita Water Use Forecast. Forecasts for the urban water use study were based on three types of input data: actual values of base year water and socioeconomic variables, forecasted values of socioeconomic variables for the year 2020, and savings assumptions for BMPs. Table 4-6 lists the input variables specified for each water service area. Table 4-7 shows data sources for the study.

TABLE 4-6

Urban Water Use Study Input Variables

Water Use
Water use by sector, base year
Single family
Multifamily
Commercial
Industrial
Landscape
Seasonal water use, base year
Socioeconomic
Population, base year, and forecast year
Total population
Population by dwelling type
Persons per household by dwelling type
Group quarters population
Housing, base year, and forecast year
Number of housing units by dwelling type
Growth rate of housing stock by dwelling type
Employment, base year, and forecast year
Commercial
Industrial
Income, base year, and forecast year
Water price, base year, and forecast year

The urban water use study estimated future change in per capita water use in 20 representative water service areas. (The results in Tables 4-8 and 4-9 display changes from 1990, rather than from the Bulletin's 1995 base year, to illustrate all effects of water conservation implementation, including the changes in plumbing fixture standards that began in 1992.) The results of the 20 individual model runs were extrapolated to forecast 2020 level per capita water use by hydrologic region (Tables 4-9 and 4-10). The difference between the 1995 and 2020 base levels reflects the influence of water conservation measures, socioeconomic change, and differential population growth on per capita water use in each region.

The forecast results for the representative water service areas were expressed as a percent change in per capita use by 2020, and were averaged (weighted by service area population) to arrive at the percent change in per capita use by hydrologic region. For each region, the 2020 change was applied to the 1995 level per capita water use in each DAU to obtain 2020 per capita water use. The 2020 per capita water use then

TABLE 4-7

Urban Water Use Study Data Sources

Water Use
Survey of Public Water System Statistics, DWR
Urban water management plans
Regional and local water agency reports on water use and conservation
Socioeconomic
Census of Population and Housing, U.S. Department of Commerce
Survey of Current Business, USDC
Statistical Abstract of the United States, USDC
California Statistical Abstract, DOF
California Population Characteristics, Center for Continuing Study of the California Economy
Population Projections by Race and Ethnicity for California and its Counties 1990-2040, DOF
Regional and local planning agencies

TABLE 4-8

Model Study Results—Per Capita Water Use With Economic Growth and Conservation Measures

Region	*Representative Water Service Area*	*1990 (gpcd)*	*2020 (gpcd)*	*Percent Change from 1990*	
				Economic Effects	*Conservation Effects*
North Coast	City of Santa Rosa	156	136	-14	2
San Francisco Bay	EBMUD	196	171	-16	3
	Marin Municipal WD	153	136	-16	5
	City and County of San Francisco	132	115	-16	3
Central Coast	California Water Service Company, Salinas	153	132	-14	0
	City of Santa Barbara	177	156	-15	4
South Coast	City of Los Angeles	180	158	-16	4
	City of San Bernardino	269	243	-11	1
	San Diego County WA	196	176	-14	4
Sacramento River	California Water Service Company, Chico	296	272	-10	2
	City of Sacramento	290	263	-13	3
San Joaquin River	California Water Service Company, Stockton	187	162	-12	-1
	City of Merced	336	299	-10	0
Tulare Lake	California Water Service Company, Visalia	273	235	-11	-3
	City of Fresno	285	262	-10	2
North Lahontan	South Lake Tahoe PUD	179	147	-15	-2
South Lahontan	Indian Wells Valley WD	247	230	-10	3
	Victor Valley County WD	340	322	-8	3
Colorado River	City of Blythe	349	326	-11	4
	City of El Centro	221	197	-13	2

TABLE 4-9

2020 Change in Per Capita Use by Hydrologic Region—Application of Model Results[a]

Region	*Economic Effects % Change from 1990*	*Conservation Effects % Change from 1990*
North Coast	2	-14
San Francisco Bay	3	-16
Central Coast	2	-15
South Coast	4	-14
Sacramento River	3	-12
San Joaquin River	-1	-12
Tulare Lake	1	-10
North Lahontan	-2	-15
South Lahontan	3	-9
Colorado River	3	-12
Statewide	**3**	**-15**

[a] Model results applied to per capita use in each DAU.

TABLE 4-10

Effects of Conservation on Per Capita Water Use[a] by Hydrologic Region (gallons per capita per day)

Region	*1995*	*2020*	
		without conservation	*with conservation*
North Coast	249	236	215
San Francisco Bay	192	188	166
Central Coast	179	188	166
South Coast	208	219	191
Sacramento River	286	286	264
San Joaquin River	310	307	274
Tulare Lake	298	302	268
North Lahontan	411	390	356
South Lahontan	282	294	268
Colorado River	564	626	535
Statewide	**229**	**243**	**215**

[a] Includes residential, commercial, industrial, and landscape use supplied by public water systems and self-produced surface and groundwater. Does not include recreational use, energy production use, and losses from major conveyance facilities. These are normalized data.

was multiplied by the population forecast to compute 2020 urban applied water use for each DAU. The DAU-level results were aggregated and combined with minor components of urban use (conveyance losses, recreation water use, and energy production water use) to obtain total applied urban water demands.

This method of computing future water use captures localized effects of differential population growth. The most significant example of variation in growth patterns is the relatively high growth rate in warmer, drier inland areas of California where increased landscape irrigation requirements are reflected in higher per capita use values. Growth in inland areas tends to partially offset reductions in per capita use due to water conservation.

Summary of Urban Water Use

Table 4-11 summarizes Bulletin 160-98 urban applied water use by hydrologic region. Statewide urban use at the 1995 base level is 8.8 maf in average water years and 9.0 maf in drought years. (Drought year demands are slightly higher because less precipitation is available to meet exterior urban water uses, such as landscape watering.) Forecasted 2020 use increases to 12.0 maf in average years and 12.4 maf in drought years. Full implementation of urban BMPs is estimated to result in demand reduction of 1.5 maf in average year water use by 2020. Without implementation of urban BMPs, average year use would have increased to 13.5 maf.

TABLE 4-11

Applied Urban Water Use by Hydrologic Region (taf)

	1995		2020	
Region	*Average*	*Drought*	*Average*	*Drought*
North Coast	169	177	201	212
San Francisco Bay	1,255	1,358	1,317	1,428
Central Coast	286	294	379	391
South Coast	4,340	4,382	5,519	5,612
Sacramento River	766	830	1,139	1,236
San Joaquin River	574	583	954	970
Tulare Lake	690	690	1,099	1,099
North Lahontan	39	40	50	51
South Lahontan	238	238	619	619
Colorado River	418	418	740	740
Total (rounded)	**8,770**	**9,010**	**12,020**	**12,360**

As indicated in the Table 4-11, the South Coast and San Francisco Bay Hydrologic Regions together amount to over half of the State's total urban water use. The table also illustrates that precipitation plays a small role in meeting urban outdoor water needs (landscape water needs) in arid regions such as the Tulare Lake, South Lahontan, and Colorado River regions.

All of the acreage amounts discussed in this chapter are irrigated acres, because estimates of irrigated acreage are needed to calculate agricultural water use. Crop production also occurs (to a much lesser extent) on non-irrigated lands. Dry-farmed grains are an example of crop production on non-irrigated lands.

Agricultural Water Use

The Department's estimates of agricultural water use are derived by multiplying water use requirements for different crop types by their corresponding irrigated acreage, and summing the results to obtain a total for irrigated crops in the State. This section begins by covering crop water use requirements, including demand reduction from water conservation programs. Irrigation efficiency and distribution uniformity are discussed in detail. A description of the process for forecasting irrigated acreage and factors affecting acreage forecasts follows. Forecasted 2020 agricultural water demands are summarized at the end of the section.

Crop Water Use

The water requirement of a crop is directly related to the water lost through evapotranspiration. The amount of water that can be consumed through ET depends in the short term on local weather and in the long term on climatic conditions. Energy from solar radiation is the primary factor that determines the rate of crop ET. Also important are humidity, temperature, wind, stage of crop growth, and the size and aerodynamic roughness of the crop canopy. Irrigation frequency affects ET after planting and during early growth because evaporation increases when the soil

There is a perception that only drip irrigation is an efficient agricultural water use technology. As described in Chapter 5, high efficiencies are possible with a variety of irrigation techniques. Considerations such as soil type, field configuration, and crop type influence the choice of irrigation technique.

surface is wet and is exposed to sunlight. Growing season ET varies significantly among crop types, depending primarily on how long the crop actively grows.

Direct measurement of crop ET requires costly investments in time and sophisticated equipment. There are more than 9 million acres of irrigated crop land in California, encompassing a wide range of climate, soils, and crops. Even where annual ET for two areas is similar, monthly totals may differ. For example, average annual ET for Central Coast interior valleys is similar to that in the Central Valley. Central Valley ET is lower than that in coastal valleys during the winter fog season and higher during the hot summers. Obtaining actual measurements for every combination of environmental variables would be prohibitively difficult and expensive. A more practical approach is to estimate ET using methods based on correlation of measured ET with observed evaporation, temperature, and other climatologic conditions. Such methods can be used to transfer the results of measured ET to other areas with similar climates.

The Department uses the ET/evaporation correlation method to estimate growing season ET. Concurrent with field measurement of ET rates, the Department developed a network of agroclimate stations to determine the relationship between measured ET rates and pan evaporation. Data from agroclimatic studies show that water evaporation from a standard water surface (the Department uses the U.S. Weather Bureau Class A evaporation pan) closely correlates to crop ET. The ET/evaporation method estimates crop water use to within ± 10 percent of measured seasonal ET.

Crop coefficients are applied to pan evaporation data to estimate evapotranspiration rates for specific crops. (Crop coefficients vary by crop, stage of crop growth, planting and harvest dates, and growing season duration.) The resulting data, combined with information on effective rainfall and water use efficiency, form the basis for calculating ETAW and applied water use. Crop applied water use includes the irrigation water required to meet crop ETAW and cultural water requirements.

The amount of water applied to a given field for crop production is influenced by considerations such as crop water requirements, soil characteristics, the ability of an irrigation system to distribute water uniformly on a given field, and irrigation management practices. In addition to ET, other crop water requirements can include water needed to leach soluble salts below the crop root zone, water that must be applied for frost protection or cooling, and water for seed germination. The amount required for these uses depends upon the crop, irrigation water quality, and weather conditions.

Part of a crop's water requirements can be met by rainfall. The amount of rainfall beneficially used for crop production is called effective rainfall. Effective rainfall is stored in the soil and is available to satisfy crop ET or to offset water needed for special cultural practices such as leaching of salts. Irrigation provides the remainder of the crop water requirement. Irrigation efficiency influences the amount of applied water needed, since a portion of each irrigation goes to system leaks and deep percolation of irrigation water below the crop root zone.

The Bulletin's 1995 base applied agricultural water use values were computed from normalized data to account for variation in annual weather patterns and water supply. Normalizing entails applying crop coefficients to long-term average evaporative demand data. Actual applied crop water use during 1995 was less than the Bulletin 160-98 base in many areas due to wet hydrologic conditions that increased effective rainfall, thus decreasing crop ETAW. Likewise, applied water use during a dry year (assuming no constraints on water supplies) would likely exceed the base due to less than average effective rainfall with an attendant increase in crop ETAW. For most hydrologic regions, 1995 base applied water use was computed for the major crop types found in each of the Department's DAUs. Analyses were done at the planning subarea level in the South Lahontan and Colorado River Regions.

Figure 4-5 shows ranges of 1995 base applied water and ETAW for some common California crops or crop types. ETAW represents a major depletion of water supply, and therefore is an important component of statewide and local water supply planning, groundwater modeling, and water transfer feasibility studies. Except in areas adjacent to the ocean, or areas where the groundwater or surface water is unacceptable for reapplication, irrigation water applied in excess of ET and cultural requirements (e.g., frost protection) is available to downstream users or to users pumping from groundwater.

The purpose of the data presented in Figure 4-5 is to illustrate how great the range of applied water and ETAW can be for a single crop or crop type in California. Climate and soil types are major factors that affect crop water use. Other factors include farming practices, irrigation systems, and water availability. Crop water use is extremely site-specific, and no one value of crop water use can be expected to represent a statewide condition.

Factors Influencing Agricultural Water Use

Irrigation Water Use Efficiency. Distribution uniformity is an important element in on-farm irrigation water use efficiencies. DU measures the variation in the amount of water applied to the soil throughout the irrigated area. Since no irrigation system is capable of applying and distributing water uniformly to all parts of a field, growers often apply enough water to meet crop water requirements of the driest part of the field to achieve optimum crop yields. Achieving a high DU requires excellent system design, maintenance, and management. Irrigation experts maintain that current hardware design and manufacturing technology limit the DU of most systems to 80 percent. As design and manufacturing technology advance and more refined manufacturing processes and hardware are developed, it may be possible to achieve DUs up to 90 percent. Chapter 5 describes the relationship of DU to irrigation efficiencies in more detail.

Seasonal application efficiency is the sum of ETAW and cultural water requirements (such as for leaching salts below the root zone) divided by applied water.

SAE is an appropriate index of water use efficiency for planning purposes, because it is based on the amount of water required to fully satisfy crop water needs while maintaining the favorable salt balance in the root zone required for long-term sustainability of agriculture. It differs from values of irrigation efficiency calculated by growers to compare the amount of water beneficially used to the amount applied, because the amount beneficially used may be less than that needed to fully satisfy crop and cultural water requirements. Efficiency measures used by growers, such as DU and IE, are typically based on the average amount of water infiltrating the quarter of the field receiving the least water. These methods presume that one-half of the low quarter, or 12.5 percent of the field, is under-irrigated to some degree. The result is inadequate leaching and a reduction in crop yield in that part of the field.

Values of SAE cannot be directly compared to IE values commonly cited in literature because they are based on different levels of irrigation effectiveness. Optimal SAE occurs when the driest part of the field receives an amount of water equal to ETAW plus leaching water requirements, resulting in a 100 percent effective irrigation. On the other hand, optimal IE occurs when the amount infiltrated in the low quarter equals ETAW plus leaching requirements, resulting in an 87.5 percent effective irrigation. (Since DU is also calculated based on the low-quarter method, optimal IE is equivalent to DU.) SAE is related to DU and to optimal IE by a linear function so that, for example, a DU of 75 percent implies an optimal SAE of 67 percent. The relationship among DU and optimal values of IE and SAE is illustrated in Table 4-12. The maximum efficiency values achieved on-farm are generally less than shown due to conveyance losses, evaporation, and uncollected surface runoff.

TABLE 4-12

Relationship Among Agricultural Water Use Efficiency Measures

Distribution Uniformity	*Irrigation Efficiency*[a]	*Seasonal Application Efficiency*[a]
90	90	87
85	85	80
80	80	73
75	75	67
70	70	60

[a] Optimal values

Relationships between on-farm and regional efficiencies are complex. Often a portion of irrigation water applied to a field runs off the field or percolates into groundwater. Runoff and/or deep percolation from a given field may be considered a water loss to that particular field; nevertheless, this water is not lost to the system unless it goes directly to a nonreusable water source such as saline groundwater or to the ocean. If water quality is good, that water may be reapplied on a field or on other fields several times. Irrigation efficiency formulas developed for on-farm irrigation management cannot necessarily be applied to larger areas or regions. Numerical values of on-farm and regional efficiencies almost always differ. On-farm

Efficient Water Management Practices for Agricultural Water Suppliers in California

List A—Generally Applicable EWMPs

- Prepare and adopt a water management plan
- Designate a water conservation coordinator
- Support the availability of water management services to water users
- Improve communication and cooperation among water suppliers, water users, and other agencies
- Evaluate the need, if any, for changes in institutional policies to which the water supplier is subject
- Evaluate and improve efficiencies of the water supplier's pumps

List B—Conditionally Applicable EWMPs

- Facilitate alternative land use
- Facilitate using available recycled water that otherwise would not be used beneficially, meets all health and safety criteria, and does not cause harm to crops or soil
- Facilitate financing capital improvements for on-farm irrigation systems
- Facilitate voluntary water transfers that do not unreasonably affect the water user, water supplier, the environment, or third parties
- Line or pipe ditches and canals
- Increase flexibility in water ordering by, and delivery to, water users within operational limits
- Construct and operate water supplier spill and tailwater recovery systems
- Optimize conjunctive use of surface and groundwater
- Automate canal structures

List C—Other EWMPs

- Water measurement and water use reporting
- Pricing or other incentives

efficiencies are usually lower than regional efficiencies due to reapplication of water in a region. A region can reach very high efficiencies as a result of a few reapplications, even if on-farm efficiencies are fairly low. Practices that encourage reapplication, such as tailwater return and spill recovery systems, provide an opportunity to increase regional efficiency. Water reapplication can be the fastest and most economical way to boost regional efficiencies.

Agricultural Water Conservation Programs. The amount of applied water saved depends on the actions of both water suppliers and irrigation water users. Achieving high on-farm water use efficiency is accomplished by optimizing many factors including management (such as irrigation scheduling), irrigation method, crop selection, and supply reliability. On-farm evaluations conducted by the Department and others show that irrigation management is more important than irrigation method in improving water use efficiency. (Chapter 5 describes common irrigation methods.)

Bulletin 160-98 quantifies agricultural water conservation based on assumed statewide implementation of the 1996 agricultural MOU described in Chapter 2. The agricultural MOU provides a mechanism for planning and implementing EWMPs (see sidebar) that benefit water suppliers. The primary objective of EWMPs is for suppliers to better serve farmers in order to facilitate improvements in on-farm practices. As of May 1998, 31 agricultural water agencies serving about 3 million acres of land had signed the MOU. Signatories to the MOU have committed to implement specified EWMPs, based on their evaluation of the benefits of each practice.

EWMPs can lessen runoff and deep percolation of irrigation water, reducing the amount of water farmers must order from an irrigation district or pump from their wells. Because the MOU is orientated to water suppliers, it does not specify water use reduction factors and installation and/or compliance rates for farm irrigation system improvements. Therefore, the Department estimated water savings due to EWMPs based on their potential to remove impediments to optimal on-farm efficiency, expressed as increased SAE. SAE resolves the interrelated effects of EWMPs and improved on-farm management into one variable that quantifies the net result of water conservation efforts by water suppliers and irrigation water users. It is expected that increasing use of EWMPs will yield more information on their water savings potential.

Water savings due to agricultural water conservation were quantified for each DAU on the basis of expected improvements in SAE. It is assumed that by 2020 SAE will reach 73 percent in all regions of California, averaged across crop types, farmland characteristics, and management practices. The DU of irrigation methods limits SAE. The average DU of irrigation systems in California is currently in the 70 to 75 percent range, based on irrigation system evaluations conducted by the Department, resource conservation districts, water districts, and others. By 2020, the average DU is expected to be about 80 percent. An irrigation method with a DU of 80 percent can achieve a maximum SAE of about 73 percent, assuming that irrigation events are properly timed, the soil is well drained, and none of the field is under-irrigated.

The Bulletin 160-98 forecast of conservation savings was calculated by comparing two scenarios of 2020 crop applied water demand under differing levels of SAE. First, crop applied water demand was computed based on the 2020 forecast of irrigated acreage and crop mix, but at existing (1995 base) levels of SAE for each major crop category. Then SAE for each crop category was set to the 2020 forecast value and applied water demand was recomputed. Applied water savings due to conservation were taken as the difference in applied water demand under the two scenarios.

Table 4-13 shows that agricultural water conservation would reduce applied water demands by about 800 taf annually by 2020. Such reductions of applied water generally do not create new water supply; in most areas of California, excess irrigation water becomes available to other users. Even so, a reduction in ap-

TABLE 4-13

2020 Agricultural Water Use Reductions Due to Conservation (taf)

Region	*Applied Water*	*Depletion*
North Coast	1	0
San Francisco Bay	1	0
Central Coast	82	0
South Coast	31	10
Sacramento River	203	0
San Joaquin River	148	2
Tulare Lake	45	1
North Lahontan	17	0
South Lahontan	20	10
Colorado River	249	210
Total	**797**	**233**

plied water can serve other beneficial purposes such as reducing leaching of plant nutrients, reducing degradation of groundwater quality, and reducing agricultural drainage.

Only practices that lessen evaporation from water surfaces, reduce evapotranspiration, or diminish irrecoverable losses actually reduce depletions. Efficient water management practices have relatively little effect on evaporation and ET. It is the location of water use, rather than the conservation measure employed, that is key to determining whether a reduction in irrigation water application translates into a depletion reduction. Agricultural lands adjacent to the ocean, or where the groundwater or surface water is unacceptable for reapplication, have the greatest potential for reducing depletions through efficient water management practices. In California, such agricultural lands are found in the South Coast Region, the west side of the San Joaquin Valley, and the Colorado River Region.

Other water conservation planning requirements exist in addition to those in the agricultural MOU, most notably those applying to water agencies contracting with USBR. (CALFED's proposed future water use efficiency program is discussed in Chapter 6.) The Reclamation Reform Act of 1982 directed DOI to establish a water conservation planning program. In 1992, CVPIA established additional water conservation requirements for federal contractors receiving CVP supplies. USBR published criteria for CVPIA conservation plans and is reviewing the plans which contractors are required to submit. As of March 1998, more than 70 federal water contractors had submitted plans pursuant to CVPIA criteria. Discussions are underway with the agricultural council established by the 1996 MOU regarding developing a way for CVPIA plans to be accepted as plans complying with the agricultural MOU. CVPIA further requires that new, renewed, or amended CVP water service or repayment contracts mandate that surface water delivery systems have water measurement devices or comparable methods of measuring water use.

Agricultural Water Pricing. The relationship of agricultural water pricing to water use and the role of pricing in achieving water conservation have been subjects of discussion in recent years. For water supplied by public agencies, the elected board members of those agencies ultimately have the responsibility for balancing desires to achieve demand reduction through water pricing with desires to provide affordable water rates to growers. For self-supplied agricultural water users, good business practices dictate maximizing water use efficiency, in terms of crop yield per unit of water applied. Agricultural water prices in California vary widely and are affected by factors such as geographic location and source of water supply. Appendix 4A provides background information on agricultural water pricing. As described in the price elasticity information in the appendix, demand for irrigation water is generally price inelastic over the price ranges evaluated. There is no other commodity that can be substituted for the water required to grow crops. Water costs are typically a relatively small percentage of the total cost of producing most crops.

Crop markets, not water prices, generally dominate the economics of crop production. Bulletin 160-98 considers markets and other economic effects in the modeling performed to forecast future irrigated acreage, as described later in this chapter. When fully implemented, CVPIA tiered pricing requirements may provide new data on water price/water use relationships for CVP contractors, as described in the appendix.

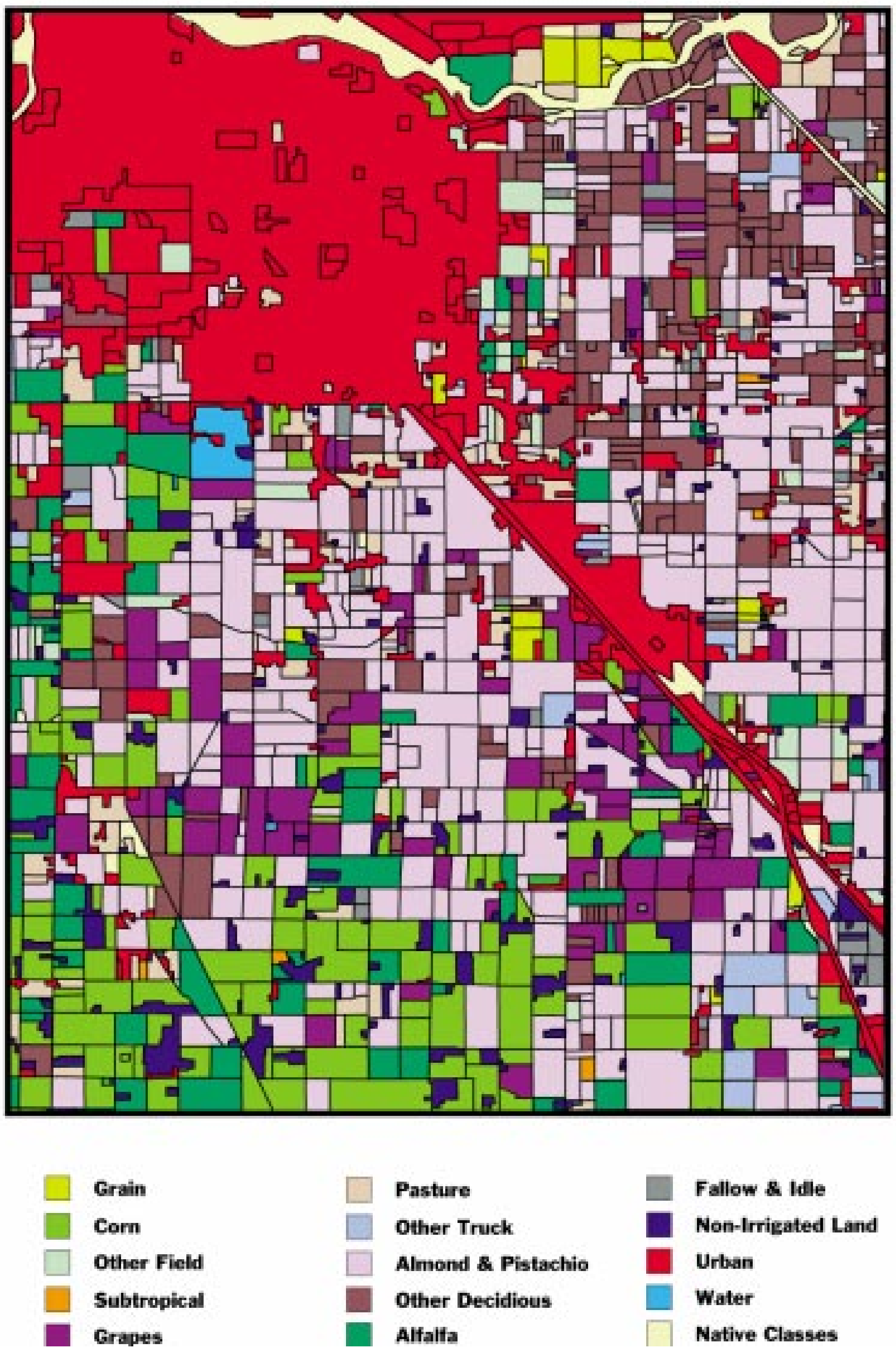
Agricultural Acreage Forecasting

This section describes how 1995 base year irrigated acreage is established, and how that information is used to forecast 2020 irrigated acreage.

Quantifying Present Irrigated Acreage. Forecasts of future agricultural acreage start with land use data that characterize existing crop acreage. The Department has performed land use surveys since the 1950s to quantify acreage of irrigated land and corresponding crop types, and currently maps irrigated acreage in six to seven counties per year. The base data for land use surveys is obtained from aerial photography or satellite imagery, which is superimposed on a cartographic base. Site visits are used to identify or verify crop types growing in the fields. From this information, maps showing locations and acreage of crop types are developed. Figure 4-6 is an example of a typical land use survey map, showing crop types in the Ceres 7.5 minute USGS quadrangle from the Department's 1996 Stanislaus County survey.

The Department's land use surveys focus on quantifying irrigated agricultural acreage. Although fields of dry-farmed crops are mapped in the land use surveys, their acreage is not tabulated for calculating water use. In certain areas of the State, climate and market conditions are favorable for producing multiple crops per year on the same field (for example, winter veg-

FIGURE 4-6
Typical Land Use Survey Map



California's Nursery Industry

When people think of irrigated agriculture, crops that often come to mind are commodities such as hay, grains, rice, row crops, and cotton. However, nursery products (flowers, plants, turf-grass) rank as the State's fourth largest farm product in gross value, behind milk/cream, grapes, and cattle, and ahead of cotton, almonds, and hay, according to 1996 California Department of Food and Agriculture statistics. The prominence of the nursery industry reflects the extent of urbanization in California, as well as favorable climatic conditions.

California nursery products had a $1.6 billion farmgate value (wholesale value at the farm) in 1996. San Diego is the leading California county in nursery product valuation, followed by Santa Barbara, San Mateo, and Los Angeles Counties. California wholesale production represents about 26 percent of national nursery product sales.

An important difference between the nursery industry and other agricultural sectors is the extent to which the industry's revenues are tied to urban, as well as to agricultural, water supplies. Bulletin 160 treats nursery water use as an agricultural use. Many of the industry's products, however, are destined for urban and commercial locations where urban water supply availability influences landscaping choices and the market for nursery products.

About 25,000 acres are devoted to nursery products in California. Much of the acreage is in proximity to urbanized, coastal regions of the State near markets and major transportation routes.

etables followed by a summer cotton crop). In these cases, annual irrigated acreage is counted as the sum of the acreage of the individual crop types. In the years between county land use surveys, the Department estimates crop types and acreage using data collected from county agricultural commissioners, local water agencies, University of California Cooperative Extension Programs, and the California Department of Food and Agriculture.

The starting point for determining Bulletin 160-98 1995 base acreage was normalized 1990 irrigated acreage from Bulletin 160-93. Changes in crop acreage between 1990 and 1995 were evaluated to determine if they were due to short-term causes (e.g., drought or abnormal spring rainfall), or if there was an actual change in cropping patterns. Base year acreage was normalized to represent the acreage that would most likely be expected in the absence of weather and market related abnormalities. (More detail on the concept of normalizing base year data is presented in Chapter 3.) Figure 4-7 illustrates some general trends in California cropping patterns over time.

The Central Valley produces most of California's tomato crop. Much of the crop is used for processed tomato products, such as canned tomatoes and tomato sauces. Acreage devoted to truck crops like tomatoes is expected to increase in the future.

Crop acreage by region for the normalized 1995 base is presented in Table 4-14. The 1995 base irrigated land acreage is about 9.1 million acres, which, when multiple cropped areas are tabulated, becomes a base irrigated cropped acreage of about 9.5 million acres.

Forecasting Future Irrigated Acreage. The

FIGURE 4-7

General Trends in Cropping Patterns Over Time

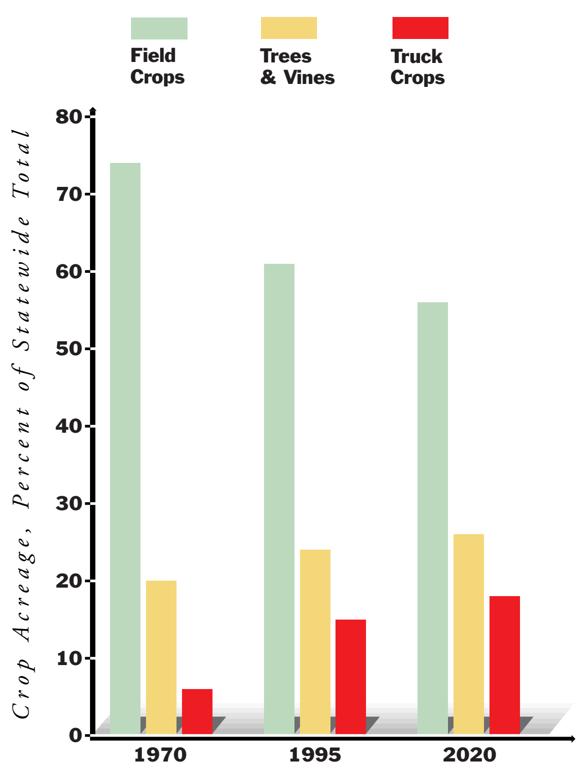


TABLE 4-14

California Crop and Irrigated Acreage by Hydrologic Region, 1995 level (thousands of acres)

Irrigated Crop	*NC*	*SF*	*CC*	*SC*	*SR*	*SJ*	*TL*	*NL*	*SL*	*CR*	*Total*
Grain	72	2	26	11	270	180	260	7	2	70	900
Rice	0	0	0	0	494	22	0	1	0	0	517
Cotton	0	0	0	0	9	185	1,026	0	0	24	1,244
Sugar beets	6	0	3	0	54	47	30	0	0	38	178
Corn	1	1	3	4	92	212	116	0	0	9	438
Other field	3	1	16	4	155	120	97	0	1	70	467
Alfalfa	53	0	21	10	149	231	296	44	34	256	1,094
Pasture	122	5	18	20	352	199	49	107	18	43	933
Tomatoes	0	0	10	7	138	82	111	0	0	9	357
Other truck	23	11	382	87	56	130	194	2	3	172	1,060
Almond/pistachios	0	0	0	0	106	251	177	0	0	0	534
Other deciduous	7	6	18	3	219	154	191	0	3	1	602
Subtropical	0	0	19	161	28	8	202	0	0	37	455
Grapes	36	39	56	6	17	184	378	0	0	20	736
Total Crop Area	**323**	**65**	**572**	**313**	**2,139**	**2,005**	**3,127**	**161**	**61**	**749**	**9,515**
Multiple Crop	0	0	142	30	52	56	63	0	0	104	447
Irrigated Land Area	323	65	430	283	2,087	1,949	3,064	161	61	645	9,068

Water Use Impacts from Urbanization of Agricultural Lands—A San Joaquin Valley Example

The Department projects a decline in California's irrigated acreage by 2020, due in part to urbanization of agricultural lands. Much of this urbanization will occur in the South Coast Region and in the San Joaquin Valley. Potential changes in water use resulting from land use conversion are often of concern to local agencies responsible for land use planning or for providing water supplies. Changes in water use must be evaluated on a site-specific basis, as the following example for the San Joaquin Valley illustrates.

Changes in water use depend on the kinds of crops grown and the density and type of urban development in an area. In the case of single-family dwellings, applied water use varies with housing density. Numerous studies have shown that dwellings on larger lots use more water per dwelling unit due to the larger landscaped areas. However, higher density developments have the greater applied water use per acre of land. A recent Department study of the Fresno area showed that applied water use of single-family dwellings and agricultural crops were similar at low housing densities (four or five units per acre). However, higher density single-family dwellings (six units or more per acre) that have become common in today's new home construction market tended to have greater applied water requirements than some crops.

Growth in the Fresno area has caused expansion of urban development onto adjoining agricultural lands. Figure 4-8 is a plot of Department land use data illustrating the long-term expansion of urban development onto agricultural lands in the area. Department data show that average urban applied water use in the Fresno area (urban water use includes residential, commercial, and industrial purposes) is equivalent to about 3.2 af/acre. Typical agricultural applied water use for crops grown in the area is shown below. Actual agricultural applied water use for an individual crop will vary with field-specific conditions such as soil type and irrigation method.

Type of Use	*Applied Water Use (af/acre)*
Urban	3.2
Agricultural	
Barley	1.3
Grapes	2.9
Cotton	3.2
Deciduous orchard	3.5
Pasture (improved)	4.5
Alfalfa	4.7

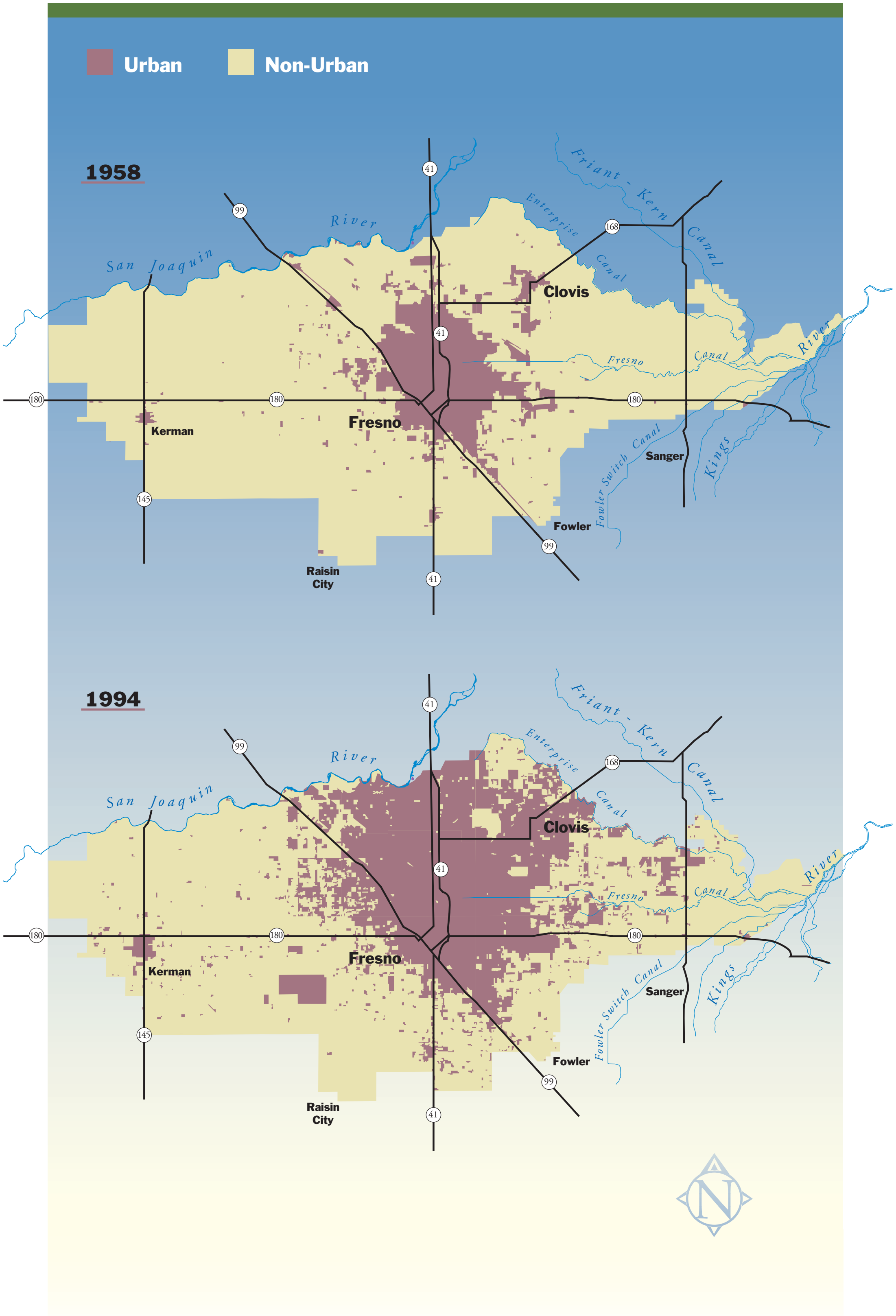
Department's 2020 irrigated acreage forecast was derived from staff research, a crop market outlook study, and results from the Central Valley Production Model. As with any forecast of future conditions, there are uncertainties associated with each of these approaches. The Department's integration of the results from three independent approaches is intended to represent a best estimate of future acreage, absent major changes from present conditions. It is important to emphasize that many factors affecting future cropped acreage are based on national (federal Farm Bill programs) or international (world export markets) circumstances. California agricultural products compete with products from other regions in the global economy and are affected by trade policies and market conditions that reach far beyond the State's boundaries.

The Federal Agriculture Improvement and Reform Act of 1996, for example, affects agricultural markets nationwide, by changing federal price supports for specified agricultural commodities. Under the terms of that act, federal payments to growers will be reduced by 2002, and prior farm bill provisions that required growers to reduce planted acreages of regulated commodities are no longer in force. (Commodities with significant federal price support include wheat, feed grains, rice, cotton, dairy products, sugar, and peanuts.) The overall impact of the act to California may be less than its impact to states whose agriculture is less diversified and who are less active in export markets. In 1994, for example, federal farm bill production payments to California growers represented about 1 percent of California's agricultural revenue. The potential impacts of FAIRA to California's agricultural market are considered in Bulletin 160-98 by the crop market outlook study.

Intrastate factors considered in making acreage forecasts included urban encroachment onto agricultural land and land retirement due to drainage problems (discussed in more detail in the following section). Urbanization on lands presently used for irrigated agriculture is a significant consideration in the South Coast Region and in the San Joaquin Valley, based on projected patterns of population growth. (See sidebar on water use impacts of land conversion.) DOF 2020 population forecasts, along with information gathered from local agency land use plans, were used

FIGURE 4-8

Changes in Land Use Over Time, DAU 233



to identify irrigated lands most likely to be affected by urbanization. Local water agencies and county farm advisors were interviewed to assess their perspective on land use changes affecting agricultural acreage. For example, urbanization may eliminate irrigated acreage in one area, but shift agricultural development onto lands presently used as non-irrigated pasture. Soil types and landforms are important constraints in agricultural land development. If urbanization occurs on prime Central Valley farmland, some agricultural production may be able to shift to poorer quality soils on hilly lands adjoining the valley floor. A consequent shift in crop types and irrigation practices would likely result—for example, from furrow-irrigated row crops to vineyards on drip irrigation.

The Department's crop market outlook, a form of Delphi analysis, was developed using information and expert opinions gathered from interviews with more than 130 University of California farm advisors, agricultural bankers, commodity marketing specialists, managers of cooperatives, and others. Three basic factors guided the CMO: current and future demand for food and fiber by the world's consumers; the share California could produce to meet this worldwide demand; and technical factors, such as crop yields, pasture carrying capacities, and livestock feed conversion ratios that affect demand for agricultural products. (Milk and dairy products are California's largest agricultural product, in terms of gross value. The demand for these products is reflected in the markets for alfalfa, grains, and other fodder used by dairies.) The CMO forecasts a statewide crop mix and estimates corresponding irrigated acreage. The major findings of the CMO for year 2020 were that grain and field crop acreage would decrease, while acreage of truck crops and permanent crops would increase.

The Central Valley Production Model is a mathematical programming model that simulates farming decisions by growers. Inputs include detailed information about production practices and costs as well as water availability and cost by source. The model also uses information on the relationship between production levels of individual crops and crop market prices. The model's geographic coverage is limited to the Central Valley, which represents about 80 percent of the State's irrigated agricultural acreage. The CVPM results also indicated future crop shifting, from grains and field crops to vegetables, trees, and vines. The CVPM forecast showed a small reduction in crop acreage from 1995 to 2020.

Other Factors Affecting Forecasted Irrigated Acreage. The process of estimating future irrigated acreage considered statewide factors such as crop markets and urban expansion onto agricultural lands. The Department considered an additional region-specific factor, the long-standing agricultural drainage management issues on the west side of the San Joaquin Valley. Drainage management issues in this area have a dual focus—salt management to permit continued agricultural production on lands requiring drainage systems, and trace minerals management (principally selenium) to limit adverse water quality and environmental impacts.

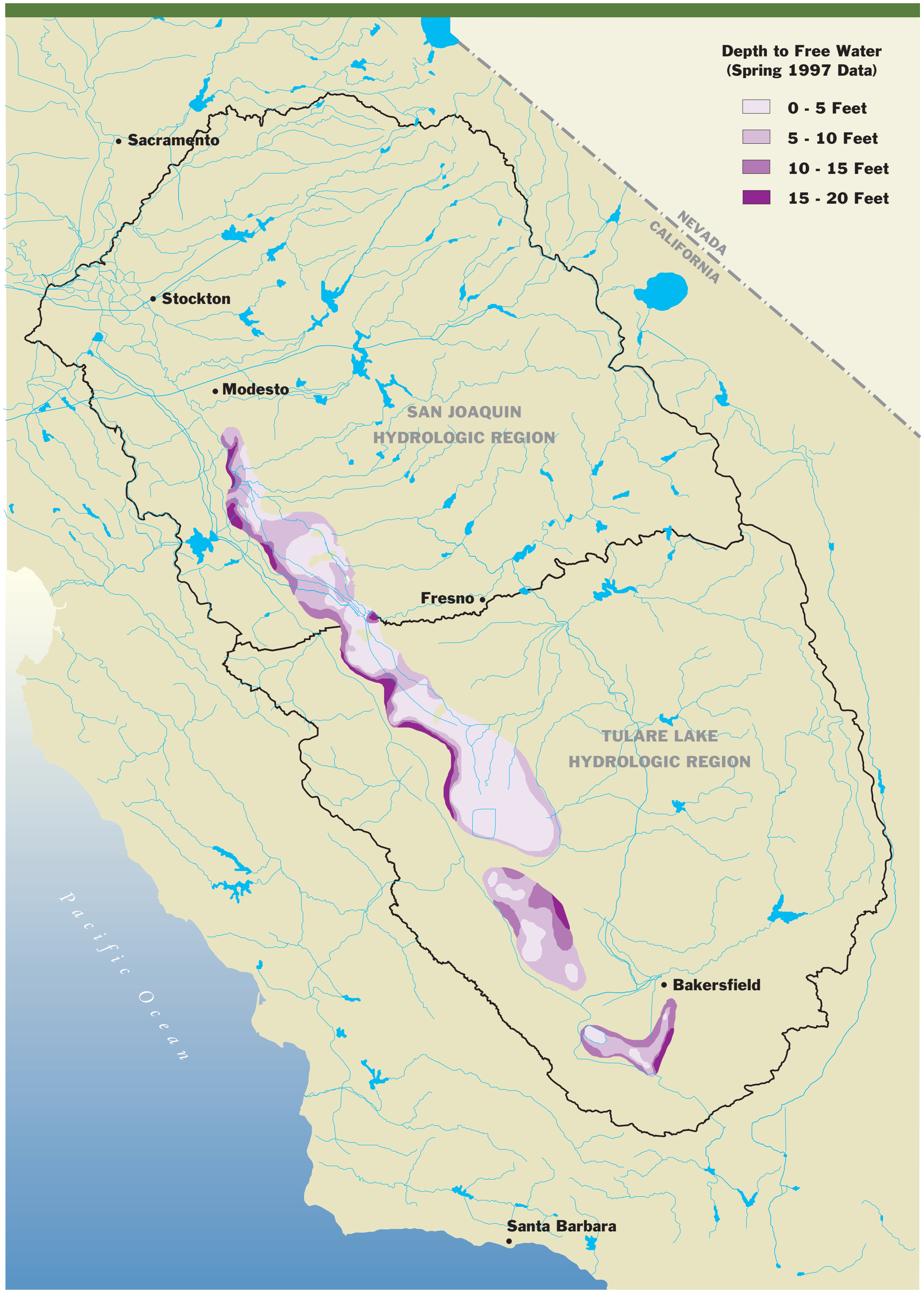
The need for drainage systems to permit farming in some westside areas was recognized concurrently with the development of irrigated agriculture in the region. USBR's San Luis Drain, for example, was originally planned to convey drainage water out of the valley to the Delta. The drain was instead terminated at Kesterson Reservoir, where waterfowl mortalities led to discovery of elevated selenium levels in the early 1980s. The drain was subsequently closed. (A discussion of trial reopening of part of the drain for the Grasslands Bypass Channel Project is provided in Chapter 8.) Post-Kesterson studies of valley drainage problems have sought to quantify factors such as extent of areas with shallow depths to groundwater, tributary areas in Coast Range sediments from which trace minerals are derived, and water quality characteristics of drain water and shallow groundwater.

The 1990 report of the interagency San Joaquin Valley Drainage Program projected that as much as 460,000 acres of irrigated land would be taken out of production by the year 2020 if the report's recommendations were not implemented. The report recommended retirement of 75,000 acres of land having the worst drainage problems by 2040. The Bulletin 160-98 year 2020 acreage forecast follows the same procedure used in Bulletin 160-93 and assumes that the 75,000 acres would be retired at an average rate of 1,500 acres per year. Thus, 45,000 acres of land would be retired between 1990 and 2020. USBR's 1997 request for proposals for the CVPIA land retirement program (described in Chapter 6) elicited offers to sell 31,000 acres of drainage-impaired lands, suggesting that the assumed 45,000 acres of land retirement could occur by 2020.

Data from the Department's monitoring program for groundwater levels in the San Joaquin Valley are shown in Figure 4-9. Agricultural acreage with a water

FIGURE 4-9

Areas of Shallow Groundwater in the San Joaquin Valley



Agroforestry Research

Agroforestry is being tested for managing drainage impaired lands. Agroforestry systems integrate trees and shrubs into cropping activities to produce marketable products and/or provide resource conservation. Agroforestry principles could be applied to on-farm water management, where increasingly saline water would be applied to successively more salt-tolerant plants to reduce drainage volumes. For example, drainage water from salt-sensitive crops could be used to irrigate a salt-tolerant crop like cotton. Drainage water from the cotton would then be used to irrigate salt-tolerant trees, such as eucalyptus. Drainage water from the trees would be reused again to irrigate highly salt-tolerant plants such as saltgrass. Finally, the drainage water would be discharged into a solar evaporator. This is an experimental program. To be commercially successful, markets would need to be found for the eucalyptus trees and other biomass produced. In 1985 a cooperative effort among several growers and agencies began at a 27-acre site near Mendota. A second research project of 622 acres was established at Red Rock Ranch in Fresno County in 1993, and a third research project was started by Tulare Lake Basin Drainage District.

table within 10 feet of the surface increased from 1,061,000 acres in 1991 to 1,262,000 acres in 1997. Agricultural lands with a water table within 5 feet of the surface increased from 311,000 acres in 1991 to 743,000 acres in 1997. Increases in the extent of shallow groundwater coincide with the end of drought conditions and above-average rainfall. (The Department's monitoring program is limited to measurement of groundwater levels. There has been no region-wide monitoring of selenium and other constituents in shallow groundwater since the 1987 work performed for the 1990 report.)

To implement recommendations of the 1990 report, four State agencies (DWR, SWRCB, DFG, and DFA) and four federal agencies (USBR, USFWS, USGS, and Natural Resource Conservation Service) signed a 1991 MOU to participate in a cooperative interagency program. The program was to address the management plan's eight major recommendations: source control, drainage reuse, evaporation ponds, land retirement, groundwater management, limiting discharge to the San Joaquin River, and institutional change. (The plan's recommendations did not address disposal of drain water outside of the Central Valley.) Significant progress has been made on some recommendations. Some examples of drainage management activities are described in Chapters 7-9.

In 1997, the interagency drainage program drafted

Factors that influence the conversion of irrigated lands to urban use include the lands' proximity to existing urban areas and transportation corridors, and local agency land use planning and zoning policies.

an activity plan to update the report's recommendations with new information. The activity plan is scheduled for completion in 1999. Source control objectives of the 1990 report have been achieved or exceeded over large areas. In the first year of Grasslands Bypass Channel Project implementation (described in Chapter 8), irrigation and drainage modifications by Grasslands area farmers reduced selenium discharges to the San Joaquin River. Tiered water pricing has been implemented in the drainage problem area of the Grasslands subarea. Three agroforestry drainage reuse research projects have been implemented (see sidebar).

One factor not included in Bulletin 160-98 irrigated acreage forecasts is the potential large-scale conversion of agricultural land to wildlife habitat for reasons other than the westside drainage problems described above. The CALFED program represents the largest pending example of potential conversion of irrigated agricultural lands to habitat, as described in CALFED's March 1998 draft programmatic EIR/EIS and supporting documents. CALFED's potential land conversion amounts have not been included in the Bulletin 160-98 irrigated acreage forecast because they are preliminary at this time (a site-specific environmental document with an implementation schedule for land conversion has not yet been prepared), and because CALFED's preliminary numbers are so large relative to the Bulletin's market-based forecast of irrigated acreage that they would negate the results of the forecast. Overall, CALFED program activities as presently planned could convert up to 290,000 irrigated acres to habitat and other uses, an amount almost as great as the 325,000 acre reduction in irrigated acreage forecast in the Bulletin. Water use implications of large-scale land conversions are not included in the Bulletin 160-98 forecast. Impacts of such land conversions are expected to be addressed in the next water plan update, when CALFED's program may be better defined.

The difficulty in estimating impacts from large-scale land conversion programs stems from the domino effect that changes in acreage in one location have on acreage and crop types in other areas, and how crop markets determine which crop shifts are feasible. For example, CALFED's preliminary reports suggest that up to 190,000 irrigated acres in the Delta could be converted to other land uses. This amount represents about 40 percent of Delta irrigated acreage, where principal crops are corn, alfalfa, tomatoes, grain, orchard

Alfalfa and Market Conditions

The market for California alfalfa is closely tied to the State's dairy industry. California is the nation's leading dairy state. According to DFA's 1996 statistics, milk/cream production amounted to $3.7 billion, making it the State's top-valued agricultural commodity. California, with about 1.3 million dairy cows and over 2,300 dairy farms, accounted for almost 17 percent of the nation's dairy production in 1996. Leading dairy counties are Tulare, San Bernardino, Merced, Stanislaus, and Riverside.

Alfalfa supports the dairy and livestock industries (including the recreational horse industry) and also provides about one-third of the nation's honey production. In-state alfalfa production does not meet all of the demand within California. Alfalfa is trucked from the intermountain states to Central California dairies. Although some alfalfa is exported from California (mostly to Japan), imports into California have exceeded exports by 1 to 8 percent over the past several years.

California milk/cream production has increased more than 50 percent in the past 12 years. About half of this increase is due to increases in milk yield per cow and the remainder is due to increased numbers of cows. This has created a continuing demand for alfalfa. Most dairy rations in California contain some component of alfalfa.

Relatively little raw milk flows into or out of the State. California's dairy industry is based on in-state production and processing capacity. The demand for milk products is greatest in the State's major population centers — the San Francisco Bay Area and urbanized Southern California. Dairy production has been concentrated in the San Joaquin Valley and in the Inland Empire region of Southern California, within convenient distances of major markets. Increasing urbanization of formerly agricultural lands in Southern California is shifting more dairy production to the southern San Joaquin Valley. To supply feed to these dairies, the San Joaquin Valley has become the largest production area for alfalfa in the State, producing nearly half of California's alfalfa.

According to DFA, California's Grade A milk production can be broken down into the following categories:

Cheese	36%
Butter & nonfat dry milk	29%
Fluid milk products	24%
Frozen dairy products	6%
Soft products	5%

TABLE 4-15
California Crop and Irrigated Acreage by Hydrologic Region, 2020 Level
(thousands of acres)

Irrigated Crop	*NC*	*SF*	*CC*	*SC*	*SR*	*SJ*	*TL*	*NL*	*SL*	*CR*	*Total*
Grain	66	1	21	5	249	152	201	8	0	97	800
Rice	0	0	0	0	484	15	0	1	0	0	500
Cotton	0	0	0	0	15	171	888	0	0	46	1,120
Sugar beets	6	0	2	0	52	18	13	0	0	29	120
Corn	2	0	3	2	90	188	101	1	0	3	390
Other field	3	1	14	1	154	139	110	0	0	33	455
Alfalfa	62	0	20	6	147	181	238	50	24	217	945
Pasture	123	5	16	6	316	165	26	103	18	32	810
Tomatoes	0	0	8	4	141	93	130	0	0	14	390
Other truck	28	11	373	43	79	197	300	2	1	231	1,265
Almond/pistachios	0	0	0	0	127	270	198	0	0	0	595
Other Deciduous	7	6	20	3	234	153	199	0	2	1	625
Subtropical	0	0	18	117	33	10	215	0	0	32	425
Grapes	38	41	75	3	29	183	366	0	0	15	750
Total Crop Area	**335**	**65**	**570**	**190**	**2,150**	**1,935**	**2,985**	**165**	**45**	**750**	**9,190**
Multiple Crop	0	0	150	10	70	80	100	0	0	145	555
Irrigated Land Area	335	65	420	180	2,080	1,855	2,885	165	45	605	8,635

The proximity of California agriculture to densely populated urban markets encourages the production of specialty crops. Pumpkin patches and Christmas tree lots are examples of specialized urban niche markets.

crops, and truck crops (e.g., asparagus). Some land conversion in the Delta might result in production on new agricultural lands—most likely, rolling hills on the edge of the valley floor which are suitable for only limited crop types (orchards and vineyards). Some of the land conversion might result in increased demand in other areas for the affected crops, such as increased demand for asparagus from the Imperial and Salinas Valleys.

Results of 2020 Acreage Forecast. Table 4-15 shows the 2020 irrigated acreage forecast. The total irrigated crop acreage is forecasted to decline by 325,000 acres from 1995 to 2020, primarily in the San Joaquin Valley and South Coast areas. Reductions in crop acreage are due to urban encroachment, drainage problems in the westside San Joaquin Valley, and a more competitive economic market for California agricultural products. Pasture and field crops are forecasted to decline by about 631,000 acres. Truck crops and permanent crops are forecasted to increase by about 238,000 and 68,000 acres, respectively. Acreage with multiple cropping is forecasted to increase by 108,000 acres, reflecting the expected increased production of truck crops. These statewide findings are used in developing the forecasted agricultural water demands.

Summary of Agricultural Water Use

Crop water use information and irrigated acreage data are combined to generate the 2020 agricultural water use by hydrologic region shown in Table 4-16. As previously noted, the 2020 forecasted values take into account EWMP implementation, which results in a 2020 applied water reduction of about 800 taf.

TABLE 4-16

Applied Agricultural Water Use by Hydrologic Region (taf)

	1995		*2020*	
Region	*Average*	*Drought*	*Average*	*Drought*
North Coast	894	973	927	1,011
San Francisco Bay	98	108	98	108
Central Coast	1,192	1,279	1,127	1,223
South Coast	784	820	462	484
Sacramento River	8,065	9,054	7,939	8,822
San Joaquin River	7,027	7,244	6,450	6,719
Tulare Lake	10,736	10,026	10,123	9,532
North Lahontan	530	584	536	594
South Lahontan	332	332	257	257
Colorado River	4,118	4,118	3,583	3,583
Total (rounded)	**33,780**	**34,540**	**31,500**	**32,330**

Environmental Water Use

Bulletin 160-98 defines environmental water as the sum of:

- Dedicated flows in State and federal wild and scenic rivers
- Instream flow requirements established by water right permits, DFG agreements, court actions, or other administrative documents
- Bay-Delta outflows required by SWRCB
- Applied water demands of managed freshwater wildlife areas

This definition recognizes that certain quantities of water have been set aside or otherwise managed for environmental purposes, and that these quantities cannot be put to use for other purposes in the locations where the water has been reserved or otherwise managed. This definition also recognizes that these uses of environmental water can be quantified. Unlike urban and agricultural water use, much of this environmental water use is brought about by legislative or regulatory processes. Certainly the environment uses more water than is encompassed in this definition—the rainfall that sustains the forests of the Sierra Nevada and the North Coast, the winter runoff that supports flora and fauna in numerous small streams, the shallow groundwater that supports riparian vegetation in some ephemeral streams—but the Bulletin's definition captures uses of water that are managed (in one fashion or another) and quantifiable. As described earlier, average annual statewide precipitation over California's land surface amounts to about 200 maf. About 65 percent of this precipitation is consumed through evaporation and transpiration by the State's forests, grasslands, and other vegetation. The remaining 35 percent comprises the State's average annual runoff of about 71 maf. The environmental water demands discussed in this section are demands that would be met through a designated portion of that average annual runoff.

The following discussion covers factors affecting the four categories of environmental water use. As with urban and agricultural water use, options for meeting future environmental water needs—such as federal acquisition and transfer of water to meet CVPIA AFRP goals—are covered in Chapter 6 and in the regional water management chapters. The environmental water use categories below are discussed in order of size—from greatest (wild and scenic rivers) to smallest (wildlife refuges). Environmental water use is shown on an applied water basis.

Flows in Wild and Scenic Rivers

Flows in wild and scenic rivers constitute the largest environmental water use in the State. Figure 4-10 is a map of California's State and federal wild and scenic rivers.

The 1968 National Wild and Scenic Rivers Act, codified to preserve the free-flowing characteristics of rivers having outstanding natural resources values, prohibited federal agencies from constructing, authorizing, or funding the construction of water resources projects having a direct or adverse effect on the values for which the river was designated. (This restriction also applies to rivers designated for potential addition to the national wild and scenic rivers system.) There are two methods for having a river segment added to the federal system—congressional legislation, or a state's petition to the Secretary of the Interior for federal designation of a river already protected under state statutes. No new federal designations have been made since publication of Bulletin 160-93.

A number of river systems within lands managed by federal agencies are being studied as candidates. For example, U.S. Forest Service draft environmental documentation in 1994 and 1996 recommended designation of 5 streams (129 river miles) in Tahoe National Forest and 160 river miles in Stanislaus National Forest. These waterways drain to the Central Valley where their flows are used for other purposes, and wild and scenic designation would not affect the existing downstream uses.

The California Wild and Scenic Rivers Act of 1972 prohibited construction of any dam, reservoir, diversion, or other water impoundment on a designated river. As shown on Figure 4-10, some rivers are included in both federal and State systems. No new State designations have been made since Bulletin 160-93, although the Mill and Deer Creeks Protection Act of 1995 (Section 5093.70 of the Public Resources Code) gave portions of these streams special status similar to wild and scenic designation, by restricting construction of dams, reservoirs, diversions or other water impoundments.

Tables 4-17 and 4-18 show the wild and scenic river flows used in Bulletin 160-98 water budgets by waterway and by hydrologic region. The flows shown are based on the rivers' unimpaired flow. (The unimpaired flow in a river is the flow measured or calculated at some specific location that would be unaffected by stream diversions, storage, imports or exports, and return flows.) For the average year condition, the

FIGURE 4-10
California Wild and Scenic Rivers

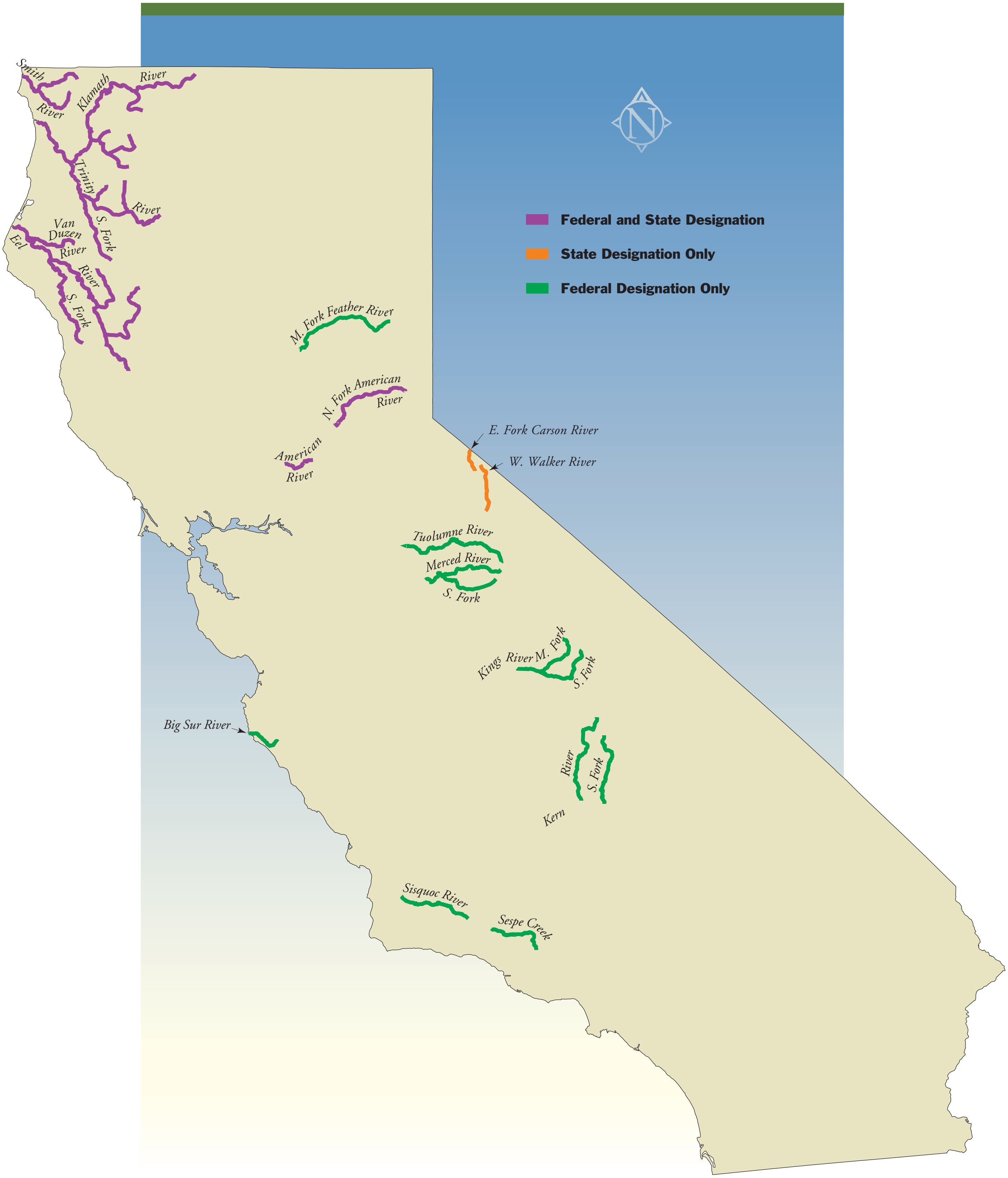


TABLE 4-17

Wild and Scenic River Flows by Waterway (taf)

Waterway	1995 Average	1995 Drought	2020 Average	2020 Drought
Klamath	9,070	3,980	9,070	3,980
Smith	2,920	1,720	2,920	1,720
Eel	5,810	2,200	5,810	2,200
Big Sur	83	22	83	22
Sisquoc	15	6	15	6
Sespe Creek	69	51	69	51
Middle Fork Feather	1,129	497	1,129	497
North Fork American	584	239	584	239
Lower American	20	0	20	0
Tuolumne	1,192	572	1,192	572
Merced	782	367	782	367
Kings	896	448	896	448
North Fork Kern	628	275	628	275
South Fork Kern	90	28	90	28
East Fork Carson	71	34	71	34
West Walker	200	120	200	120
Total (rounded)	**23,560**	**10,560**	**23,560**	**10,560**

TABLE 4-18

Wild and Scenic River Flows by Hydrologic Region (taf)

Region	1995 Average	1995 Drought	2020 Average	2020 Drought
North Coast	17,800	7,900	17,800	7,900
San Francisco Bay	0	0	0	0
Central Coast	98	28	98	28
South Coast	69	51	69	51
Sacramento River	1,733	736	1,733	736
San Joaquin River	1,974	939	1,974	939
Tulare Lake	1,614	751	1,614	751
North Lahontan	271	154	271	154
South Lahontan	0	0	0	0
Colorado River	0	0	0	0
Total (rounded)	**23,560**	**10,560**	**23,560**	**10,560**

long-term unimpaired flow from the Department's Bulletin 1 was used. The estimated average unimpaired flow for the 1990-91 water years was used for the drought condition.

Instream Flows

Instream flow is the water maintained in a stream or river for instream beneficial uses such as fisheries, wildlife, aesthetics, recreation, and navigation. Instream flow is a major factor influencing the productivity and diversity of California's rivers and streams.

Instream flows may be established in a variety of ways—by agreements executed between DFG and a water agency, by terms and conditions in a water right permit from SWRCB, by terms and conditions in a FERC hydropower license, by a court order, or by an agreement among interested parties. Required flows on most rivers vary by month and year type, with wet year requirements generally being higher than dry year requirements. Converting from net water use budgets used in prior editions of Bulletin 160 to the applied water budgets used in Bulletin 160-98 created a challenge in properly accounting for multiple instream flows within a river basin. Bulletin 160-98 used a simplified approach in which only the largest downstream flow requirement was included in the water budgets.

Part of Sespe Creek is included in the wild and scenic river system. The creek, located in Ventura County, is tributary to the Santa Clara River.

This simplified approach undercounts applied instream flow requirements on streams having multiple requirements. The Department is developing a new modeling approach for the next water plan update that will more accurately quantify applied instream flows.

Since the determination of 1990-level instream flow values used as base conditions in Bulletin 160-93, subsequent agreements or decisions have increased or added instream flow requirements for the Trinity River, Mokelumne River, Stanislaus River, Tuolumne River, Owens River, Putah Creek, and Mono Lake tributaries. In addition, ten new waterways have been added to the Bulletin 160-98 instream flow water budgets—the Mad River, Eel River, Russian River, Truckee River, East Walker River, Nacimiento River, San Joaquin River (at Vernalis), Walker Creek, Lagunitas Creek, and Piru Creek. The sidebar on American River environmental water use illustrates how environmental water demands are treated in Bulletin 160 water budgets.

Factors Affecting Future Instream Flows. It is difficult to forecast future regulatory actions or agreements that could change existing instream flow requirements. Bulletin 160-98 thus does not attempt to quantify the outcome of future regulatory or administrative actions. Factors likely to affect future flow requirements include listings or potential listings of new fish species, habitat restoration programs, and programs to acquire water for environmental purposes.

Recent decisions on federal listing of coho salmon and steelhead trout (see Chapter 2) are likely to influence water management decisions affecting these species, but the specific actions will ultimately depend on the outcome of consultations, biological assessments, biological opinions, and habitat conservation plans. In 1997, the Governor's Executive Order W-159-97 created the Watershed Protection and Restoration Council. The council oversees State watershed protection and enhancement activities, including restoration of anadromous fish. One goal of this effort is to provide sufficient protection to coho, steelhead, and other anadromous salmonids to satisfy ESA requirements. Successful implementation of this program could lessen water supply impacts of salmonid listings.

Coho salmon are found in coastal streams and in large river systems such as the Klamath River and its tributaries. Some of the greatest potential for new water supply impacts could be on the Klamath River system (including its Trinity River tributary), where USFWS is finalizing instream flow studies for several salmonids. Steelhead populations are distributed throughout coastal streams and rivers, and are also found in the Sacramento Valley. (Wild stocks of steelhead in the Sacramento River system are mostly confined to upper watershed tributaries such as Antelope, Deer, and Mill Creeks, and the Yuba River. The San Joaquin River system no longer supports a significant natural steelhead population—most steelhead found in the system are hatchery fish.) Data from the SWP and CVP pumping plants in the southern Delta indicate that most juvenile steelhead move through the Delta during the winter and early spring, when Bay-Delta Accord restrictions are already in place. Water supply impacts on coastal rivers and streams must be evaluated from a basin-specific standpoint.

The spring-run chinook salmon traditionally spawned in upper reaches of Central Valley rivers and their tributaries. Today, Deer, Mill, and Butte Creeks are considered crucial Sacramento River tributaries for spring-run spawning. Sustaining populations of spring-run are also found in Battle Creek, and the Feather and Yuba Rivers, although there are questions about the genetic integrity of these populations because of interbreeding between fall-run and spring-run salmon. Portions of Deer and Mill Creeks have been given special status by State legislation to help protect the fishery.

As described in Chapters 5 and 6, many habitat restoration programs are underway and substantial funding is available for restoration actions. Improvements such as facilitating fish passage, replenishing spawning gravel, and restoring shaded riverine habitat will help in efficient management of water used for environmental purposes. Specific benefits of habitat restoration will have to be evaluated on a watershed-by-watershed basis—it is not possible to quantify potential water supply implications of present and future habitat restoration actions at a statewide level. Examples of programs or projects now underway are described in later chapters.

The 1997 draft programmatic EIS for CVPIA implementation describes federal water acquisition alternatives for the AFRP. Table 4-19 shows the amounts proposed in alternative 4 of the draft PEIS. These flows represent the high end of potential federal water acquisition actions. Under USBR's assumptions for alternative 4, the instream flows are not allowed to be exported at the Delta. Quantification of alternative 4 flows was provided by PROSIM operations studies. The federal agencies' ability to acquire the water would be subject to their finding willing sellers.

In addition to water acquisition on major rivers

Environmental Water Use—An American River Example

As discussed in Chapter 3, the return flow from one water use can become the supply for the next downstream use. The applied water budgets in Bulletin 160-98 reflect the multiple uses which supplies in a river basin may have. Reapplication of flows in the American River for environmental purposes provides an illustration of how the Bulletin accounts for multiple uses in its water budgets.

The American River originates in the Sierra Nevada, flowing generally from east to west down through the foothills into the Sacramento Valley, ultimately reaching the Sacramento River and the Delta. The upper watershed of the American River consists of the north, middle and south forks. The mainstem, or Lower American River, begins near Folsom at the confluence of the north and south forks. Environmental water supplies are reapplied at several locations between the upper watershed and the Delta.

Wild and scenic environmental water demands exist on the American River's north fork (584 taf) and mainstem (20 taf). In Bulletin 160-98 water budgets, American River wild and scenic flows are classified as environmental water use on the demand side of the budget and as required environmental instream flow on the supply side of the budget. These environmental demands are not consumptive; hence, the surface supplies are available for downstream use.

The American River has several instream flow requirements on its three forks as well as on its mainstem. For example, a 54 taf (75 cfs) requirement exists below Ralston Afterbay Dam on the middle fork and a 72 taf (100 cfs) requirement exists below Chili Bar Dam on the south fork. The river's largest instream flow requirement is on the mainstem below Nimbus Dam. This 234 taf requirement is the only American River instream flow requirement accounted for in the water budgets. As with wild and scenic demands, the American River instream flow requirement is shown as environmental water use on the demand side of the budget and as required environmental instream flow on the supply side of the budget. This environmental demand is not consumptive; therefore, the surface supply is available for downstream use.

Required instream flow in the American River is reapplied downstream to meet Delta outflow requirements. The Bulletin 160-98 water budgets classify this flow as reapplied surface water supply. About 70 percent of the Delta's 5.6 maf environmental demand (4.0 maf) is satisfied through reapplication of water released to meet environmental instream requirements in rivers tributary to the Delta.

TABLE 4-19

Proposed Instream Flows, CVPIA PEIS Alternative 4 (taf)

Location	*Region*	*Target*	*Average*
Merced River	San Joaquin River	200	194
Tuolumne River	San Joaquin River	200	197
Stanislaus River	San Joaquin River	200	194
Calaveras River	San Joaquin River	30	27
Mokelumne River	San Joaquin River	70	62
Yuba River	Sacramento River	100	87
Total		**800**	**761**

for the Alternative 4 instream flows shown in the table, the draft PEIS also proposes water acquisition on smaller Sacramento River tributaries such as Deer, Mill, and Battle Creeks. The draft PEIS does not quantify target flows and acquisitions for these smaller tributaries.

The public comment period on the draft CVPIA PEIS closed in April 1998 and USBR and USFWS expect to release a final PEIS in 1999, after the publication date of this Bulletin.

CVPIA authorizes DOI to acquire supplemental water from willing sellers. At this time, no long-term sources (e.g., long-term contracts for water transfers) have been established—water acquired has been purchased on a year-to-year basis. It is not possible to identify specifically how and where the supplemental water would be obtained in the future, or what other water demands might be reduced as a result of CVPIA water transfers. Chapter 6 provides more detail on how water marketing arrangements are treated in Bulletin 160 water budgets.

As discussed in Chapter 2, CVPIA also affects Trinity River instream flows, by requiring that Trinity River flows be maintained at not less than 340 taf/yr while USFWS conducts an instream flow study that was to be completed by 1996. USFWS's preliminary results suggest that instream flows of 592 taf/yr (weighted average of five water year types) may be proposed. USBR, USFWS, Trinity County, and the Hoopa Valley Tribe are preparing an EIR/EIS to evaluate impacts of the proposed flows. A draft EIR/EIS has not yet been released. Bulletin 160-98 uses the existing instream flow requirement of 340 taf/yr since a formal proposal for new Trinity River instream flows has not yet been released.

Instream Flow Summary. Tables 4-20 and 4-21 show instream flows used in Bulletin 160-98 water budgets by waterway and by hydrologic region. The drought year scenario shown in the tables represents the minimum annual required flow volume. For average water years, the annual required flow volume is computed by combining the expected number of years in each year type (wet, above normal, normal, below normal, and/or dry, as specified in the existing agreement or order).

In water budget computations, the Department counts instream flows as depleted if the flows go directly to a salt sink, such as the ocean. In the Central Valley where some instream flows may reach the ocean, any depletions are counted toward required Delta outflow (see following section). This approach avoids counting depletions twice—once as instream flow and once as Delta outflow.

Bay-Delta Outflow

Environmental water use for Bay-Delta outflow is computed by using operations studies to quantify SWRCB Order WR 95-6 requirements. This section briefly describes the Delta's setting and some of its environmental resource issues. Readers interested in detailed descriptions of Delta hydrodynamics, facilities, and environmental resources may wish to review the extensive materials prepared by the Interagency Ecological Program, San Francisco Estuary Program, or CALFED program.

Setting. The Bay-Delta has two high tides and two low tides every day. An enormous volume of water (an average of about one-fourth of the estuary's total volume), moves in and out of the estuary with each tidal cycle. Tidal action and Delta outflow are two important physical processes which establish salinity gradients and carry sediments through the system. Tidal action and Delta outflow cause seaward-flowing fresh water from the rivers to mix with denser landward-flowing salt water from the ocean. The average tidal flow rate in the Delta is about 170,000 cfs, much greater than the average seaward flow of fresh water from rivers and streams.

CVPIA Anadromous Fish Restoration Program

One provision of CVPIA directed DOI to develop (by October 1995) and to implement a program "which makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991". (The San Joaquin River between Friant Dam and Mendota Pool is not covered by this goal.) In response to this provision, USFWS prepared a 1995 working paper listing many potential restoration actions (some involving instream flows, and some not) without regard to their reasonableness. Elements of that working paper were subsequently incorporated into a revised draft restoration plan prepared in May 1997. One function of the draft plan was to evaluate (at a programmatic level) the reasonableness of implementing potential restoration actions, given the authority and funding provided DOI by CVPIA. (For example, a potential restoration action that would involve modifying the diversion works of a local water agency would only be reasonable if the local agency wished to participate with USBR or USFWS in the action.) The revised draft plan is scheduled to be followed by an implementation plan that would review priority actions to be taken in the next three to five years.

The CVPIA tools available to USFWS and USBR to carry out the AFRP include the 800 taf of project water dedicated for environmental purposes, the authority to acquire supplemental water to achieve AFRP goals, and the many physical habitat restoration measures required in the act (e.g., restoring spawning gravel, screening diversions, improving fish passage at Red Bluff Diversion Dam). The CVP dedicated water is only available to USFWS and USBR on CVP-controlled rivers below the major project dams. For other Central Valley waterways, the agencies are proposing to carry out a water acquisition program to buy water to meet AFRP needs. The quantity of water to be acquired is subject to available federal funding and the availability of water on the market. USBR's 1997 draft CVPIA PEIS illustrates costs and impacts associated with different levels of supplemental water acquisition.

Fish species covered by the CVPIA's doubling goal are salmon, steelhead, striped bass, sturgeon, and American shad. This sturgeon was photographed at the Steinhart Aquarium.

TABLE 4-20

Instream Flow Requirements by Waterway (taf)[a]

River or Creek	*1995* *Average*	*1995* *Drought*	*2020* *Average*	*2020* *Drought*
Klamath	833	833	833	833
Trinity	341	341	341	341
Mad	46	46	46	46
Eel	49	15	49	15
Russian	142	51	142	51
Lagunitas Creek	10	9	10	9
Walker Creek	6	0	6	0
Carmel	4	2	4	2
Nacimiento	16	7	16	7
Piru Creek	4	4	4	4
Clear Creek	25	25	25	25
Cache Creek	7	7	7	7
Putah Creek	22	22	22	22
Sacramento	1,945	1,702	1,945	1,702
Feather	880	588	880	588
Yuba	274	196	274	196
Bear	10	10	10	10
American	234	234	234	234
Mokelumne	158	84	158	84
Stanislaus	187	158	187	158
Tuolumne	214	94	214	94
Merced	79	67	79	67
San Joaquin	532	309	532	309
Truckee	70	70	70	70
East Walker	15	15	15	15
Mono tributaries	82	56	82	56
Owens	25	25	25	25
Total (rounded)	**6,210**	**4,970**	**6,210**	**4,970**

[a] On streams with multiple instream requirements, only the largest downstream requirement is included in Bulletin 160-98 water budgets.

TABLE 4-21

Instream Flow Requirements by Hydrologic Region (taf)

Region	*1995* *Average*	*1995* *Drought*	*2020* *Average*	*2020* *Drought*
North Coast	1,410	1,285	1,410	1,285
San Francisco Bay	17	9	17	9
Central Coast	20	9	20	9
South Coast	4	4	4	4
Sacramento River	3,397	2,784	3,397	2,784
San Joaquin River	1,169	712	1,169	712
Tulare Lake	0	0	0	0
North Lahontan	85	84	85	84
South Lahontan	107	81	107	81
Colorado River	0	0	0	0
Total (rounded)	**6,210**	**4,970**	**6,210**	**4,970**

Recovery Efforts for Winter-Run Chinook Salmon

As indicated by the plot of winter-run salmon escapement, there has been a long-term decline in the species' population. The ultimate goal for recovery of winter-run salmon would be restoration of a self-sustaining, naturally spawning population. Two efforts being conducted to help achieve this goal are a captive broodstock program and an artificial propagation program. The purpose of the broodstock program is to maintain the genetic composition of the existing population, and that of the artificial propagation program is to stabilize and increase the naturally spawning population.

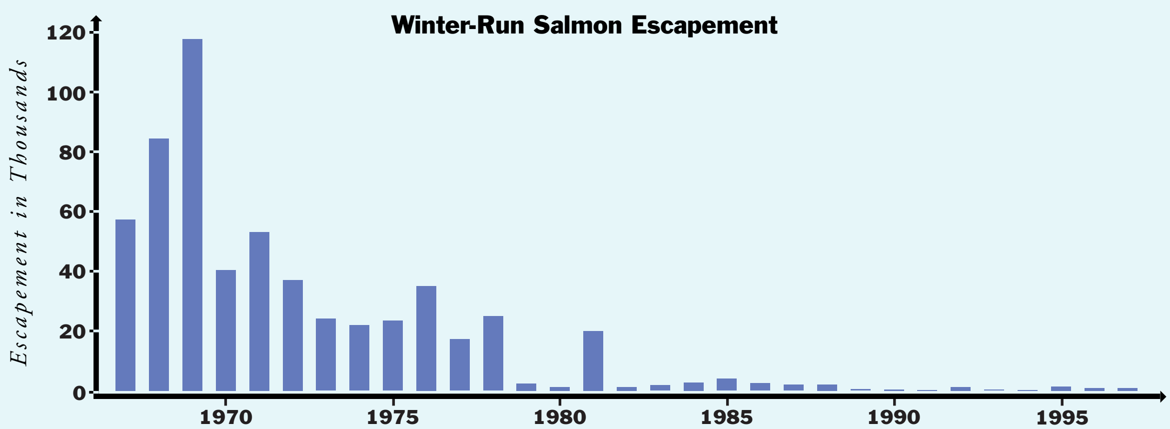
Discussions among State and federal agencies and stakeholder groups in 1991 and 1992 led to creation of a program to evaluate the feasibility of rearing Sacramento River winter-run fry in captivity, so that a broodstock would be available if wild winter-run fish were to disappear. (The population's small size makes it vulnerable to catastrophic loss of a year class, such as a loss that could be caused by a chemical spill in the vicinity of winter-run spawning areas. The captive broodstock would provide an alternative source of genetic material as insurance against such a loss.) Agencies participating in funding the program include USBR, USFWS, NOAA, the Department, and DFG. Rearing facilities were established at the University of California's Bodega Marine Laboratory and the California Academy of Sciences' Steinhart Aquarium. Juvenile fish, beginning with the 1991 year class, were delivered to the facilities in 1992. The parent broodstock were wild winter-run captured in the Sacramento River. Presently, fish from four year classes are being held at the facilities.

The artificial propagation program entails trapping known wild adult winter-run fish, spawning them in a controlled environment, and rearing the offspring for release back to the river system. As adults, the artificially propagated fish would return to winter-run spawning areas and commingle with wild winter-run. Artificial propagation activities were originally begun at USFWS's Coleman National Fish Hatchery on Battle Creek, but fish reared at Coleman imprinted on Battle Creek water and returned there to spawn, rather than going to the upper Sacramento River as desired. (There were also difficulties associated with distinguishing between winter-run and spring-run chinook, in selecting the fish to be propagated. Better genetic identification techniques have been developed to address this problem.)

CVPIA directed USFWS to rehabilitate and expand Coleman National Fish Hatchery. The hatchery was constructed in 1942 to mitigate loss of Sacramento River salmon spawning areas due to construction of Shasta and Keswick Dams.

The most recent development in the artificial propagation program was construction of an interim rearing facility, the Livingston Stone National Fish Hatchery, on the mainstem Sacramento River immediately downstream from Shasta Dam. This facility will allow the artificially spawned winter-run salmon to imprint on mainstem Sacramento River water, so that they will return to natural spawning grounds on the mainstem as adults. Water supply for the hatchery is provided via piping from the dam's penstocks. The hatchery is beginning operations in 1998.

Additional efforts to help recover winter-run chinook salmon, such as screening diversions and habitat improvement projects, are described in Chapter 8.



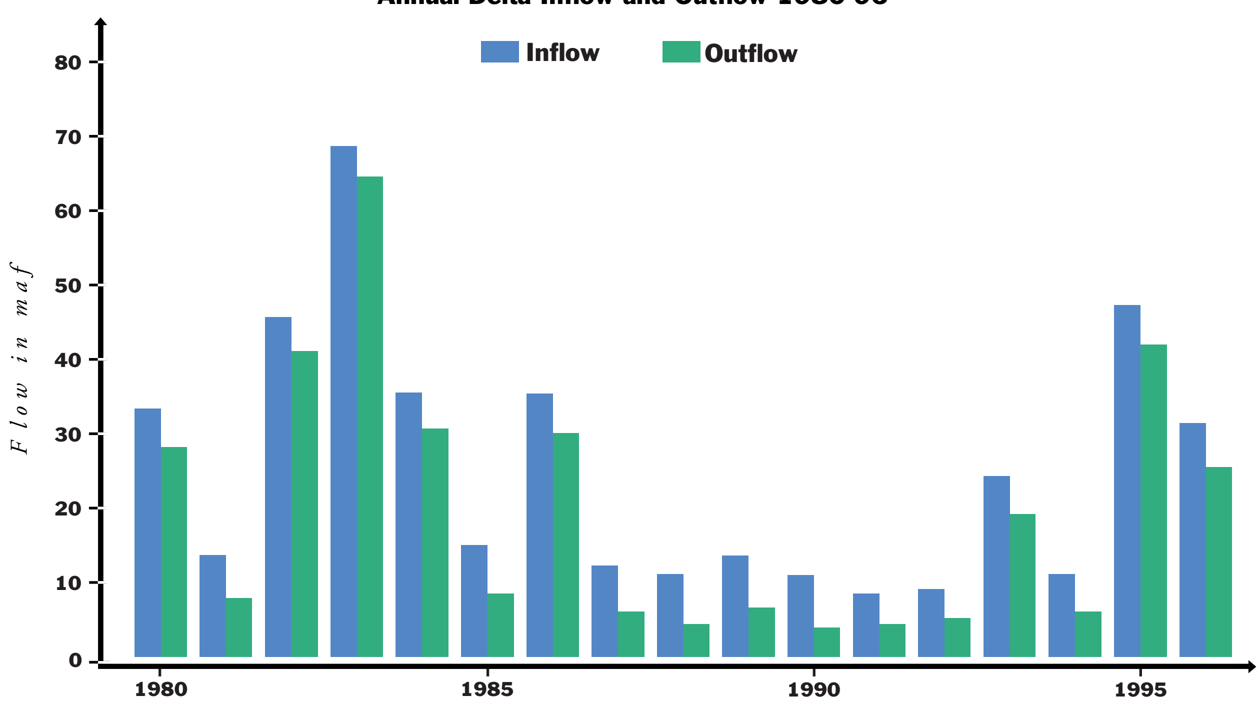
Three major components of Delta inflow include precipitation, inflow from the Sacramento and San Joaquin Rivers, and inflow from east side streams (including the Calaveras, Mokelumne and Cosumnes Rivers). Figure 4-11 shows annual inflow and outflow values for 1980-96. For this period, the average annual inflow to the Delta was 25.7 maf, more than 75 percent of which was contributed by the Sacramento and San Joaquin Rivers.

Delta outflow is the calculated amount of water flowing past Chipps Island at the western edge of the Delta into Suisun Bay. The magnitude of Delta outflow controls salt water intrusion from the ocean into the estuary. The magnitude of Delta outflow also influences the distribution of many estuarine fishes and invertebrates. Generally, the greater the outflow, the farther downstream estuarine fish and invertebrates occur. The relationship between Delta outflow and abundance of fish and invertebrates is much less clear. Some species, such as longfin smelt and juvenile splittail, show strong correlations between abundance and Delta outflow. The effects of outflow on species can vary depending on the time of year volume of outflow.

Suisun Bay, the first bay below the Delta, receives fresh water inflow that contributes dissolved nutrients needed to support estuarine food chains. Adjacent to Suisun Bay is Suisun Marsh, which includes about 58,600 acres of diked managed wetlands, tidal marsh, and adjacent grasslands, 29,500 acres of waterways, and a buffer zone of 27,900 acres of varying land use. Suisun Marsh is one of the largest contiguous brackish water marshes in the United States. Nearly half of the waterfowl and shorebirds migrating on the Pacific flyway pass through the Bay-Delta each year, using the Suisun marsh and other Delta wetlands as feeding and resting stations.

Fresh water outflow from the Delta passes through Suisun Bay and through the Carquinez Straits, entering San Pablo Bay, and eventually reaching the Golden Gate. By comparison, there is limited fresh water outflow and tidal circulation at the southern end of San Francisco Bay. Fresh water outflow to the South Bay comes from local tributaries such as Coyote Creek and the Guadalupe River. San Pablo Bay and the South Bay both offer shallow water habitat. National wildlife refuges—the San Pablo Bay NWR and the San Francisco Bay NWR—occupy parts of the shoreline in these areas. See Figure 4-12 for a location map of the Bay-Delta.

FIGURE 4-11
Annual Delta Inflow and Outflow 1980-96[a]



[a] 1983 was the wettest year in Northern California in this century.

FIGURE 4-12

Bay-Delta Estuary

The Delta is characterized by miles of meandering waterways and leveed islands used mainly for agricultural purposes.

Delta Fish Species of Special Concern. About two-thirds of California's salmon migrate through the Delta, including species having commercial importance (fall-run chinook salmon), as well as listed or candidate species (winter-run chinook, spring-run chinook, and steelhead trout). Resident fish species of special concern include Delta smelt (listed as threatened under both the State and federal ESAs) and splittail (proposed for federal ESA listing). Habitat needs of anadromous and resident Delta species of special concern were reflected in actions taken in the Bay-Delta Accord and in SWRCB's Order WR 95-6. The accord's provisions for coordination of CVP and SWP operations in the Delta with the presence of fish species of concern have been reflected in actions by the CALFED Operations Group to reduce Delta exports at times when monitoring indicated that significant numbers of certain fish species were present in the southern Delta. Day-to-day management of CVP and SWP Delta operations under near real-time conditions requires extensive data collection and monitoring support. The Interagency Ecological Program, a cooperative effort of nine State and federal agencies (DWR, DFG, SWRCB, USBR, USFWS, EPA, NMFS, USACE, and USGS), acquires and disseminates near real-time fish distribution and abundance

Delta smelt, native to the Bay-Delta, have a one year life span and relatively low reproductive rate, making their population abundance sensitive to short-term habitat changes.

data used by the CALFED Operations Group.

Populations of native species of special concern are affected by a variety of factors, many of which are not related to Delta outflow. One nonflow factor now receiving more attention is competition from introduced aquatic species (see Chapter 2 for a description of the National Invasive Species Act of 1996). Introduction of non-native species into an ecosystem can alter the pre-existing balance achieved among the native species. Native species' populations can be reduced, for example, when introduced species out-compete the native species for food or otherwise alter the food chain, or when introduced species prey upon native species.

In the Bay-Delta, new introductions are occurring in a system that already has numerous introduced species. Researchers estimate that the Bay-Delta is now home to at least 150 introduced plant and animal species, some of which were introduced deliberately (planting of game fish species such as striped bass) and others whose arrival was accidental (discharge of invertebrates in ship ballast water). The Asian clam, for example, was first detected in the Bay in 1986 and has now become the most abundant mollusk in the northern part of the Bay. This clam is a voracious feeder on the phytoplankton which supports other aquatic species. The zebra mussel—which has caused millions of dollars of damage in the Great Lakes states—has not yet been detected in the Delta, but experts believe that it may be only a matter of time before the mussel arrives. Invasive plant species in the Delta include *Egeria densa* and *Arundo Donax* (giant reed). Hydrilla, another well-known invasive aquatic plant, is now found in Clear Lake in Northern California, and control measures are being taken to eradicate it there, to prevent its spread to Delta waterways.

The Asian clam was first detected in the San Francisco Bay in 1986. By the early 1990s, it was the most abundant mollusk in the northern part of the Bay.

Much of the land in the Suisun Marsh is owned and managed by private gun clubs for duck hunting. DFG manages a wildlife area on Grizzly Island.

Quantifying Delta Outflow Requirements. SWRCB Order WR 95-6 established numerical objectives for salinity, river flows, export limits, and Delta outflow. DWRSIM operations studies were used to translate these numerical objectives into Delta outflow requirements for average and drought year scenarios. The studies computed outflow requirements of approximately 5.6 maf in average years and 4.0 maf in drought years.

Wetlands

The wetlands component of environmental water use is based on water use at freshwater managed wetlands, such as federal national wildlife refuges and State wildlife management areas. The following text reviews the status of wetland acreage in California and wetland management programs, then discusses quantification of water demands and supplies for wetlands.

In general, wetlands can be divided into saltwater and brackish water marshes (usually located in coastal areas) and freshwater wetlands (generally located in inland areas). Five areas of California contain the largest remaining wetlands acreage in the State—the Central Valley, Humboldt Bay, San Francisco Bay, Suisun Marsh, and Klamath Basin. The majority of the State's wetland protection and restoration efforts are occurring in these areas. Nontidal wetlands usually depend on a supplemental water supply, and protecting or restoring them may create demands for freshwater supplies.

Wetlands Policies and Programs. Many programs and policies have been adopted by federal, State and regional agencies and private entities to protect and restore wetlands in California. Several of the more re-

California is a wintertime destination for migratory waterfowl on the Pacific flyway. Managed wetlands provide feeding, resting, and overwintering sites for the waterfowl.

cent wetland programs and policies are discussed below.

Ecosystem restoration is a large part of the CALFED program. CALFED's draft ERP plan proposes habitat restoration goals that include creating 64,000 acres of seasonal and perennial wetlands and 2,000 acres of riparian habitat, returning 37,000 to 57,000 acres to tidal action and enhancing 8,000 acres of existing seasonal wetlands. About 1,700 acres of wetland restoration projects were funded under the accord's Category III program in 1995 and 1996.

CVPIA required DOI to provide water supplies to the wetlands areas shown in Table 4-22. The Sacramento Valley refuges were to be provided with water supplies specified in a 1989 refuge water supply investigation prepared by USBR, and the San Joaquin Valley wetlands areas with supplies specified in USBR's San Joaquin Basin Action Plan/Kesterson Mitigation Action Plan. This water supply was to be provided in two increments—the first corresponding to the exist-

California Wetlands Conservation Policy

In 1993, a California wetlands conservation policy was established. The goals of the policy were to establish a framework and a strategy that would:

- Ensure no overall net loss and achieve a long-term net gain in the quantity, quality, and permanence of wetlands acreage and values in California in a manner that fosters creativity, stewardship, and respect for private property.
- Reduce procedural complexity in the administration of State and federal wetlands conservation programs.
- Encourage partnerships to make landowner incentive programs and cooperative planning efforts the primary focus of wetlands conservation and restoration.

The policy recommended completion of a statewide inventory of wetlands which would lead to the establishment of a formal wetland acreage goal. This inventory is in progress. The Resources Agency expects these policies to result in improved status for 30 to 50 percent of the State's wetlands by the year 2010. Based on an estimate of 450,000 acres of existing wetlands in the State, as much as 225,000 acres of wetland could be improved, restored or protected.

TABLE 4-22

CVPIA Refuge Water Supplies[a] (taf)

Refuge	*Level 2 Supply at Refuge Boundary*	*Level 4 Supply at Refuge Boundary*
Sacramento Valley Refuges		
Sacramento National Wildlife Refuge	46.4	50.0
Delevan National Wildlife Refuge	20.9	30.0
Colusa National Wildlife Refuge	25.0	25.0
Sutter National Wildlife Refuge	23.5	30.0
Gray Lodge Wildlife Management Area	35.4	44.0
Total for Sacramento Valley Refuges	**151.2**	**179.0**
San Joaquin Valley Refuges		
San Luis National Wildlife Refuge	19.0	19.0
Kesterson National Wildlife Refuge[b]	10.0	10.0
Volta Wildlife Management Area	13.0	16.0
Los Banos Wildlife Management Area	16.6	25.5
San Joaquin Basin Action Lands		
Freitas	5.3	5.3
West Gallo	10.8	10.8
Salt Slough	6.7	10.0
China Island	7.0	10.5
Grasslands Resource Conservation District	125.0	180.0
Mendota Wildlife Management Area	27.6	29.7
Merced National Wildlife Refuge	15.0	16.0
East Gallo	8.9	13.3
Kern National Wildlife Refuge	9.9	25.0
Pixley National Wildlife Refuge	1.3	6.0
Total for San Joaquin Valley Refuges	**276.1**	**377.1**
Total for all Refuges	**427.3**	**556.1**

[a] Table is excerpted from 1997 draft CVPIA PEIS.
[b] Kesterson NWR was merged with San Luis NWR subsequent to CVPIA enactment.

ing average annual deliveries that the wetlands had been receiving from drain water and other sources, and the second corresponding to the ultimate or optimum management levels of the wetlands. The first increment of water supply (Level 2) was to be provided by reallocation of CVP supplies. The second increment (Level 4) was to be acquired through purchases from willing sellers. DOI was to acquire all of the second increment of supply by 2002. USBR has operated the CVP to provide the Level 2 supplies, and has been making year-to-year short-term water purchases for the increments of Level 4 supply. USBR and USFWS have been studying conveyance alternatives (and groundwater extraction, in addition to surface water supply alternatives) associated with making these increased supplies available to the refuges.

CVPIA also required DOI to prepare a report by September 1997 to investigate methods of improving water supplies in the Central Valley for existing private wetlands and for 120,000 acres of new wetlands. The 120,000 acres came from wetland restoration objectives of a Central Valley Habitat Joint Venture report. USFWS's report is currently in preparation.

Additionally, the act required that financial incentives be made available to farmers within the CVP service area for flooding agricultural lands to provide waterfowl habitat. The incentives include cost-sharing for water purchases, pumping costs, facility construction (e.g., water control structures), and upgrades or maintenance to existing facilities. CVPIA caps the funding for this program at $2 million per year and the program terminates in 2002.

In 1986, the North American Waterfowl Management Plan was signed by the United States and Canada. The plan was updated in 1996 and Mexico became a signatory. NAWMP provides a framework for waterfowl management in North America through 2010; it includes numerical goals for waterfowl populations and for habitat protection, restoration, and enhancement. Implementing NAWMP is the responsibility of joint ventures in which governmental agencies and private organizations pool resources to address habitat needs.

There are four NAWMP joint ventures covering parts of California. A fifth joint venture is being considered in Southern California. The four existing joint ventures are described below.

The Central Valley Habitat Joint Venture, established in 1988, was the first California joint venture. CVHJV adopted six goals for the Central Valley:

- Protect 80,000 acres of wetlands through fee acquisition or conservation easement.
- Restore (and protect) 120,000 acres of former wetlands.
- Enhance 291,555 acres of existing wetlands.
- Enhance water-based habitat on 443,000 acres of private agricultural land.
- Secure 402,450 af of water for 15 refuges in the Central Valley.
- Secure CVP preference power for public and private lands dedicated to wetland management (i.e., provide access to low-cost power generated at CVP facilities).

In 1990, the Legislature authorized the Inland Wetlands Conservation Program administered by the Wildlife Conservation Board. This program carries out some CVHJV objectives by administering a $2 million per year program to acquire wetland habitat.

The Pacific Coast Joint Venture encompasses coastal wetlands, major rivers, and adjacent uplands from northern British Columbia to the northern edge of San Francisco Bay. In California, there are two focus areas with strategic plans outlining specific target areas and acreage objectives. Almost all the wetlands are coastal projects with little or no freshwater requirements. Objectives for the northern focus area (Del Norte and Humboldt counties) are:

- Maintain 22,000 acres of seasonal wet pasture in agricultural usage compatible with water-associated wildlife.
- Permanently protect an additional 10,500 acres of key wetlands through easements or fee acquisitions.
- Protect, restore, and enhance 10,100 acres of wetlands on existing public lands.
- Assist landowners to protect, enhance, and restore 5,000 acres through cooperative projects.

Objectives of the southern focus area (Mendocino, Sonoma, and Marin Counties excepting watersheds draining to San Francisco Bay) are:

- Permanently secure through fee acquisition or easements an additional 20,000 acres of coastal and interior wetlands, riparian habitats, and associated uplands.
- Restore 3,500 acres of reclaimed coastal and interior wetlands on private and public lands.
- Enhance 5,500 acres of coastal and interior wetlands and riparian habitats on public and private lands.

Approximately half of the acreage in the southern focus area is inland (nontidal) habitat requiring fresh water.

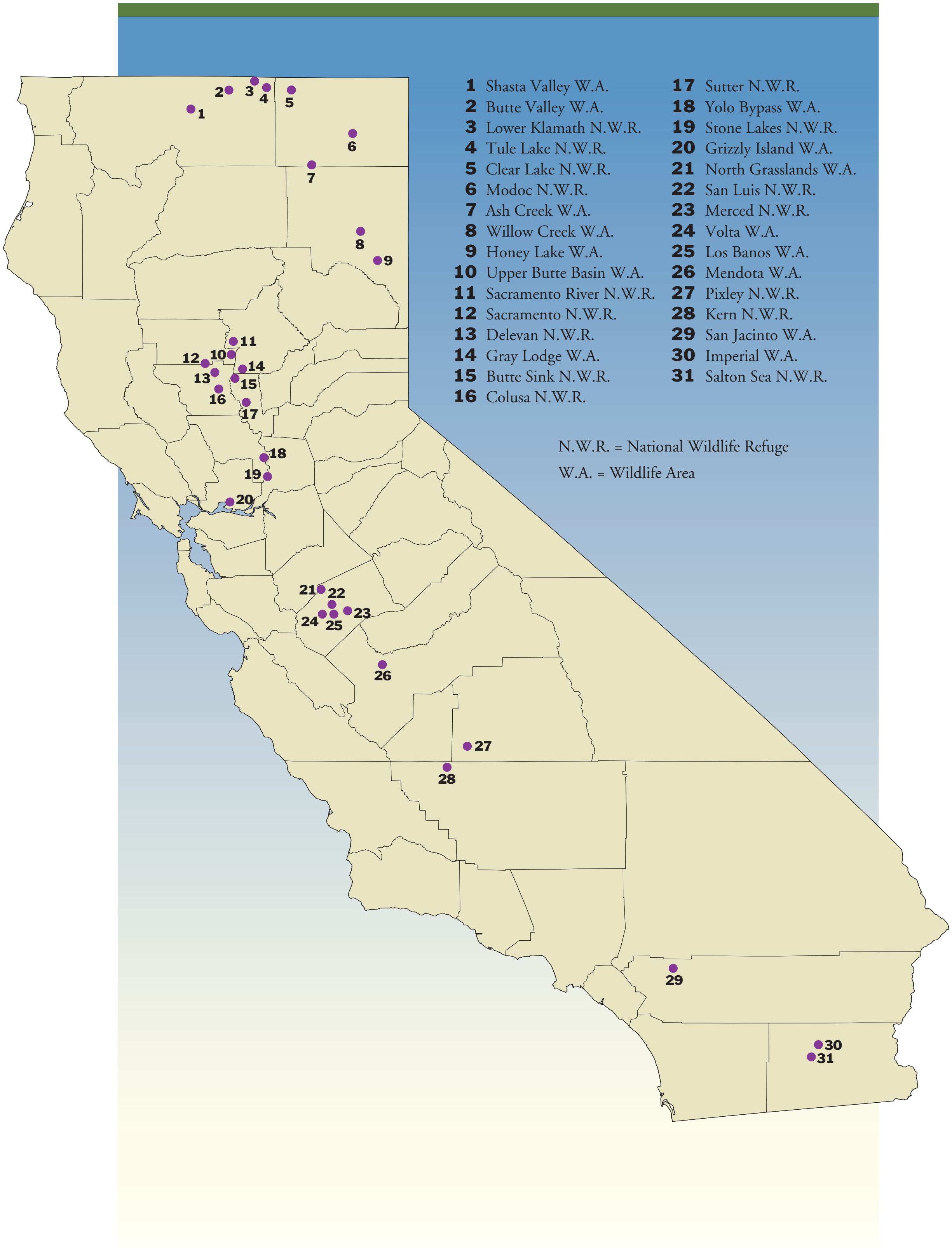
The Intermountain West Joint Venture encompasses parts of Canada and Mexico and all or part of eleven western states, including eastern California. The California action group has completed a working agreement and drafted plans for six focus areas. Acreage goals for acquisition, restoration, and enhancement have not been established.

The San Francisco Bay Joint Venture was established in 1995. Its management board is drafting an implementation strategy. Formal acreage goals and timelines for acquisition and restoration projects will be established. It is expected that many of the areas protected or restored by the SFBJV will be tidal areas with little or no fresh water requirement.

Refuge Water Supply Conservation Programs. In the spring of 1997, a refuge water supply interagency coordinated program task force was formed as an outgrowth of discussions in CALFED and CVPIA programs regarding the need to have best management practices for water conservation on wildlife refuges. The goal of the task force is to develop a common methodology for water management planning, including water conservation actions, for the federal, State, and private refuges covered in CVPIA's refuge water supply provisions. A draft document containing BMPs or efficient water use guidelines for the refuges is scheduled to be released for public review in 1998.

Wetlands Water Use. Bulletin 160-98 quantifies applied water needs only for managed wetlands, because other wetlands types such as vernal pools or coastal wetlands use naturally-occurring water supply (precipitation or tidal action). Managed wetlands are defined for the Bulletin as impounded freshwater and nontidal brackish water wetlands. Managed wetlands may be State and federal wildlife areas or refuges, private wetland preserves owned by nonprofit organizations, private duck clubs, or privately owned agricultural lands flooded for cultural practices such as rice straw decomposition. Figure 4-13 shows California's publicly owned wetlands. Some of the largest concentrations of privately owned wetlands are the duck clubs in the Suisun Marsh and the flooded rice fields in the Sacramento Valley. (Acreage of rice fields flooded to enhance decomposition of stubble remaining after harvest and to provide habitat for

FIGURE 4-13
Publicly-Owned Fresh Water Wetlands



overwintering waterfowl was identified by Department land use surveys.)

State and federal wetlands in the Central Valley are normally managed to support several types of wildlife use areas—permanent marsh, seasonal marsh, irrigated waterfowl food crops (such as millet, rice, or smartweed), and non-irrigated uplands. Each has different applied water requirements, as indicated in Table 4-23, which shows typical ranges for Central Valley wetlands. Table 4-24 shows wetlands water demands by region.

TABLE 4-23

Ranges of Applied Water on Central Valley Managed Wetlands (af/acre/year)

Type of Use	*Applied Water*
Permanent marsh	5-10
Seasonal marsh	2-10
Irrigated waterfowl food crops	1-4

Summary of Environmental Water Use

Table 4-25 shows base 1995 and forecasted 2020 environmental water use by hydrologic region. The large values in the North Coast Region illustrate the magnitude of demands for wild and scenic rivers in comparison to other environmental water demands.

Water Use Summary by Hydrologic Region

Tables 4-26 and 4-27 summarize California applied water use by hydrologic region. The tables combine the urban, agricultural, and environmental water use described in this chapter. These demands, together with the water supply information presented in Chapter 3, are used to prepare the statewide water balance shown at the beginning of Chapter 6 and the regional water balances shown in Chapters 7-9.

TABLE 4-24

Wetlands Water Use by Hydrologic Region (taf)

	1995		*2020*	
Region	*Average*	*Drought*	*Average*	*Drought*
North Coast	325	325	325	325
San Francisco Bay	160	160	160	160
Central Coast	0	0	0	0
South Coast	27	27	31	31
Sacramento River	632	632	632	632
San Joaquin River	230	230	240	240
Tulare Lake	50	50	53	53
North Lahontan	18	18	18	18
South Lahontan	0	0	0	0
Colorado River	39	38	44	43
Total (rounded)	**1,480**	**1,480**	**1,500**	**1,500**

TABLE 4-25

Applied Environmental Water Use by Hydrologic Region (taf)

	1995		*2020*	
Region	*Average*	*Drought*	*Average*	*Drought*
North Coast	19,544	9,518	19,545	9,518
San Francisco Bay	5,762	4,294	5,762	4,294
Central Coast	118	37	118	37
South Coast	100	82	104	86
Sacramento River	5,833	4,223	5,839	4,225
San Joaquin River	3,396	1,904	3,411	1,919
Tulare Lake	1,672	809	1,676	813
North Lahontan	374	256	374	256
South Lahontan	107	81	107	81
Colorado River	39	38	44	43
Total (rounded)	**36,940**	**21,240**	**36,980**	**21,270**

TABLE 4-26

California Average Year Water Use by Hydrologic Region (taf)

Region	1995 Urban	1995 Agricultural	1995 Environmental	1995 Total (rounded)	2020 Urban	2020 Agricultural	2020 Environmental	2020 Total (rounded)
North Coast	169	894	19,544	20,610	201	927	19,545	20,670
San Francisco Bay	1,255	98	5,762	7,110	1,317	98	5,762	7,180
Central Coast	286	1,192	118	1,600	379	1,127	118	1,620
South Coast	4,340	784	100	5,220	5,519	462	104	6,080
Sacramento River	766	8,065	5,833	14,660	1,139	7,939	5,839	14,920
San Joaquin River	574	7,027	3,396	11,000	954	6,450	3,411	10,820
Tulare Lake	690	10,736	1,672	13,100	1,099	10,123	1,676	12,900
North Lahontan	39	530	374	940	50	536	374	960
South Lahontan	238	332	107	680	619	257	107	980
Colorado River	418	4,118	39	4,570	740	3,583	44	4,370
Total (rounded)	**8,770**	**33,780**	**36,940**	**79,490**	**12,020**	**31,500**	**36,980**	**80,500**

TABLE 4-27

California Drought Year Water Use by Hydrologic Region (taf)

Region	1995 Urban	1995 Agricultural	1995 Environmental	1995 Total (rounded)	2020 Urban	2020 Agricultural	2020 Environmental	2020 Total (rounded)
North Coast	177	973	9,518	10,670	212	1,011	9,518	10,740
San Francisco Bay	1,358	108	4,294	5,760	1,428	108	4,294	5,830
Central Coast	294	1,279	37	1,610	391	1,223	37	1,650
South Coast	4,382	820	82	5,280	5,612	484	86	6,180
Sacramento River	830	9,054	4,223	14,110	1,236	8,822	4,225	14,280
San Joaquin River	583	7,244	1,904	9,730	970	6,719	1,919	9,610
Tulare Lake	690	10,026	809	11,530	1,099	9,532	813	11,440
North Lahontan	40	584	256	880	51	594	256	900
South Lahontan	238	332	81	650	619	257	81	960
Colorado River	418	4,118	38	4,570	740	3,583	43	4,370
Total (rounded)	**9,010**	**34,540**	**21,240**	**64,790**	**12,360**	**32,330**	**21,270**	**65,960**

4A

Urban and Agricultural Water Pricing

This appendix is provided as background to respond to interest expressed by Bulletin 160-98 reviewers in water pricing information. Water prices in California vary widely, as discussed below. The more than 2,800 local agencies in California that provide water service establish their prices based on factors specific to their individual service areas, and those prices are generally reviewed by agencies' elected or appointed boards of directors, or by the California Public Utility Commission. Public agencies are not permitted to make a profit from their water sales, and the profits that privately owned water purveyors are allowed to make are established by the PUC.

Water Retail Pricing

Many factors influence the prices charged by water agencies. For public water agencies, the types of charges they may levy depend upon the legislation under which they were created. Table 4A-1 shows types of California water supply agencies. Descriptions of the general powers of the public agencies shown in the table can be found in DWR's Bulletin 155-94, *General Comparison of Water District Acts*. Investor-owned utilities' water rates are set by the California Public Utilities Commission. Privately owned mutual water companies set rates for their members.

TABLE 4A-1

Types of Local Supply Water Agencies in California[a]

Type	*Ownership*	*Number*
County Service Area	Public	880
Mutual Water Company	Private	801
Community Services District	Public	309
Investor-Owned Water Utility	Private	195
County Water District	Public	178
Water District	Public	157
Irrigation District	Public	97
Public Utility District	Public	52
Flood Control and Water Conservation District	Public	41
County Water Works District	Public	40
Municipal Water District	Public	40
Water Agency or Water Authority	Public	31
Water Conservation District	Public	13
Water Storage District	Public	8
Municipal Utility District	Public	5
Water Replenishment District	Public	2
Metropolitan Water District	Public	1
Total		**2,850**

[a] Water supply may also be provided by local agencies having other purposes (e.g., reclamation districts).

Source: Department of Health Services and State Controller's Office data, 1994-96.

Acquisition and Delivery Costs

Acquisition costs are costs associated with obtaining water from a source. These costs may vary greatly from one source to another. Some water agencies have developed their own supply sources, some purchase water wholesale from larger agencies, and some have a mix of their own supplies plus wholesale purchases. Other costs include transportation and local delivery charges and water treatment costs. Supplies delivered for urban use require treatment, which is becoming an increasingly greater component of total cost as more stringent drinking water quality regulations are put into place. Compliance with surface water filtration and information collection requirements of the Safe Drinking Water Act, for example, is a substantial cost item for many water agencies.

Some water agencies use water rates to fully recover the costs of acquiring, treating, and delivering supplies, others use a combination of water rates and local property taxes. Another important consideration is whether a water agency sets its rates to reflect short-term or long-term costs. This is significant if a water agency's system is currently operating at capacity and major system improvements are needed. In this case, the water agency may have to increase rates to reflect the higher marginal costs of future system expansion.

During droughts, the rates water agencies charge may vary depending on supply availability. Agencies may have to acquire water from outside sources to meet service area needs or may have to construct interties or other conveyance system improvements to bring purchased supplies to their system. Many water agencies adopted higher rates to fund programs to encourage water conservation during the 1987-92 drought, and several implemented drought penalty rates intended to reduce water use drastically.

Characteristics of Service Area

A water agency's costs will be affected by the mix of residential, commercial, industrial, governmental, and agricultural users within the service area because the cost of service to different classes of users is likely to be different. If a water agency serves a heavily populated area with many connections per square mile, the average fixed costs per customer will tend to be less. Conversely, if the purveyor serves a sparsely populated area, average fixed costs of serving each customer will normally be high. Because of pumping costs, changes in elevation within a service area can also affect delivery costs.

Rate Structure

Water rates are the primary source of income for most water agencies. Although rates can be structured many ways, they typically include fixed charges, consumption-based charges, or both.

Fixed charges recover some or all of costs incurred regardless of the amount of water used, such as debt service incurred from project construction. Fixed charges are typically used by water agencies that do not meter consumption. Examples of fixed charges for metered urban water agencies include billing and administrative charges (service charges), lifeline charges for a minimum level of service, readiness to serve charges, and fire protection charges. Agricultural fixed charges (often called water availability or standby charges) can be levied on a per acre or connection basis. Fixed charges which are levied on a per acre or parcel basis will likely be affected by Proposition 218, discussed in more detail in Chapters 2 and 6.

Consumption-based charges are set on a per unit volume basis so the total charge varies with the user's consumption. These charges typically recover variable costs of water deliveries (water purchases, treatment, and pumping). As with fixed rates, there are several forms of consumption-based rates. One form is the constant charge, which is the same unit price for all units of water consumed. Another is block rates, which decrease (declining block) or increase (increasing block) with water consumption. A declining block rate sets a reduced price per unit for increased usage. Increasing block rates set increasing prices per unit for increased usage. Constant and increasing block rates are the predominant urban rate structures currently used in California. Some forms of declining rates are still used in urban areas, especially in communities using lower water rates as an incentive for industry to locate in their area. Some agencies use declining block rates and other incentives to encourage use of recycled water in lieu of potable supplies. Agricultural water agencies levy consumption-based charges based upon either the actual amount of water delivered or on the number of irrigated acres (charges may vary depending upon the crop type).

Fixed charges and consumption-based charges typically account for most of a water agency's total revenues. Revenues can also be obtained from assessments, or taxes, levied upon lands in accord with benefits received from an agency's actions. Assessments recover a portion of an agency's fixed costs, and can be levied either on lands which directly benefit from water deliveries (for example, land receiving irrigation water) or on lands which indirectly benefit from water deliveries (adjoining lands which may benefit from groundwater recharge resulting from the deliveries).

Cities may charge for sewers and sewage treatment based on water use. In some cities, the sewer charges are included in monthly service charges and commodity rates paid by the water users. Other cities charge for sewers based on water use, but keep the sewer charges separate from the water charges.

Urban Retail Water Costs

Since 1990 there have been a few statewide surveys of urban retail water costs in California. One, conducted by the Department in 1991, included about 70 communities. The results of this survey are described in the Department's Bulletin 166-4, *Urban Water Use in California*. DHS conducted another survey in 1990, and three others were conducted by a private consulting firm in 1993, 1995, and 1997. (The 1993-1997 surveys were based on an assumed monthly consumption of 1,500 cubic feet of water per connection, an amount much lower than that used by many households. This assumption limits the usefulness of the survey data.) At a statewide level of coverage, there are no recent retail pricing data based on actual water use amounts.

In 1994, the accounting firm of Ernst & Young conducted a national water rates survey which MWDSC summarized in its 1995 Integrated Resources Plan. That survey showed that the national average for retail urban water supply was almost $600/af. MWDSC's average was about $625/af; San Francisco's was about $560/af; and Oakland's was almost $700/af. (Other urban areas had higher costs. Indianapolis was about $725/af; Houston was almost $900/af, and Nashville was more than $1,100/af.)

Impacts of Retail Prices on Water Use

Price elasticity studies are used to characterize price responsiveness—the degree that water users increase or decrease use in response to a change in water price. Economists define price elasticity of demand as the ratio of the percentage change in quantity of water used to the percentage change in the price of water.

When faced with a significant water price increase, urban water users may react in one of three ways:

- They may use substantially less water. In this case, water users are sensitive to price changes, and demand is defined to be elastic (its absolute elasticity value is equal to or greater than one). For example, if a 10 percent increase in price caused a 10 percent reduction in demand, economists would define demand as elastic.
- They may use a little less water. In this case, water users are not very sensitive to price changes, and demand is said to be inelastic (absolute elasticity value is less than one). For example, if a 10 percent price increase caused a 5 percent reduction in demand, demand would be defined as inelastic.
- They may continue to use the same amount as before. In this case, the water users are completely insensitive to price changes, and demand is said to be perfectly inelastic (elasticity value is equal to zero).

A 1989 EBMUD study, for example, estimated price elasticity of demand for its residential water supply to be -0.202 from 1981 through 1987. This means that a water price increase of 10 percent could be expected to lower the amount of water use by about 2 percent. The demand for water in this case was inelastic—residential water users were found to be relatively insensitive to price changes. This has been the case for most studies of residential water demand.

Factors that can affect elasticity include climate, housing type, water users' income, percentage share of water bills in users' budgets, water rate structure, water conservation measures and education, and users' preferences regarding water use (some users may prefer to irrigate large turf areas regardless of cost). Table 4A-2 provides a survey of recent literature on urban water price elasticities of demand. These studies were performed with statistical modeling which employed historical water use, water price, and demographic and climatic data.

Elasticity estimates derived for one geographic area are not necessarily representative of another area because of these many potential variables. It is generally not correct to take a value of residential price elasticity estimated for one community during one period of time and to assume that it is applicable to another community, or for another period of time. Only by carefully examining the factors described above can elasticities developed under one set of circumstances be reasonably used for estimating elasticities under other circumstances.

For Bulletin 160-98, the Department contracted

TABLE 4A-2

Urban Water Demand Price Elasticity Studies

Author(s)	*Study Date*	*Study Area*	*Type of Demand*	*Estimated Elasticity*	*Range of Study Water Prices*	*Equivalent Prices ($/af)[a]*
Moncur	1987	Honolulu, Hawaii	Short-term residential Long-term residential	-0.265 -0.345	$0.22 - $0.36 /1,000 gal (1983 dollars)	$72 - $117
Metzner[a]	1989	San Francisco	Long-term residential	-0.25	$0.73 - $0.78 /100 cu ft (1995 dollars)	$318 - $340
Weber	1989	EBMUD	Long-term residential	-0.01 to -0.25	$0.24 - $0.94 /100 cu ft (1989 dollars)	$105 - $409
Nieswiadomy[b] & Molina	1989	Denton, Texas	Long-term residential	-0.55 to -0.86	$0.27 - $0.56 /1,000 gal (1967 dollars)	$88 - $183
Billings & Day	1989	Tucson, Arizona	Long-term residential	-0.72	$6.60 - $11.20 monthly bills 1974 -1980 (1974 dollars)	$7 - $11 monthly bills
MWDSC	1990	South Coast Region	Long-term single-family residential Summer Winter	 -0.29 to -0.36 -0.03 to -0.16	Not Available	Not Available
Schneider & Whitlach	1991	Columbus, Ohio	Short-term residential Long-term residential Short-term total urban Long-term total urban	-0.262 -0.110 -0.504 -0.123	Not Available	Not Available
Renwick et al.	1996	8 California cities	Long-term single-family residential	-0.16	$0.47-$4.25 /100 cu ft	$205-$1,851

[a] Water rate data was unavailable from the study author. The Department retrieved the historical data and inflated the prices to 1995 levels for display purposes only.

[b] Study was for summer months only and was a five-year period of recently adopted increasing block rates. Adjusted R^2 for models which produced -0.86 and -0.55 elasticities was only 0.26 and 0.11, respectively.

with University of California researchers for an evaluation of the effects of water pricing and non-pricing demand reduction actions (e.g., public education, rationing, subsidies for adoption of more efficient water use technologies) on urban residential water use. The study covered single-family residential use during 1989 to 1996, a time period incorporating the recent drought and allowing evaluation of actions taken by water purveyors to reduce residential water use during the drought. Eight water retailers whose service areas represent 24 percent of California's population were included—San Francisco PUC, Marin MWD, Contra Costa WD, East Bay MUD, City of San Bernardino, City of Santa Barbara, Los Angeles DWP, and City of San Diego. All of these agencies experienced price increases over the study period and all used

TABLE 4A-3

DWR Survey of 1996 Agricultural Surface Water Costs[a]

Region	*1996 Total Deliveries (taf)*	*1996 Costs ($/af)*			*Water Rates Basis (number of agencies)*				
		Weighted Average	*Max.*	*Min.*	*By Acre*	*By Crop & Acre*	*By af Used*	*By Acre & af Used*	*Total*
North Coast	80	10	12	2	2	0	1	0	3
San Francisco Bay[b]	—	—	—	—	—	—	—	—	—
Central Coast	37	128	533	87	0	0	2	2	4
South Coast	92	373	604	131	0	0	1	7	8
Sacramento River	1,275	12	32	2	1	4	1	2	8
San Joaquin River	1,339	22	238	6	2	0	1	4	7
Tulare Lake	2,672	42	161	9	1	0	4	6	11
North Lahontan[b]	—	—	—	—	—	—	—	—	—
South Lahontan	18	61	61	61	0	0	1	0	1
Colorado River	3,403	13	14	8	2	0	0	2	4
Statewide	**8,916**	—	—	—	**8**	**4**	**11**	**23**	**46**

[a] Average retail costs to the farmer
[b] No responses

non-pricing demand reduction actions during the study period. Price elasticity was estimated to be -0.16 (meaning that a 10 percent price increase would result in a 1.6 percent demand reduction) over a range of marginal prices of $0.47 to $4.25 per hundred cubic feet, showing that residential demand was price inelastic over this range.

The urban water demand forecast used for Bulletin 160-98 assumed single-family residential price elasticities of -0.1 for winter months and -0.2 for summer months. Studies of urban water pricing to date indicate that the role of pricing by itself in achieving demand reduction is small. The plot of urban water production over time shown in Figure 4-4 illustrated the strong response of water use to the 1987-92 drought. Actions taken by water agencies during the drought to encourage demand reduction—including public education programs, voluntary rationing, rebates for plumbing retrofits—decreased residential water use. However, water use throughout the State is rebounding to earlier levels, even after significant price increases by some agencies. For example, Contra Costa WD increased its average water rates substantially to finance construction of Los Vaqueros Reservoir. Between 1980 and 1997, CCWD's average water price increased by about 217 percent (adjusted for inflation). Its use per residential unit declined by 9 percent, much of which is likely due to plumbing retrofit and building code requirements for new plumbing, and public education.

Agricultural Water Costs

In December 1996, the Department mailed water cost surveys to more than 60 agricultural water agencies in California. This survey was conducted to determine the range of average agricultural retail surface water costs in the State and to obtain information on types of water charges being used. Table 4A-3 summarizes the results of this survey by hydrologic region. Many responding agencies based their charges on both water use and number of acres irrigated. The information is presented here to illustrate the variability of prices based on local circumstances.

Agricultural groundwater costs vary considerably throughout California. Factors influencing these costs include depth to groundwater, water quality, and well yields. Many groundwater users are self-supplied, meaning that individual water users pump their own supplies rather than receiving them from a water agency. Bulletin 160-93 showed general ranges of agricultural groundwater production costs. The Department does not have sufficient new data to accurately update those general cost ranges for Bulletin 160-98.

Impacts of Price on Agricultural Water Use

Price elasticity of demand for agricultural water is a measure of farmers' responsiveness to changes in the price of water. Researchers have used a variety of models (programming and econometrics) to estimate the agricultural water use price elasticity in different parts of the country, and have concluded that demand for irrigation water is generally price inelastic, within price ranges typical for agricultural water use. Obviously, there is no other commodity that can be substituted for the water needed to grow crops. As Table 4A-4 illustrates, water costs are typically a relatively small percentage of the total cost of producing most crops. The Central Valley Production Model was used to estimate agricultural price elasticity in the Central Valley. CVPM price elasticity estimates for irrigation water demand are based on the level of production of various crops. CVPM also allows for changes in cropping patterns as water becomes more scarce, more expensive, or both.

Results of CVPM studies are summarized in Table 4A-5. Surface water prices were increased for the study by different increments, and groundwater costs increased as a result of changes in pumping depths. Both short- and long-term elasticities were estimated. In the short-term study, it was assumed that farmers did not have enough time to adjust to increases in water costs, while in the long-term farmers could switch to more efficient irrigation technologies.

The values in the table are estimates of a farmer's ability to respond to water price changes. For example, if surface water prices increase by 10 percent in the Sacramento Valley, the demand for surface water will decline by 3.2 percent. The model runs indicated that demand for irrigation water was price inelastic over the price ranges analyzed. Where groundwater is available in the Central Valley, farmers may increase their groundwater use if pumping costs are less than the costs of their surface water supplies.

TABLE 4A-4

Average Water Costs as a Percent of Total Production Costs for Selected Crops in the Tulare Lake Region[a]

Crop	*Water Costs as a Percent of Total Costs*
Irrigated pasture	36
Alfalfa hay	19
Barley	16
Dry beans	14
Wheat	14
Cotton	12
Sugar Beets	12
Safflower	11
Dry Onions	9
Almonds	6
Pistachios	6
Processing tomatoes	6
Wine grapes	5

[a] Data from output of the Department's Central Valley Net Crop Revenue Model.

CVPIA Tiered Pricing

Section 3405(d) of CVPIA required that new, renewed, or amended contracts for project water incorporate an inverted block rate pricing structure specified in the act. The first rate tier applied to a quantity of water up to 80 percent of the contract total. The second rate tier applied to the quantity of water from 80 percent to 90 percent of the water under contract, and was to be halfway between the rate for the first tier and the third tier. The third tier applied to the quantity of water beyond 90 percent of the contract total, and was to be not less than USBR's full cost rate. USBR's municipal and industrial customers are already charged the full cost rate, which includes cost of service, principal and interest on facility construction costs, and CVPIA Restoration Fund charges.

As noted in Chapter 2, all of USBR's contract renewals to date have been interim renewals, since the PEIS required by the act has not yet been completed. No long-term renewal contracts can be executed until USBR completes the PEIS, which is now expected to occur in 1999. Through 1996, interim contracts for project water supply represented about 16 percent of project water under contract.

In its 1998 public draft PEIS, USBR used CVPM to estimate potential impacts of implementing tiered pricing as set forth in the act. USBR estimated that implementing tiered pricing would reduce average year CVP applied irrigation water in the CVP service area

TABLE 4A-5

Price Elasticities for Surface Water Irrigation Demand

Region	*Short-Term Elasticity*	*Long-Term Elasticity*	*Range of Water Prices ($/af)*
Sacramento River	-0.24	-0.32	20 - 240
San Joaquin River	-0.20	-0.30	20 - 240
Tulare Lake	-0.18	-0.24	20 - 240

by 266 taf from CVPIA's assumed no-action condition. This amount took into consideration the shift from CVP water use to groundwater use, in those areas having access to groundwater supplies. (The estimate assumed that USBR's ability to pay policy for irrigation remained in effect for principal on capital and Restoration Fund charges, at an estimated payment capacity of $11/af north of the Delta and $70/af south of the Delta.)

USBR also evaluated alternatives to the tiered pricing specified in the act, including an analysis which assumed that ability to pay provisions were not in force. This approach would reduce applied irrigation water by an additional 25 taf in an average water year. The greatest reduction in applied irrigation water use occurred in USBR's alternative which exceeded the requirements of the statute by applying full cost pricing to the first 80 percent of contract water supply, 110 percent of full cost pricing to the second tier, and 120 percent of full cost pricing to the last 10 percent of contract water supply. The draft PEIS estimated that this alternative would reduce applied irrigation water by about 570 taf in an average year.

After USBR completes the CVPIA PEIS, long-term contract renewals can begin. The effects of tiered pricing on CVP water use will be manifested over time, as more contracts are renewed. The relationship of CVP tiered pricing to CVP water use, however, cannot necessarily be generalized to price/water use relationships for agricultural users served from non-USBR sources. Agricultural water users served by the SWP, local water projects, and self-supplied sources already pay full cost rates for their supplies.

Comparing Agricultural and Urban Water Costs

Generally, agricultural water supply costs are lower than urban costs. Much of the State's earliest large-scale water development was for agriculture, and the irrigation works were constructed when water development was inexpensive by present standards. Also, there are basic differences in the delivery systems providing agricultural and urban water supplies. The price of water is determined by the cost of water at the source (from a reservoir or at the Delta, for example) plus the costs of using the facilities associated with conveying, storing, treating, and delivering the water to the final users. Some contracts for agricultural supplies have allowed agricultural users to pay a lower price for water supplies in return for accepting supplies with a lower level of reliability. Typically this was achieved by deficiency provisions incorporated in the water supply contracts.

Both urban and agricultural water agencies must pay transportation costs incurred to bring the water supplies to their service areas. However, agricultural agencies are often closer to the surface water sources and in many cases are able to rely on gravity-operated conveyance and distribution systems, avoiding energy costs associated with pressurized pipelines. Urban water supplies often travel through hundreds of miles of canals or pipelines, adding considerably to the transportation costs. For example, by 2000, power costs to deliver SWP water to the San Joaquin Valley service area are estimated to be about $15/af. Power costs to deliver the same acre-foot of SWP water to the South Bay, Central Coast, and Southern California service areas are estimated to be about $34, $78, and $87, respectively.

Urban water systems have additional delivery costs compared to agricultural systems. For example, urban water users must pay for terminal storage and pressurization of water. Monitoring and treating water for public health protection is expensive, and costs are expected to increase as a result of more stringent drinking water standards. Most urban water systems also incur substantial costs to install and read meters, and to prepare billings.

4B

BMP Revisions and Water Savings Assumptions

Table 4B-1 provides a synopsis of revisions to urban water conservation BMPs, as adopted by CUWCC in September 1997.

Table 4B-2 summarizes BMP water savings assumptions specified in the Urban MOU. These assumptions served as the basis for urban water use study conservation savings calculations, according to the following general formula:

$$S_{c,w,t} = U_{w,t} * R_{c,w} * P_{c,w,t}$$

where

$S_{c,w,t}$ = water savings resulting from the implementation of conservation measure *c*, in water use category *w*, at time *t*, expressed in gallons per day

$U_{w,t}$ = base year water use in water use category *w* at time *t*, expressed in gallons per capita per day

$R_{c,w}$ = reduction in water consumption resulting from the implementation of conservation measure *c*, in water use category *w*, expressed as a proportion of base year water use

$P_{c,w,t}$ = population affected by conservation measure c, in water use category *w*, at time *t*

TABLE 4B-1

BMP Revisions

Changes to Existing BMP Definitions, Implementation Schedules, Coverage Requirements, and Reporting Requirements Contained in Exhibit 1 of the MOU

BMP Number	*BMP Name*	*Changes to BMP Definition*	*Changes to Implementation Schedule*	*Changes to Coverage Requirement*	*Changes to Reporting Requirement*
1	Water Survey Programs for Single-Family Residential and Multifamily Residential Customers	Removes requirement to specifically target top 20% of residential water users. Allows agencies to develop targeting and marketing approaches tailored to their service areas. Specifies minimum audit elements. Requires agencies to develop database to track program.	Extends the implementation schedule 10 years from the date the BMP is revised or the date an agency signs the MOU, whichever is later.	Replaces the requirement that 70% of the top 20% of residential customers accept an audit by September 1, 2001, with the requirement that 15% of residential customers accept an audit within 10 years of the date of implementation for the agency.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.
2	Residential Plumbing Retrofit	Adds requirement that agencies maintain device distribution programs at levels sufficient to distribute retrofit kits to not less than 10% of residential accounts each reporting period until coverage requirement is met. Allows agencies to use mass distribution methods as appropriate. Allows agencies to develop targeting and marketing approaches tailored to their service areas. Requires agencies to develop data base to track program.	Replaces the requirement that agencies realize the coverage requirement by September 1, 2001, with the requirement that they maintain the program at specified level until they can demonstrate coverage requirement is met.	Replaces the requirement that 75% of single-family and 80% of multifamily residences constructed prior to 1980 are retrofitted with the requirement that 75% of single-family and multifamily residences constructed prior to 1992 are retrofitted.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.

TABLE 4B-1

BMP Revisions

Changes to Existing BMP Definitions, Implementation Schedules, Coverage Requirements, and Reporting Requirements Contained in Exhibit 1 of the MOU (continued)

BMP Number	*BMP Name*	*Changes to BMP Definition*	*Changes to Implementation Schedule*	*Changes to Coverage Requirement*	*Changes to Reporting Requirement*
3	System Water Audits, Leak Detection and Repair	Replaces requirement that agencies conduct a complete system audit every three years with requirement that agencies conduct annual pre-screen audits and conduct full system audits only if indicated by the pre-screen audit.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later.	No change.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.
4	Metering with Commodity Rates for All New Connections and Retrofit of Existing Connections	Adds requirement that agencies assess feasibility of program to retrofit mixed-use metered accounts with dedicated irrigation meters.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later. Extends date that coverage requirement must be met from September 1, 2001, to 10 years from the date the BMP is revised or the date an agency signs the MOU, whichever is later.	No change.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.

TABLE 4B-1

BMP Revisions

Changes to Existing BMP Definitions, Implementation Schedules, Coverage Requirements, and Reporting Requirements Contained in Exhibit 1 of the MOU (continued)

BMP Number	*BMP Name*	*Changes to BMP Definition*	*Changes to Implementation Schedule*	*Changes to Coverage Requirement*	*Changes to Reporting Requirement*
5	Large Landscape Conservation Programs and Incentives	Adds requirement that agencies develop water use budgets for accounts with dedicated irrigation meters. Removes requirement to specifically target landscapes of 3+ acres for audits. Continues to require audits for customers without landscape water use budgets. Continues to require customer incentive programs. Allows agencies to develop targeting and marketing approaches tailored to their service areas. Requires agencies to develop database to track program.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later. Allows agencies 10 years from date BMP implementation is to be underway to meet coverage requirement. Allows agencies four years to develop water use budgets for dedicated irrigation meter accounts.	Removes requirement that agencies offer audits to 100% of accounts with 3+ acres of landscape by September 1, 2001. Adds requirement that agencies provide landscape audits to 15% of mixed-use, non-residential accounts within 10 years from date BMP implementation is to be underway for agency. Adds requirement that agencies offer audits to not less than 20% of mixed-use, non-residential accounts each reporting period. Allows agencies to satisfy audit requirements by implementing a mixed-use meter retrofit program or a program to develop landscape water use budgets for accounts with mixed-use meters.	Requests data on the number of accounts with dedicated irrigation meters, and number of water budgets established during reporting period. Otherwise, requests similar types and amounts of information as currently being collected in CUWCC annual reports.

TABLE 4B-1

BMP Revisions

Changes to Existing BMP Definitions, Implementation Schedules, Coverage Requirements, and Reporting Requirements Contained in Exhibit 1 of the MOU (continued)

BMP Number	*BMP Name*	*Changes to BMP Definition*	*Changes to Implementation Schedule*	*Changes to Coverage Requirement*	*Changes to Reporting Requirement*
6 (New)	High-Efficiency Washing Machine Rebate Programs	Adds requirement that agencies offer maximum cost-effective customer rebate for high-efficiency washing machines if energy service provider in service area is also offering rebates.	N/A	N/A	N/A
7	Public Information Programs	Adds requirement that agencies conduct public awareness surveys every three years to assess conservation attitudes and guide program design.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later.	No change.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.
8	School Education Programs	No substantive changes.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later.	No change.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.
9	Conservation Programs for Commercial, Industrial, and Institutional Accounts	Replaces audit requirement with a two track approach. An agency can choose either to implement an audit program for CII customers, or to meet a water savings performance target for the CII sector. Requires CUWCC to develop long-term CII ULFT implementation targets based on findings of CUWCC CII ULFT water savings study within one year of BMP adoption.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later. Allows agency 10 years from date BMP implementation is to be started to begin meeting coverage requirement.	Requires either 10% of commercial, industrial, and institutional accounts to accept an audit within 10 years or a reduction in water use by commercial, industrial, and institutional accounts by an amount equal to 10% of the use by the top 10% of accounts.	Requires agencies to substantiate either completed audits or water savings estimates. Requests substantially more information on program design and implementation than what is currently being collected through CUWCC annual reports.

TABLE 4B-1

BMP Revisions

Changes to Existing BMP Definitions, Implementation Schedules, Coverage Requirements, and Reporting Requirements Contained in Exhibit 1 of the MOU (continued)

BMP Number	*BMP Name*	*Changes to BMP Definition*	*Changes to Implementation Schedule*	*Changes to Coverage Requirement*	*Changes to Reporting Requirement*
10 (New)	Wholesale Agency Assistance Programs	Defines wholesale agency support roles in terms of financial, technical, and programmatic assistance to retail agencies implementing BMPs.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later.	Requires wholesalers to justify financial, technical, and programmatic support levels.	Requires additional reporting by wholesale agencies over what is currently being collected through CUWCC annual reports.
11	Conservation Pricing	Retains current definitions of non-conserving and conserving rate structures. Adds requirement that CUWCC undertake a study to empirically assess the affect of rate structure on customer water use patterns and quantities, and to specifically examine the relationship between customer demand and the proportion of agency revenue requirement recovered through commodity charges, fixed charges, and other service charges.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later.	No change.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.
12 (formerly BMP 14)	Conservation Coordinator	No substantive change.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later.	No change.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.

TABLE 4B-1

BMP Revisions

Changes to Existing BMP Definitions, Implementation Schedules, Coverage Requirements, and Reporting Requirements Contained in Exhibit 1 of the MOU (continued)

BMP Number	*BMP Name*	*Changes to BMP Definition*	*Changes to Implementation Schedule*	*Changes to Coverage Requirement*	*Changes to Reporting Requirement*
13	Water Waste Prohibition	No substantive change.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later.	No change.	Requires similar types and amounts of information as currently being collected in CUWCC annual reports.
14 (formerly BMP 16)	Residential ULFT Replacement Programs	Removes reference to CII ULFT replacement requirements; otherwise no substantive change.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later. Allows agency 10 years from date implementation is to commence to meet coverage requirement.	No change.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.

TABLE 4B-2

BMP Water Savings Assumptions

BMP Number	*BMP Name*	*MOU Savings Assumptions*		*Urban Water Use Study Modeling Assumptions*
		Coverage Requirement	*Reduction Factor*	
1	Water Survey Programs for Single-Family and Multifamily Customers	15% of residential accounts.	*Pre-1980 Construction* Shower head replacement: 7.2 gpcd Toilet retrofit: 1.3 gpcd Landscape Audit: 10% of outdoor use *Post-1980 Construction* Shower head replacement: 2.9 gpcd Toilet retrofit: 0 gpcd Landscape Audit: 10% of outdoor use	Modeled based on MOU savings assumptions.
2	Residential Plumbing Retrofit	75% of single-family and multifamily residences.	*Pre-1980 Construction* Shower head replacement: 7.2 gpcd Toilet retrofit: 1.3 gpcd *Post-1980 Construction* Shower head replacement: 2.9 gpcd Toilet retrofit: 0 gpcd	Modeled based on MOU savings assumptions.
3	System Water Audits, Leak Detection, and Repair	Maintain active distribution system auditing program and repair system leaks when cost-effective.	Unaccounted water losses assumed to be no more than 10% of total water into the suppliers' system.	Not modeled because statewide average unaccounted water loss currently meets the MOU target value.
4	Metering with commodity rates for all new connections and retrofit of existing connections	100% of unmetered accounts to be metered and billed by volume of use.	20% reduction in demand by retrofitted accounts.	Modeled based on MOU savings assumptions.
5	Large Landscape Conservation Programs and Incentives	ET_o - based water use budgets for 90% of accounts with dedicated irrigation meters; irrigation water use surveys for 15% of CII accounts with mixed use meters.	15% reduction in irrigation water demand for surveyed landscapes.	Not modeled due to insufficient base year data on landscape water use and acreage.
6	High-Efficiency Washing Machine Rebate Programs	Cost-effective customer incentive for the purchase of high-efficiency washing machines to be offered if incentives are being offered by local energy provider or wastewater utility.	Not quantified at this time.	Not modeled due to "not quantified" status in MOU.

TABLE 4B-2

BMP Water Savings Assumptions (continued)

BMP Number	*BMP Name*	*MOU Savings Assumptions*		*Urban Water Use Study Modeling Assumptions*
		Coverage Requirement	*Reduction Factor*	
7	Public Information Programs	Maintain an active public information program to promote and educate customers about water conservation.	Not quantified.	Not modeled due to "not quantified" status in MOU.
8	School Education Programs	Maintain an active school education program to educate students in agencies' service areas about water conservation and efficient water uses.	Not quantified.	Not modeled due to "not quantified" status in MOU.
9	Conservation Programs for Commercial, Industrial, and Institutional Accounts	10% of CII customers to accept a water use survey or reduce water use by CII customers by an amount equal to 10% of baseline CII water use.	*Commercial Water Use* 12% reduction in water use (gallons per employee per day) occurring from 1980-2000.	Modeled based on MOU savings assumptions.
			Industrial Water Use 15% reduction in water use (gallons per employee per day) occurring from 1980-2000.	Modeled based on MOU savings assumptions.
10	Wholesale Agency Assistance Programs	Report on cost effectiveness of each BMP the agency is potential obligated to support, agency avoided cost per acre-foot of new water supplies, monetary value of financial incentive and resources provided to retail members to assist or support BMP implementation, and amount of verified water savings achieved by each wholesaler-assisted BMP.	Not quantified.	Not modeled due to "not quantified" status in MOU.
11	Conservation Pricing	Maintain rate structure consistent with the definition of conservation pricing specified in the MOU.	Not quantified.	Although not quantified by the MOU, this BMP was modeled on the basis of DWR water price forecasts and recent studies of urban water price elasticity in California.

TABLE 4B-2

BMP Water Savings Assumptions (continued)

BMP Number	*BMP Name*	*MOU Savings Assumptions*		*Urban Water Use Study Modeling Assumptions*
		Coverage Requirement	*Reduction Factor*	
12	Conservation Coordinator	Maintain and staff the position of conservation coordinator and provide support staff as necessary.	Not quantified.	Not modeled due to “not quantified” status in MOU.
13	Water Waste Prohibition	Adopt water waste prohibitions consistent with the provisions specified in the MOU for this BMP.	Not quantified.	Not modeled due to “not quantified” status in MOU.
14	Residential ULFT Replacement Programs	Savings to equal or exceed water savings achievable through an ordinance requiring the replacement of high water using toilets with ULFTs upon resale.	At least as effective as requiring toilet replacement at the time of resale. (Exhibit 6 of the MOU presents a detailed methodology for estimating savings).	Modeled based on MOU savings assumptions.

4C

Normalizing Urban Water Use Data

Some of the public comments the Department received on the draft Bulletin 160-98 dealt with how normalized urban water use data were developed and why normalized data differed from actual water production data. This appendix is provided to address those comments.

Bulletin 160-98 estimates of urban water use begin with raw data from the Department's survey of public water systems. This survey provides local agencies' annual water production which, when combined with population data, can be shown as agency per capita water production. For each of the Bulletin 160 DAUs (or in some cases, PSAs) representative water purveyors are selected, and their production data are quality-controlled to fill in missing data points, check production numbers, and resolve inconsistencies in the data.

Figure 4-4 in Chapter 4 showed how average statewide urban water production has varied over time. Information used to prepare the figure came from the public water systems surveys. Figure 4C-1 shows sample data for 12 cities or water agencies, to illustrate geographic variability in production, together with statewide average water production. These plotted data do not include self-produced water, water that is developed by entities for their own use. Most self-produced water is developed by industrial users. The Department estimates quantities of self-produced water through periodic surveys of industrial water users.

Statewide, the residential sector accounts for over half of total urban water use. The landscape component of residential (and some commercial and institutional) use strongly influences year-to-year variations in urban use, reflecting availability of precipitation and other water sources. Landscape water use increases in dry years in most parts of the State, if water supplies are available, since less precipitation occurs. Regional variations in landscape water use reflect climatic differences and the extent to which available water supplies depend on local precipitation or on supplies from other sources.

FIGURE 4C-1

Sample Urban Water Production Data

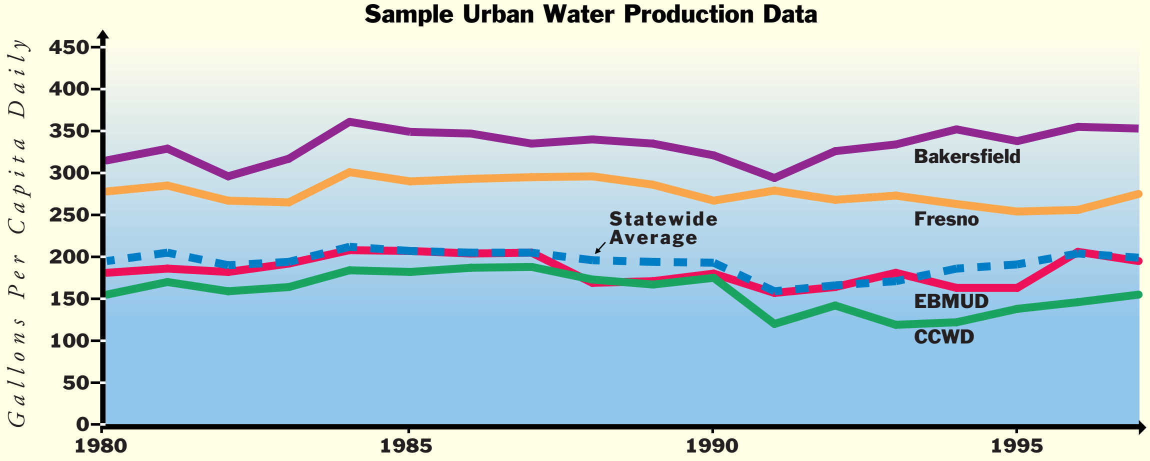


FIGURE 4C-1
(continued)

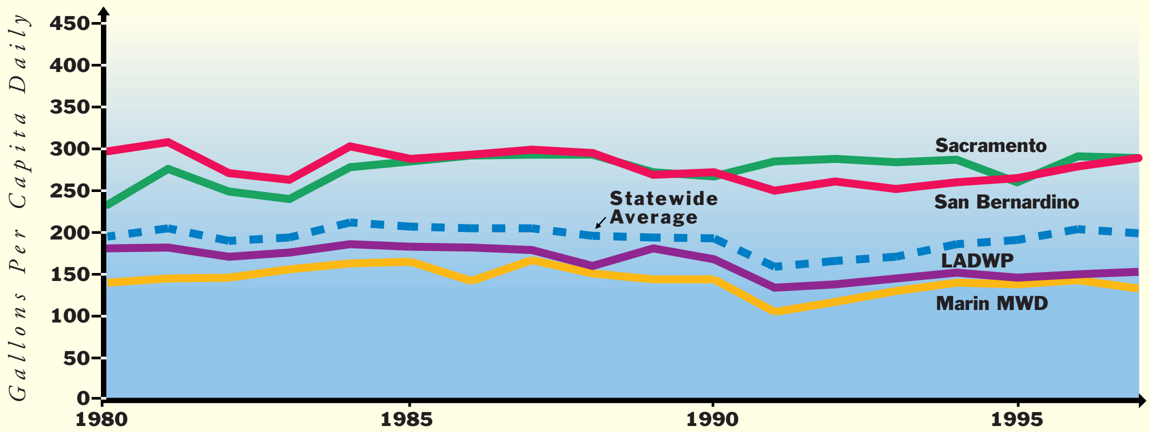
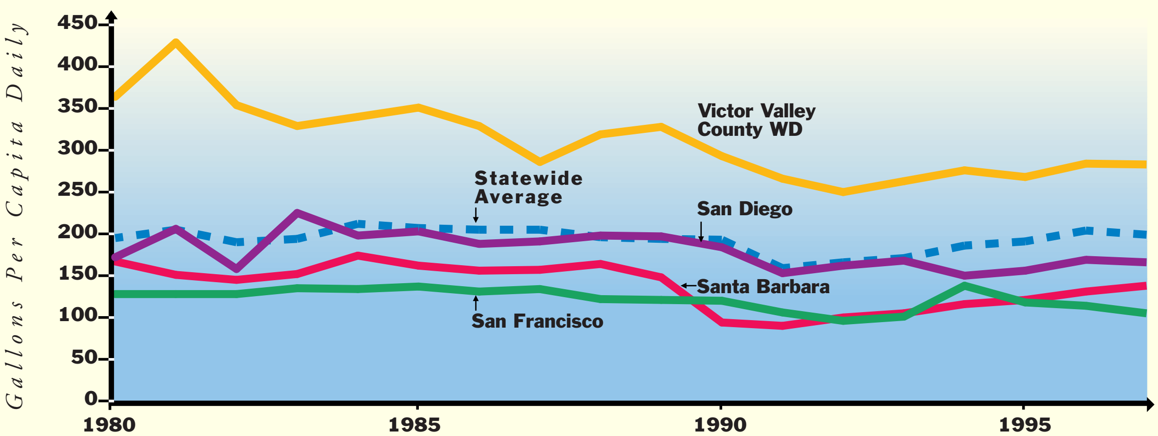


FIGURE 4C-1
(continued)

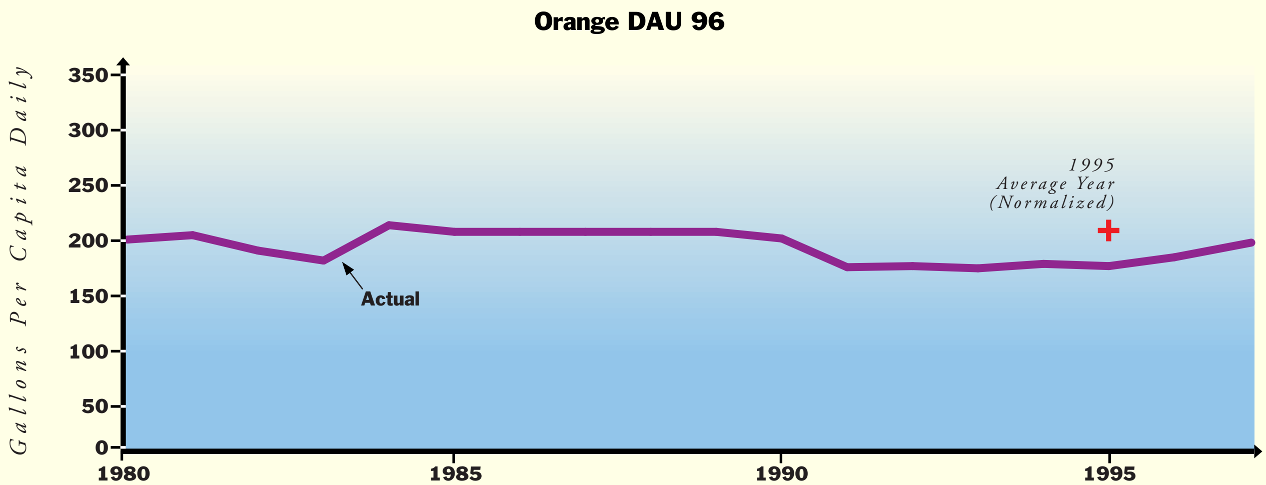


Addressing the impacts of the 1987-92 drought was a major consideration in reviewing the water purveyor data used for Bulletin 160-98. As shown in Figure 4-4, statewide average urban per capita water production declined during the drought years due to water rationing and other short-term restrictions in use, but then began to rebound. Capturing this rebound effect was important to estimating 1995 normalized urban use for Bulletin 160-98. As described in Chapter 4, the normalizing process is intended to remove water use irregularities due to droughts, extremely wet years, or other conditions. Calendar year 1995 was a wet year. Actual urban water production data for 1995 are thus lower than the Bulletin 160 normalized urban water use data.

Normalized urban water use is calculated for each DAU, except in the sparsely populated desert areas in southeastern California, where calculations are done at a PSA level. Recent production data from representative water purveyors are combined with normal water supplies and water use patterns to produce a composite per capita water production value for each DAU. Data for years during and immediately following the drought are removed from consideration due to the effects of water shortages of unprecedented severity and duration and a multi-year rebound in per capita water use. The composite per capita water production value is adjusted to account for self-produced water supplies, permanent effects of urban BMPs, and post-1990 changes to federal and State plumbing fixture standards to result in base year per capita water use.

The amount by which a normalized value differs from actual production data for a given year varies from DAU to DAU, as shown in Figure 4C-2 for some sample DAUs. (The 1995 statewide average normalized per capita urban water use was 229 gpcd, of which 9 gpcd represented self-produced water.) Normalized per capita water use data (water purveyor production plus self-produced water) are multiplied by the corresponding population to arrive at base 1995 normalized urban water use for each DAU. When DAU-level information is combined into hydrologic regions for Bulletin 160 water budgets, the "other" component of urban water use is added to the regional water budgets. This "other" component is small in comparison and includes recreation water use, energy production water use, and losses from major conveyance facilities. (With the addition of the "other" component, total 1995 normalized statewide average per capita water use is 244 gpcd.)

FIGURE 4C-2
Actual and Normalized Production Data



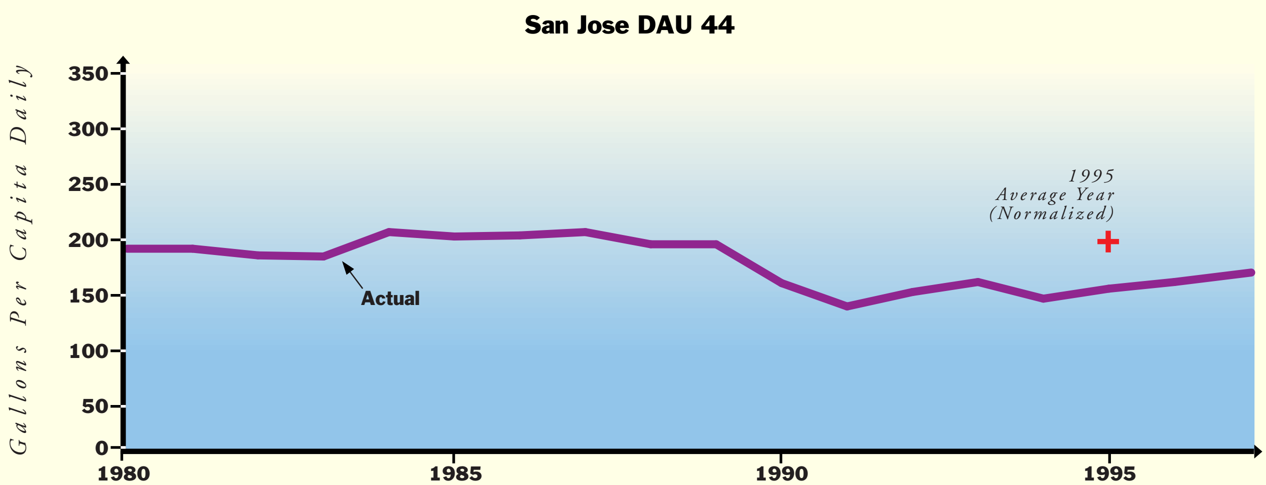
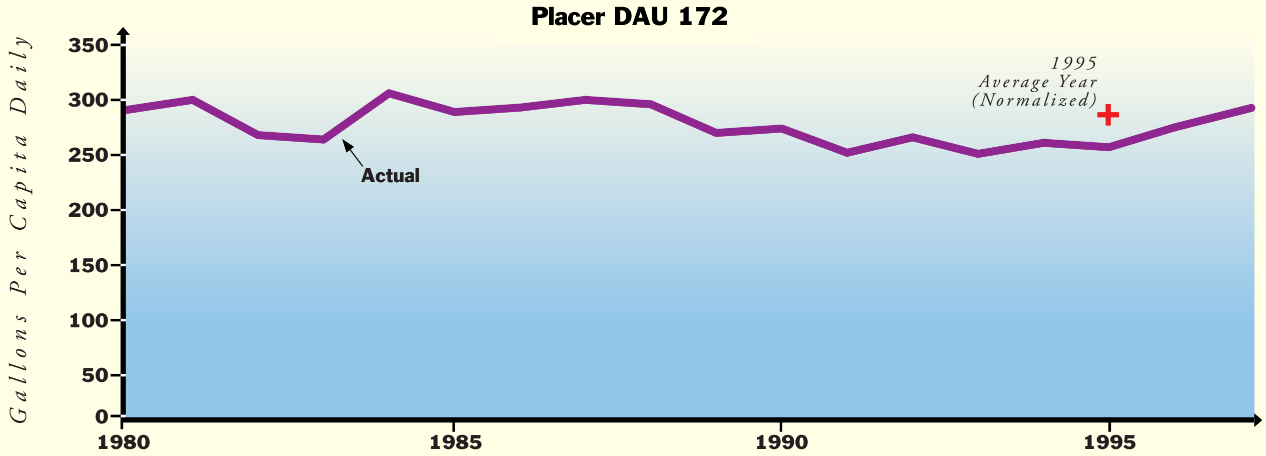
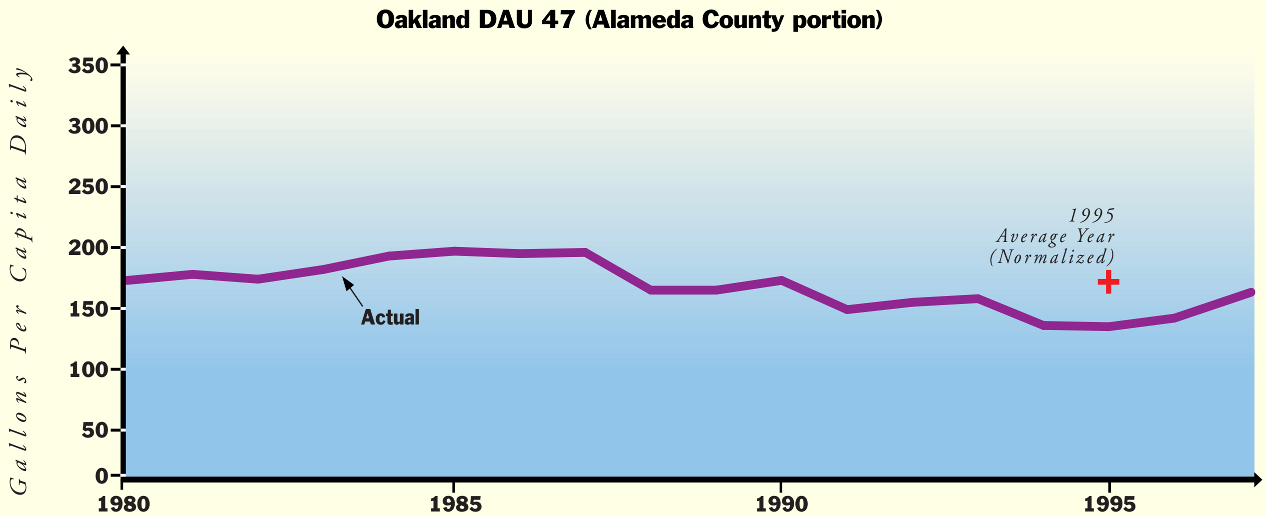
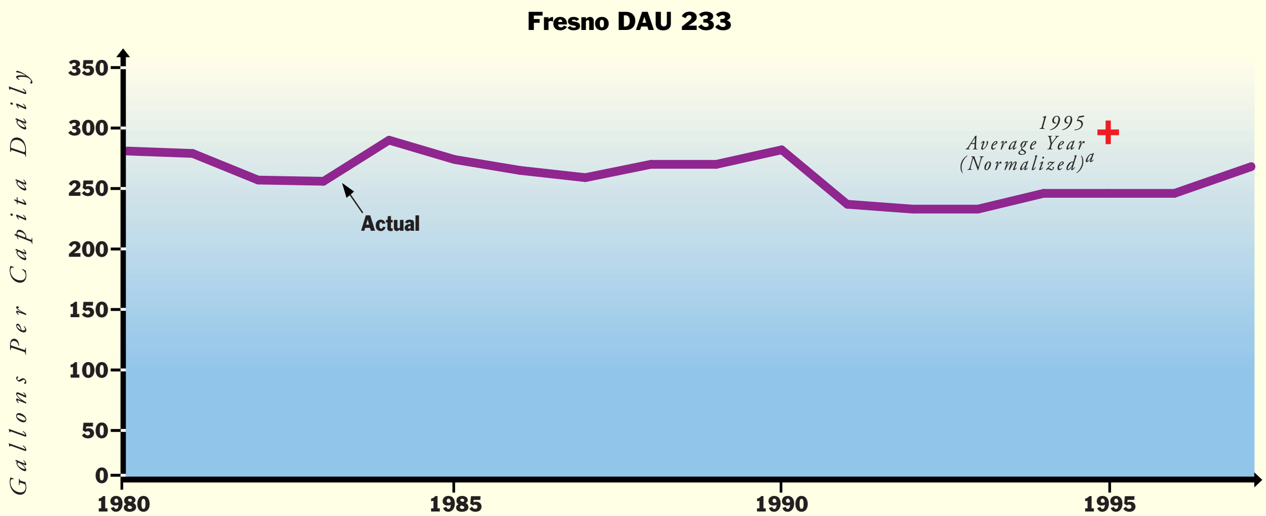


FIGURE 4C-2

(continued)







[a] Includes 29 gpcd self-produced industrial water use not accounted for in the plot of actual production data.

5

Technology In Water Management

This chapter highlights the present status and anticipated development of water management technologies. Review of water management technologies provides an important foundation for evaluating water management options described in later chapters of the Bulletin. For example, it is a common public perception that seawater desalting will solve most of California's future water problems. However, the current and reasonably foreseen state of desalting technology suggests that it will be used to meet relatively small, specialized needs due to its high cost. This chapter presents some case histories of selected technology applications and illustrates a few innovative examples.

Demand Reduction Technologies

Technological advances have improved urban and agricultural water use efficiency throughout the State. Future advances are expected to affect landscape irrigation, residential indoor water use, interior commercial, institutional, and industrial water use, and agricultural water use. Since the purpose of the Department's Bulletin 160 series is to assess water supply benefits, it is that aspect of demand reduction that the Bulletin addresses. Demand reduction technologies may provide additional benefits, such as reducing water treatment costs, reducing fish entrainment at water supply

The city of Santa Barbara's desalter was operated during the drought in 1992 and is now on standby status.

diversion structures, or reducing nonpoint source runoff. These other benefits are recognized in the Bulletin's options evaluation process, as described in Chapter 6.

Landscape Irrigation Technology

New irrigation control system technology can save water by setting irrigation cycles to account for changes in such factors as soil moisture and ET. New technology includes both retrofit devices and redesigned irrigation controllers.

Residential landscape irrigation systems often include sophisticated control devices such as electronic timers and electric solenoid-controlled valves. This increased sophistication does not always translate into water savings because homeowners often lack information on landscape plant water requirements. Consequently, many residential irrigation timers are permanently set to meet maximum summer season water requirements. A 1997 study by Utah State University showed that significant water savings could be achieved by retrofitting existing residential irrigation control systems with inexpensive (about $100) soil moisture-sensing devices. The devices are placed inline between the existing timer and valves and override a planned irrigation cycle when adequate soil moisture is available. Study results showed that the devices reduced landscape irrigation water use by an average of 10 percent. Follow-up questionnaires revealed that over 70 percent of the study participants observed that their lawns were as green or greener than before installation of the device.

New irrigation system controllers for the commercial, industrial, and institutional sectors are programmed for irrigation schedules based on normal year ET rates, and are adjustable to account for deviations from normal year ET. Some of the most advanced controllers can be automatically adjusted to current ET rates using telecommunication pager technology to access weather data from automated weather stations. Rainfall sensors represent an inexpensive method to automatically terminate irrigation controller programs during precipitation.

Residential Indoor Water Use Technology

Technological advances in residential indoor water use efficiency have come primarily from redesigning plumbing fixtures to meet new State and federal standards. Future efficiencies will come from improved fixtures and installation of more water-efficient home appliances. In addition, new technology to characterize residential water use may yield data allowing more accurate forecasts of components of urban water demand. This information would help allocate demand reduction program resources.

Previously, the breakdown of residential water use was estimated from water meter data and assumptions about the water use of various fixtures and appliances. However, a 1995 study in Boulder, Colorado, showed that detailed information on water use patterns could be gathered through analysis of data obtained from data loggers attached to residential water meters. The traces have sufficient detail to identify flow signatures of individual fixtures and appliances. The technique also provides information to differentiate between indoor and outdoor water use. Based on the success of the Boulder study, a larger study was organized by the American Water Works Association Research Foundation. The goal of this study is to collect information from 1,200 homes in 12 cities, for two 2-week periods—one period in the winter and another in the summer. The information will be sorted into its major end use components: toilets, showers, baths, faucets, dishwashers, washing machines, and leaks. Preliminary results are shown in Table 5-1. These data will be combined with information from a survey of study participants to construct a residential water use model. A final report on the study is scheduled for publication in 1999.

Plumbing Fixtures. State law requires all toilets sold or installed in California to use no more than 1.6 gallons per flush. These standards have pushed traditional gravity operated toilets to the limit of acceptable operation. The performance of gravity operated toilets is limited to the flow rate achieved through the bowl under the force of gravity, placing a limit on the potential for reducing the amount of water used in each flush.

Pressure-assisted toilets use pressurized flow, in conjunction with siphon action, to give acceptable

TABLE 5-1

Distribution of Residential Indoor Water Use

Component	*Average Use (%)*
Toilet	26
Washing Machines	23
Shower/Bath	20
Faucets	15
Leaks	13
Dishwasher	1
Other Uses	2

operation with less flushing water. The increased flow rate (more than 70 gpm compared to about 25 gpm for gravity designs) provides greater force to remove solids from the bowl and hastens the start of the siphon action. In addition, the surge of water from a pressure-assisted toilet is more effective at pushing waste through the drain line.

In the past, use of pressure-assisted technology was limited to the commercial sector due to high costs and increased noise. Current residential designs are less expensive than previous models and only slightly noisier than gravity toilets. Pressure-assisted toilets range in price from $220 to $815, compared to $65 to $575 for gravity toilets. Future residential designs may use 0.5 gallons or less per flush.

Washing Machines. Horizontal-axis washing machines (front loading washing machines) use significantly less water than traditional vertical-axis, central agitator machines. Rather than fully immersing the clothes, the tub of the washer rotates through a horizontal axis in alternating directions to lift and tumble the clothes through a pool of water. Recent studies show that these washers use about 25 to 35 percent less water than central agitator models.

Currently, horizontal axis washing machines produced by American manufacturers range in price from about $700 to $1,100. Models by some European manufacturers are considerably more expensive. Prices are expected to decrease to within about $200 of central agitator models as the market grows. A recent survey of appliance retailers showed the residential market for front loading washers could increase from about 2 percent at present to between 5 to 20 percent over the next five years.

Water Heaters. Hot water demand systems save water by either eliminating the need to drain cold water sitting in the pipe between the water heater and the plumbing fixture, or by reducing the distance between the heater and fixture. Demand systems are designed in two basic configurations: central storage tank and tankless systems. Central storage tank systems are based on traditional water heater and plumbing systems, modified with the addition of a valve to open a loop back to the hot water tank, and a pump to push the cold water back to the water heater while drawing hot water into the pipe. When hot water reaches the fixture, the loop closes and the hot water exits the fixture. Tankless systems, also known as instantaneous or on-demand water heaters, heat water only when needed. They can be located near the plumbing fixture to reduce the amount of cold water that must be displaced for hot water to reach the fixture. Because they do not store hot water, tankless systems save energy by eliminating standby losses.

Water savings depend on the amount of water to be displaced before hot water reaches the fixture (or the amount of water that would have been displaced, in the case of tankless systems). Measurements by the California Energy Commission show that about two times the pipe volume between the water heater and the fixture must be replaced before hot water reaches the fixture, due to heat lost to the pipe. A 1996 study of potential water savings in Southern California showed that hot water demand systems could save approximately 30 gpd per unit.

Interior CII Water Use Technology

Plumbing Fixtures. The water savings potential of 0.5 gpf toilets also applies to the commercial sector. In addition, while State law requires that urinals use no more than an average of 1.0 gpf, this water requirement could be further reduced or eliminated through the use of waterless urinals. Waterless urinals attach to

High efficiency horizontal axis washing machines are being used in commercial applications, but are just becoming available for home use. A check of large appliance dealers in 1998 showed that two brands of horizontal axis washers were commonly in stock, at prices ranging from $700 to $1,100. Comparable standard washers cost from $100 to $600 less. Some utilities are offering their customers rebates on the order of $100 to $150 for purchasing the horizontal axis machines.

standard plumbing stubs, but require no flushing water to operate.

Water savings from waterless urinals depends on the frequency of use and the flushing water requirement of the fixture that is replaced. A 1996 study in Southern California showed potential savings from about 11 gpd per fixture in office buildings to about 55 gpd per fixture in airports and movie theaters. In 1995, the U.S. Navy equipped sample bathroom facilities at the Naval Air Station North Island in San Diego with waterless urinals. The study found that replacement saved about 45,000 gallons of water per year, with a pay-back period of about 3 years. Based on the success of the trial, more than 200 waterless urinals were installed at the station. To date, the urinals remain in operation and perform well when maintained according to manufacturer recommendations.

Cooling Towers. The largest use of water in the industrial sector is for cooling. Water is used to cool heat-generating equipment, manufactured products, and food products and containers in canneries. The most water-intensive cooling method is once-through cooling, where water contacts and lowers the temperature of a heat source, then is discharged to waste. Recirculating cooling tower systems reduce water use by using the same water for several cycles.

The majority of cooling towers in California are recirculating evaporative systems, where the temperature of the cooling water is reduced through evaporation. As cooling water is recycled through the tower, the salt concentration increases. Salt build-up must be managed to avoid scaling on condenser tubes, which results in reduced heat transfer efficiency. Blowdown is the release of some of the circulating water to remove the suspended and dissolved solids left behind due to evaporation. Make-up water is added in place of the blowdown to reduce the total dissolved solids. Water savings can accrue by minimizing blowdown or by converting to a dry cooling process based on air heat exchangers.

Evaporative cooling towers are used by a wide range of industries.

Blowdown can be minimized by treating the recirculating water with sulfuric acid or ozone (to control scaling and biological fouling), by mechanical filtration of solids, and by the use of conductivity sensors and automatic valves to precisely control the blowdown/makeup process. Savings can be maintained through regular calibration of the conductivity sensors. A 1996 study conducted for MWDSC suggested that the majority of potential cooling tower water savings in Southern California could be realized through the addition and/or calibration of conductivity controllers. Water savings estimates ranged from about 400 to more than 900 gpd per site.

Air heat exchangers use fans to blow air past finned tubes carrying the recirculating cooling water. The Pacific Power and Light Company's Wyodak Generating Station in Wyoming uses dry cooling to eliminate water losses from cooling water blowdown and evaporation. The processed steam is condensed by routing it through finned carbon steel tubes as fans force air, at a rate of 45 million cubic feet per minute, through an 8 million square foot finned-tube surface. This technique results in a water requirement of 300 gpm, compared to about 4,000 gpm of make-up water for equivalent evaporative cooling.

Agricultural Water Use Technology

Future technological advances in irrigation systems and irrigation scheduling are expected to result in more efficient agricultural water use.

Irrigation Systems. Many terms are used in describing the performance of irrigation systems, but the two most important are DU and SAE, defined in Chapter 4. The accompanying sidebar defines several agricultural technology terms used throughout this section. Irrigation experts generally agree that an 80 percent DU is achievable by all irrigation systems and is an upper limit for existing systems. With today's systems, SAEs of more than 73 percent indicate under-irrigation, potentially resulting in a reduction of

Definition of Irrigation Terms

- Distribution Uniformity: A measure of the variation in the amount of water applied to the soil surface throughout an irrigated area.
- Seasonal Application Efficiency: The water beneficially used for ETAW and cultural practices divided by applied water.
- Intake Opportunity Time: The amount of time that applied irrigation water is in contact with the soil.
- Allowable Depletion: Depth of water needed to bring soil moisture to field capacity—a measure of how dry the soil is allowed to become before an irrigation is applied.
- Reference Evapotranspiration (ET_o): The ET of well-watered 4 to 6 inch tall turf.

crop production and an increase in soil salinization. Whether a gravity or pressurized system, a well-designed and well-managed irrigation system appropriate to a field's terrain, soil, crop, and flow constraints can achieve the maximum DU and result in high SAE, provided the irrigation water supply is of adequate quality and is available when needed at the proper rate of delivery.

Adoption of new irrigation technology to reduce applied water must result in a reduction of deep percolation, tailwater runoff, ET, or leaching requirement. Reduced deep percolation and tailwater runoff could be achieved by improving in DUs and irrigation management. Evapotranspiration could be reduced by minimizing losses from surface evaporation, or by intentional underirrigation with no loss in production or quality. Reducing the leaching requirement (the amount of water used to leach salts from the soil) is not a goal because insufficient leaching results in salinization of the soil, rendering it less productive and consequently reducing water use efficiency.

Gravity, or surface irrigation, systems use the soil surface to spread and move water on and over a field. The major types of gravity irrigation systems used in California—furrows, border-strip, and level basin—are discussed in the sidebar. The field is optimally rectangular, with the water entering the field from the highest side. The water moves over the surface of the soil, eventually covering the area intended for irrigation, and infiltrates the soil to replenish soil moisture. The rate of infiltration varies by soil type and time (a sandy soil has a much higher infiltration rate than a clay soil). All soils have a maximum infiltration rate at the beginning of irrigation. The longer the water is in contact with the soil, the more the infiltration rate decreases; in some soils it decreases to almost zero.

Important factors for achieving high DUs are intake opportunity time and soil infiltration rate. The IOT varies within an irrigated field. On furrow systems, the part of the field closest to the source of water usually has the highest IOT. For high DUs, the IOT within a field must have a high uniformity. In addition, soil will affect the DU. Different soils with the same IOT will have different infiltration rates. The more nonhomogeous the soil, the more soil infiltration rates will vary, resulting in a lower DU.

Irrigation timing, applying the correct amount of water, and having a high DU are important considerations for achieving high SAE. With most surface systems, the grower must decide how dry the soil can become (its allowable depletion) before an irrigation is applied. The grower's decision is based on the field, irrigation system design, crop, soil depth, and other factors. If the soil has an AD of 3 inches, irrigation should occur when the soil in the field has dried to that level. The amount of water applied over the field should be more than 3 inches, because water cannot be applied with a DU of 100 percent. Irrigating before reaching the AD could result in an over-application of water, and a lower SAE. Irrigating after reaching the AD might result in an under-application, and an overly high SAE, which is not desirable because plant stress may occur.

Pressurized, or piped, irrigation systems use pipelines and water emission devices to discharge water into a field and onto or under the soil surface. Water is pressurized using a pump and is usually passed through a filter to reduce the chance of clogging the emission devices. The water is distributed from a main pipeline system and sub-mains to lateral pipelines in the cropped field. Water flows from the emission devices as either a spray or a very small continuous stream. As the water meets the soil, it infiltrates to replenish soil moisture.

Pressurized systems are very different from surface systems. The performance of surface systems depends upon soil infiltration rates, IOT, and the amount of water applied. With pressurized systems, DU is constant and depends on the hardware design and maintenance. The DU will not change, unless pipeline leaks or clogging of devices occur, or winds distort the spray pattern. One of the most important design considerations for achieving high DUs is pressure regulation, as flow rates change with pressure. Excessive pressure variations in the design will result in a low DU.

The most important considerations for achieving high SAE with pressurized systems are applying the correct amount of water during an irrigation, and maintaining a high DU. Since a pressurized system can apply any amount of water with the same uniformity, the amount of water needed to replenish the crop root zone must be determined before the irrigation. Then the irrigation can be operated for the correct amount of time to apply the required water. The major types of pressurized irrigation systems used in California—sprinkler and micro-irrigation—are discussed in the sidebar.

Irrigation Scheduling. All irrigation systems require proper scheduling to achieve high SAEs. To develop an optimized irrigation schedule, the grower considers several factors: allowable or desirable crop water stress, the soil's water holding capacity within the crop root zone, water availability and/or delivery constraints, amount of effective rainfall, and application rate. With this information, along with soil moisture determinations, plant stress indices, and/or estimates of crop ET, a grower can develop a water budget schedule. The water budget compares crop ET with soil AD, allowing the grower to decide when and how long to irrigate.

Soil moisture is monitored many ways. Subsurface soil samples can be taken and visually inspected to estimate the moisture status. Soil moisture can be estimated with mechanical devices such as tensiometers or with electrical resistance devices such as gypsum blocks that rely on the change in electrical conductivity of water in the device. A neutron probe, another moisture-sensing device, measures the amount of neutrons reflected from water molecules in the soil.

Gravity (Surface) Irrigation Systems

Furrow Systems

Furrow is the most common gravity system, and is used for field crops, truck crops, trees, and vines. Channels or corrugations are cut or pressed into the soil of a field, usually one furrow between planted rows of crops. Efficient furrow systems have a slight grade, sloping from the head of the field where water enters the furrows to the bottom of the field. Water is delivered to the furrows using an earthen ditch and siphon tubes, gated pipe, or underground piping and above ground valves. In furrow systems, only the soil in the channel is wetted. Between 20 to 50 percent of the soil surface in a furrow irrigated field usually comes in contact with the irrigation water.

To irrigate sloping furrow systems efficiently, tailwater is allowed to run off the end of the furrows. A tailwater recovery system is needed to reapply this water, either on the same field or on another field. Efficient management requires a relatively high flow at the beginning of the irrigation, to get the water down the furrow quickly, then the flow is cut back to reduce tailwater. With furrow systems, high DUs can be achieved when the advance time (the time it takes the water to move from the top of the field to the end) is relatively short compared to the total time of irrigation.

Furrow systems can be designed and operated to achieve good SAEs for a range of ADs, except for very small ADs. The AD changes as the root zone changes. The early season irrigation of annual crops will not be as efficient as later season irrigations, because the early season AD would be small (shallow root depths), while the later season AD would be large (deep roots). Infiltration rates are typically higher soon after planting and lower later in the season.

Technologies and actions to optimize DUs and increase SAEs for furrow systems include:

- Dragging torpedoes (heavy metal cylindrical devices) within a furrow to smooth and compact the soil surface will decrease the advance time. This is most effective for early season irrigations, where the soil surface is rough due to tillage, and the soil intake rate is high.
- Shortening the length of the furrow will result in decreased advance time. (Shortening furrows increases the number of furrows, which can also result in less planted acreage and an increase in the cost of irrigation.)
- Laser leveling of fields to achieve a uniform slope, and a steeper slope (if practical), will decrease the advance time.
- Using surge irrigation, a technique where short term opening and closing of valves provides water to the furrows, resulting in the water "surging" down the furrow. (This technique is better suited to some soil types than others.) This technique will improve the uniformity of IOT in a furrow. It requires a surge valve designed for this application, and can easily be automated.
- Reducing the flow rate in each furrow after the water has reached the end of the furrow is essential to reducing the amount of tailwater produced.
- Using a properly planned and designed tailwater recovery system, along with efficiently using the captured tailwater on the same field or other irrigated fields.

Border-Strip Systems

Border-strip systems are generally used for alfalfa and pasture, but can be used on field crops and trees and vines. A field is divided into a number of strips, usually between 20 to

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100 feet wide. Low levees, or borders, divide each strip. Each strip has a slight slope from the head of the strip to the bottom, and ideally little or no slope between the sides. Water is delivered to each strip using an earthen ditch and siphon tubes, gated pipe, or underground piping and above ground valves. Usually all the soil surface in the strip, other than that in the borders, comes in contact with irrigation water.

A relatively large flow of water is directed into each strip during irrigation. The time it takes for the water to reach the end of the field is the advance time. When the water is between 60 to 90 percent of the way down the strip, the water is shut off, and the water already in the strip continues to move down the strip. The time it takes for the water to recede from the soil surface (from the top of the strip to the bottom) is the recession time. To achieve a high DU, the advance time must be very similar to the recession time, resulting in a uniform IOT over the strip. Generally, a border-strip system is designed and operated to have a small amount of tailwater, which requires a tailwater recovery system for reducing applied water. Border-strip systems can be designed to have a high DU and can achieve a high SAE, but only for a specific AD. Border-strip systems are well suited to crops with a constant deep root zone, such as alfalfa, pasture, trees, and vines.

Technologies and actions for border-strip systems to optimize DUs and increase SAEs include:

- Modify the advance rate to match the recession rate by adjusting the flow rate, changing border spacing, and using laser leveling to achieve a uniform slope and minimize cross slope.
- Use a properly planned and designed tailwater recovery system, and use the captured tailwater efficiently on the same field or on other irrigated fields.

Level Basin Systems

Level basin systems can be used on alfalfa, pasture, trees, vines, and field crops. The size of each basin is variable and depends upon soil infiltration rate and flow rate of water. Basins can vary from small (50 x 50 feet) to large (10 or more acres). There should be little or no slope within a basin. Earthen berms are built up on all sides of the basin. Water is delivered into each basin from pipelines and valves for smaller basins or from lined or unlined ditches with large gates. Normally, level basins are designed to have no tailwater. To achieve a high DU, the basin must be level, the flow of water must be high enough to cover the soil surface in a very short time (without any soil erosion from the flow), and the soil should be homogeneous.

Technologies and actions to optimize DUs and increase SAEs for level basin systems include:

- Use laser leveling to achieve a precise grade.
- Minimize soil variability within a basin. Large basins can be subdivided into smaller basins with uniform soil characteristics.

A side roll, wheel move sprinkler system.

Moisture content can also be estimated by dielectric sensors, devices that measure the dielectric content of a soil.

Plant stress indicator devices include pressure bombs and infrared thermometers. A pressure bomb is used to determine the turgor pressure within the cells of a plant's leaf, which provides information on the plant's moisture status. Infrared thermometers are hand-held devices used to measure plant canopy temperature. Plants can control water loss by regulating the stomatal openings in their leaves. Monitoring plant canopy temperatures with this device aids in determining if crop stress is occurring, and can indicate the status of soil moisture.

Crop ET estimates are developed using either evaporation pans or weather information. Class A evaporation pans are commonly used for measuring evaporation. The pans, constructed of galvanized steel or aluminum, are situated in the center of a large irrigated turf area. The pan station includes devices to measure rainfall, temperature, wind speed, and relative humidity. Evaporation is measured by monitoring the change in height of the water in the pan. The evaporation readings are multiplied by crop coefficients to estimate ET of a specific crop.

Many growers use automated weather station data for determining crop ET, such as the California Irrigation Management Information System. CIMIS is a

Pressurized (Piped) Irrigation Systems

Sprinkler Systems

Sprinkler systems are the most common type of pressurized systems and can be used for almost all crops. There are many different sprinkler head designs with flow rates that can vary from 10 gpm to less than 1 gpm. The spacing of the sprinkler heads in the field depends upon the flow rates and the radius of the area where the spray contacts the soil. To achieve high DUs, systems for field and truck crops are designed to space sprinkler heads close enough so that there is the proper amount of overlap of their wetted areas. Sprinkler systems for tree crops do not generally depend on overlap.

To achieve high DUs, a system must be designed to have minimal pressure variation, which ensures uniform flow rates from the sprinkler heads. Sprinkler nozzles must be maintained, because clogged or partially clogged nozzles lower DU, and worn nozzles will change flow rates, resulting in larger variations in pressure in the system. The application rate must be the same or less than the soil's infiltration rate. There are many variations in sprinkler systems used in California.

Permanent Systems. Permanent systems use underground pipelines. Risers connect to an underground lateral, usually with a sprinkler head attached less than a foot from the surface. These systems are commonly used for orchard irrigation (under tree), but when connected to taller risers they can be used for vines.

Solid Set Systems. Solid set systems use above ground aluminum pipelines, usually in 30 foot sections. Short risers connect the aluminum laterals to sprinkler heads. With a solid set system, the irrigation system covers a complete field. The system may stay in the field for the whole growing season, and be removed before harvest, or may be used only for germination or transplant establishment of vegetable crops. These systems are used mainly for field and truck crops.

Hand Move Systems. Hand move systems are similar to the solid set systems, using the same aluminum pipelines, but do not normally cover a whole field. After an irrigation, the sprinkler laterals are disconnected from the sub-mains, and moved by hand to the next location in the field. After each irrigation, the laterals are systematically moved to the next location. These systems are usually designed for each part of the field to receive irrigation water every 7 to 14 days. These systems are used on field crops, truck crops, and orchards.

Wheeled Systems. Wheeled systems have the lateral, risers, and sprinkler heads all mounted on wheels that can be moved throughout the field during the irrigation season. Side roll systems are designed to be stationary during the irrigation. After the irrigation, they are moved (using an on-board engine) to the next location.

Linear Move Systems. Linear move systems have the lateral, risers, and sprinklers mounted on pipes between large wheeled towers. The system continuously travels down the field during irrigations. The water is usually supplied to the system via a canal parallel to the travel of the system.

Center Pivot Systems. Center pivot systems are similar in structure to linear move systems, except instead of the lateral traveling down the field, it travels in a circle in the field. One end of the lateral is fixed in the middle of the field, where the water enters the lateral. The entire lateral rotates around this pivot (which is usually a well), and continuously moves during irrigations.

Low-Energy Precision Application Systems. LEPA systems are similar to linear move sprinkler systems, except that they have drop tubes from the lateral to the soil surface instead of sprinkler heads. These systems are used in fields that have furrows, sometimes with small checks or dams in the furrow. The LEPA system travels perpendicularly to the furrows, and drop tubes emit water uniformly into the furrows.

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Technologies and actions for sprinkler systems to optimize DUs and increase SAEs include:

- Minimize pressure variation within the system. Design sprinkler heads, nozzles, and spacings for the proper amount of overlap in spray. Ensure that application rates are lower than the soil infiltration rate, and that filtration is adequate. The sprinkler system must be properly maintained.
- To avoid spray losses, avoid irrigation during windy conditions, and ensure that pressures and nozzles are compatible to avoid misting.
- Where appropriate, use flow control nozzles.

Micro-Irrigation (Low Volume) Systems

Use of these systems increases each year. In many areas with trees and vines, they are the predominant method of irrigation. Low volume systems have many of the same components of sprinkler systems: pressurized water sources, filters, main pipelines, sub-mains, and laterals. The main difference is the devices that emit the water to the soil. These emit water at a very low flow rate (from 0.5 to 10 gallons per hour). There are two types of devices used, drip and micro-spray. With drip devices (emitters), water flows out as a constant stream (0.5 to 2 gallons per hour) directly to the soil. With micro-spray, the devices (spray heads) produce a spray (4 to 20 gallons per hour) over the soil surface. Other key differences between micro-irrigation systems and sprinkler systems are that the entire main and sub-main pipelines are usually underground rigid plastic pipe, the laterals are flexible plastic hose, and the filters are designed to remove much smaller particles to prevent clogging. Emitter and spray heads use small orifices, channels, or nozzles to regulate flow rates, and are subject to clogging by particulate matter and biological growth.

Drip system emitters are usually spaced 2 to 5 feet apart. Drip systems can be buried or placed on the soil surface. Emitter spacing is based upon the soil type being irrigated, with sandier soils needing a closer spacing, and clay soils using the greatest spacing. Drip systems are mostly used for orchards and vines, strawberries, and nurseries, but their use is increasing for vegetable crops. In these systems, the emitters are spaced much closer and are installed 8 to 18 inches below the soil surface.

Micro-spray systems use small plastic sprinklers or jets that spray water over the soil surface, creating a wetted area 12 feet or more in diameter. The droplet sizes are small compared to a sprinkler system, and the application rate is low. Micro-spray heads are connected to plastic lateral hoses, usually one hose per row of trees. These systems are not designed to wet the entire soil surface like a typical sprinkler system. These systems are used almost exclusively in orchards.

Drip and micro-spray systems can achieve high DUs if pressure variation is minimized. Because of the small nozzles and emitter pathways, partial or full clogging is always a potential problem, and can significantly reduce DU. These systems require regular maintenance to reduce clogging, including frequent flushing of pipelines and lateral hoses, and addition of chemicals (such as chlorine and acids) to kill bacteria and other biological growth and to reduce scale buildup. The systems require filtration and the filters need regular maintenance to ensure that they operate as designed.

Achieving a high SAE with these systems is dependent on maintaining a high DU and on proper irrigation scheduling. One advantage to these systems is that irrigation scheduling is more easily controlled than most sprinkler and surface systems. Flow can be started and stopped easily (providing the water delivery system can accommodate this), and they are easier to automate, even to the extent of using remotely sensed field information for making irrigation timing decisions.

Technologies and actions for optimizing DUs and increasing SAEs of micro-irrigation systems include:

- Ensure that pressure variation within the system is minimized, the filtration system is adequate, and prevent emitter clogging.
- Perform regular inspections of filters, emitters/spray heads, pressure levels, and tubing/pipelines, and provide regular maintenance, including filter cleaning and hose/pipeline flushing.
- Where appropriate, use pressure compensating emitters or microsprinklers.

repository of climatological data collected at 93 computerized weather stations throughout the State. CIMIS was developed by the Department and the University of California at Davis, and has been in operation since 1985. Weather data are collected daily from each weather station site and automatically transmitted to a central computer in Sacramento. Currently, the CIMIS computer receives over 25,000 requests for ET data annually, representing approximately 75,000 end users. The weather data (solar radiation, temperature, relative humidity, and wind speed) are used with a modified Penman equation to calculate ET_o. ET_o is used in irrigation scheduling to estimate plant ET, by multiplying ET_o by the appropriate crop or landscape coefficients.

Regulated deficit irrigation is a technique to reduce crop ET. Irrigation is reduced during a specific stage of the crop's growth, resulting in some crop stress at the time, but with little or no negative effects on production, quality, or on future growth. Research has shown that this management technique may be applied to some tree crops such as pistachios, almonds, and olives. This irrigation strategy may have its greatest value in drought situations, where a grower may be forced to under-irrigate.

Water Treatment Technologies

As discussed in Chapter 3, water quality is a critical factor in determining the usability and reliability of any particular water source. Traditional public health practices emphasize the need to use best available quality sources for municipal supplies and to implement source protection measures to maintain high quality raw water sources. Where raw water supplies are of less than pristine quality, greater reliance must be placed on treatment technology. Water recycling and desalting are becoming larger components of potential future supplies, especially for urban areas. To transform these lower quality raw water sources into reliable water supply options, the basic water treatment technologies described in this section are used. Application of these technologies to specific options (such as treating contaminated groundwater) is also outlined.

Description of Water Treatment Technologies

Activated Carbon Adsorption. Treatment by activated carbon adsorption is most applicable to organic contaminants. By bringing contaminated water in contact with activated carbon in granular or powdered form, the contaminants are adsorbed onto the carbon.

An evaporation pan with weather station in the background.

The process may be accomplished by batch, column, or fluidized-bed operations. Spent carbon may be regenerated or may be disposed of in accordance with regulatory requirements. In addition to the traditional use of activated carbon for taste and odor control and dechlorination, carbon adsorption is widely used for removal of volatile organic chemicals and synthetic organic chemicals.

Granular activated carbon adsorption is a unit process with a proven ability to remove a broad spectrum of organic chemicals from water. EPA considers GAC adsorption as the best available technology for removal of VOCs and SOCs. Powdered activated carbon has traditionally been used to control taste and odor in water, and is also used for removal of certain SOCs, especially pesticides. PAC, in combination with conventional water treatment technology, can provide acceptable levels of pesticide removal in surface waters. A typical application of PAC would be for seasonal removal of pesticides found in municipal treatment plant raw water supplies during wet weather. Some limitations to use of PAC include the potential need for large doses of carbon to achieve desired levels of treatment, and the resultant high sludge production.

Air-Stripping. This treatment technique removes VOCs from contaminated water. Countercurrent air-stripping in a packed tower is the most common process. The conventional configuration of a unit consists of a tower with water inflow at the top and air inflow at the bottom. The tower is filled with small diameter random packing. As clean air moves upward, the VOCs transfer from the water phase into the air phase. Treated water exits from the bottom, and the air containing VOCs is discharged from the top of the tower, either into the atmosphere or into a gas treatment system.

Since air-stripping transfers contaminants to the atmosphere, they must take into consideration allowable VOC emissions. In some parts of the State, such as in the South Coast Air Quality Management District, emissions are strictly regulated and additional treatment to reduce emissions to acceptable levels is needed. GAC adsorption may be used with air-stripping to control emissions from a packed-tower aeration system.

The closed-loop air-stripping process is an innovative extension of the traditional air-stripping technology. The closed-loop air-stripping process combines air-stripping with an ultraviolet photo-oxidation

This air stripping system at McClellan Air Force Base in Sacramento is being used to clean groundwater contaminated with solvents.

process to control VOC emissions. In this process, exhaust air is irradiated with UV radiation in a photo-oxidation chamber, and VOCs are destroyed. The end products are carbon dioxide, hydrochloric acid, and ozone. The treated air is recycled to the PTA unit.

Advanced Oxidation. In contrast to GAC or air-stripping, advanced oxidation processes can destroy organic contaminants rather than transferring them from one medium to another. Examples of AOPs include treatment with UV, ozone/hydrogen peroxide, and ozone/UV. AOPs provide more powerful oxidation and at faster rates than conventional oxidants such as chlorine. As a result, they can remove compounds which are not treatable with conventional oxidants. These oxidants can also reduce disinfection by-products created by processes such as chlorination. To date, much AOP work has focused on removing low-molecular weight solvents such as TCE and PCE from contaminated groundwater, and on reduction of DBPs.

Membrane Technologies. Membrane technologies include reverse osmosis, electrodialysis, microfiltration, ultrafiltration, and nanofiltration. RO, MF, UF, and NF are pressure-driven processes of barrier separation; electrodialysis employs electrical potential as the driving force. Membrane processes have been used for desalting, removal of dissolved organic materials, softening, liquid-solid separation, pathogen removal, and heavy metals removal. Other promising membrane technologies are membrane phase-contact processes. These processes are not pressure driven but remove contaminants by extraction into another phase, as do air-stripping and solvent extraction.

RO membranes permit water to flow through them while rejecting the passage of dissolved contaminants. This is based on the natural osmotic process where water passes through a semipermeable membrane from a solution of higher concentration to a lower one. In RO, a pressure greater than osmotic pressure is applied to the contaminated water. Water passes through the membrane but contaminants are retained. RO systems using newer membranes operate at about 250 psi for desalting brackish groundwater and up to 1,000 psi for seawater desalting.

Electrodialysis induces contaminant ions to migrate through a membrane, removing them from the water. In an electrodialysis unit, contaminated water is pumped into narrow compartments separated by alternating cation-exchange and anion-exchange membranes, selectively permeable to positive and negative ions. A variation of this process is called electrodialysis reversal. In electrodialysis, the electrical current flow is always in the same direction. In EDR, the electrical polarity is periodically reversed, which reverses ion movement and flushes scale-forming ions from the membrane surfaces.

MF, UF, and NF operate similarly to RO, but at lower pressures. More stringent drinking water regulations coupled with diminishing sources of pristine waters have stimulated interest in the use of membrane technologies in drinking water treatment. The use of low-pressure membrane filtration for municipal water treatment is a relatively new concept in the water industry, which has traditionally used membranes for removing salts or organic materials. MF operates at pressures ranging from 20 to 100 psi and is capable of removing micron-sized (10^{-6} m) materials. Colloidal particles are physically rejected by MF membranes. UF operates at pressures ranging from 3 to 150 psi and is capable of removing materials that are on the order of a nanometer in size (10^{-9} m) from water. Dissolved inorganic contaminants are not retained by MF and UF membranes. One of the most novel applications of low-pressure membrane technology is the removal of microorganisms such as coliform bacteria, viruses, *giardia,* and *cryptosporidium* from drinking water sources without using chemicals for primary disinfection. The efficiency of low-pressure membranes in removing particles from untreated water supplies has been well documented. MF and UF have shown to be capable of consistently reducing turbidities to less than 0.1 NTU, regardless of the influent turbidity level.

NF operates at pressures ranging from 150 to 300 psi and has characteristics between those of RO and MF. The capital cost of an NF plant is typically high compared to conventional treatment plants because of the cost of membranes and high-pressure equipment. Pilot and bench-scale studies have demonstrated that nanofiltration is effective in removing DBP precursors and SOCs such as pesticides. NF is also frequently used for water softening applications.

Ion-Exchange. The process passes contaminated water through a packed bed of anion or cation resins. The resin type is selected based on the contaminant to be removed. The treatment process exchanges ions between the resin bed and contaminated water. By displacing ions in the resin, contaminant ions become part of the resin and are removed from process water. During the ion-exchange process, the exchange capacity of the resin becomes depleted and needs regeneration to become effective. Sodium chloride brine is used to regenerate the resin. Ion-exchange is widely used for removing nitrates in groundwater and for removing some metals. It may also be used for water softening. Its effectiveness in removing radionuclides is being investigated in a number of full scale applications.

Chemical Precipitation. Chemical precipitation is used for removing heavy metals from water. The contaminants are precipitated from solution and removed by settling. There are several types of chemical addition systems including ones using carbonates, hydroxides, and sulfides. The carbonate system uses soda ash and pH adjustment. The hydroxide system is most widely used for removing inorganics and metals. The system uses lime or sodium hydroxide to adjust the pH upward. The sulfide system removes most inorganics (except arsenic). The disadvantage is that sulfide sludges are susceptible to oxidation to sulfate when exposed to air, resulting in resolubilization of the contaminants.

Biological Treatment. Biological treatment uses microorganisms to remove contaminants in water through metabolic processes. The process can be a suspended growth system, where the microorganisms and nutrients are introduced in an aeration basin as suspended material in a water-based solution, or a fixed-film system where the microorganisms attach to a medium which provides inert support. Biological treatment is used in municipal wastewater treatment and for treating water containing organic compounds such as petroleum hydrocarbons. Biological treatment is often used for remediation of leaking fuel tank sites, either above ground, or *in situ*.

Disinfection. This treatment inactivates pathogens in water. The most common disinfection process is chlorination, often used to treat wastewater and drinking water. Two relatively new disinfection processes applied in water recycling include UV radiation and ozonation. UV has recently been approved by the DHS for disinfecting recycled water. UV has been shown to be as effective as chlorine or ozone in reducing coliform bacteria and is more effective at virus removal. UV has the potential to be more cost effective than chlorine disinfection, and eliminates the DBPs and handling hazards associated with chlorination.

Innovative Treatment Technologies. Many innovative technologies are being used to treat contaminated groundwater at hazardous waste sites. These technologies typically combine basic processes with a few special techniques. In the future, these technologies may see broader application in groundwater recovery projects. Some examples of these technologies, primarily those applied at pilot or full scales, are covered below.

The EnviroMetal Process, a proprietary technology, treats groundwater *in situ* using reactive metal (usually iron) to enhance the abiotic degradation of dissolved halogenated organic compounds. A permeable treatment wall of the coarse-grained reactive metallic media is installed across a plume of contaminated groundwater, breaking down contaminants as they migrate through the aquifer. This technology has received regulatory approval for use in at least two industrial facilities in California for treating shallow plumes with elevated levels of VOCs.

Integrated vapor extraction and steam vacuum stripping removes VOCs, including chlorinated hydrocarbons, in groundwater and soil. The integrated system has a vacuum countercurrent stripping tower that uses low-pressure steam to treat contaminated groundwater, and a soil vapor extraction process to treat the soil. The stripper and the soil vapor extraction systems share a GAC unit to decontaminate the combined vapors. The technology has been used to treat TCE-contaminated groundwater and soil.

Steam-enhanced extraction uses injection wells to force steam through the soil to enhance vapor and liquid extraction thermally. The process extracts volatile and semivolatile organic compounds from contaminated soil and groundwater. The recovered contaminants are condensed or trapped by activated carbon filters. After treatment is complete, subsurface conditions are suitable for biodegradation.

Subsurface volatilization and ventilation technology uses a network of injection and extraction wells to treat subsurface organic contamination through soil vapor extraction and *in situ* biodegradation. A vacuum pump extracts vapors while an air compressor injects air in the subsurface. In most sites, extraction wells are placed above the water table and injection wells are placed below the groundwater level. Because it provides oxygen to the subsurface, the process can enhance *in situ* bioremediation.

The PACT wastewater treatment system is a proprietary technology that combines biological treatment and PAC adsorption to contaminated water. Microorganisms and PAC contact wastewater in an aeration tank. The biomass removes biodegradable organic contaminants, and PAC enhances adsorption of organic compounds. PACT systems treating up to 53 mgd of wastewater are in operation. This process is applicable to groundwater contamination from hazardous waste sites.

Capacitive deionization desalting is an experimental process being researched at Lawrence Livermore National Laboratory. It involves passing water through electrodes made of carbon aerogel and generating a small voltage differential between alternating positive and negative electrodes, thus drawing ions out of the solution. The ions are removed by electrostatic attraction and are retained on the electrode until the polarity is reversed. The ions are then captured with a small amount of water. Other dissolved materials such as trace metals and suspended colloids are removed by electrodeposition and electrophoresis. The process has been operating in a laboratory for over two years. Sodium chloride, sodium nitrate, and ammonium perchlorate solutions have been tested with excellent results. Electrode life has been acceptable in the laboratory, with electrodes operating for more than two years with little degradation. The electrodes appear to be regenerable with little loss of capability. Energy requirements appear less than current desalting technologies. Field testing has begun in Northern California, and will later be moved to Southern California.

Application of Water Treatment Technologies

Water Recycling. Recycled water uses include groundwater recharge, agricultural and landscape irrigation, wildlife habitat enhancement, industrial use, and recreational impoundments. Groundwater recharge and agricultural and landscape irrigation constitute the greatest uses of recycled water in the State. Table 5-2 lists some water recycling plants having a capacity of at least 10 mgd.

Indirect potable reuse of recycled water has been practiced for years through groundwater recharge programs. In Los Angeles County, the Montebello Forebay Groundwater Recharge Project began recharging the Central Basin aquifer with recycled water in 1962. Currently up to 60 taf/yr of recycled water percolates into the groundwater basin, from which it is later extracted for distribution in potable water systems. Water Factory 21 in Orange County and the West Basin Water Recycling Facility have been producing advanced treated recycled water for seawater intrusion barrier injection, with the majority of the injected water entering the groundwater and becoming part of the water supply.

As advanced treatment technologies become more cost-effective, and as public acceptance increases, augmentation of surface water supplies may become another application for recycled water. The San Diego water repurification program, discussed in the sidebar, would be the first example of planned, indirect potable reuse where repurified water is discharged directly into a surface reservoir without percolation or injection into groundwater. (Unplanned, indirect potable reuse occurs whenever treated effluent is discharged into a waterway upstream of another user's water supply intake.) Reservoir retention allows for additional monitoring of the repurified water prior to introduction to a potable water supply. Surface water supply augmentation projects are approved by DHS on a case-by-case basis.

TABLE 5-2

Water Recycling Plants with a Capacity of at Least 10 mgd

Name	*Capacity (mgd)*[a]	*Treatment Process*	*Type Of Reuse*	*Annual Supply (taf)*
San Jose Creek Water Reclamation Plant (Los Angeles County Sanitation District)	100	Primary sedimentation, activated sludge, coagulation, filtration and chlorination	Groundwater recharge, agricultural and landscape irrigation, and nursery stock irrigation	43.2
Donald C. Tillman Water Reclamation Plant (City of Los Angeles)	80	Primary sedimentation, activated sludge, coagulation, filtration, chlorination, and dechlorination	Recreational lake, wildlife lake, and Japanese garden	20.0
Fresno-Clovis Metropolitan Area Regional Wastewater Facilities	60	Primary sedimentation, trickling filter, and activated sludge	Agricultural irrigation	13.7
Los Coyotes Water Reclamation Plant (Los Angeles County Sanitation District)	37	Primary sedimentation, activated sludge, coagulation, filtration, and chlorination	Landscape irrigation, industrial reuse (process water, concrete mix, and dust control), and crop irrigation	5.9
West Basin Water Recycling Facility (West Basin Water District)	37	Coagulation, filtration, clarification and reverse osmosis (5 mgd), microfiltration and reverse osmosis (2.5 mgd)	Industrial use, landscape irrigation, and seawater intrusion barrier	8.4
Chino Basin Municipal Water District Regional Plant No. 1	32	Activated sludge, coagulation, filtration, chlorination, and dechlorination	Landscape irrigation and recreational lakes	1.7
City of San Diego North City Water Reclamation Plant	30	Primary sedimentation, activated sludge, coagulation, filtration, and chlorination	Landscape irrigation	3.0
Terminal Island Treatment Plant (City of Los Angeles)	30	Primary sedimentation, activated sludge, filtration, reverse osmosis, and microfiltration	Seawater intrusion barrier and industrial use	0[b]
Salinas Valley Reclamation Plant (Monterey Regional Water Pollution Control Agency)	30	Primary sedimentation, trickling filters, coagulation, filtration, and disinfection	Agricultural irrigation	13.2
Long Beach Water Reclamation Plant	25	Primary sedimentation, activated sludge, coagulation, filtration, and disinfection	Landscape irrigation, nursery irrigation, and repressurization of oil-bearing strata	5.1
City of Modesto Wastewater Quality Control Facility	25	Primary sedimentation, trickling filter, oxidation ponds, and chlorination	Fodder crop irrigation	14.4
Central Contra Costa Sanitary District Water Reclamation Plant	25	Primary sedimentation, activated sludge, UV disinfection, coagulation, filtration, and chlorination	Landscape irrigation, and light industrial	1.2

TABLE 5-2

Water Recycling Plants with a Capacity of at Least 10 mgd (continued)

Name	*Capacity (mgd)*[a]	*Treatment Process*	*Type Of Reuse*	*Annual Supply (taf)*
Los Angeles-Glendale Water Reclamation Plant (City of Los Angeles)	20	Primary sedimentation, activated sludge, coagulation, filtration, chlorination, and dechlorination	Landscape irrigation and industrial reuse	3.3
City of Bakersfield Wastewater Treatment Plant No. 2	19	Primary sedimentation and oxidation ponds	Crop irrigation	16.8
Laguna Treatment Plant (City of Santa Rosa)	18	Primary sedimentation, activated sludge, coagulation, filtration and chlorination	Fodder irrigation	9.3
Fairfield-Suisun Subregional Wastewater Treatment Plant	17	Activated sludge, coagulation, filtration, chlorination, and dechlorination	Sod farming and duck hunting marsh maintenance	2.4
Michelson Water Reclamation Plant (Irvine Ranch Water District)	17	Primary sedimentation, activated sludge, coagulation, filtration, and chlorination	Landscape irrigation, nursery irrigation, and toilet flushing	8.2
Whittier Narrows Water Reclamation Plant (Los Angeles County Sanitation District)	15	Primary sedimentation, activated sludge, coagulation, filtration, and chlorination	Groundwater recharge and nursery stock watering	9.4
San Jose/Santa Clara Water Pollution Control Plant	15	Activated sludge, filtration and chlorination	Landscape irrigation and industrial processes	7.5
Pomona Water Reclamation Plant (Los Angeles County Sanitation District)	13	Primary sedimentation, activated sludge, coagulation, filtration, and chlorination	Agricultural irrigation landscape irrigation, and industrial process	12.5
City of Visalia Water Conservation Plant	12	Primary sedimentation, trickling filter, activated sludge, and chlorination	Non-food crop irrigation	4.9
Valley Sanitary District Wastewater Treatment Facility (Riverside County)	12	Primary sedimentation, trickling filter, activated sludge, and oxidation ponds	Non-food crop irrigation	4.3
City of Bakersfield Wastewater Treatment Plant No. 3	12	Primary sedimentation, trickling filter	Agricultural irrigation	11.6
Desert Water Agency Wastewater Reclamation Facility (Riverside County)	10	Coagulation, filtration, and chlorination	Landscape irrigation	2.7
Water Factory 21 (Orange County Water District)	10	Coagulation, sedimentation, filtration, carbon adsorption (5 mgd), reverse osmosis (5 mgd), and disinfection	Groundwater injection for intrusion barrier	2.6
Lancaster Water Reclamation Plant	10	Primary sedimentation, oxidation ponds, and chlorination	Wildlife refuge and fodder irrigation	9.7

[a] One mgd equals 1,120 af/yr

[b] Expected to operate by 2000 with annual supply of 19 taf

San Diego Water Repurification Program

The City of San Diego, in conjunction with the San Diego County Water Authority, proposes to repurify 16 taf/yr of wastewater for indirect potable purposes. Results of pilot studies conducted by the agencies show that wastewater can be repurified to a level suitable for human consumption. The agencies would construct an 18 mgd wastewater repurification facility using state-of-the-art technology to treat recycled water from the City of San Diego's North City Water Reclamation Plant. The repurified water would be transported over 20 miles to the 90 taf San Vicente Reservoir, where it would be blended with imported raw water supplies and stored for a period of time. The blended water would eventually be conveyed via the existing El Monte Pipeline to the city's Alvarado Filtration Plant for traditional treatment before being delivered to the city's drinking water system.

Repurified water is based on a concept of multiple barriers. Recycled water from the North City Water Reclamation Plant, treated to levels acceptable for landscape irrigation and for other nonpotable purposes, would be treated further at the proposed 18 mgd wastewater repurification facility. The repurification process would include subjecting the recycled water to four more treatment processes — low-pressure micro-filtration, reverse osmosis, ion-exchange, and ozonation. These treatment processes, while redundant in their functions, ensure reliability of the overall repurification system and produce an end product that would exceed current health and safety standards.

Pilot studies show that the City of San Diego could turn recycled water into an alternative drinking water source. The city is preparing an environmental document and has begun design of the project. The project is expected to begin operation in late 2002.

The California Potable Reuse Committee was formed in 1993 to study the viability and safety of indirect potable reuse. The committee, commissioned by DHS and the Department, developed six criteria that must be met before indirect potable reuse is allowed for augmentation of surface water supplies. (DHS has other proposed regulations and criteria for indirect potable reuse through groundwater recharge projects.) The criteria are:

(1) Application of the best available technology in advanced wastewater treatment with the treatment plant meeting operating criteria. Best available technology must include a membrane component with the functional equivalency of reverse osmosis.

(2) Maintenance of appropriate reservoir retention times based on reservoir dynamics.

(3) Maintenance of advanced wastewater treatment plant reliability to consistently meet primary microbiological, chemical, and physical drinking water standards.

(4) Compliance with applicable State criteria for groundwater recharge for direct injection of recycled water.

(5) Maintenance of reservoir water quality. In addition to meeting drinking water standards, recycled water used for reservoir augmentation shall be of equal or better quality than that in the storage reservoir on a constituent-by-constituent basis.

(6) Provision for an effective source control program. The source control program is to include pretreatment/pollution prevention measures that prohibit the discharge of any substance which, whether alone or in combination with other wastewater constituents, causes or threatens malfunction or interference with the wastewater treatment process, constitutes a hazard to human health or safety, or affects the water quality of the potable storage reservoir.

Treatment criteria for reuse of municipal wastewater are mandated in Title 22 of the California Code of Regulations. These criteria specify the treatment level for specific reuse applications. Treatment technologies used for water recycling depend on the reuse application. For most nonpotable reuse applications at least secondary treatment is required. To achieve secondary treatment, conventional biological treatment processes such as activated sludge process, trickling filters, or oxidation ponds are used, followed by sedimentation and disinfection with chlorine.

Tertiary treatment, which is often standard for recycled water, is achieved by adding a filtration step after secondary treatment and before final disinfection. Two major types of filtration technology are applied in tertiary treatment plants: conventional and direct filtration. Conventional filtration, as defined in Title 22, includes coagulation, sedimentation, and filtration to condition the water. Conventional filtration technology requires that the filters be backwashed to prevent turbidity breakthroughs. The Title 22 back-

TABLE 5-3

Sample Desalting Plants

Site	*Owner*	*Capacity (mgd)*[a]	*Comments*
Brackish Water Desalting			
Arlington	Santa Ana Watershed Project Authority	6.0	Operational
Tustin	City of Tustin	3.0	Operational
Oceanside	City of Oceanside	2.0	Operational, being expanded
West Basin	West Basin MWD	1.5	Operational
Wastewater Desalting			
Water Factory 21	Orange County WD	5.0	Operational, being expanded
West Basin	West Basin MWD	5.0	Operational, being expanded to 7.5 mgd
San Diego	City of San Diego	1.0	Operational
Seawater Desalting			
Santa Barbara	City of Santa Barbara	6.7	Standby as drought reserve
Morro Bay	City of Morro Bay	0.6	Standby as needed
Marina	Marina Coast Water District	0.3	Operational
Santa Catalina Island	Southern California Edison	0.1	Operational

[a] One mgd equals 1,120 af/yr

wash requirements result in an equipment-intensive process. Direct filtration provides a cost-effective and convenient tertiary technology when secondary effluent quality is high. The technology will likely be incorporated in areas where effluent from residential areas provides the process water. Newer water recycling facilities use direct filtration as part of the tertiary treatment process. Direct filtration bypasses the sedimentation step. Continuously backwashed direct filtration technology is available, minimizing equipment needs.

Achieving the maximum use of tertiary treated water for landscape irrigation and other outdoor applications depends on the ability to store the treated water supply when it is not needed. Landscape irrigation demands, for example, have a wide seasonal variation in the State's inland areas. (Landscape irrigation demands also vary diurnally, with most sites demanding recycled water at night when supplies are at their lowest levels.) Groundwater recharge is often a cost-effective solution to meeting seasonal demand patterns, allowing the storage of relatively large quantities of recycled water without the capital cost investment associated with above-ground reservoirs.

Desalting. According to the International Desalting Association's inventory of worldwide desalting plants, the United States is second in usage of desalting in the world, with almost 1 maf/yr of installed capacity. (Only Saudi Arabia has more installed capacity.) In 1985, the United States had less than 7 percent of the world's capacity; by 1993, that figure had risen to nearly 15 percent. Common feedwater sources for desalting plants include brackish groundwater, municipal and industrial wastewater, and seawater. Costs of desalting increase with increasing feedwater salinity. Table 5-3 lists some larger desalting plants in California.

Reverse osmosis accounts for 89 percent of the installed capacity of desalting plants in California, including all the significant plants supplying municipal water supplies or recycling municipal wastewater. Reverse osmosis is likely to continue to dominate in California, given recent improvements in membrane performance. Reverse osmosis membranes have changed greatly in the last 20 years. Membranes are available to serve many purposes. This allows water suppliers to select and operate membranes specifically suited to the feedwater quality and the required product water quality. Membranes have developed into two principal classes.

The first class is the traditional reverse osmosis membrane which rejects all salt ions (as well as other dissolved constituents) equally. This process, also called hyperfiltration, is used on water requiring the removal of all classes of dissolved constituents. The second class of membrane processes is represented by MF, UF, and NF. For example, nanofiltration membranes reject larger dissolved ions such as calcium and

**Seawater Desalting–
Marina Coast Water District**

Marina Coast Water District is the primary water supplier for the City of Marina. MCWD relies on the Salinas Valley groundwater basin as its primary water supply source, as do other Salinas Valley urban and agricultural water suppliers. Overdraft of the Salinas Basin has caused seawater from Monterey Bay to migrate into two of the three aquifers underlying the coastal part of Salinas Valley. Seawater intrusion has rendered some groundwater unfit for use. MCWD has had to replace shallower wells with deeper wells to meet demands for potable water. MCWD investigated ways to diversify its water supply sources because of potential groundwater extraction limitations, and chose desalting as its preferred option.

MCWD completed construction of a reverse osmosis seawater desalting plant in 1997. The plant produces approximately 300,000 gpd of potable water (equivalent to 340 af/yr), and uses beach wells for seawater intake and brine disposal. A shallow production well drilled into beach deposits near MCWD's water treatment plant provides intake water for the desalting plant. Using a beach well to supply seawater minimizes the need for extensive pretreatment. Beach sands filter most of the suspended material in the seawater. The reverse osmosis system is a single stage system operated at 40 to 45 percent recovery rates.

The project produces a reject brine flow of about 450,000 gpd. An injection well in a shallow sand aquifer is used to dispose of the brine. Power requirements for the desalting plant are estimated at 5,000 kWh of electricity per acre-foot of water produced, or about 15 kWh for each 1,000 gallons of desalted water. Total capital costs for the desalting plant were about $2.5 million.

sulfate, along with equally large dissolved feedwater constituents. When used in a water softening role, they will remove calcium, magnesium, and sulfate from water, but allow sodium and chloride ions to pass through. Nanofiltration membranes are often used for water softening.

Advances in membrane technology have reduced operating pressures, increased flow rates, and increased salt rejection in typical reverse osmosis applications—thereby reducing treatment costs. As operating pressures have decreased, so have energy costs. Energy requirements have accounted for at least 50 percent or more of the operating costs of a reverse osmosis plant. New membrane materials have allowed more membrane area per module and higher productivity per square foot. Increased productivity of membranes and their longer life expectancy reduces the capital cost of the plant, reducing the cost of water. Increasing salt rejection provides better water quality. In the case of groundwater desalting, the high purity product water can be blended with raw water to meet the desired overall product water quality.

Treatment of Contaminated Groundwater

The selection of technologies for treating groundwater contamination depends on site conditions and the contaminants to be removed. Although there are a variety of options, no one technology is necessarily capable of responding to all conditions found at a groundwater contamination site. In practice, treatment technologies are sometimes used in combination to remediate contamination. For example, groundwater contaminated with nitrates and pesticides requires ion-exchange technology to remove the nitrates and GAC adsorption to remove the pesticides. Table 5-4 provides some examples of contaminated groundwater treatment sites. Treatment unit capacities at the locations shown range from 0.3 mgd to 4.1 mgd.

Some local agencies have integrated groundwater treatment plants into municipal distribution systems. The West Basin Municipal Water District for example, constructed a 1.5 mgd facility that uses reverse osmosis technology to remove elevated levels of dissolved solids from contaminated groundwater. The plant supplies about 1.5 taf annually of recovered groundwater to the district for municipal use and to Dominguez Water Corporation for municipal and industrial uses.

The Glenwood nitrate water reclamation plant, owned by Crescenta Valley County Water District, is a 3.7 mgd ion-exchange treatment plant. Treated groundwater from the plant is sold to Foothill Municipal Water District and MWDSC for municipal and industrial uses. The plant's eventual project yield will be about 1.6 taf annually. The City of Pomona operates a 15 mgd ion-exchange treatment plant, treating nitrate-contaminated groundwater from the Chino Groundwater Basin. At full capacity, the treatment plant supplies about two-thirds of the city's municipal water demand.

Some aquifers in California are contaminated because of past hazardous waste disposal practices. A number of these sites are undergoing remediation. Carbon adsorption, membrane filtration, air stripping, advanced oxidation processes, biological treatment, chemical precipitation, and innovative treatment technologies are examples of technologies used. For example, Aerojet General Corporation's manufacturing facility in Rancho Cordova operates a 6.5 mgd groundwater treatment facility which removes VOCs from the groundwater. The treatment facility has air-stripping towers and GAC adsorption units. Treated groundwater is reinjected into the aquifer through wells, and is also recharged via surface impoundments. Another example is Valley Wood Treating Company in Turlock, which uses pump-and-treat and *in situ* treatment techniques for chromium-contaminated groundwater. The company pumps groundwater and uses chemical precipitation for first stage contaminant removal. Next, a reducing agent is added to the treated water, which is then reinjected into the aquifer. The resulting reaction reduces chromium *in situ* and subsequently fixes residual chromium in the soil.

TABLE 5-4

Examples of Contaminated Groundwater Treatment Sites

Location	*Contaminant*	*Treatment*
Lodi	DBCP	GAC
Lodi	Pathogens	UV
Modesto	DBCP	GAC
Modesto	Nitrates	Electrodialysis
Fresno	DBCP	GAC
Fresno	TCE	Air-stripping
Clovis	DBCP	GAC
Monrovia	TCE	Air-stripping
Monrovia	VOCs	Air-stripping
San Gabriel Valley	VOCs	GAC

Water Supply/Flood Control Technologies

Inflatable Dams

Inflatable rubber, or fabric and rubber, dams and tubes have been used for years as weirs to impound water for water supply and flood control. Inflatable dams were developed and first used in the 1950s in the Los Angeles area. They were typically inflated with water. Since that time, construction materials and control systems have been improved and features have been added, such as fins to reduce vibrations during overflow. Air is now the preferred inflation medium. The manufacturers report that there are about 1,900 of these dams worldwide, with 50 in the United States.

Alameda County Water District's Rubber Dam No. 3 is a representative example of a modern inflatable dam. The 13-foot-high, 375-foot-long dam was

Remediation of Nitrate Contamination–City of McFarland

The City of McFarland in Kern County has a population of about 7,650 people. McFarland Mutual Water Company supplies municipal water. The company depends on groundwater for raw water supply and has four active wells.

Elevated levels of nitrates in MMWC's water were detected in the early 1960s. Many wells sampled showed nitrate levels exceeding the drinking water standard. Studies identified fertilizer application on agricultural lands as a major contributor to nitrates in the groundwater. MMWC abandoned two of its wells due to nitrate contamination and provided treatment for two wells to reduce nitrate levels to meet drinking water standards. Two deeper replacement wells were constructed to extract groundwater unaffected by nitrate or pesticide contamination.

In 1978, the MMWC received an EPA grant to study groundwater treatment alternatives, leading to the 1983 construction of a 1 mgd ion-exchange treatment plant. A second 1 mgd ion-exchange treatment plant for another well was constructed in 1983. The two wells supply about 20 af annually of treated water to McFarland and adjoining rural areas within the MMWC service area.

The plants' designs rely heavily on technology and practices used in the water softening industry. Plant location was dictated by the existing wells and distribution systems. Because there was no centralized distribution system, the plants had to be designed to operate from a single well. Well pumps operate on a demand basis, so the plants had to be able to operate automatically. The system was designed to accept water directly from the well, treat for nitrate removal, and allow treated water to flow directly into the distribution system. The ability of the process to adapt to quick start-up and frequent on-off operation was an important consideration in choosing it over reverse osmosis and biological treatment methods.

Remediation of Volatile Organics Contamination–McClellan Air Force Base

In 1981, McClellan AFB initiated soil and groundwater investigation as part of a Department of Defense program to identify and evaluate suspected contamination at military installations nationwide. Groundwater contaminants identified included VOCs, SVOCs, petroleum hydrocarbons, and trace heavy metals. Subsequent investigations revealed that contaminants had migrated off the base. At least one municipal well was abandoned because of contamination. In 1986 and 1987, 500 homes with private domestic wells to the west of the base were connected to the City of Sacramento's water system.

In 1987, groundwater extraction and on-site treatment began. The treatment involved an air stripper, with incineration and caustic scrubbing of the air stream, followed by carbon adsorption and biological treatment of the effluent. The treatment plant had a capacity of 1.44 mgd and discharged its treated water to Magpie Creek and to a wetland area under permits from the Central Valley RWQCB. Later, the biological treatment unit was removed when the concentration of ketones was low enough to be removed by the air stripper and carbon adsorption units.

In 1996, the air stripper and incinerator were replaced with a UV/ hydrogen peroxide system to remove volatile organics. The GAC is still in use. Operating and maintaining the new system is less expensive than the air-stripping and incinerating process, and the higher treatment efficiency reduces carbon use in the GAC units. Several more years of extraction and treatment of the groundwater will be required before the contaminated aquifer is restored to usable quality.

constructed in 1989 on Alameda Creek in the City of Fremont. The dam impounds a 154 af reservoir for direct groundwater recharge and diverts flows into adjacent spreading grounds in former aggregate pits. The air-inflated dam is bolted to a reinforced concrete slab that was constructed across the stream channel. To clear the leveed channel for flood flows, the dam is deflated by district personnel, or it automatically deflates slowly when overtopped by substantial flows. The dam is reinflated when stream flows subside to safe levels and any water-borne debris has passed the dam. These operations are much easier and safer than alternatives such as installing, tripping, and reinstalling hinged flashboards. A similar inflatable dam has been used in the Russian River at Mirabel since 1976, where water is diverted to percolation ponds.

The San Gabriel, Los Angeles, and Santa Ana River Basins also have similar devices. OCWD installed two large air inflatable rubber dams across the Santa Ana River (Imperial Highway Dam in 1992 and Five Coves

Remediation of Pesticide and Fertilizer Contamination–Occidental Chemical Manufacturing Facility

In the late 1970s, pesticide and fertilizer contamination was discovered in soil and groundwater at the Occidental Chemical Agricultural Products manufacturing facility near Lathrop. The primary contaminants found were dibromochloropropane, ethylene dibromide, and sulfolane. OxyChem removed or capped contaminated soil at the facility in 1981 and 1982. The groundwater remediation program began operation in 1982 and continues today. The original groundwater restoration system was designed to remove DBCP and EDB to 1 ppb. It consisted of five extraction wells, a 500 gpm treatment system, and two wells for deep injection of treated groundwater into an unusable confined aquifer. Sulfolane was not removed from the groundwater, but its injection to the aquifer was considered acceptable since the aquifer was designated unusable for domestic or agricultural purposes. SWRCB Resolution No. 88-63 in 1988, a 1989 revision of MCLs for DBCP and EDB, and a 1989 DHS maximum allowable level for sulfolane in municipal water resulted in more stringent treatment requirements. OxyChem made operational changes in the treatment system and added a biological treatment system in 1992 (microbial inoculation of the carbon treatment system) to remove sulfolane from the groundwater to comply with the new treatment standards of 0.2 ppb DBCP, 0.02 ppb EDB, and 57 ppb sulfolane. Two extraction wells were added, increasing treatment capacity to 600 gpm.

The groundwater restoration system was designed to treat the contaminated groundwater and to control the hydraulic gradient in order to prevent off-site migration of the contaminants. Several dozen monitoring wells were built to monitor the effectiveness of the system. Monitoring reports have shown reductions of contaminant concentrations and control of contaminant plume. However, it is anticipated that groundwater remediation will continue for many years.

Dam in 1993) to divert flows into groundwater recharge basins. The dams are deflated when flows exceed 1,000 cfs.

Other uses of inflatable dams have evolved. In 1988, PG&E replaced flashboards on its Pit No. 3 dam on the Pit River with 6-foot-high inflatable dams. USBR recently replaced two 18-foot-high by 100-foot-long drum gates on the crest of Friant Dam with Obermeyer gates. The gates are steel panels connected to the dam crest by hinges along their upstream edge, and are raised and lowered by air-inflated bladders. During the flood of January 1997, an inflatable rubberized berm was installed on the water side of the Sutter Bypass levee to provide the additional height needed to protect the levee from overtopping. Rubber berms of this type are used as cofferdams during construction projects in wet environments or as pollution containment devices.

Weather Modification

Since the early 1950s, California water users have practiced cloud seeding to augment precipitation, mostly along the western slopes of the Sierra Nevada and along the Coast Range. In 1996, there were 14 active cloud seeding programs operating in California. The goal of these programs is to increase water supply for hydroelectric power generation and for agricultural and municipal uses. Cloud seeding programs have potential legal and institutional issues associated with them, including claims from third parties who allege damages from flooding.

The principal elements of cloud seeding include selection of cloud masses, seeding materials, and methods to dispense the agents within the clouds. Several classes of seeding agents are available. Seeding agents are introduced into the clouds by either ground-based generators or aerial delivery systems.

Precipitation from clouds is a result of two different processes or mechanisms. The first is coalescence, whereby tiny cloud droplets collide to form larger droplets that eventually fall as rain. The coalescence process works at temperatures above freezing. The second mechanism requires ice particles and occurs at subfreezing temperatures. Many clouds contain supercooled water droplets, sometimes at temperatures far below freezing. Eventually the ice particles fall as snow (which will change to rain if the lower levels of the atmosphere are above freezing). Enhancing either of the two processes of precipitation formation can lead to more efficiency in producing rain or snow from a cloud. Some natural clouds appear to be deficient in ice forming nuclei; those clouds offer an opportunity to assist the rainmaking process.

Cloud Seeding Agents. Certain materials have

This inflatable dam is owned by Alameda County Water District.

been found effective in converting supercooled water droplets into ice crystals. Commonly used seeding agents for this purpose are silver iodide and dry ice. Some other chemicals also work, including some organic compounds. Hygroscopic materials such as salt, urea, and ammonium nitrate have been used in warmer clouds to assist the coalescence process.

Dry ice was frequently used in early cloud seeding programs in the United States in the 1950s and early 1960s. A switch to silver iodide occurred in the mid-1960s, probably because of more convenient storage and dispensing capabilities (dry ice applications are limited to airborne delivery systems). Dry ice has received increased attention in recent years due to its low cost and high effectiveness.

Silver iodide has been the preferred seeding agent in the majority of cloud seeding programs in the United States. Particles of silver iodide are usually produced through a combustion process followed by rapid quenching which forms trillions of effective freezing nuclei per gram of silver iodide consumed. Cloud seeding by silver iodide can be carried out using ground-based or aerial generators.

Liquid propane is a freezing agent much like dry ice. Liquid propane has the advantage of working at higher temperatures, up to a degree or two below freezing, whereas silver iodide is not very effective when temperatures are warmer than -5^0 C. Dispensing is limited to ground-based systems because it is a flammable substance. Liquid propane sprayed into the atmosphere chills the air to temperatures well below 0^0 C. As temperatures approach -40°C, water vapor in the air rapidly condenses into trillions of cloud droplets which immediately freeze and grow into tiny ice crystals. Propane is used operationally in clearing supercooled fog from airports in Alaska and the northern portion of the continental U.S.

Pseudomonas syringae, a bacterium thought to reduce frost damage in plants, has been shown to be an effective nucleating agent. Use of this bacterium as a seeding agent has been limited to producing snow in ski resorts, although there have been some experiments with aerial applications.

Cloud Seeding Delivery Systems. Commonly available aircraft can be modified to carry an assortment of cloud seeding devices. Silver iodide nuclei dispensers include pyrotechnic dispensers and models that burn a solution of silver iodide and acetone. In the burning process, a typical silver iodide-acetone solution is forced through the nozzle into a combustion chamber where it is ignited, and the silver iodide crystals formed through combustion are expelled into the atmosphere. Pyrotechnics are similar to ordinary highway flares. Pyrotechnic flares impregnated with silver iodide can be mounted on aircraft, burned, and dropped into the clouds. Dry ice is frequently dispensed through openings through the floor of aircraft modified for cloud seeding. Types of aircraft used in operational cloud seeding programs range from a single engine aircraft to larger twin engine aircraft.

The most common type of ground generator consists of a solution tank which holds the seeding agent. Other components include a means of pressurizing the solution chamber, dispensing nozzles, and a combustion chamber. Frequently, such systems employ a propane tank with a pressure reduction regulator to pressurize the solution tank, as well as to provide as a combustible material into which the silver iodide-acetone solution is sprayed. Other systems utilize nitrogen to pressurize the solution tank. Pyrotechnics are also used at surface sites. Ground generation systems have been developed which are operated manually or by remote control.

Effectiveness. Although precise evaluations of the amount of water produced are difficult and expensive to determine, estimates range from 2 to 15 percent increase in annual precipitation, depending on the number and type of storms seeded. In 1992, both the American Meteorological Society and the World Meteorological Organization issued policy statements cautiously supportive of the effectiveness of weather modification efforts under the proper circumstances.

Long-Term Weather Forecasting

California's experience with flood and drought cycles demonstrates that significant economic benefits would result from the development and application of successful long-term weather forecasting capabilities. With the ability to predict weather patterns in an accurate and timely manner, water resources managers could plan for and mitigate losses associated with floods and droughts.

During the 1980s, research on ocean and atmospheric interactions in the tropical Pacific Ocean produced new and significant insights into the predictability of the so-called El Niño Southern Oscillation cycle. New weather forecasting capabilities developed through research on ENSO suggest potential applications in addressing water resources management issues.

Climate researchers at Scripps Institution of Oceanography are engaged in several efforts to provide experimental climate forecasts up to twelve months in advance. One of these efforts is focused on the use of climate forecasts to improve California's use of its scarce water resources. Scripps is leading a team of University of California scientists to downscale global climate predictions to describe impacts on local water supplies. See Chapter 3 for a discussion on climate variability.

Environmental Water Use Technologies

Wetlands Management

Wetland plants have been found to remove selenium from water applied to them. University of California, Berkeley, researchers are experimenting in the Tulare Lake Drainage District with wetland plants irrigated with high-selenium drain water in flow-through cells. Careful management of such facilities to remove selenium while avoiding food chain concentrations may result in developing safe operating criteria for wetlands supplied with agricultural drainage water. This may provide another alternative for drainage water management. (Drainage water not used to support wetlands would still have to be disposed of by other means, such as evaporation ponds.)

Real-Time Water Quality Management

One of the actions identified in the 1995 SJRMP plan was establishing a real-time water quality monitoring network for the San Joaquin River, to support water management decisions. The monitoring network collects water quality and quantity data for input to a computer model that forecasts water flow and quality along the lower San Joaquin River.

A goal of the real-time monitoring network is to enable water managers to meet San Joaquin River water quality objectives more often and more efficiently. For example, information provided by the network can support decisions related to reservoir releases at New Melones.

A recently completed demonstration project added instrumentation sites, developed analytical tools to collect and process the data, and disseminated weekly forecasts of daily San Joaquin River flow and salinity at Vernalis. In 1997, CALFED approved Category III funding to implement a two year program to expand the monitoring network. The program is scheduled to begin in fall 1998.

Fish Screen Technologies

State of the Art. Fish screens on water supply diversions protect fish from potential entrainment losses. A properly designed fish screen, with appropriate sweeping velocities past the screen, allows diversions to occur (even when juvenile fish may be present) without causing unacceptable fish losses. Fishery and water interests have been working together for several years to improve existing screens and add them to older diversions that lack screens.

NMFS and DFG have mandates for the installation and operation of fish screens. If a new diversion is installed or significant changes are made to an existing intake, a new fish screen is usually required. DFG has established a prioritized list of diversions that should be screened based on potential fish losses. Protecting the most significant diversions first will help achieve fish protection goals with the available financial resources. Programs to financially assist diverters in the installation of such screens are available through the CVPIA's AFRP, CALFED's ecosystem restoration program, the Natural Resources Conservation Service, and provisions of Proposition 204.

Current fish screen technology reflects criteria established by NMFS and DFG. Physical screens, combined with low approach velocities and proper cleaning systems, can effectively protect fish greater than about 1 inch long. Conventional screens will not protect smaller or larval-sized fish which may be present at some sites for limited durations.

Smaller pumped diversions (slant or vertical pump installations on a river with flows less than 40 cfs) generally use bolt-on screens available from a variety of manufacturers. These screens are similar to those used to reduce debris in sprinkler irrigation systems. Depending on the site and the system, screens may be made of corrosion resistant woven wire, perforated plate, or wedge-wire material (well screen). These materials can be formed into cylindrical shapes or flat plate panels and designed into the intake system.

The number of sites with fish screens (or fish passage improvements) has increased with the availability of public funding assistance (Figure 5-1). For example, the Maxwell Irrigation District now operates a state-of-the-art positive barrier fish screen, one of the first of its kind installed on the Sacramento River. Completed in 1994, the new pumping plant and screen

In February 1998, two large cylindrical fish screens were installed at one of the largest Delta diversions on Sherman Island.

facility diverts approximately 80 cfs at a completed cost of nearly $1.6 million. The screens are intended to protect all fish, but primarily steelhead and winter-run chinook salmon. In 1994, Pelger Mutual Water Company completed construction of its new pumping station and positive barrier fish screen near Knights Landing on the Sacramento River. The facility includes pumps with a discharge capacity of 60 cfs and was completed for a total cost of $350,000.

Larger diversion sites are screened with low approach positive velocity barrier screens. These intake screens may include significant civil works and are often off the main river channels where they must provide fish handling and bypass systems. These facilities require more attention to hydraulic conditions than smaller intake screens.

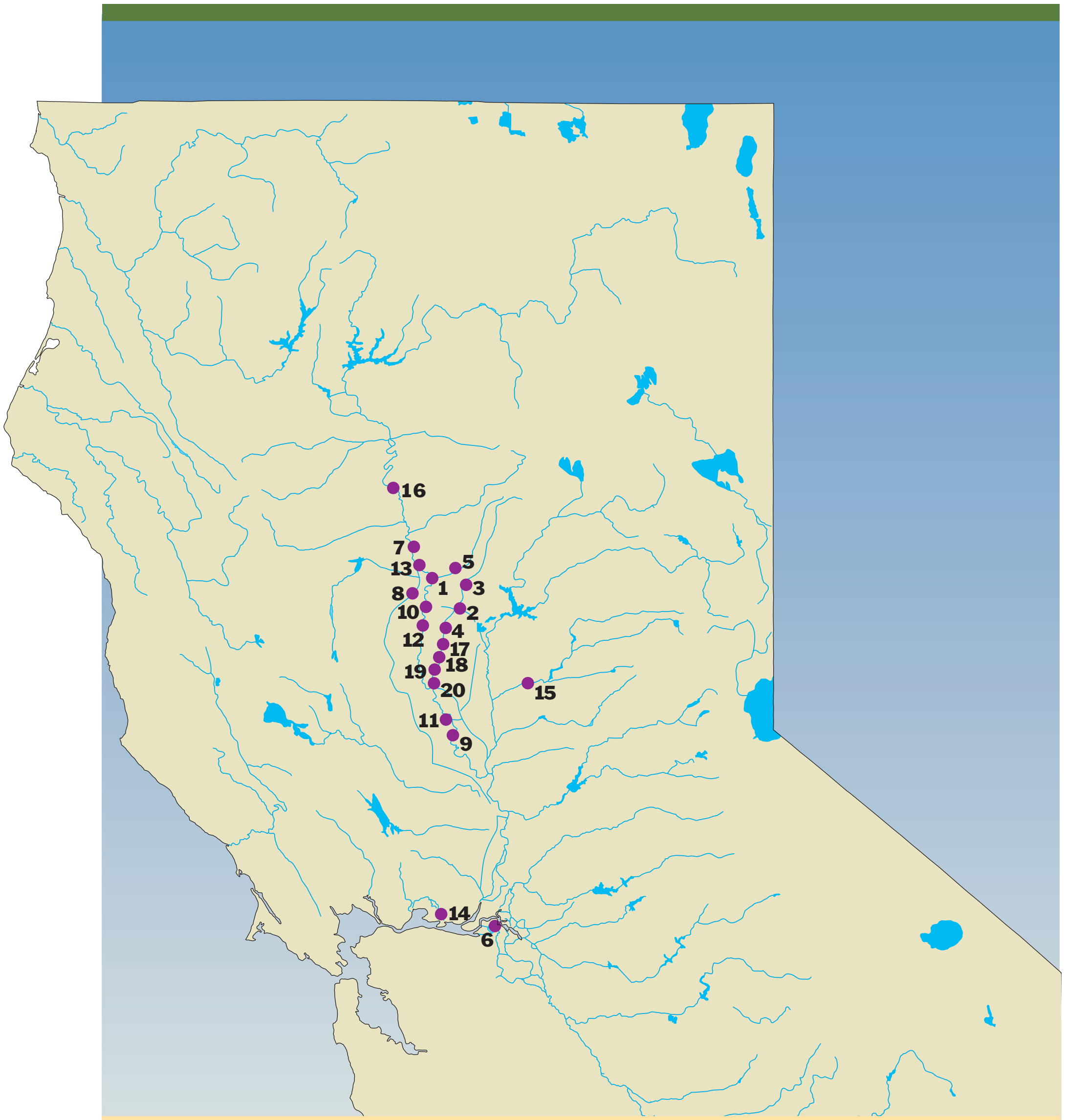
A newly constructed fish passage and screening facility on Butte Creek.

Several recently constructed facilities have been designed to current regulatory criteria for screening, including screens at the M&T Chico Ranch diversion on the Sacramento River, the Parrott-Phelan diversion on Butte Creek, and the Tehama-Colusa Canal. As part of its environmental restoration activities, M&T Chico Ranch relocated its screened pump station from the mouth of Big Chico Creek to the Sacramento River. This $5 million project provides water supply to over 8,000 acres of permanent wetlands and over 1,500 acres of seasonal wetlands, in addition to protecting habitat for migrating spring-run chinook salmon.

Several large facilities are nearing the final phases of design or construction. They include diversions on the Sacramento River at the Glenn-Colusa Irrigation District, Reclamation District 108 near Grimes, Reclamation District 1004 near Princeton, Princeton-Codora-Glenn Irrigation District and Provident Irrigation District consolidated diversion, Browns Valley Irrigation District diversion on the Yuba River, and others. Construction of GCID's Hamilton City Pumping Plant screen began in spring 1998. This $70 million project will minimize fish losses near the pumping plant and will maximize GCID's capability to divert its full irrigation supply. Reclamation District 108 began construction in 1997 on a new $10 million

FIGURE 5-1

Recent Structural Fishery Improvements



1 Sacramento River - M&T Chico Ranch, 1997
2 Butte Creek - Adams Dam, 1998
3 Butte Creek - Durham Mutual Dam, 1998
4 Butte Creek - Gorrill Dam, 1998
5 Butte Creek - Parrott - Phelan, 1996
6 Rock Slough - Contra Costa Canal, 1998
7 Sacramento River - Glenn-Colusa ID, 1998
8 Sacramento River - Maxwell ID, 1994
9 Sacramento River - Pelger MWC, 1994
10 Sacramento River - Princeton - Codora - Glenn ID/Provident ID, 1998
11 Sacramento River - RD 108, 1998
12 Sacramento River - RD 1004, 1998
13 Sacramento River - Wilson Ranch, 1995
14 Suisun Marsh - Five Projects, 1996-1997
15 Yuba River - Browns Valley ID, 1998
16 Tehama - Colusa Canal, 1990
17 Butte Creek - Western Canal WD Dams, 1998
18 Butte Creek - Point Four Diversion Dam, 1993
19 Butte Creek - McGowan Dam, 1998
20 Butte Creek - McPherrin Dam, 1998

fish screen. The project, located at the district's Wilkins Slough diversion, will protect migrating winter-run chinook salmon and other fish. The district anticipates completing the project by the 1999 irrigation season. Reclamation District 1004 began construction of its $8 million fish screen in 1998. The project includes relocation of the Princeton Pumping Plant and conveyance facilities, in addition to a positive barrier fish screen. In 1998, the Princeton-Codora-Glenn and Provident irrigation districts are expected to complete construction of an $11 million fish screen and pump consolidation project. The 600 cfs project eliminates three unscreened diversions.

Current Research. There is significant research and experience in fish screen technology. The technology has responded to a number of factors including ESA requirements in the Northwest and in California for the protection of salmonids, FERC relicensing requirements, and the heightened awareness of fish losses at diversions.

Research can be broken down into two categories: positive barrier technologies and behavioral barrier technologies. Although physical screens are considered state of the art, and are acceptable to the resource agencies, behavioral barriers have been demonstrated to deter fish from being diverted at some sites and may offer enhanced fish protection at even physically screened sites.

This circular flume, called the fish treadmill, simulates the hydraulic conditions that fish may encounter in the Delta. DWR's three year treadmill study began in 1997.

Several significant applied research projects are under way on positive barrier technologies. A research pumping plant has been constructed at the USBR's Red Bluff Diversion Dam to divert Sacramento River water into the Tehama-Colusa Canal. This facility (see photo, Chapter 2) was developed to provide water to the Tehama-Colusa Canal when the diversion dam gates are raised for fish passage. The research pumping plant is testing centrifugal and Archimedes screw pump technologies to evaluate their impacts on fish. The research plant and the biological evaluations of its effectiveness now being carried out are providing valuable data on the potential application of these technologies to other sites.

Since the early 1950s, fish screen design criteria have been developed for juvenile salmon and a few other anadromous species. Little is known about the screening requirements for resident Bay-Delta species (such as smelt) which require protection. Through a cooperative interagency program effort, a large circular screened testing flume has been constructed at University of California at Davis to investigate fish performance and behaviors under various hydraulic conditions. This research will improve understanding of the needs of fish and help design more effective screens.

Screen cleaning and proper operation and maintenance are essential for the reliability of diversion and fish protection. In the last 10 years, cleaning technologies have advanced in response to possible zebra mussel invasions and clogging from aquatic weeds. Combinations of hydraulic and air backwash systems, improved horizontal and vertical brush cleaners, and automated controls have proven effective. Screen materials and coatings have also been developed to prevent biofouling. Some investigations under way include USBR's Tracy Pumping Plant Fish Facility Improvement Program, Contra Costa Water District's new Los Vaqueros and proposed Rock Slough fish screens, and an investigation of air cleaning systems by USBR.

Higher velocity fish screens, which reduce exposure to the screen surface, are being studied. These systems are potentially less expensive because of the reduced screen area required. Modular systems are being developed for wider application. Advances in

Behavioral Barrier Demonstration Projects

Several behavioral barrier demonstration projects have been evaluated in the Central Valley.

Georgiana Slough Acoustic Barrier

Juvenile salmon survival has been shown to improve significantly if salmon are allowed to remain in the Sacramento River rather than being drawn into the central Delta via Georgiana Slough. Physical barriers and screens have been considered at this site, but are not feasible because of hydraulic conditions, water quality, recreational uses, and adult fish migration issues. A behavioral system is being studied which would improve fish survival by guiding them away from the hydraulic influence of Georgiana Slough. Twenty-one underwater acoustic speakers were installed at the Sacramento River's junction with the Slough below the town of Walnut Grove. Studies in 1993, 1994, and 1996 showed improved guidance during low flows, but mixed results at higher flow conditions. Results have been encouraging enough to continue investigations at this site under low flow conditions. Adverse effects of acoustic system operation have not been observed.

Reclamation District 108 Acoustic and Electrical Barrier

At this major Sacramento River diversion (700 cfs diversion capacity) near Grimes, acoustic and electrical barriers were tested to see if these technologies could reduce fish losses. Tests were conducted at the site from 1993 until 1996 with mixed results. The acoustic system was suspended from the surface and operated on an on/off cycle to test its effectiveness. The electrical array was mounted to an underwater louver array and was similarly evaluated. Since neither system achieved the required reduction in fish entrainment, RD 108 is constructing a positive barrier fish screen.

Reclamation District 1004 Acoustic Barrier

A similar acoustic barrier was installed at RD 1004's diversion on the Sacramento River near the town of Princeton. From 1994 to 1995, the system was evaluated and found to have marginal benefits. RD 1004 is installing a 360 cfs positive barrier fish screen at its diversion site.

Behavioral Research at Other Sites

The use of low frequency "infrasound" systems and the use of lighting systems (strobe lights) is under investigation at several sites outside of California. Many of these systems are being tested and used with other screening technologies to attempt to improve their effectiveness in difficult hydraulic environments.

automation and control systems are being used to regulate screens' hydraulics and operations and provide better fish protection and diversion reliability.

Technological advances have renewed interest in acoustic and electrical fish guidance systems. In the past, these systems have had limited success affecting fish behavior. Some guidance and protection had been observed, but the systems could not achieve the level of protection desired by State and federal resource agencies. Fish responses to behavioral technologies are variable since they may respond to other environmental stimuli, including hydraulic conditions, temperature, predator avoidance, and lighting conditions. Behavioral barriers are attractive in some cases because physical barriers may not be viable or cost-effective.

Temperature Control Technology

Temperature control technology is used to manage temperature of reservoir releases to improve conditions for downstream fisheries. During summer months, reservoir temperature gradients result in warmer water near the surface of a reservoir, with cooler water remaining near the bottom. Two types of temperature control devices are currently being used in Northern California reservoirs: variable-level outlets that permit temperature selective releases, such as USBR's Shasta Dam TCD; and temperature control curtains, such as those at Whiskeytown and Lewiston Reservoirs.

Temperature Control Devices. Some dams, such as the Department's Oroville Dam, were constructed with temperature-selective reservoir release capability. Retrofits to reservoir outlets can be constructed for those that were not, such as USBR's Shasta Dam. USBR completed the Shasta Dam TCD in May 1997, and is now fixing leakage problems that affect operation of the device. The structural steel shutter device is 250 feet wide by 300 feet high and encloses all five penstock intakes on the dam. The shutters allow for selective withdrawal of water, depending on downstream temperature needs. Prior to installation of the structure, USBR had to bypass Shasta powerplant to provide water of adequate temperature. Installation of the TCD will provide USBR with the flexibility to provide optimal water temperature downstream for the salmon fishery, and allow for hydropower generation.

Temperature Control Curtains. Curtains can control water withdrawal at intake or outlet structures to provide desired temperatures for salmonids and other aquatic species, allowing water to be conserved for other uses. Four temperature control curtains have been installed by USBR, two in Lewiston Reservoir (in 1992), and two in Whiskeytown Reservoir (in 1993). These curtains are constructed of Hypalon, a rubberized nylon fabric. They are supported in the water column by steel tank floats and anchored to stay in place.

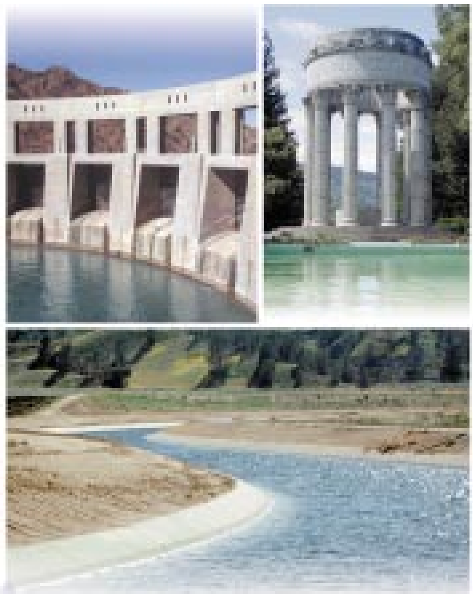
At Lewiston Reservoir, an 830-foot-long, 35-foot deep curtain is suspended from flotation tanks and secured by a cable and anchor system. This curtain was designed to block warm surface water from the Clear Creek Tunnel intake. As a result, cold water from the bottom of the reservoir is diverted to Whiskeytown Reservoir. A second curtain was installed around the Lewiston Fish Hatchery intake structure to allow warmer or colder water, depending on the season, to be taken into the hatchery. The curtain, 300 feet long by 45 feet deep, was designed to either skim warmer water or underdraw cooler water, depending on whether the curtain was in a sunken or floating position.

Ideally, cold water diverted from Lewiston should be routed through Whiskeytown's hypolimnion (deep, cold water layer) into the Spring Creek Conduit intake. To accomplish this, two curtains were installed: a tailrace curtain downstream at Carr Powerplant, and an intake curtain surrounding the Spring Creek Conduit intake. The tailrace curtain (600 feet long and 40 feet deep) was installed to force cold water from Carr Powerplant into Whiskeytown's hypolimnion with a limited amount of mixing with the epilimnion (warm surface water). This curtain restrains warm surface water from moving upstream toward Carr Powerplant. With the tailrace curtain in place, mixing is reduced where the density current plunges into the hypolimnion upstream of the tailrace curtain. The second curtain (a 2,400-foot long, 100-foot deep, surface-suspended curtain) surrounds the Spring Creek Conduit intake. This curtain, like the Lewiston curtain, was designed to retain warm surface water while allowing only cold water withdrawal.

The temperature curtains at Lewiston and Whiskeytown Reservoirs reduce the temperature of Trinity River diversions to the Sacramento River by as much as 5^0 F. According to USBR, this decrease is significant, making the temperature curtains a successful tool for conserving reservoir releases.

The smaller temperature control curtains generally cost about $1,000 per foot. The large curtain at Whiskeytown Reservoir cost about $1.8 million. The expected duration of use is about 10 years before replacement may be required. To date, none of the four curtains in place at these two reservoirs has needed major repairs.

A number of studies are ongoing to better refine the curtains' use for temperature control, and to ensure that no adverse impacts result to biological resources in the reservoirs where they are installed.



CALIFORNIA WATER PLAN UPDATE BULLETIN 160-98

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6

Evaluating Options From a Statewide Perspective

A main objective of this *California Water Plan* update is evaluating, at an appraisal level of detail, how California's water supply reliability needs could be met through 2020. This chapter outlines the process used to put together the conceptual evaluation and evaluates water management options that are statewide in scope. A brief discussion of methods available to local agencies for financing water management options is also provided.

The planning process includes developing regional water management evaluations for each of the State's ten major hydrologic regions, and integrating those results with statewide water management options to form a summary for the entire State. Development of regional water management evaluations is covered in Chapters 7-9.

Statewide water management options include demand reduction measures that many water agencies are expected to implement, and large-scale water supply augmentation measures that would provide supply to multiple beneficiaries in more than one hydrologic region. For example, a large offstream storage reservoir studied under CALFED's Bay-Delta program is considered a statewide option. A small reservoir project being studied by a local agency to provide benefits only to its service area is not a statewide option. Such local projects are covered in Chapters 7-9. This chapter opens by presenting a balance between California's water supplies and its water use, illustrating the shortages that would occur if no new water management facilities or programs were developed.

Sources of water supply must be identified to meet the needs of California's growing population. Chapters 6-9 discuss potential future water management options.

TABLE 6-1

California Water Budget with Existing Facilities and Programs (maf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	8.8	9.0	12.0	12.4
Agricultural	33.8	34.5	31.5	32.3
Environmental	36.9	21.2	37.0	21.3
Total	**79.5**	**64.7**	**80.5**	**66.0**
Supplies				
Surface Water	65.1	43.5	65.0	43.4
Groundwater	12.5	15.8	12.7	16.0
Recycled & Desalted	0.3	0.3	0.4	0.4
Total	**77.9**	**59.6**	**78.1**	**59.8**
Shortage	**1.6**	**5.1**	**2.4**	**6.2**

. . .

Statewide Water Budget

The water supply and water use information discussed in Chapters 3 and 4 and summarized in Tables 3-3, 4-26, and 4-27 is combined into the statewide applied water budget with existing facilities and programs shown in Table 6-1. Regional water budgets with existing facilities and programs are shown in Appendix 6A. The shortages shown in Table 6-1 reflect the Bulletin's assumption that groundwater overdraft is not available as a supply.

The average water year shortages at 1995 and 2020 levels illustrate the need to develop new facilities and programs to improve California's water supply reliability. Californians are facing water shortages now, and will face them in the future. As Californians experienced in 1991 and 1992, drought year shortages are large. Urban water users faced cutbacks in supply and mandatory rationing, some small rural communities saw their wells go dry, agricultural lands were fallowed, and environmental water supplies were reduced. By 2020, without additional facilities and programs, these conditions will worsen, reflecting California's forecasted population increase. Appendix 6B shows forecasted shortages by hydrologic region, assuming that no new facilities or programs were implemented.

The following section describes the planning process used in Bulletin 160-98 to evaluate actions that would reduce the State's future water shortages.

. . .

The Bulletin 160-98 Planning Process

The process used to evaluate ways to meet California's future water needs drew upon, at an appraisal level of detail, techniques of integrated resources planning. IRP evaluates water management options—both demand reduction options and supply augmentation options—against a fixed set of criteria and ranks the options based on costs and other factors. Although the IRP process includes economic evaluations, it also incorporates environmental, institutional, and social considerations which cannot be expressed easily in monetary terms.

The development of likely regional water management options used information prepared by local agencies. The regional water management options evaluations are not intended to replace local planning efforts, but to complement them, by showing the relationships among regional water supplies and water needs and the statewide perspective. Local water management options form the basis of the regional summaries which are combined into the statewide options evaluation. Figure 6-1 is an index map showing how the regional summaries are organized in Chapters 7-9.

FIGURE 6-1

Index to Regional Chapters

Initial Screening Criteria

The criteria used for initial screening of water management options were:

- ***Engineering***—an option was deferred from further evaluation if it was heavily dependent on the development of technologies not currently in use, it used inappropriate technologies given the regional characteristics (desalting in the North Lahontan Region), or it did not provide new water (water recycling in the Central Valley).
- ***Economic***—an option was deferred from further evaluation if its cost estimates (including environmental mitigation costs) were extraordinarily high given the region's characteristics.
- ***Environmental***—an option was deferred from further evaluation if it had potentially significant unmitigable environmental impacts or involved use of waterways designated as wild and scenic.
- ***Institutional/Legal***—an option was deferred from further evaluation if it had potentially unresolvable water rights conflicts or conflicts with existing statutes.
- ***Social/Third Party***—an option was deferred from further evaluation if it had extraordinary socioeconomic impacts, either in the water source or water use areas.
- ***Health***—an option was deferred from further evaluation if it would violate current health regulations or would pose significant health threats.

Major Steps in Planning Process

Major steps involved in the Bulletin 160-98 water management options evaluation process included:

- Identify water demands and existing water supplies on a regional basis.
- Compile lists of regional and statewide water management options.
- Use initial evaluation criteria to either retain or defer options from further evaluation. For options retained for further evaluation, group some by categories and evaluate others individually.
- Identify characteristics of options or option categories, including costs, potential demand reduction or supply augmentation, environmental considerations, and significant institutional issues.
- Evaluate each regional option or category of options in light of identified regional characteristics using criteria established for this Bulletin. If local agencies have performed their own evaluation, review and compare their evaluation criteria with those used for the Bulletin.
- Evaluate statewide water management options.
- Develop tabulation of likely regional water management options.
- Develop a statewide options evaluation by integrating the regional results.

The first step in evaluating regional water management options was to prepare applied water budgets for the study areas to identify the magnitude of potential water shortages for average and drought year conditions. In addition to identifying shortages, other water supply reliability issues in the region were reviewed. Once the shortages were identified, a list of local water management options was prepared. Where possible, basic characteristics of these options (yields, costs, significant environmental or institutional concerns) were identified.

After identifying options, they were compared with the initial screening criteria shown in the sidebar. For options deferred from further evaluation, the major reasons for deferral were given. Options retained for further evaluation were placed into the following categories:

- Conservation (urban and agricultural)
- Modifications to existing reservoirs/operations
- New reservoirs/conveyance facilities
- Groundwater/conjunctive use
- Water marketing
- Water recycling
- Desalting (brackish groundwater and seawater)
- Other local options
- Statewide options

Because each of these categories may contain many individual options, some options within each category were further combined into groups based upon their estimated costs. For example, water recycling projects costing less than $500/af were grouped into one category. Options were evaluated and scored against the set of fixed criteria shown in the sidebar.

The Bulletin 160-98 options evaluation process relied heavily upon locally developed information. Methods used to develop this information vary from one local agency to the next, making direct comparisons between cost estimates difficult. To make cost information comparable, a common approach for estimating unit cost was developed (Appendix 6C). However, due to lack of detailed information, not all

Options Category Evaluation

Evaluation Criteria	*What is Measured?*	*How is it Measured?*	*Score*
Engineering	Engineering feasibility	Increase score for greater reliance upon current technologies	
	Operational flexibility	Increase score for operational flexibility with existing facilities and/or other options	
	Drought year supply	Increase score for greater drought year yield/ reliability	
	Implementation date	Increase score for earlier implementation date	
	Water quality limitations	Increase score for fewer water quality constraints	
Engineering Score			**0 - 4**
Economics	Project financial feasibility	Increase score for lower overall costs and the ability to finance	
	Project unit cost	Increase score for lower overall unit cost (including mitigation costs)	
Economics Score			**0 - 4**
Environmental	Environmental risk	Increase score for least amount of environmental risk	
	Irreversible commitment of resources	Increase score for least amount of irreversible commitment of resources	
	Collective impacts	Increase score for least amount of collective impacts	
	Proximity to environmentally sensitive resources	Increase score for little or no proximity to sensitive resources	
Environmental Score			**0 - 4**
Institutional/Legal	Permitting requirements	Increase score for least amount of permitting requirements	
	Adverse institutional/legal effects upon water source areas	Increase score for least amount of adverse institutional/legal effects	
	Adverse institutional/legal effects upon water use areas	Increase score for least amount of adverse institutional/legal effects	
	Stakeholder consensus	Increase score for greater amount of stakeholder consensus	
Institutional/Legal Score			**0 - 4**
Social/Third Party	Adverse third party effects upon water source areas	Increase score for least amount of adverse third party effects	
	Adverse third party effects upon water use areas	Increase score for least amount of adverse third party effects	
	Adverse social and community effects	Increase score for least amount of adverse social and community effects	
Social/Third Party Score			**0 - 4**
Other Benefits	Ability to provide benefits in addition to water supply	Increase score for environmental benefits	
		Increase score for flood control benefits	
		Increase score for recreation benefits	
		Increase score for energy benefits	
		Increase score for additional benefits	
		Increase score for improved compliance with health and safety regulations	
Other Benefits Score			**0 - 4**
Total Score			**0 - 24**

option costs could be made comparable. Unit cost estimates took into account capital costs associated with construction and implementation (including any needed conveyance facilities), annual operations costs, and option yield.

Water management options can serve purposes other than water supply; they can also provide flood control, hydroelectric power generation, environmental enhancement, water quality enhancement, and recreation. In recognition of the multipurpose benefits provided by some water management options, the options evaluation scoring process assigned a higher value to multipurpose options, as shown in the sidebar. However, since the focus of the Bulletin 160 series is water supply, cost estimates were based solely on the costs associated with water supply.

Once options were evaluated and scored, they were ranked according to their scores. This ranking was used to prepare a tabulation of likely regional water management options, taking into account options that may be mutually exclusive or could be optimized if implemented in conjunction with other options. Depending on a region's characteristics, its potential options, and its ability to pay for new options, the tabulation of likely options may not meet all of a region's water shortages (especially in drought years).

This appraisal-level evaluation of options at a statewide level of detail is based on presently available information. The ultimate implementability of any water management option is dependent on factors such as the sponsoring entity's ability to complete the appropriate environmental documentation, obtain the necessary permits, and finance the proposed action.

Shortage Management

Water agencies may choose to accept less than 100 percent water supply reliability, especially under drought conditions, depending on the characteristics of their service areas. Shortage contingency measures such as restrictions on residential outdoor watering or deficit irrigation for agricultural crops can be used to meet temporary shortages. Demand hardening is an important consideration in evaluating shortage contingency measures. Implementing water conservation measures such as plumbing retrofits and low water use landscaping reduces the ability of water users to achieve future drought year water savings through shortage contingency measures.

Supply augmentation actions (purchasing water from the DWB) and demand reduction actions (urban rationing and agricultural land fallowing) are available to water agencies for coping with shortages that exceed planned levels of reliability. Table 6-2 summarizes actions taken by some of California's larger urban water suppliers to respond to water shortages in 1991, the driest year of the recent 1987-92 drought. Measures taken by agricultural water agencies and water users included increased pumping of groundwater, land fallowing, and intra- and interdistrict water transfers. The WaterLink system established by Westlands Water District (described in Chapter 8) is an example of an action that could be used by agricultural water suppliers to facilitate intradistrict water transfers as part of managing shortages.

The impacts of allowing planned shortages to occur in water agency service areas are necessarily site-specific and must be evaluated by each agency on an individual basis. In urban areas where conservation measures have already been put into place to reduce landscape water use, imposing rationing or other restrictions on landscape water use can create significant impacts to homeowners, landscaping businesses, and entities that manage large turf areas such as parks and golf courses. Drought year cutbacks in the agricultural sector create economic impacts not only to individual growers and their employees, but also to local businesses that provide goods and services to the growers.

Using Applied Water Budgets to Calculate New Water Needs

As discussed in Chapter 3, some municipal wastewater discharges, agricultural return flows, and required environmental instream flows are reapplied several times before finally being depleted from the State's hydrologic system. An applied water budget explicitly accounts for this unplanned reuse of water. Because reapplication has the potential to account for a substantial portion of a region's water supply, applied water budgets may overstate the supply of water actually needed to meet future water demands. Shortages calculated from an applied water budget must be interpreted with caution to determine new water needs for a region.

The amount of new water required to meet a region's future needs depends on several factors, including the region's applied water shortage, opportunities to reapply water in the region, and the types of water management options that are implemented

TABLE 6-2

1991 Urban Water Shortage Management

Water Agency[a]	*Reduction Goal*[b]	*Contingency Measures* A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*
Alameda County WD	18%		✔		✔		✔	✔	✔			✔
Contra Costa WD	26%	✔		✔	✔		✔	✔	✔		✔	✔
East Bay MUD	15%	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	
LA Dept. of Water and Power	15%	✔	✔		✔	✔	✔	✔	✔	✔	✔	✔
MWD of Southern California	31%	✔	✔	✔	✔	✔		✔			✔	✔
MWD of Orange County	20%		✔	✔	✔	✔	✔	✔	✔	✔		✔
Orange County WD	20%			✔		✔		✔	✔			✔
San Diego Co. Water Authority	20%	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
City of San Diego	20%			✔			✔	✔	✔	✔		✔
San Francisco PUC	25%	✔	✔		✔		✔	✔	✔		✔	✔
Santa Clara Valley WD	25%	✔	✔		✔			✔	✔	✔	✔	✔

A = Rationing
B = Mandatory Conservation
C = Extraordinary Voluntary Conservation
D = Increasing Rate or Surcharges
E = Economic Incentives
F = Device Distribution
G = Broadcast Public Information
H = Mailed Public Information
I = Water Patrols and Citations
J = Fines and Penalties
K = Water Transfer

[a] Agencies listed include both wholesale and retail water agencies and, as a result, the shortage contingency measures available to them are different.

[b] The actual performance of an agency's drought management may have exceeded the adopted goal. Several of the retail agencies are located within wholesalers' boundaries. Contingency measures shown can include both retail and wholesale measures.

in the region. If no water reapplication opportunities exist, then the region's new water need is equivalent to its applied water shortage. In this case, the new water need would be independent of the types of water management options that are implemented. However, if opportunities are available to reapply water in a region, then the region's new water need is less than its applied water shortage. In this case, the new water need depends on the types of water management options that are implemented.

Not all water management options are created equal in their ability to meet new water needs. Because supply augmentation options provide new water to a region, the opportunity exists for the options' effectiveness to be multiplied through reapplication. For example, a supply augmentation option may provide 100 taf of new water to a region. But through reapplication within the region, the option effectively meets applied water demands in excess of 100 taf. Demand reduction options, on the other hand, do not provide new water to a region. Hence, the opportunity does not exist to multiply the options' effectiveness through reapplication. To satisfy an applied water shortage of 100 taf, a demand reduction option must conserve 100 taf of water.

Calculation of regional and statewide new water needs is more complex than computing regional and statewide applied water shortages—new water needs also depend on reapplication and implemented water management options. An applied water shortage provides an upper bound on the new water need. A lower bound on the new water need can be estimated for each region by assuming that new water supplies are reapplied in the same proportion that existing supplies are reapplied. Minimum new water needs are computed for each region in Appendix 6D.

The tabulations of likely regional water management options in Chapters 7-9 use minimum new water needs as target values for selecting the appropriate number of regional options. If a region is unable to meet minimum new water needs as a result of regional characteristics, lack of potential options, or inability to pay for potential options, specifying minimum new water needs rather than applied water shortages as regional target values has no impact on options selection. On the other hand, if a region is able to meet its minimum new water needs, this does not necessarily guarantee that all applied water shortages would be met. The remaining applied water shortages would depend on the selected option mix—the more water conservation selected, the greater the remaining applied water shortages would be (as water conservation options do not provide reapplication opportunities.) This approach is consistent with the treatment of shortages in prior water plan updates, which used net water budgets. Because data in net water budgets factor out reapplied water, net water shortages are essentially the same as minimum new water needs. Appendix 6E provides a compilation of Bulletin 160-98 net water budgets, statewide and by region.

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Demand Reduction Options

Demand reduction has taken on a key role in the planning and management of water resources. By making wise use of water through water conservation, the need for new sources of supply can be minimized. Many agencies have implemented programs to achieve a high level of water use efficiency.

For nearly three decades, Californians have recognized the importance of water conservation. Since the 1976-77 drought, attention has focused on plans, programs, and measures to encourage efficient use of water. The water conservation options evaluated in this Bulletin are limited to actions that would have the effect of creating new water supply through reductions in existing consumptive use or water depletions. (The potential for depletion reductions exists where applied water would be lost to evapotranspiration, or to a saline water body, and could not be beneficially reapplied.) The options evaluated in this Bulletin would yield depletion reductions above the 2020-level demand reduction of 2.3 maf assumed to result from statewide implementation of existing BMPs and EWMPs. (Existing BMPs and EWMPs are discussed in Chapter 4.) Quantifying depletion reductions allows the comparison of water conservation options with water supply augmentation options such as water storage or recycling facilities.

The options presented are for planning purposes only and are not mandated targets. They represent an attempt to quantify potential water savings that may be achieved by implementing measures beyond current BMPs and EWMPs. Local water agencies can evaluate these options against other available options to assess appropriate actions for their service areas.

Since the purpose of the Department's Bulletin 160 series is to assess water supply benefits, it is that aspect of water conservation that the Bulletin addresses. Water conservation projects may provide additional benefits, such as reduction in water treatment costs, reduction in fish entrainment at water supply diversion structures, or reduction in nonpoint source runoff. These other benefits are recognized in the Bulletin's options evaluation process, as described earlier. As discussed in Chapter 3, the Bulletin treats demand reduction actions on an equal footing with water supply actions. Each action must create water that is new to the State's hydrologic region.

Data on Urban Landscaping

As plumbing code changes designed to reduce interior urban water use are implemented, a main potential for future urban water conservation lies in reducing exterior urban water use—specifically landscape water use. Estimating water use reductions from landscape irrigation changes is made difficult by the lack of data on irrigated urban landscaping. Only a handful of water districts in California have actual data on the extent of irrigated acreage (residential lots plus large turf areas, such as parks, cemeteries, and golf courses) in their service areas, and data are nonexistent at a statewide level. For planning purposes, California's irrigated urban acreage has historically been estimated at about one million acres at a 1980s/1990s level of development, based on estimated ratios of landscape acreage to total urban acreage from land use surveys. Such ratios vary widely by county (the Department's, for example, vary from percentages in the low teens to almost 40 percent), and are inherently subject to uncertainty. Water agencies are beginning to evaluate ways to quantify existing irrigated urban acreage—aerial photography or satellite imagery, estimated ratios from parcel maps, surveys, or questionnaires. Estimates of future irrigated landscape acreage are generally made by increasing an assumed base acreage by ratios of forecasted population growth—which implicitly assumes no major changes in housing density or single to multifamily housing ratios.

These uncertainties illustrate the present difficulty of quantifying landscape conservation savings, and lack of hard data to support planning estimates. Better estimates of urban landscape acreage would greatly improve future conservation planning.

TABLE 6-3

Urban Depletion Reduction Potential Due to Water Conservation Options Beyond BMPs[a] (taf)

Region	Opt 1	Opt 2	Opt 3	Opt 4	Opt 5	Opt 6	Opt 7	Opt 8
	New	New & Existing	60 gpcd	55 gpcd	3%	5%	7%	5%
	$0.8\ ET_0$ Outdoor Water Use		Indoor Water Use		CII Water Use Reduction		Distribution System Losses	
North Coast	1	6	3	6	1	2	6	9
San Francisco Bay	2	52	38	77	11	18	D	13
Central Coast	4	13	8	17	2	3	3	8
South Coast	67	246	110	220	30	49	D	84
Sacramento River	D	D	D	D	D	D	D	D
San Joaquin River	D	D	D	D	D	D	D	D
Tulare Lake	D	D	D	D	D	D	D	D
North Lahontan	D	1	D	1	D	D	D	D
South Lahontan	20	31	7	15	2	4	4	12
Colorado River	9	18	2	3	1	2	9	13
Total (rounded)	**100**	**370**	**170**	**340**	**50**	**80**	**20**	**140**

[a] In some regions, these levels of conservation are already being achieved. Urban water conservation options beyond BMPs would not result in significant, cost-effective additional reductions in depletion in interior regions and are deferred (D). Only depletion reductions greater than 1 taf are considered in this table.

Although water conservation options will be carried out at the local level, they are discussed in this chapter conceptually as statewide demand reduction options for simplicity of presentation. Analyses of water conservation options for each hydrologic region are discussed in Chapters 7-9.

Urban Water Conservation Options

As discussed in Chapter 4, urban water use forecasts were calculated from estimates of population, urban per capita water use, and conservation savings from urban BMPs. The Bulletin assumes that urban BMPs are put into effect by 2020, resulting in an estimated 1.5 maf of demand reduction statewide.

The urban water conservation options described below assume a more intensive application of current BMPs and potential evolution of additional BMPs. If all of the options described below were implemented, nearly 1 maf/yr of depletion reduction could theoretically be attained. The level of water conserved from these options would vary for each region depending on current urban water use and the region's hydrology. Since little or no depletion reductions would be achieved in the Central Valley, urban water conservation options beyond BMPs are deferred for valley regions. Table 6-3 summarizes statewide urban water conservation options and the potential depletion reductions associated with each option. These options are evaluated for each region in Chapters 7-9.

Outdoor Water Use

Ideally, landscape water use could be derived by the method used for estimating agricultural water use—multiplying water use requirements for different landscape types by their corresponding statewide acre-

Courtesy of Barbara Cross

The greatest potential reductions in urban water use would come from reducing outdoor water use for landscaping. Data for accurately quantifying present acreage of urban landscaping (or for forecasting future acreage) are virtually non-existent today.

age, and summing the results to obtain a total for irrigated landscapes in the State. As discussed in the sidebar, no firm numbers are available for statewide irrigated urban landscape acreage. For this Bulletin, based on water budget data and projected increases in population, landscape water use in California is estimated to increase from about 2.4 maf in 1995 to 3.6 maf in 2020.

The Department estimates that landscape in California will be irrigated on average at 1.0 ET_0 by 2020. Options to reduce outdoor water use assume that statewide landscape irrigation could be reduced on average to 0.8 ET_0 either in new development, or in all development. These reductions would be realized through landscape water audits and incentive programs by retailers. So that the cost of implementing these options can be equitably compared with other supply augmentation options, the economic evaluations in Chapters 7–9 assume that implementation costs are funded by water purveyors and not by homeowners. This assumption implies that water purveyors could choose to carry out landscape water management programs in much the same manner as some urban purveyors have implemented ultra low flush toilet retrofit programs.

Option 1: Outdoor Water Use in New Development to 0.8 ET_0. The Model Landscape Ordinance indicates that a landscape plant factor of 0.8 ET_0 could be attainable through measures such as proper landscape and irrigation system design, more intensive landscape water audit programs, installing automatic rain sensors, better irrigation scheduling, and incentive programs tied to an ET-based billing structure. Statewide, about 100 taf/yr of depletion reductions could be achieved by reducing outdoor water use to 0.8 ET_0 at a cost of about $750/af. The ordinance is directly applicable to new construction; existing landscaping would require retrofitting.

Option 2: Outdoor Water Use in New and Existing Development to 0.8 ET_0. This option extends the provisions of Option 1 to include existing development. Statewide, about 370 taf/yr of depletion reduction could be achieved by reducing outdoor water use in new and existing development to 0.8 ET_0. The cost of this option is difficult to quantify and is greatly affected by site-specific factors. It is expected to be high due to the cost involved in retrofitting existing landscape.

Residential Indoor Water Use

Options to reduce indoor residential water use assume that by 2020, indoor water use in the State would average 65 gallons per capita daily. Options 3 and 4 would reduce this average to 60 gpcd and 55 gpcd, respectively. These reduced levels of indoor water use could be achieved statewide if strong incentive programs, such as financial incentives for retrofits, were provided. More aggressive indoor water audits would be needed. Conversion to horizontal axis washing machines is assumed to occur in 25 percent of all residences under Option 3 and 75 percent under Option 4.

Option 3: Reduce Residential Indoor Water Use to 60 gpcd. This option is based on the potential for a 3 gpcd reduction in leaks, a 1 gpcd reduction in shower usage, and a 1 gpcd reduction in laundry use. These savings result in an 8 percent reduction of applied water beyond current BMPs at the retail level. This option could achieve about 170 taf/yr in depletion reductions at a cost of about $400/af.

Option 4: Reduce Residential Indoor Water Use to 55 gpcd. This option is based on the potential for a 5 gpcd reduction in leaks, a 2 gpcd reduction in shower usage, and a 3 gpcd reduction in laundry use. These savings result in a 15 percent reduction of applied water beyond current BMPs at the retail level. This option could achieve about 340 taf/yr in depletion reductions at a cost of $600/af.

Interior CII Water Use

Urban BMPs account for 12 to 15 percent reduction in commercial, industrial, and institutional water use by 2020. Options 5 and 6 assume that CII water use could be reduced beyond BMPs with aggressive audits and information programs by the retailer. These options could reduce CII water use by an additional 3 percent and 5 percent. The reduction levels are based on measures with varying payback schedules, and also on a national study funded by EPA which identifies potential savings beyond BMPs attainable for various enterprises.

Option 5: Interior CII Water Use by 3 percent. This option is based on measures requiring a five-year start up time with payback in two years. The additional 3 percent CII reduction would require increased water audits and compliance with existing standards and regulations. This option could achieve about 50 taf/yr in depletion reductions, primarily in coastal regions, at a cost of about $500/af.

Option 6: Interior CII Water Use by 5 percent. This option is based on measures requiring an additional five-year start up period with a payback within two to five years. The additional 5 percent reduction would accrue through increased audits and compliance with

CALFED Water Conservation Planning

A technical appendix published with CALFED's March 1998 draft PEIR/PEIS outlined a proposed water conservation approach for urban and agricultural agencies wishing to participate in CALFED program benefits. CALFED's conservation levels differ from those used in Bulletin 160-98. CALFED's assumptions represent its vision of future conservation goals. Bulletin 160-98 uses the approach of forecasting the future based on present conditions. For example, CALFED assumes that new sources of financial assistance and other incentives would be provided to water agencies to encourage high levels of conservation. Bulletin 160-98 assumes that demand reduction options beyond BMPs and EWMPs must be cost-competitive with supply augmentation options, and that no new subsidies or financial assistance programs are provided.

Demand reductions estimated to occur from implementation of CALFED conservation measures were not included in CALFED's quantification of new water supplies potentially generated by the program. Thus, they are also not included in the Bulletin 160-98 quantification of potential new supplies from CALFED.

existing standards, and new efficiency standards. About 80 taf/yr of depletion reduction could be achieved, primarily in the coastal regions, at a cost of $750/af.

Distribution System Losses

The Department estimates that the average unaccounted water in the State's hydrologic regions ranges between 6 and 15 percent. Two percent is attributed to unmetered water use (including water used for construction, fire fighting, and for flushing drains and hydrants) and meter errors; therefore, distribution system losses range between 4 percent and 13 percent. Options to reduce distribution system losses assume that they could be reduced to 7 and 5 percent statewide with more aggressive leak detection and repair programs by the retailer.

Option 7: Distribution System Losses to 7 percent. This option assumes that water system audits would be carried out every three years, leak detection surveys would be conducted from the audits, and repairs would be made. The cost of this option is estimated to be about $200/af. This option would achieve about 20 taf/yr of depletion reductions.

Option 8: Distribution System Losses to 5 percent. This option assumes full metering of all water sources and points of use, annual water audits, leak detection of newly constructed pipelines, and systematic leak detection and repair programs linked to water audits. Implementation of this option would achieve about 140 taf/yr of depletion reduction at a cost of $300/af.

Agricultural Water Conservation Options

Agricultural water use in the Bulletin's 2020 forecast is calculated from estimates of crop acreage, unit applied water, unit ETAW and SAEs. Irrigated crop acreage was 9.5 million acres in 1995 and is expected to decline to 9.2 million acres by 2020 because of urbanization (mostly in the South Coast Region and San Joaquin Valley), westside San Joaquin Valley drainage problems, and changes in CVP water supply in the Central Valley.

Bulletin 160-98 assumes that water purveyors statewide will implement EWMPs by 2020, as described in Chapter 4. The resultant demand reduction is included in the Bulletin's 2020 agricultural water use forecast. Statewide implementation of EWMPs results in about 800 taf/yr of applied water reductions by 2020, largely from canal lining or piping and other measures increasing average on-farm SAE to 73 percent. Recent Department studies have shown that average SAEs might be increased to 80 percent through improved irrigation equipment and irrigation management practices.

The agricultural water conservation options described below were based on attaining SAEs greater than 73 percent, on average, through implementation of conservation measures in excess of present EWMPs. Average efficiencies of 76, 78, and 80 percent were used for the water management options. The Department's mobile laboratory data have shown these efficiencies can be achieved in certain locations and with some crops and irrigation methods.

Stressing orchards to reduce ET (also referred to as regulated deficit irrigation) was not evaluated as an option. The RDI method was used successfully during the drought, but may impact crop yields and needs further testing as a long-term management strategy. RDI and other irrigation techniques are discussed in Chapter 5.

Agricultural demand reduction options are evaluated for each hydrologic region and summarized in Table 6-4. The water conserved from these options varies for each region according to prevailing irrigation practices and the regional soil types and hydrology. As with urban conservation options, the purpose of implementing these agricultural conservation options is to generate new water supply by reducing depletions. Reducing consumptive use results in additional water supply only where water would otherwise be lost to evapotranspiration or to a saline water body such as the Pacific Ocean. In California agriculture, this condition exists primarily in the Colorado River Region (which drains to the Salton Sea), parts of the coastal regions, and the westside of the San Joaquin Valley. In the Sacramento River and the San Joaquin River Regions, almost all excess applied irrigation water is reused, ultimately percolating to usable groundwater or draining back into rivers that flow toward the Delta.

If all of the options discussed below were implemented, about 230 taf of depletion reduction could theoretically be achieved. In areas where no depletion reductions would be achieved by conservation beyond EWMPs (such as the Sacramento and San Joaquin River Regions), this additional conservation was deferred as a water supply option. Most of the potential for achieving depletion reductions through additional agricultural conservation occurs in the Colorado River Region. The environmental impacts of such conservation on the Salton Sea must be carefully evaluated. The Salton Sea provides valuable habitat for migratory waterfowl, and alternatives for stabilizing its increasing salinity are now being studied. Since agricultural drainage provides the bulk of fresh water inflow to the sea, actions reducing the freshwater inflow may not be implementable on a large scale.

Irrigation Management (Options 1, 2, and 3)

By 2020, the Department assumes that on-farm SAEs will average 73 percent statewide. Based on mobile laboratory studies, average SAE could reach 80 percent through programs that include irrigation system evaluations, better system design, and improved irrigation systems and management practices. Options 1, 2, and 3 represent the depletion reductions that would be obtained with improved average SAE at 76, 78, and 80 percent, respectively. Increasing average SAE from 73 to 76 percent would yield a depletion reduction of about 40 taf/yr statewide at about $100/af. Improving SAE from 73 to 78 percent would increase depletion reductions to 60 taf/yr statewide at a cost of $250/af. Improving irrigation management from 73 to 80 percent SAE would result in statewide depletion reductions of about 80 taf/yr at a cost of $450/af.

TABLE 6-4

Agricultural Depletion Reduction Potential Due to Water Conservation Options[a] Beyond EWMPs (taf)

Region	*Opt 1*	*Opt 2*	*Opt 3*	*Option 4*	*Option 5*	*Option 6*
	76%	*78%*	*80%*			
	Seasonal Application Efficiency			*Flexible Water Delivery*	*Canal Lining and Piping[b]*	*Tailwater Recovery*
North Coast	D	D	D	D	D	D
San Francisco Bay	D	D	D	D	D	D
Central Coast	D	D	D	D	D	D
South Coast	4	7	10	D	D	D
Sacramento River	D	D	D	D	D	D
San Joaquin River	D	D	D	2	2	2
Tulare Lake	7	12	17	D	D	D
North Lahontan	D	D	D	D	D	D
South Lahontan	2	3	5	D	D	D
Colorado River[c]	22	36	50	30	45	65
Total (rounded)	**40**	**60**	**80**	**30**	**50**	**70**

[a] Implementing options in certain regions would not result in any depletion reduction. These options are deferred (D). Only depletion reductions greater than 1 taf are presented in this table.
[b] Excludes lining of major conveyance facilities (eg., All American Canal, Coachella Canal), which are treated as individual options in the regional water management chapters.
[c] These options are subject to environmental review to ensure that reduced depletions will not have significant impacts to the Salton Sea.

Land Retirement in Drainage-Impaired Areas

Land retirement has been considered for purposes that include drainage management and creation of wildlife habitat, as well as for potential water supply gains. Currently, two programs have authority to fund land retirement—the CVPIA land retirement program and the San Joaquin Valley Drainage Relief Program created by State legislation in 1992. USBR's CVPIA program has significant funding for land retirement, as described in Chapters 2 and 4. Retiring drainage-impaired land on the westside of the San Joaquin Valley would result in reduction of applied water and depletions associated with the current agricultural land use. The use of this associated water—whether for agricultural, urban, or environmental purposes—would depend on the authority and purpose of the program implementing the retirement.

For illustrative purposes, Bulletin 160-98 quantified demand reductions associated with two land retirement scenarios on the westside of the San Joaquin Valley, where some agricultural lands face serious drainage problems and where the existing land retirement programs are authorized to make acquisitions. This analysis is presented to show the demand reduction amounts and potential associated socioeconomic impacts for these drainage management options. Since the scope of Bulletin 160-98 is limited to water supply/demand planning, the Bulletin does not include land retirement for drainage purposes as a water management option. The results of the land retirement analysis are shown in Appendix 6F.

Water Delivery Flexibility (Option 4)

The manner of water delivery to the farm affects water use and efficiency of use. Flexible water delivery allows a farmer to turn water on and off at will. This is currently impractical for many gravity flow agricultural water delivery systems because of the large volumes of water that must be delivered. However, some agricultural water agencies have been able to allow farmers to give shorter notice to the district before receiving water and to allow farmers to adjust flow rates and the duration of the irrigation. Flexible water delivery beyond that achieved through implementation of existing EWMPs would yield about 30 taf/yr at a cost of about $1,000/af.

Canal Lining and Piping (Option 5)

Increased water use efficiency could be achieved by improving on-farm distribution systems beyond the level of effort provided in existing EWMPs. Distribution system losses can be reduced by lining open canal systems or using pipelines. Pipelines would reduce depletions from evaporation and from seepage of applied water to unusable groundwater. (This option applies only to canal lining and piping of on-farm delivery systems. Lining of major conveyance facilities such as the All American Canal and lining of water agency-owned canals are treated as individual options in Chapters 7-9.)

Lining irrigation canal systems in the San Joaquin River Region could reduce depletions by about 2 taf/yr in areas that drain into unusable shallow groundwater. Less than 1 taf in annual depletion reduction would accrue in the Tulare Lake Region because many irrigation systems on the westside of the valley where there is unusable shallow groundwater are already lined or piped. This option could reduce depletions by 45 taf/yr in the Colorado River Region. It is estimated that this option would cost about $1,200/af.

Tailwater and Spill Recovery Systems (Option 6)

This option would improve irrigation efficiency by the construction of additional tailwater and spill recovery systems. The tailwater recovery option is only applicable to areas with furrow or border irrigation systems. Spill recovery systems would lessen the amount of water reaching unusable groundwater and surface water by reducing losses from operational spills in irrigation district delivery canals. About 70 taf/yr of depletion reductions could be achieved with this option, primarily in the Colorado River Region, at a cost of about $150/af.

Environmental Water Conservation Options

Unlike the urban and agricultural efforts discussed above, little formal planning for environmental water conservation has occurred. Development of a formal program to evaluate efficient water use on wetlands is currently the only active program. DFG, USBR, and USFWS are working with the Grasslands Resource Conservation District to develop an interagency program for water use planning for Central Valley wildlife refuges covered by the CVPIA. The program will include best management practices for efficient water use. Draft work products are expected in 1998. The Bulletin does not quantify options for wetlands water conservation.

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Water Supply Augmentation Options

Presently, most active planning for statewide water supply options is being done either for the CALFED Bay-Delta program or for SWP future supply. In accordance with CVPIA requirements, an appraisal level water supply augmentation report (for replacing the project water dedicated to environmental use) was recently prepared for the CVP. There has not been action to implement potential CVP supply options described in that report, apart from initiation of a conjunctive use study described later in this chapter. Statewide-level supply augmentation options are described in the following text, and a summary table of their potential yield is provided at the end of this section.

Conveyance Facilities

Two programs, the SWP Interim South Delta Program and the CALFED program, are studying conveyance actions in and around the Delta. Past studies have evaluated a potential Mid-Valley Canal, a major conveyance facility to supplement water supplies to the eastern San Joaquin Valley.

SWP Interim South Delta Program

The Department's Interim South Delta Program proposes to improve water levels and circulation in south Delta channels for local agricultural diversions, and to enhance existing delivery capability of the SWP by improving south Delta hydraulic conditions, allowing increased diversions into Clifton Court Forebay. This would allow for more frequent use of full pumping capacity (10,300 cfs) at the Banks Pumping Plant during high flows in the Delta, and more operational flexibility for reducing fishery impacts.

The ISDP partly responds to the proposed settlement of a lawsuit brought by the South Delta Water Agency against the Department and USBR. In the proposed settlement agreement, the three parties committed to develop mutually acceptable long-term solutions to the water supply problems of water users within SDWA. The Department has taken the lead responsibility for planning and constructing the project, with cost-sharing provided by USBR.

The ISDP preferred alternative would cost an estimated $60 million to construct and includes five components:

(1) Construction and operation of a new intake structure at the northeastern corner of Clifton Court Forebay, as part of providing greater operational flexibility in export pumping.
(2) Channel dredging along 4.9 miles of Old River just north of Clifton Court Forebay.
(3) Construction and seasonal operation of a barrier at the head of Old River in spring and fall to improve fishery conditions for salmon migrating in the San Joaquin River. (Construction of an Old River fishery barrier is included in CVPIA's list of mandated federal environmental restoration actions.)
(4) Construction and operation of three flow control structures at Old River, Middle River, and Grant Line Canal to improve existing water level and circulation patterns for agricultural users in the south Delta.
(5) Increased diversions into Clifton Court Forebay up to a maximum of 20,430 af daily on a monthly average basis, resulting in the ability to pump an average of 10,300 cfs at Banks Pumping Plant.

ISDP could augment SWP supplies by 125 taf/yr in average years and 100 taf/yr in drought years at a 2020 level of demand, based on present studies. This figure does not take into account any new operational restrictions that may be imposed on the project as a result of the environmental review and permitting process which it is now undergoing. A draft EIR/EIS for the program was released in July 1996 and ESA consultation is ongoing. A final EIR/EIS is scheduled for completion in 1999.

CALFED Delta Conveyance

The CALFED Bay-Delta program is carrying out a three-phase process for solutions for the Bay-Delta system. In Phase I, the program identified the problems in the Bay-Delta system, developed guiding principles, and devised three basic alternatives to solving the identified problems. The second phase consisted of preparing a programmatic EIR/EIS covering three main alternatives for conveyance of water across the Delta:

- Alternative 1. Water would be conveyed through the Delta using the current system of channels.
- Alternative 2. Water conveyance through the Delta would be substantially improved by making significant changes to the existing system of channels.

Delta levees protect infrastructure such as EBMUD's Mokelumne River Aqueduct, highways, railroads, and power transmission lines.

- Alternative 3. Water conveyance through the Delta would be substantially improved by making significant changes to the existing system of channels and constructing a conveyance facility, isolated from the Delta's natural channels, to transport part or all of the water intended for export.

Each alternative presents options for water storage, as well as a system for conveying water through and/or around the Delta. The water storage element could include expanding existing storage, constructing new surface storage, or conjunctive use and groundwater banking. Additional storage would increase flexibility in operating the Bay-Delta system, allowing operators to respond to changing conditions and needs throughout the year, and would help respond to the effects of drought. Surface storage could be in the Delta, upstream of the Delta, or south of the Delta. Groundwater storage components include conjunctive use and groundwater banking programs in the Sacramento and San Joaquin Valleys and in the Mojave River Basin.

A public review draft of the PEIR/PEIS was released in March 1998. CALFED expects to issue a revised draft PEIR/PEIS by the end of 1998. The revised draft would identify CALFED's draft preferred alternative. The third phase of the CALFED process would involve staged implementation of the preferred alternative, over a time period perhaps as long as 30 years, and would require site-specific compliance with NEPA and CEQA.

In June 1998, it was announced that the second draft of CALFED's PEIR/PEIS would focus on a first stage of program implementation that would be defined as the period prior to final action on any major new surface storage or conveyance projects that might be addressed in CALFED's draft preferred alternative. The first stage was estimated to span seven to ten years. The first stage was to focus on implementation of demonstration projects and actions associated with CALFED common program elements (see accompanying sidebar) and on further planning for water storage and conveyance actions.

The total costs of the CALFED program are difficult to estimate at this time because of its broad scope and programmatic nature, and because decisions have not yet been reached about specifics of implementation. CALFED's PEIR/PEIS estimated total program costs as potentially in the range of

CALFED Bay-Delta Program Common Programs

The following six common program elements provide the foundation for overall improvement in the Bay-Delta system. Each of the individual elements is a major program of its own.

- Long-Term Levee Protection Plan—Improve reliability of the Delta levees to benefit all users of Delta water and land.
- Water Quality Program—Reduce point and non-point source pollution for the benefit of all water uses and the Bay-Delta ecosystem.
- Ecosystem Restoration Program—Improve habitat, restore critical flows, and reduce conflict with other Delta system resources.
- Water Use Efficiency Program—Provide for efficient use of existing water supplies and assure efficient use of any new supplies developed through the program.
- Water Transfer Policy—Provide a framework to facilitate and encourage a water market to move water among users on a voluntary and compensated basis.
- Watershed Management Coordination—Encourage locally-led watershed management activities that benefit Delta system resources.

$10 billion, over a program life of several decades. There is presently no information available on what portion of those costs would be allocated to any new water supply CALFED would develop.

Mid-Valley Canal

The Mid-Valley Canal was a proposed conveyance facility to supplement water supplies to the eastern San Joaquin Valley. With two components—a main branch and a north branch—the canal would convey existing CVP water supply from the Delta to portions of Merced, Madera, Fresno, Kings, and Tulare Counties and, by exchange, Kern County.

The main branch of the Mid-Valley Canal would convey water from the Mendota Pool down the east side of the valley, providing additional water deliveries to the southern San Joaquin Valley and Tulare Lake Basin. The north branch would divert water out of the Mendota Pool to provide additional water deliveries to the eastern San Joaquin Valley. Water deliveries could be provided for conjunctive use and groundwater banking programs, alleviating groundwater overdraft conditions. Improved groundwater conditions through delivery of surplus Delta flows could increase the reliability of drought year supplies. Because of the uncertainty of Delta exports, this option is deferred from further analysis in this Bulletin as a statewide option.

Surface Storage Facilities

Developing additional surface storage is an important option for improving statewide water supply reliability. New facilities could store water for the environment, agriculture, municipalities, industry, or a combination of these uses. More storage would increase flexibility in operating the Bay-Delta system, improving operators' ability to respond to changing conditions and needs throughout the year. At this time, the only statewide-level studies of new surface storage facilities are those relating to the CALFED program.

Area of Origin Protections

As described in Appendix 2A, there are explicit statutory protections for area of origin water development, with regard to actions taken by SWRCB in administering water rights and by the Department in providing SWP supply. These provisions apply to the construction and operation of CVP and SWP facilities and would apply to any CALFED-related facilities constructed by the projects.

At the time when initial planning was being performed for a statewide water resources development system, the State filed applications for the appropriative water rights (including rights to store water) needed for coordinated development of California's water resources. Some of these State filings were subsequently assigned to CVP or SWP facilities, and some to local projects. SWRCB may not, in acting on water right applications for these State filings (e.g., applications for a new surface storage facility), deprive the county of origin of the water needed for its present and future development. Many of these original State filings have now been assigned and the associated facilities have been constructed.

Water Code Sections 11460 et seq. require the Department, with regard to construction and operation of the SWP, to not deprive areas of origin, or "an area immediately adjacent thereto which can conveniently be supplied with water therefrom," of the water reasonably needed for their beneficial uses. Water agencies in the area of origin and adjoining areas could contract with the Department for SWP supply pursuant to this provision. The terms and conditions contained in the contract would depend on the nature of the agencies' needs. If the agency wished to become a SWP contractor on a par with the existing 29 water contractors, the contract would be negotiated in the same manner as the existing SWP contracts. An area of origin agency with different needs might seek a different contractual format. For example, an alternative contractual form might be negotiated for agencies that could carry out local conjunctive use programs to reduce their need for a firm supply from the SWP. Existing SWP contractors pay a share of the costs of developing SWP supply, plus a transportation charge that reflects the cost of water delivery to a contractor's service area. Actual water supply and transportation charges for an area of origin contractor would be determined by the type of water supply needed and the associated transportation facilities. To date, no area of origin agencies have negotiated water supply contracts with the Department.

CALFED Surface Storage

New water supply provided by the CALFED program would come about by implementing some combination of surface storage facilities and conjunctive use programs (discussed later in this chapter). Bulletin 160-98 describes potential CALFED storage facilities and their water supply contributions for illustrative purposes, but does not attempt to identify which facility or facilities CALFED might construct. As presently scheduled, CALFED would not begin construction of a new surface storage facility until after its initial implementation of common program elements. Given the long lead time associated with moving forward on large storage facilities, new water supply from a CALFED facility may not be available by the Bulletin's 2020 planning horizon. The potential new water supply provided by CALFED storage (quantified later in this chapter) is necessarily a placeholder, as no decision has yet been made on a draft preferred alternative. Quantification of CALFED actions for Bulletin 160-98 is based on information provided in CALFED's March 1998 first draft PEIS/PEIR and supporting technical appendices.

For illustrative purposes, the Bulletin's discussion of new CALFED storage facilities treats some of the facilities as if they were part of the SWP, to provide a benchmark for calculating their yields via operations studies. Many of these sites have been studied historically as potential SWP future water supply facilities, and data available for them reflect that intended purpose. The Bulletin's treatment of these facilities as potential components of the SWP is to facilitate their quantification, and is not intended to be a proposal as to the agency that would actually finance, construct, and own them. To date, there has been no determination of how any new supplies developed by CALFED would be allocated.

The following sections present an overview of the locations where new CALFED surface storage facilities could be developed.

Surface Storage Upstream of the Delta. Review of potential statewide surface storage options upstream of the Delta revealed that most of the water development potential of the eastern Delta and San Joaquin River tributaries is likely to be dedicated to local plans. The Sacramento River Basin presents nearly all the potential for additional development to meet statewide needs.

The Sacramento River Basin produces nearly one-third of California's surface runoff. About 16 maf total reservoir storage throughout the basin regulates much of that runoff to support extensive agricultural development within the region, and also provides significant water supply for export to other regions from CVP and SWP facilities. A potential remains for developing additional storage in the basin, as evidenced by frequent winter outflows in excess of in-basin and Delta needs.

Over the past century, hundreds of potential reservoir storage sites have been examined encompassing every significant tributary of the Sacramento River Basin. The most economical and practicable of those were developed, the largest of which are Shasta, Oroville, Berryessa, Almanor, Folsom, and New Bullards Bar. Options for additional storage are primarily past project proposals that were not developed.

The average annual surplus outflow in the Sacramento River Basin is about 9 maf. While this suggests potential for additional storage development, much of the surplus runoff occurs during short periods in years of exceptional flood runoff. For example, a maximum daily flow of about 600,000 cfs flowed past Sacramento during the floods of February 1986 and January 1997. New storage capacity could be developed to capture a small fraction of this surplus. Prospects for the development of additional onstream surface storage reservoirs are discussed in the sidebar.

Besides the onstream reservoir sites proposed over the years, many potential offstream storage sites have been investigated to develop surplus water in the upper Sacramento River Basin. Major planning on such projects began in the 1970s, in the wake of wild and scenic rivers legislation that effectively eliminated additional development of the North Coast rivers. By then, it was also apparent that new storage sites on the Sacramento River were not environmentally feasible, so attention shifted to various onstream tributary reservoirs and to offstream sites. With one exception (Tuscan Buttes Reservoir on Inks Creek, north of Red Bluff), the most promising offstream storage sites investigated during this time lay west of the river from the Stony Creek Basin (Newville and Glenn Reservoirs) south (from Colusa and Sites Reservoirs) to the Putah Creek Basin (enlarged Lake Berryessa). All these projects would require conveyance facilities to divert surplus flow (usually during flood periods) from the Sacramento River, some with potential pump lifts of 300 to 900 feet. (CALFED's studies of storage options are presently examining whether existing facilities such as the Tehama-Colusa Canal could be modified to serve as conveyance facilities for some of the potential offstream storage sites.) Offstream storage projects of this type can be sited to minimize environmental impacts within the inundation area, but diversions from the river involve engineering and environmental challenges.

There has been a revival of interest in other offstream storage possibilities, some new and some that appeared in the Department's Bulletin 3, *The Califor-*

Prospects for Onstream Surface Storage Upstream of the Delta

The seven areas outlined below contribute more than 80 percent of Sacramento River Basin runoff. The remaining runoff originates within the substantial valley floor area and adjacent low- elevation foothills. With few exceptions, streams draining this area are ephemeral, flowing only during and following storms. No consideration has been given to onstream storage on these minor tributaries or nearby valley floor areas, except for discussion of possible winter storage in rice fields.

Upstream from Shasta Dam

About 26 percent of basin runoff originates in this 6,700-square mile tributary area, primarily in the Pit, McCloud, and upper Sacramento Rivers. The availability of water to support additional storage has long been recognized. In the 1930s, Shasta Dam planners considered a larger project, but opted for construction of storage downstream at the Table Mountain or Iron Canyon sites near Red Bluff. When the downstream dam proved environmentally unacceptable, alternatives examined eventually included enlarging Shasta Dam. New storage upstream is possible, but sites are limited by steep topography and extensive existing power development of the Pit and McCloud systems.

Upper Sacramento River Tributaries, Shasta Dam to Red Bluff

This large, but low-elevation, area contributes about one-eighth of Sacramento River Basin runoff. The principal tributaries (in descending order of runoff) are Cottonwood, Cow, Clear, and Battle Creeks. Clear Creek is fully developed by Whiskeytown Lake (a CVP facility). Several reservoir sites have been investigated on the other tributaries, with primary emphasis on Cottonwood Creek. Previously studied reservoir sites are available in this area, but none have proven viable.

Feather River

This is the Sacramento River's largest tributary and contributes 20 percent of basin runoff, an annual average of about 4.5 maf. Lake Oroville at 3.5 maf regulates Feather River flows in most years, but the huge spills in wet years show that the river could support additional storage. Enlargement of Lake Oroville has not been considered practical and the few upstream sites identified in the past have fallen by the wayside for various environmental and economic reasons. No serious planning attention has been devoted to major reservoir storage in the Feather River Basin since construction of Oroville Dam.

Yuba and Bear Rivers

The Yuba River constitutes 11 percent of Sacramento River Basin runoff, but is substantially diminished by power diversions to the adjacent Bear and Feather Rivers. Still, a significant potential for additional storage remains. Proposals for large reservoirs at the Marysville (or nearby Narrows) site have been discussed in the past 40 years. Upstream development potential is restrained by extensive existing power facilities and diversions. The Bear River is small, but its runoff is bolstered by the diversions from the Yuba River.

American River

With 12 percent of Sacramento Basin runoff, the American River could support more than the 1.0 maf of storage provided by Folsom Lake and the nearly 0.5 maf of upper basin storage. For the past decade, recognition of a flooding hazard along the lower American River has added urgency to finding options, including enlarging Folsom Lake and constructing additional storage upstream at Auburn. The controversy over Auburn Dam prompted reappraisal of storage sites farther upstream and on the South Fork, but none appeared to justify follow-up attention.

Westside Tributaries South of Cottonwood Creek

The principal tributaries in this group are (from south to north): Putah, Cache, Stony, Thomes, Elder, and Red Bank Creeks. The existing Lake Berryessa, which has an unusually high storage/inflow ratio, fully develops Putah Creek. Clear Lake and Indian Valley Reservoir provide about 0.6 maf of active storage in the upper Cache Creek Basin, but only modest potential exists for additional storage in the lower basin. East Park, Stony Gorge, and Black Butte Reservoirs partially control Stony Creek, but some surplus water remains. Thomes, Elder, and Red Bank Creeks are presently uncontrolled; Thomes Creek contributes about two-thirds of the runoff from this northern trio. Potential reservoir sites have been considered on the various westside tributaries, principally within the Stony/Thomes Basins.

Other Tributaries, Feather River to Red Bluff

From south to north, the major streams of this group are Butte, Big Chico, Deer, Mill, and Antelope Creeks. These drainages are narrow, steep canyons with good sustained summer flows. Past studies have identified a few small potential storage sites, but none are considered practical because of environmental considerations (primarily anadromous fish and wilderness issues).

nia Water Plan, in 1957. Among the latter is a potential local project, Waldo Reservoir, to store surplus Yuba River water diverted from the existing Englebright Reservoir. Similar proposals have been developed to store surplus American River water from Folsom Reservoir in the nearby Deer Creek or Laguna Creek Basins. Offstream storage projects of this type are attractive because they eliminate the need for onstream reservoirs and divert from existing facilities upstream from current anadromous fishery habitat.

To illustrate how specific surface storage projects upstream of the Delta compare with one another, Bulletin 160-98 planning criteria were used to screen and evaluate the reservoir sites (Appendix 6G). CALFED is performing its own evaluation of possible storage sites. An initial screening may be included in its final PEIS/PEIR. More detailed evaluations of the remaining sites would be carried out after CALFED begins to implement initial elements of the common programs.

Off-Aqueduct Surface Storage South of the Delta. Off-aqueduct surface storage south of the Delta has been investigated for many years. CALFED's storage evaluations include reviewing off-aqueduct storage.

The CVP and SWP operate by releasing water from upstream reservoirs, which flows through the Delta and is diverted, together with unstored flows available for export, by the projects' pumping plants located in the south Delta. Storage south of the Delta is provided by San Luis Reservoir, a joint SWP/CVP facility in the San Joaquin Valley. Water pumped at the Banks and Tracy Pumping Plants is transported to San Luis Reservoir during the winter and early spring and later delivered to agricultural and urban water contractors. Additional storage south of the Delta would increase water availability through greater capture of surplus winter runoff, as well as provide for greater flexibility in operating the projects.

Dependable water supplies from the SWP are estimated at about 3.1 and 2.1 maf for average and drought years, respectively. Operation studies show that under 2020 level of demand, there is a 25 percent chance of delivering full entitlement in any given year with existing facilities. Operation studies show similar CVP delivery capabilities to its Delta export service area. (See Chapter 3 for discussion of SWP and CVP operations.) Additional off-aqueduct storage south of the Delta would increase water supply reliability of both projects.

In addition to increasing water supply reliability for both projects, more off-aqueduct storage south of the Delta would allow flexibility in pumping from the Delta. This flexibility would allow for shifting of Delta pumping toward months when the impacts of Delta diversions on fisheries are at their lowest. Having additional storage south of the Delta would allow the projects to operate efficiently by taking advantage of times when maximum pumping is permissible.

Operation of the SWP and CVP is governed by several limiting factors including available water supplies, demands on these supplies by project contractors, Delta water quality standards, instream flow requirements, and conveyance capability. The availability of water supplies varies with natural conditions and upstream development. Winter floods can produce Delta flow rates of up to several hundred thousand cfs, while summer rates can be as low as a few thousand cfs. Annual Delta inflow varies substantially, ranging from more than 70 maf in wet years to less than 7 maf in drought years.

Since the 1950s, alternative off-aqueduct storage reservoir sites south of the Delta have been investigated by the Department. An agreement between the State and federal governments was signed in 1961 for construction and operation of San Luis Reservoir, a joint-use offstream storage facility completed in 1968. Before completion of San Luis Reservoir, it was recognized that additional storage south of the Delta was needed. As a result, a Delta storage development program was authorized by legislative action in 1963-64, and work started to analyze the remaining potential off-aqueduct storage sites in the San Joaquin Valley. Under this program a cursory examination of potential sites identified the Kettleman Plain, Los Banos, and Sunflower sites for more in-depth study. Kettleman and Sunflower Reservoir sites were dropped after reconnaissance level review because of their physical characteristics. The Los Banos site was deemed satisfactory for further study, and a 1966 report recommended additional geological exploration.

In the 1970s, a Delta alternatives study reviewed all drainages south of the Delta and selected Los Vaqueros, Los Banos Grandes, and Sunflower Reservoirs for further studies. In a 1976 Delta alternatives memorandum report, the Sunflower site was again eliminated when compared with the other sites on the basis of low storage availability and marginal foundation conditions. The Los Vaqueros site in Contra Costa County was included in the Department's proposed Delta program and was part of a comprehensive water management program proposed for authorization via 1977-78 legislation. (LBG was an alternative to Los Vaqueros in that legislation.) After that legislation failed passage, Los Vaqueros was included with the Peripheral Canal in SB 200. LBG was not specifically mentioned in SB 200, but the bill provided for additional off-aqueduct storage south of the Delta. In 1980, SB 200 was signed into law, but was overruled by voters in the 1982 general election.

The Los Banos Grandes damsite area, looking westerly toward the Coast Range.

The Department initiated a more comprehensive investigation of alternative off-aqueduct storage reservoirs south of the Delta in 1983, and after an initial examination of 18 storage sites, completed a reconnaissance report on 13 potential San Joaquin Valley sites. The study recommended that LBG be investigated to determine its most cost-effective size, and its engineering, economic, financial, and environmental feasibility. In 1984, the Legislature unanimously approved Assembly Bill 3792, authorizing LBG as a facility of the SWP. The Department released a draft EIR and a feasibility report on LBG in 1990.

Since the 1990 reports, increased restrictions on Delta pumping and rising costs have prompted reconsideration of the LBG proposal. Given the uncertainty of future Delta exports and the reluctance of some SWP contractors to participate in the project, the Department reevaluated the feasibility and optimal size of additional off-aqueduct storage. A subsequent *Alternative South-of-the-Delta Offstream Reservoir Reconnaissance Study* identified all alternative reservoir sites south of the Delta by cursory examination of all topographic possibilities. An overview of sites studied in the past is provided in Appendix 6G.

In-Delta Storage. CALFED has also considered in-Delta storage. A private developer has proposed a water storage project involving four islands in the Delta. The project would divert and store water on two of the islands (Bacon Island and Webb Tract) as reservoir islands, and seasonally divert water to create and enhance wetlands for wildlife habitat on the other two islands (Bouldin Island and Holland Tract). The developer would improve and strengthen levees on all four islands and install additional siphons and pumps on the perimeters of the reservoir islands.

The developer's project would divert surplus Delta inflows, or would manage transferred or banked water for later sale and/or release for Delta export or to meet Bay-Delta water quality or flow requirements. The reservoir islands would be designed to provide a total estimated initial capacity of 238 taf—118 taf from Bacon Island and 120 taf from Webb Tract—at a maximum pool elevation of 6 feet above mean sea level.

A draft EIR/EIS for the Delta Wetlands Project was completed in September 1995. SWRCB held water rights hearings in 1997. Issues included water quality concerns, levee integrity, seepage impacts on adjacent islands, and fishery impacts. SWRCB is currently reviewing and evaluating the evidence to develop a draft decision.

Multipurpose Storage Facilities

Most reservoirs are constructed to serve multiple purposes. As discussed in Chapter 3, multipurpose reservoirs are often operated to prioritize certain uses or to balance competing uses during different times of the year. Good planning policy dictates that new surface storage facilities be designed to accommodate as many purposes—such as water supply, flood control, hydropower generation, fish and wildlife enhancement, water quality management, and recreation—as are practicable.

Although Bulletin 160 is focused on evaluation of water supply options, this focus is not intended to minimize the need to consider the other benefits potentially available from reservoir sites—especially flood control. The January 1997 flooding, the largest and most extensive flood disaster in the State's history, demonstrated the urgent need to improve flood protection levels throughout the Central Valley. The 1997 *Final Report of the Governor's Flood Emergency Action Team* contained a variety of recommendations for improving emergency response management and flood protection in the Central Valley.

The 1997 floods highlighted a fundamental fact of Central Valley geography—the valley floor is relatively flat, and only an extensive system of levees confines floodwaters to those areas where people would

The January 1997 flooding in the Central Valley emphasized the vulnerability of lands protected by levees.

prefer that they remain. At the beginning of the valley's development in the Gold Rush era, much of the valley floor was an inland sea during the winter months and travel was possible only by boat. This condition was once again experienced on a localized scale in 1997, when numerous levee breaks occurred throughout the valley. Although more emphasis is being given to floodplain management and prevention of future development in flood-prone areas, extensive urban development has already occurred in areas that rely on levees for flood protection. Efforts to improve flood protection for these urban areas necessarily include evaluation of upstream storage alternatives—reoperation or enlargement of existing reservoirs and construction of new reservoirs.

From a flood control standpoint, there are locations within the Sacramento and San Joaquin River systems where additional storage (onstream, or perhaps offstream with appropriate diversion and pumping capability) would be particularly useful. Communities in the Sacramento Valley with greatest need for additional flood protection include the Yuba City/Marysville and Sacramento/West Sacramento areas, as identified in the 1997 *Final Report of the Governor's Flood Emergency Action Team*. An enlarged Shasta Lake could provide additional management of flood flows on the Sacramento mainstem. The need for more flood control storage on the Yuba River has been evaluated for some time, in conjunction with reservoir sites such as the old Marysville site, or the more recent Parks Bar alternative. The proposed Auburn Dam on the American River, selected as the preferred flood protection alternative by the State Reclamation Board, would provide much-needed flood protection for the Sacramento area, which has one of the lowest levels of flood protection of any metropolitan area in the nation.

In the San Joaquin Valley, urbanized areas needing additional protection are those affected by flooding on the mainstem San Joaquin River and on its largest tributary, the Tuolumne River. In the January 1997 flood event, runoff at New Don Pedro Dam on the Tuolumne River and Friant Dam on the San Joaquin River exceeded the flood control capability of both reservoirs. On the Tuolumne River, it appears that new upstream reservoirs are a less likely flood control option, given the basin's existing storage development. Enlarging Friant Dam (or constructing its offstream alternative) would be the most probable new storage development option for the San Joaquin River.

Bulletin 160-98 includes Auburn Dam and Friant Dam enlargement as statewide options likely to be implemented (by CALFED or by others) by 2020. According to CALFED, the capital cost of a 2.3 maf Auburn Dam would be about $2.3 billion in 1995 dollars. According to USBR, the cost of raising Friant Dam by 140 feet with 500 taf additional storage is about $580 million. (This estimate, in 1997 dollars, does not include costs associated with purchasing property, the cost of relocating utilities, and mitigation costs.) Potential yields associated with these projects were estimated through operations studies. A 2.3 maf Auburn Reservoir is estimated to provide 620 taf in average years and 370 taf in drought years. An enlarged Friant Dam is estimated to provide 90 taf in average years. As noted in Appendix 6G, an enlarged Shasta Lake would provide major water supply and other benefits, but additional studies of its costs and environmental impacts would be needed before the

Courtesy of California State Library.

High technology (circa 1900) being used to construct a Sacramento River levee south of the then-downtown area.

project could proceed to implementation. It is recommended that feasibility-level studies of enlarging Shasta be initiated to quantify its costs and benefits. Preliminary studies show that a 9 maf enlargement of Shasta would yield about 760 taf in average years and 940 taf in drought years.

Groundwater and Conjunctive Use

The potential sustainable water supply that could be derived from groundwater storage is constrained by the water available to recharge the storage, the available storage capacity, and the wheeling capability of the conveyance facilities. In most areas the sources of recharge are natural percolation from overlying streams, infiltration of precipitation, deep percolation of applied irrigation water, and seepage from irrigation canals and ditches. In some areas, these sources are augmented by artificial recharge.

Potential for Conjunctive Use in the Central Valley

Plans for local development of additional groundwater and conjunctive use programs are covered in Chapters 7–9. This section reviews the potential for groundwater development and conjunctive use as elements of statewide water management, concentrating on the potential for augmenting supplies of the major State or federal water projects. As noted earlier, conjunctive use programs are also a component of CALFED's storage evaluations.

Sacramento Valley. As noted in the previous discussion of surface storage facilities, the Sacramento River Basin constitutes most of the potential for additional water development to meet statewide demands. Just as surface storage reservoirs are being evaluated to develop a portion of the basin's surplus runoff (about 9 maf), managed conjunctive use programs are being evaluated to the same end.

Although there is a tendency to think of Sacramento Valley groundwater in terms of a homogeneous underground reservoir that fluctuates gradually with wet and dry cycles, the reality is more complex. While much of the Sacramento Valley groundwater basin is interconnected, aquifer structure is far from uniform and horizontal movement of groundwater is slow. Differences in groundwater conditions exist from one area of the valley to another. Even within a small subarea, groundwater resources can range from abundance to scarcity within a few miles.

Potential conjunctive use programs must be evaluated on a site-specific basis, just as surface water storage facilities are evaluated. In concept, Sacramento Valley conjunctive use programs would operate by encouraging existing surface water diverters to make greater use of groundwater resources during drought periods. The undiverted surface water would become available for other users, and groundwater extractions would be replaced during subsequent wetter periods through natural recharge, direct artificial recharge, or in-lieu recharge (supply of additional surface water to permit a reduction of normal groundwater pumping).

The DWB provides an example of conjunctive use in the Sacramento Valley. In 1991, 1992, and 1994, the DWB executed contracts to compensate Sacramento Valley agricultural water districts for reducing their diversions of surface water. Most of the reduced surface water diversions were made up by increased groundwater extractions from existing wells. The 1994 program in this area was the largest, amounting to approximately 100 taf. The DWB program included a groundwater monitoring component to evaluate the effects of increased extractions on neighboring nonparticipating groundwater users. Such monitoring programs would be an important component of future conjunctive use programs.

San Joaquin Valley. Potential conjunctive use projects in the San Joaquin Valley would involve recharging empty groundwater storage space for later withdrawal. Although aquifer storage capacity is available (over 50 maf), a lack of recharge water limits opportunity for conjunctive operation. Even with Delta improvements, prospects for additional groundwater conjunctive use storage south of the Delta are limited. From the standpoint of statewide water supply, the areas of conjunctive use potential are those within reach (either directly or through exchange) of the California Aqueduct or CVP facilities. Examples of projects studied in the past include the Kern Water Bank and the Stanislaus/Calaveras River Basin program. The Kern Water Bank project, described in Chapter 8, was initially developed by the Department and was subsequently turned over to the KWB Authority. The KWB is discussed as a local water management option for the Tulare Lake Region in Chapter 8.

The Department and USBR, in coordination with local agencies, evaluated the possibility of a conjunctive use project in the Stanislaus/Calaveras River Basin. SEWD and CSJWCD proposed a conjunctive use project in 1986 for their CVP interim water supply contracts (155 taf/yr). The districts would divert CVP surface water supply in wet years and would pump

Recharge facilities in the Kern Water Bank area. Levees and conveyance facilities have been constructed to manage spreading of water in the recharge areas.

groundwater and divert South Gulch Reservoir supplies in drought years. Water would be stored in the proposed South Gulch Reservoir, an offstream storage reservoir near the Calaveras River, in wet years. In drought years the districts would allow the water to be released to the Stanislaus River for fishery needs, water quality improvement in the southern Delta channels, and CVP and SWP water supply improvement. Subsequent enactment of CVPIA and issuance of SWRCB's Order WR 95-6 substantially reduced the quantities of surface water available to SEWD and CSJWCD. The Department deferred further participation in this program as a source of SWP supply. Local agencies are continuing to evaluate other conjunctive use programs in this area, as described in Chapter 8.

Recent Groundwater Studies with Statewide Scope

The Department is evaluating conjunctive use opportunities that could provide future water supplies for the SWP. USBR suggested that conjunctive use could be a major option for CVP water users in its 1995 report to Congress, *Least-Cost CVP Yield Increase Plan*. CALFED is examining conjunctive use opportunities as part of its storage evaluations.

SWP Conjunctive Use Studies. The Department's investigation of Sacramento Valley conjunctive use potential for additional SWP supply is following three parallel tracks. The first track is an evaluation of the legal and institutional framework to define potential projects and their limitations. The second track is an inventory of water supply infrastructure, water use, and hydrogeologic characteristics of the valley to identify areas most suitable for conjunctive use projects. The third track is a pre-feasibility investigation of specific potential projects. Where appropriate, these studies recommend more comprehensive feasibility studies, or development of small scale demonstration and testing projects. One such project under evaluation, the American Basin conjunctive use project, is discussed in the sidebar. Under the terms of Monterey Agreement contract amendments now in place for most SWP water contractors, only those contractors interested in receiving supplies from the project would participate in it. Since no other SWP conjunctive use projects are currently in active planning, the yield of the potential American Basin project is used as a surrogate for the yield of SWP conjunctive use programs.

Least-Cost CVP Yield Increase Plan. USBR's 1995 yield increase plan evaluated possible actions to replace the water supply that CVPIA dedicated to environmental purposes. The plan identified conjunctive use as offering the largest potential, estimating that active recharge in the Central Valley would yield over 800 taf/yr. A regional groundwater model characterizing the Central Valley was used to identify potential sites for active recharge programs. Table 6-5 lists potential yield estimates from the study. Yield estimates for active recharge programs were based on the availability of floodflows on adjacent rivers. Local water supply availability has almost always limited the potential of a particular site. Implementation of conjunctive use options would require additional feasibility investigations and identification of potential environmental impacts.

Madera Ranch Project. As described in Chapter 8, USBR is in initial stages of evaluating a conjunctive use project known as the Madera Ranch project, which might yield up to 70 taf/yr. Water supplies for the project would come from excess flows available at the Delta for export. USBR, in cooperation with the San Luis and Delta-Mendota Authority, has completed a preliminary investigation of the project and is now evaluating land acquisition. Since supplies from the potential project would be provided only to one group of CVP contractors and not CVP-wide, the project is discussed as a local project in Chapter 8.

TABLE 6-5

CVP Yield Increase Plan Conjunctive Use Options

General Site Locations	*Potential Source(s) of Water*	*Activity*	*Evaluated Capacity[a] (taf)*	*Annual Yield[b] (taf)*
Region 1				
E of Anderson	Upper Sacramento River	Active recharge	60	15
Region 2				
SW and W of Orland, Tehama-Colusa Canal and vicinity	Upper Sacramento River	Active recharge	360	90
Within Glenn County	Groundwater	Developable yield	N/A	55
Region 3				
S of Chico, near Wheatland, E of Sutter Bypass, and NE of Rio Linda	Feather and Bear Rivers and Dry Creek (north of Sacramento)	Active recharge	280	85
Within Yuba County	Groundwater	Developable yield	N/A	25
Region 4				
NW of Woodland and SW of Davis (near Dixon), Yolo Bypass nearby	Cache Creek, Sacramento River	Active recharge	120	30
Region 5				
NE of Galt, SE of Elk Grove, SE of Lodi, and S of Manteca	American (using Folsom South Canal), Cosumnes, Mokelumne, Calaveras, and Stanislaus Rivers	Active recharge	400	185
Region 6				
NW of Volta and at Oro Loma	Delta-Mendota Canal, California Aqueduct	Active recharge	275	200
Region 7				
N of Modesto	Stanislaus or Tuolumne Rivers	Active recharge	100	20
Region 8				
E of Atwater, NE of Merced, W of La Vina, and NE of Red Top	Merced, Chowchilla, Fresno, and San Joaquin Rivers	Active recharge	350	140
Region 9				
none identified				
Region 10				
N of Raisin City, S of Kingsburg, S of Hanford, W of Visalia, and SW of Tipton	Kings, Kaweah, and Tule Rivers	Active recharge	unknown	125
Region 11				
W of McFarland, and SW of Bakersfield	Kern River, California Aqueduct	Active recharge	500	50

[a] Capacity is taken to be the amount of water that can be recharged and extracted over any area without causing a water level fluctuation of more than 30 feet compared to historical water levels and has been estimated using a large-scale regional model. Values are not maximums and are used for comparison purposes.

[b] Location(s) descriptions are reflective of general areas where active recharge programs were estimated to be feasible. Each reference to a city or town represents a single site (NW of Woodland and SW of Davis refers to two potential site areas). Many regions have multiple sites where active recharge is possible.

CALFED Conjunctive Use Component. CALFED is evaluating conjunctive use potential as part of its storage component. The CALFED conjunctive use program will not identify specific projects, but will attempt to identify potential for groundwater development and provide technical support to voluntary local conjunctive use projects. CALFED is defining operating rules and assumptions in order to evaluate potential water supply benefits. Storage for conjunctive use is currently assumed to be 250 taf in the Sacramento Valley and 500 taf in the San Joaquin Valley. Groundwater withdrawal and recharge capacities of 500 cfs are being assumed. Groundwater withdrawal is being assumed to take place only in drought years. Potential water supply benefits of the CALFED conjunctive use program have not been quantified at this time.

Water Marketing

Water agencies are increasingly including marketing as a component of their future resources mix—not just as a drought management technique, but as a source of supply in normal water years. It is becoming increasingly common to see local agency plans with a menu of marketing alternatives which include one-time spot transfers, short or long-term agreements for drought year marketing, and long-term agreements for average year water marketing.

In this update of the *California Water Plan*, water marketing may include:

- A permanent sale of a water right by the water right holder.
- A lease from the water right holder (who retains the water right), allowing the lessee to use the water under specified conditions over a specified period of time.
- A sale or lease of a contractual right to water supply. Under this arrangement, the ability of the holder to transfer a contractual water right is usually contingent upon receiving approval from the supplier. An example of this type of arrangement is a sale or lease by a water agency that receives its supply from the CVP, SWP, or other water wholesaler.

One common concern with marketing proposals is that only real water is sold, and that marketing of paper water is avoided (see sidebar). The difference is that real water involves a change in the place and type of an existing use without harming another legal user of water, while paper water might involve sale of water that would not otherwise be beneficially used during the period of the proposed marketing arrangement. Another common concern is third-party impacts associated with proposed marketing arrangements. This concern must be addressed as appropriate on a site-specific basis for proposed transfers.

For water marketing options identified as likely to be implemented, Bulletin 160-98 water budgets show increases in supply for the gaining regions and reflect corresponding reductions in demand in regions

Feasibility Study for American Basin Conjunctive Use Project

The Department has completed a feasibility investigation of the American Basin conjunctive use project. Discussions are under way with local project participants and potentially participating SWP contractors. If negotiations are successful, CEQA/NEPA compliance and permit acquisition would follow, and initial project operation might begin in 2001. The project area is in southeastern Sutter County, western Placer County, and northwestern Sacramento County. Local water purveyors participating in the project could include South Sutter Water District, Natomas-Central Mutual Water Company, Pleasant Grove-Verona Mutual Water Company, and Placer County Water Agency. Three of the four potential participants have a surface water supply within the project area from either the Bear or Sacramento River systems, and one relies on groundwater.

As evaluated in the feasibility study, the project could develop about 55 taf of water during drought periods to supplement diminished SWP surface water supplies, depending on the number of agencies participating in the project. In the feasibility study, costs of the drought year supply for the SWP were estimated to be on the order of $150/af.

The 40-30-30 Index (see description in Chapter 3) would be used to determine when project recharge and recovery would occur. When the index is classified as above normal or wet, project recharge would occur. Recharge would be accomplished by in lieu means, which would require delivery of SWP water to those in the project area that use groundwater. Construction of new facilities to deliver SWP water from the Feather River to each project participant's service area would be required. When the index is classified as dry or critical, project recovery would occur by groundwater substitution. Groundwater substitution would involve each district forgoing part of its normal surface water supply, by leaving it in the river for use by others. Reductions in surface water supply would be supplemented by extracting groundwater that was placed in the aquifer system earlier.

Is That Real Water?

The initial rush of enthusiasm for water marketing stimulated much discussion about supposedly unused water. Some water users in the State hold rights (statutory or contractual) to more water than they currently use to meet their needs. Why not sell those rights to others?

Such arrangements looked attractive to both prospective sellers and buyers. The sellers would receive payment for something they were not using, while the buyers would meet urgent water needs. This view, however, overlooks the fact that water to meet the transferred rights has been part of the basin supply all along, and has almost always been put to use by downstream water right holders or is supporting an environmental need. This type of marketing arrangement became known as a "paper water" deal: the money goes to the seller, while the water is sold to the buyer from the supply of an uninvolved third party.

A similar outcome can result from some water conservation measures. Changes in irrigation management can reduce drainage outflow that otherwise contributes to the supply of downstream users or meets an instream need. Proposals to market water saved through such drainage reduction can also represent paper water.

The California Water Code includes a number of provisions to regulate and facilitate marketing arrangements (Water Code Sections 1435, 1706, 1725, 1736, 1810d), as well as a "no-injury" clause that prohibits transfers that would harm another legal user of the water. This clause is the basis for prohibiting sale of paper water.

In analyzing water marketing and water conservation proposals, the Department uses the terms real water and new water to contrast with paper water. Real water is water not derived at the expense of any other lawful user, i.e., water that satisfies the Water Code's no injury criterion. New water is water not previously available, created by reducing irrecoverable losses or outflow to the ocean or inland salt sinks. New water, by definition, must be real, but not all real water is new. For example, water made available through land fallowing is real (because it reduces ETAW), but not new.

from which water is being transferred, if specific participants have been identified and the options are large enough to be visible in the water budgets. Presently, the only marketing arrangements that fit this category are those associated with the draft CRB 4.4 Plan.

One of the larger potential water marketing programs identified in Bulletin 160-98 is CVPIA water acquisition for instream flows and wildlife refuges. Impacts of different levels of supplemental water acquisition were described in USBR's draft CVPIA PEIS, which did not identify a preferred quantity of water acquisition. At this time, no long-term purchase agreements have been executed—CVPIA supplemental water acquired to date has been purchased on a year-to-year basis. It is not possible to identify how and where the supplemental water would be obtained in the future, or what other water demands might be reduced as a result of CVPIA water acquisition.

Sources of Water for Marketing

The increased attention to marketing following the 1987-92 drought brought clear recognition that water marketing alone does not create new supplies—it is a process by which supplies developed by other means are moved to a new place of use. In any water marketing agreement, the reliability of the supply acquired by the transferee depends upon the specific details of the agreement and the relative priority of the water rights involved. Potential sources of water that have been most often considered for marketing are described below:

Land Fallowing. A potential source of water for marketing is to forgo growing crops in a given area and move the water that would have been consumed to a different service area. Although there can be some difficulty in quantifying the amount of water made available and its impact on the economy of local agricultural communities, land fallowing is a proven demand reduction technique. Land fallowing may be undertaken on either a permanent basis (land retirement) or only during drought periods in various forms of shortage contingency programs. Drawbacks of fallowing include potential impacts on non-participating third parties.

Crop Shifts. Some of the third party effects of fallowing could be reduced by substituting crops that consume less water for those that would use more. For example, safflower might be planted in place of tomatoes, or wheat in place of corn. The substituted crop is usually less profitable for the grower, so the potential buyer provides an appropriate incentive payment. Such arrangements can produce real water savings, but they introduce a further layer of complexity and uncertainty. (For example, how can it be demonstrated that the higher water-using crop would really have been planted in the absence of the arrangement? And, what are the related effects on groundwater recharge and drainage contributions to downstream surface supplies?) Crop shift proposals were solicited by the Department for the 1991 DWB, but played a limited role. Because crop acreage is market driven, the ability to do large scale crop shifts is limited. Crop shifts are thus expected to have a small role in water marketing.

Water Conservation and Water Recycling. Where conservation or recycling options result in real water savings, conserved water may be available for marketing to other users. Recent proposals to market conserved water have mostly occurred in the agricultural sector, where considerable confusion has sometimes resulted over the distinction between reducing applied water and producing real water savings. Most of California's irrigated areas overlie usable groundwater basins and are linked by networks of surface streams and drains. Water leaving one area usually contributes to the supply of other areas or, in the Central Valley, to required Delta outflow. Under such conditions, real water savings result by reducing consumptive use or by reducing losses to saline sinks.

From a statewide perspective, opportunities for marketing conserved water occur primarily in areas such as the Imperial Valley, where agricultural drainage water flows to the Salton Sea. (Agricultural runoff entering the sea supplies the relatively fresher water needed to sustain the sea's biological resources. The ability to market conserved water that would otherwise flow to the sea must take into consideration impacts of such transfer on the sea.)

From a local perspective, however, the situation may be different. For example, Sacramento Valley conservation measures that reduce agricultural drainage make more water available for use in the conserving area—but at the expense of downstream users. Local districts in such areas have substantial incentive to practice conservation to improve the utility of their existing supplies, but the potential for creating real water for sale to others is limited.

Water recycling in coastal urban areas can create new water, and there is often a potential market for this water among other urban users for landscape or turf irrigation. These sales typically entail multi-jurisdictional partnerships, since the recycled water is most often provided by a wastewater treatment agency but is distributed or supplied to end users by one or more water agencies.

Groundwater Substitution. Many California growers have rights and access to surface water supplies, even though their land may overlie productive groundwater basins. In such cases, a grower may agree to forgo use of surface water rights for a period, substituting groundwater instead. The unused surface water then becomes available for marketing to other users. This technique was tested during the DWBs of 1991, 1992, and 1994. Under favorable conditions (where wells and pumps are already installed), it can produce considerable water on relatively short notice. One major concern with groundwater substitution is the potential impact on neighboring non-participating pumpers. Substantial monitoring is needed to assure there are no unreasonable third-party impacts. Another consideration with groundwater substitution is that additional pumping may induce recharge that depletes usable streamflow. Only that portion of groundwater replenished from future surplus flows is really a new supply. Further experience will be needed to define the potential of this source, resolve concerns over impacts on nearby pumpers and regional surface supplies, and explore possibilities for constructing recharge facilities.

Surface Storage Withdrawals. Existing reservoirs within California have a combined storage capacity of approximately 40 maf. These facilities are operated by a wide spectrum of entities for a variety of water supply, flood control, power, and recreation objectives. At any given time, water may be stored somewhere in the system that is not planned to be released, but could be made available to meet urgent needs, subject to compliance with existing water rights. Such withdrawals come at a price—usually a reduction of power generation or recreational usage, or increased risk of future water supply shortage. Payments to the reservoir owner implicitly include a component to compensate for reduced benefits, increased risk, and other costs. Surface storage withdrawals are easily quantified and clearly represent real water, provided the storage is refilled from future surplus flows. Storage withdrawals played an important role in recent transfers; the refill constraints were handled through a contract clause whereby reservoir owners agreed to defer refill until a time of future high runoff when there would be no detrimental effect on other water users. In the long run, the prospects for such arrangements will tend to diminish as water demands increase in the reservoirs' primary service areas.

Prospects for Water Marketing

Water marketing will continue to play a role in meeting California's water needs, but there will be a continuing shift in emphasis toward systemwide appraisal of impacts and growing recognition of the need to protect the rights of all lawful water users. Water marketing programs (and land retirement or fallowing programs that may be used to supply water for sale) are often controversial in the area where the trans-

Water Code Section 1810 *et seq.*

1810. Notwithstanding any other provision of law, neither the state, nor any regional or local public agency may deny a bona fide transferor of water the use of a water conveyance facility which has unused capacity, for the period of time for which that capacity is available, if fair compensation is paid for that use, subject to the following:

(a) Any person or public agency that has a long-term water service contract with or the right to receive water from the owner of the conveyance facility shall have the right to use any unused capacity prior to any bona fide transferor.

(b) The commingling of transferred water does not result in a diminution of the beneficial uses or quality of the water in the facility, except that the transferor may, at the transferor's own expense, provide for treatment to prevent the diminution, and the transferred water is of substantially the same quality as the water in the facility.

(c) Any person or public agency that has a water service contract with or the right to receive water from the owner of the conveyance facility who has an emergency need may utilize the unused capacity that was made available pursuant to this section for the duration of the emergency.

(d) This use of a water conveyance facility is to be made without injuring any legal user of water and without unreasonably affecting fish, wildlife, or other instream beneficial uses and without unreasonably affecting the overall economy or the environment of the county from which the water is being transferred.

1811. As used in this article, the following terms shall have the following meanings:

(a) "Bona fide transferor" means a person or public agency as defined in Section 20009 of the Government Code with a contract for sale of water which may be conditioned upon the acquisition of conveyance facility capacity to convey the water that is the subject of the contract.

(b) "Emergency" means a sudden occurrence such as a storm, flood, fire, or an unexpected equipment outage impairing the ability of a person or public agency to make water deliveries.

(c) "Fair compensation" means the reasonable charges incurred by the owner of the conveyance system, including capital, operation, maintenance, and replacement costs, increased costs from any necessitated purchase of supplemental power, and including reasonable credit for any offsetting benefits for the use of the conveyance system.

(d) "Replacement costs" means the reasonable portion of costs associated with material acquisition for the correction of unrepairable wear or other deterioration of conveyance facility parts which have an anticipated life which is less than the conveyance facility repayment period and which costs are attributable to the proposed use.

(e) "Unused capacity" means space that is available within the operational limits of the conveyance system and which the owner is not using during the period for which the transfer is proposed and which space is sufficient to convey the quantity of water proposed to be transferred.

1812. The state, regional, or local public agency owning the water conveyance facility shall in a timely manner determine the following:

(a) The amount and availability of unused capacity.

(b) The terms and conditions, including operation and maintenance requirements and scheduling, quality requirements, term or use, priorities, and fair compensation.

1813. In making the determinations required by this article, the respective public agency shall act in a reasonable manner consistent with the requirements of law to facilitate the voluntary sale, lease, or exchange of water and shall support its determinations by written findings. In any judicial action challenging any determination made under this article the court shall consider all relevant evidence, and the court shall give due consideration to the purposes and policies of this article. In any such case the court shall sustain the determination of the public agency if it finds that the determination is supported by substantial evidence.

1814. This article shall apply to only 70 percent of the unused capacity.

ferred water would originate because of potential third-party impacts. Mechanisms for evaluation and approval of water marketing arrangements have been developed, and will likely continue to evolve. For example, USBR developed guidelines for implementing sale of CVP water under CVPIA; the California Water Code directs the Department to facilitate voluntary exchanges and transfers of water; and 1992 changes to State law authorized water suppliers (local public agencies and private water companies) to contract with water users to reduce or eliminate water use for a specified period of time, and to sell the water to other water suppliers and users.

The ability to carry out marketing is dependent on conveyance provided by California's existing rivers, canals, and pipelines. Agencies planning to use long-term marketing arrangements as part of their core water supplies must have access to reliable conveyance for these supplies. The California Water Code requires that public agencies make available unused conveyance capacity if fair compensation is paid and other conditions are met (see sidebar). The CVP and SWP wheel water for marketing; only the SWP can convey water from the Central Valley to the highly urbanized South Coast Region. A long-term Delta fix is necessary for providing reliable conveyance of acquired supplies across the Delta. Actions that constrain agencies' abilities to con-

TABLE 6-6
Sample of Potential Water Purchases (taf)

	Average	*Drought*
Drought Water Bank	—	250
CVPIA Interim Water Acquisition Program	365	365
Zone 7 Water Agency	50	50
Alameda County Water District	15	25
Contra Costa Water District	50	40
Santa Clara Valley Water District	100	100
Westlands Water District	200	200
Metropolitan Water District of Southern California	—	300
San Diego County Water Authority	200	200
Total	**980**	**1,530**

vey water across the Delta limit their ability to enter into marketing arrangements.

As more agencies rely on water marketing to balance future demand and supply, and as several large-scale environmental restoration programs begin acquiring water for fishery and habitat purposes, competition for available water will increase. The availability of water for sale in marketing programs is inherently limited by the willingness of the existing water rights holders to participate in such programs. Table 6-6 shows a few larger marketing arrangements proposed in water agency planning documents to illustrate the magnitude of purchases being considered.

Water marketing depends on the availability of conveyance for the transferred water. For example, the East Branch of the California Aqueduct is the only inter-regional conveyance facility serving rapidly urbanizing areas in the southwestern corner of the Mojave Desert. Availability of aqueduct capacity would dictate the conditions under which transfers to this area could occur.

The following sections describe some specific water marketing proposals. Many local agencies may intend to buy water on the spot market as needed to respond to service area demands, but do not have agreements or defined programs in place at this time.

Drought Year Marketing

Marketing Involving SWP Facilities. The DWB program is a water purchasing and allocation program that allows the Department to purchase water from willing sellers and market the water to buyers under specific critical needs allocation guidelines. The DWB's EIR established the bank as a 5 to 10 year program. Chapter 3 describes past DWB activities. The quantities and prices of water made available in previous years through surplus reservoir releases, groundwater substitution, and land fallowing programs are summarized in Table 6-7. Past experience suggests that about 250 taf/yr could be allocated in the future through similar programs; this quantity is used for the future supplies associated with the DWB.

The Department had proposed a supplemental water purchase program to increase water supply reliability for SWP contractors. A draft programmatic EIR for the six-year program originally proposed transfer of up to 400 taf of water in drought years. The water would be purchased from willing sellers and provided to participating SWP contractors. After a number of public workshops, the Department reevaluated the program and eliminated its groundwater component. Without the groundwater component, the maximum supply available for transfer would have been 200 taf/yr. Additional public comments received on the draft PEIR raised issues that would need to be addressed

TABLE 6-7

Drought Water Bank Summary

Year	*Purchase Price ($/af)*	*Source of Drought Water Bank Water (taf)* Surplus Reservoir Storage	Groundwater Substitution	Fallowing	Total Sources	*Amount Allocated[a] (taf)*
1991	125	147	259	415	821	390
1992	50	32	161	0	193	159
1994	50	33	189	0	222	174

[a] Amount allocated for urban, agricultural, and environmental uses. This represents the actual supply developed by the bank after conveyance and fish and wildlife requirements were met.

in site-specific environmental documents. The Department withdrew the draft PEIR due to the difficulty of addressing site-specific concerns in a programmatic environmental analysis and after reevaluating the potential benefits of the program. The supplemental water purchase program is not considered as a future water management option in the Bulletin.

Semitropic Water Storage District has developed a groundwater storage program with a maximum storage capacity of 1 maf and maximum annual extraction of 223 taf. Under this program, a banking partner may contract with SWSD to deliver its SWP water or other water supplies to SWSD for in-lieu groundwater recharge. At the contractor's request, groundwater would be extracted and delivered to the California Aqueduct or would be pumped by SWSD farmers in exchange for SWP entitlement deliveries. Currently, MWDSC and SCVWD have long-term agreements with SWSD for 350 taf of storage for each district. ACWD has a similar agreement for 50 taf of storage, as does Z7WA for 43 taf. There is about 200 taf of capacity available for other banking partners and for increased commitments by existing partners. Participants are not restricted to SWP contractors, although access to the SWP's conveyance system is necessary. This program, discussed in more detail in Chapter 8, is considered a marketing arrangement in this Bulletin because of the possible exchange of SWSD's SWP entitlement for banked SWP water. The cost of recharging and extracting this water is about $175/af.

A similar marketing agreement has been reached by Arvin-Edison WSD and MWDSC for up to 350 taf of storage in Arvin-Edison's groundwater basin. About 60 taf would be withdrawn and delivered to MWDSC through the California Aqueduct in drought years at a cost of about $200/af, exclusive of delivery costs to member agencies.

Marketing Involving CVP Facilities. Historically, users of CVP water have made intra-district, and sometimes inter-district transfers of project supply. The 1992 enactment of CVPIA provided the authority to market project water outside of project boundaries to nonproject water users.

The San Luis & Delta-Mendota Water Authority, which represents 32 urban and agricultural water districts on the west side of the San Joaquin Valley and in San Benito and Santa Clara Counties, has developed an agreement that will help its members cope with water supply uncertainties. Under a three-way agreement between the authority, SCVWD, and USBR, participating member districts (shortage year providers) can receive some of SCVWD's federal water allocation in normal and above-normal water years in exchange for committing to make available a share of the shortage year provider's federal allocation during drought years. The agreement, which does not require any additional exports from the Delta, will be an internal reallocation of existing federal supplies to allow greater flexibility in meeting urban and agricultural water demands.

Specifically, SCVWD will provide 100 taf of water within a 10-year period for reallocation by USBR to shortage year providers. In exchange, shortage year providers will provide SCVWD with shortage year protection. The agreement directs USBR to reallocate drought year supplies (not to exceed an annual total of 14.3 taf) so that at least 97.5 taf is delivered to SCVWD in years when the CVP's urban water deliveries are 75 percent or less of contract entitlement. As part of the agreement, SCVWD will optimize its use of non-CVP water supplies, which will benefit all CVP irrigation water service contractors in the Delta export service area. Westlands Water District and San Luis Water District have already agreed to become shortage year providers; other authority members may also enter into the agreement over time.

CVPIA authorized marketing of project water outside the CVP service area, subject to numerous specified conditions, including a right of first refusal by existing CVP water users within the service area. As of this writing, no marketing arrangements have either been approved or implemented under this provision. One proposed transfer that had been discussed was between Arvin-Edison WSD and MWDSC.

Marketing Involving Colorado River Aqueduct. In its 1996 session, the Arizona Legislature enacted legislation establishing the Arizona Water Banking Authority. The Authority is authorized to purchase unused Colorado River water and to store it in groundwater basins to meet future needs. Conveyance to storage areas is provided by the Central Arizona Project. The legislation further provided that the Authority may enter into agreements with California and Nevada agencies to bank water in Arizona basins, with specific limitations. Under this legislation, future interstate banking in Arizona would have a maximum drought year yield of 100 taf. As described in Chapter 9, federal regulations to implement interstate banking are being promulgated.

As discussed and quantified in Chapters 7 and 9, a variety of arrangements are being examined as part of the development of CRB's draft 4.4 Plan. Land fallowing programs could be implemented to provide water for marketing to urban areas during drought periods, as demonstrated by one test program conducted in the Colorado River Region. In 1992, MWDSC began a two-year land fallowing test program with Palo Verde Irrigation District. Farmers in PVID fallowed about 20,000 acres of land. The saved water, about 93 taf/yr, was stored in Lake Mead for future use by MWDSC. (The water was subsequently released when flood control releases were made from Lake Mead). MWDSC paid each farmer $1,240 per fallowed acre, making the costs of the water to MWDSC about $135/af. It is expected that similar programs could be implemented in the future by agencies in the South Coast Region and Colorado River Region to provide about 100 taf during drought years.

Every Year Marketing

Permanent Sales. The Monterey Agreement provides that 130 taf of SWP agricultural entitlement be sold to urban contractors on a willing buyer-willing seller basis. Several sales of entitlement have already been implemented. KCWA permanently sold 25 taf/yr of entitlement to MWA and is in the process of finalizing the permanent sale of 7 taf/yr to Z7WA. KCWA is arranging sale of additional entitlement to Castaic Lake Water Agency. As with the SWP, marketing of contractual entitlements among CVP contractors is occurring. The CVP drought year reallocation agreement described above represents a new approach to marketing among project water users.

CVPIA Interim Water Acquisition Program. Sales of developed supplies for environmental purposes (where the transfer occurs as part of a willing buyer-willing seller arrangement, and not as the result of a regulatory action) are a relatively recent occurrence. Under the CVPIA supplemental water provisions, USBR established an interim water acquisition program that was in effect from October 1995 through February 1998. Water was acquired to meet near-term fishery and refuge water supply needs while long-term planning for supplemental water acquisition continued.

As provided in the program's environmental documentation, USBR could acquire up to 100 taf annually on each of the Stanislaus, Tuolumne, and Merced Rivers. Acquired water would be used for instream flows on the three rivers, and for flow and water quality improvements on the San Joaquin River. The specific quantities of water to be acquired each year and associated release patterns would depend upon projected flow conditions in the individual rivers, and projected flow and water quality conditions in the San Joaquin River at Vernalis. USBR would also acquire up to 13 taf of water annually from the Sacramento and Feather River Basins for Sacramento Valley wildlife refuges. Likewise, up to 52 taf would be purchased annually from willing sellers in the San Joaquin Valley for refuges there.

CVPIA AFRP Water Acquisition Program. USBR's 1997 draft PEIS analyzed four alternatives for long-term acquisition of fishery and refuge waters.

- Alternative 1. No water would be acquired to meet fish and wildlife targets.
- Alternative 2. AFRP water would be acquired annually from willing sellers on the Stanislaus (60 taf/yr), Tuolumne (60 taf/yr), and Merced Rivers (50 taf/yr) and on Upper Sacramento River tributary creeks that support spring-run salmon populations. Acquisition amounts on the tributary creeks were not quantified in the PEIS. Acquired water would be managed to meet target instream flows and would also be used to improve flows in the Delta. The acquired AFRP water could not be exported by the CVP or SWP.

Refuge water supply would be acquired to provide the incremental difference between Level 2 and Level 4 refuge supply requirements. Annual water acquisition in the Sacramento River, San Joaquin River, and Tulare Lake Regions would be about 30 taf, 80 taf, and 20 taf, respectively.

- Alternative 3. AFRP water would be acquired annually from willing sellers on the Yuba (100 taf/yr), Mokelumne (70 taf/yr), Calaveras (40 taf/yr), Stanislaus (200 taf/yr), Tuolumne (200 taf/yr), and Merced Rivers (200 taf/yr) and on Upper Sacramento River tributary creeks for in-stream flows. As in Alternative 2, acquisition amounts on the tributary creeks were not quantified in the PEIS. The acquired AFRP water would not be managed for increased flows through the Delta. Therefore, it could be exported if Order WR 95-6 conditions were met. Refuge water would be acquired to meet Level 4 requirements in the same quantities as described in Alternative 2.
- Alternative 4. AFRP water would be acquired annually for instream flow as under Alternative 3. Acquired water would be managed to meet target instream flows and to improve flows in the Delta. Therefore, the acquired water could not be exported by the CVP or SWP. Refuge water would be acquired for Level 4 water supplies in the same manner as described in Alternative 2.

To help put the magnitude of these amounts into perspective, the draft PEIS estimates a reduction of 142,000 acres of irrigated agricultural land would be needed to provide CVPIA water acquisitions under Alternative 4, entailing water acquisition costs of up to $120 million per year. Approximately 21,000 acres would be fallowed in the Sacramento River Region, 118,000 acres would be fallowed in the San Joaquin River Region, and 3,000 acres would be fallowed in the Tulare Lake Region. Since USBR has not yet identified a preferred alternative or specific proposals for transfers, Bulletin 160-98 does not include these CVPIA transfers in the water budgets. To the extent that the acquired water reduces demands by other water users, the water acquisition would have minimal net impact on the water budgets.

Colorado River Marketing Arrangements. Water agencies in the South Coast Region will continue to pursue programs to offset the reduction in existing supplies resulting from California reducing its use of Colorado River water. This subject is covered in detail in Chapter 9. MWDSC and IID have already implemented an agreement to transfer conserved water to urban users in the South Coast Region; a similar agreement was recently executed by SDCWA and IID. Both of these arrangements represent long-term transfers of core supplies. The next step in implementing the IID/SDCWA arrangement is preparation of environmental documentation. Once implemented, transferred amounts would increase over time (up to a 75-year term) to a maximum of 200 taf annually. In order to convey the acquired water, SDCWA negotiated a wheeling agreement with MWDSC for use of capacity in MWDSC's Colorado River Aqueduct.

Water Recycling and Desalting

Water Recycling

The Department, in cooperation with the WateReuse Association of California conducted a water recycling survey as described in Chapter 3. Table 6-8 shows 2020 base level of water recycling and potential future options. These options represent potential maximum levels of recycling. Not all options are expected to be implemented, due to economic and other considerations.

New water supply would be generated by water recycling where the outflow of water treatment plants would otherwise enter a salt sink or the Pacific Ocean. In the Central Valley and other inland communities, outflow from wastewater treatment plants is discharged

TABLE 6-8

2020 Level Water Recycling Options and Resulting New Water Supply (taf)

Projects	*Total Water Recycling*	*New Water Supply*
Base	577	407
Potential options	835	655
Total	**1,412**	**1,062**

TABLE 6-9
Potential 2020 Water Recycling Options by Hydrologic Region (taf)

	Total Water Recycling	*New Water Supply*
North Coast	15	0
San Francisco Bay	101	91
Central Coast	39	37
South Coast	639	527
Sacramento River	6	0
San Joaquin River	7	0
Tulare Lake	25	0
North Lahontan	0	0
South Lahontan	3	0
Colorado River	0	0
Total	**835**	**655**

into streams and groundwater basins and is generally reapplied. Recycling of such outflow would not generate new water supplies. All new recycled water is expected to be produced in coastal regions—the San Francisco Bay, Central Coast, and South Coast regions.

Water agencies in the South Coast Region are concerned that the lack of future high-quality water for blending supplies, or the cost of desalting recycled water, could affect implementation of future water recycling facilities. Due to extensive use of Colorado River water and groundwater supplies that are relatively high in TDS, salt management is an important consideration in marketing recycled water in the region. Salt management options include blending Colorado River water and groundwater supplies with other sources such as SWP water, or treating (i.e., desalting) the recycled water to reduce its salt content. MWDSC and its member agencies and USBR are cooperating in a salinity management study. The study's initial phase focuses on identifying problems and salinity management needs of MWDSC's service area. This study is discussed in Chapter 7.

Table 6-9 shows potential water recycling options by hydrologic region. Two major water recycling programs being planned are the Bay Area regional water recycling program and the Southern California comprehensive water reclamation and reuse study, discussed in detail in Chapter 7.

Desalting

Today, California has more than 150 desalting plants providing fresh water for municipal, industrial, power, and other uses. The freshwater capacity of these plants totals about 66 taf annually, a 100 percent increase since 1990. Common feedwater sources for desalting plants include brackish groundwater, municipal and industrial wastewater, and seawater. Groundwater recovery currently makes up the majority of desalting plant capacity, 45 taf/yr. Wastewater desalting accounts for 13 taf/yr and seawater desalting accounts for 8 taf/yr of total capacity.

Groundwater recovery and wastewater recycling will be the primary uses of desalting in California in the foreseeable future. (The use of desalting in wastewater treatment plants is part of water recycling and is included in the water recycling section.) Improvements in membrane technology will spur considerable growth in these areas, as discussed in Chapter 5. Seawater desalting is expected to grow very slowly.

Groundwater Recovery. High TDS and nitrate levels are common groundwater quality problems. Groundwater recovery programs can be designed to treat mineralized groundwater or groundwater with nitrate contamination, as shown in the examples given in Chapter 5. Currently, most groundwater recovery programs under consideration are located in the South Coast Region (excluding groundwater recovery solely to remediate contamination at hazardous waste sites). Some of the polluted water must be treated and some can be blended with better quality water to meet water quality standards. The potential annual contribution of groundwater recovery by year 2020 is about 110 taf, with 95 taf in the South Coast Region. Options are discussed in the regional chapters.

Seawater Desalting as a Future Water Management Option

Seawater desalting was often viewed with optimism as a future water management option for California in the 1950s and 1960s, because of the proximity of the State's major urban areas to the Pacific Ocean. Most planning efforts then were focused on studies and small-scale or pilot plant demonstration projects. Seawater desalting is expected to have only limited application during the Bulletin 160-98 planning horizon, largely due to its costs. The excerpt below, taken from a 1965 USGS report entitled *Natural Resources of California*, describes an early demonstration project. (A 1 mgd plant, operated continuously, would provide 1.1 taf per year.)

California is cooperating with the Federal Government in a saline water conversion program. The Department of the Interior and the State jointly financed the building of a saline water conversion plant in San Diego on a site donated by the city. Capable of producing 1 million gallons of water a day, it was operated for 2 years before being dismantled in March of 1964 and shipped to Cuba to serve Guantanamo Naval Base there. It is being replaced by a joint effort of the Department [of Interior] and the California Water Resources Board. The State and the Federal Government are also cooperating in the development of a multi-million-gallon saline water conversion plant.

Seawater Desalting. The major limitation to seawater desalting has been its high cost, much of which is directly related to high energy requirements. Seawater desalting costs typically range from $1,000 to $2,000/af depending in part on the extent to which existing infrastructure, such as brine disposal facilities, is present. With few exceptions, its costs are greater than costs of obtaining water from other sources. However, seawater desalting can be a feasible option for coastal communities that are not connected to statewide water distribution infrastructure and have limited water supplies. Because of such circumstances, seawater desalting plants have been constructed in the Cities of Avalon, Santa Barbara, and Morro Bay. Seawater desalting plants can be designed to operate only during drought to improve water supply reliability, as is the case for Santa Barbara's desalter.

During the 1987-92 drought, plans to install and operate several seawater desalting plants were under consideration in the Central Coast and South Coast Regions, including plans for several large distillation plants using waste heat from existing thermal power plants in the South Coast Region. The total potential of the proposed plants was about 123 taf /yr. With the return to average water supply years, most of these plans have been put on hold. Currently, seawater desalting is most favorable as a drought year option. If desalting costs are substantially reduced in the future, plant capacity which is surplus to the plant owners in wetter water years could be used to produce water for conjunctive use or marketing programs.

MWDSC's research distillation plant is the only large non-reverse osmosis facility now under study. MWDSC, in cooperation with the federal government and the Israel Science and Technology Foundation, is completing final design of a 12.6 mgd demonstration desalting plant to evaluate a future full scale 60 to 80 mgd seawater desalting plant. The technology is based on a multiple-effect distillation process which uses heat energy from an adjacent powerplant. The

Mission Basin Brackish Groundwater Desalting Research and Development Project

The Mission Basin groundwater desalting project is an example of the type of desalting projects likely to occur within the Bulletin's planning horizon.

The City of Oceanside owns and operates the Mission Basin Groundwater Desalting Facility. Under current operations, about 2.1 taf/yr of demineralized groundwater supply is produced from treating brackish groundwater through a reverse osmosis process. Because of the plant's successful operation over the past three years, the city plans to expand its production capacity to 7.1 taf/yr, 22 percent of the city's average annual demand. The cost of the expansion is estimated to be $9.0 million. The additional water supply is expected to be available in year 2000.

The Mission Basin aquifer holds about 92 taf of water. The city anticipates that at least half of its future water supply can ultimately be derived from this source. Expansion of the Mission Basin Desalting Facility has several important benefits. It would provide the city with a local source in the event of a natural disaster, such as an earthquake. In addition to reducing the city's reliance on imported water, the quality of water produced at the desalting facility is better than that of the city's imported source (TDS concentration of 400-500 mg/L versus 600-700 mg/L for imported water).

goal is to demonstrate that the multiple-effect distillation process can produce desalted seawater at a cost of less than $1,000/af. If successful, a full scale plant could produce about 85 taf/yr.

Weather Modification

Weather modification (cloud seeding) has been practiced in California for years. Most projects have been located on the western slopes of the Sierra Nevada and in parts of the Coast Range. Before the 1987-92 drought, there were about 10 to 12 weather modification projects operating, with activity increasing during dry years. During the drought the number of projects operating in California had increased to 20. Some projects were subsequently dropped and others suspended operations after the drought ended.

Operators engaged in cloud seeding have found it beneficial to seed rain bands along the coast and orographic clouds over the mountains. The projects are operated to increase water supply or hydroelectric power generation. Although the amounts of water produced are difficult and expensive to determine, estimates range from a 2 to 15 percent increase in annual precipitation, depending on the number and type of storms seeded.

The Department, on behalf of the SWP, planned a five-year demonstration program of cloud seeding in the upper Middle Fork Feather River Basin, beginning in the 1991-92 season. The program was to test the use of liquid propane injected into clouds from generators on a mountain top. The test program was terminated after three years due to institutional difficulties.

A 1993 USBR feasibility study for a cloud seeding program in the watersheds above Shasta and Trinity Dams indicated potential for the Trinity River Basin, but cast doubt on the effectiveness of a project for Shasta Lake. USBR had proposed a cloud seeding demonstration program in the upper Colorado River Basin, but the demonstration program was opposed by the State of Colorado. Presently, USBR is phasing out its participation in weather modification projects.

Cloud seeding is more successful in near-normal water years, when moisture in the form of storm clouds is present to be treated. It is also more effective when combined with carryover storage to take full advantage of additional precipitation and runoff. Institutional issues associated with cloud seeding programs include claims from third-parties who allege damage from flooding or high water caused by the cloud seeding program. Because of the many legal and institutional difficulties surrounding third-party impacts, new cloud seeding projects are deferred from further consideration in this Bulletin.

Monterey County Water Resources Agency's Cloud Seeding Program

MCWRA initiated a cloud seeding program in 1990 to alleviate impacts of the drought and has continued the program as a cost-effective way to augment water supplies. MCWRA's program costs were less than $10/af. In addition to airborne seeding, an experimental ground based propane dispenser was installed for rainfall enhancement in 1991. The program was designed to increase rainfall and runoff in the watersheds of Arroyo Seco (a small undammed tributary of the Salinas River) and San Antonio and Nacimiento Reservoirs.

Monterey County relies solely on groundwater and local surface supplies, and faces chronic groundwater overdraft and seawater intrusion. The area's semiarid, Mediterranean-style climate provides only marginally sufficient rainfall during average years to sustain reservoir releases for aquifer recharge during the summer months. Furthermore, the occurrence interval and typical productivity of weather systems passing over the central coast are such that soil mass only reaches saturation near the end of the rain event, and the weather system moves on prior to the occurrence of substantial runoff. Cloud seeding, in most cases, provides additional rainfall that converts directly into runoff.

The typical interval for cloud seeding in Monterey County is from early November through the end of March. The primary target area is the 650 square miles of combined watershed above Nacimiento and San Antonio Reservoirs. To the north, the Arroyo Seco watershed is a secondary target area. Seeding flights in the early part of the water year cover the entire area, affecting the reservoir drainage areas and Arroyo Seco. This early seeding provides additional runoff to the reservoir system as well as added groundwater recharge in the Arroyo Seco drainage area. Later in the water year when Arroyo Seco flows have reached the confluence with the Salinas River, flights are rerouted to concentrate the seeding effect on the reservoirs.

The five-year program has experienced varying degrees of success in terms of providing additional water supply. Usually the wetter the storms, the greater the moisture available for conversion to precipitation and the more productive the seeding. Overall, evaluations show that rainfall increased about twenty percent above normal for the five-year study period. According to MCWRA, no known adverse environmental effects have occurred as a result of the project.

Other Supply Augmentation Options

This section discusses several other methods to augment water supplies. These options are conceptual, or have not yet been widely practiced. Hence, they are deferred from further evaluation in this Bulletin.

Importing Water from Out of State

Constructing an undersea pipeline, towing water in giant nylon bags, shipping water by tanker, and towing icebergs have all been suggested to help augment California's water supply by importing water from out of state.

The idea of constructing an undersea pipeline to carry fresh water from Alaska to California was studied three decades ago and was last revisited in 1991. As proposed, a 2,600 mile-long suboceanic pipeline would be constructed along the coastline. The pipeline would be sized to carry about 3 maf/yr of Alaskan water from the Stikine and/or Copper Rivers, and would terminate either at Shasta Lake or in Southern California. A preliminary study estimated that the project would cost between $110 and $150 billion and take at least 15 years to complete. A feasibility study by the Congressional Office of Technology Assessment concluded that huge costs and unanswered engineering problems made the idea of building an undersea pipeline unrealistic.

A proposal to fill giant floating nylon bags with water and tow them from Alaska to California had been suggested in the past. During the height of the most recent California drought, a California company sought investors to finance a test run. The water would be filtered, chlorinated, and then loaded into floating bags (the bags float because fresh water is lighter than salt water). An ocean-going tugboat would tow the bags (each holding about 220 af) along the coast. This proposal did not go forward. In 1996, a privately developed water bag delivery system was tested on a pilot scale when two bags of 2.4 af each were towed from Port Angeles, Washington, to Seattle. Some problems emerged in the test run. If implemented at a full scale, costs associated with this option would include towing, constructing, operating, and maintaining the loading/unloading docks and pumps to transfer the bagged water ashore to local treatment and distribution systems.

Shipping water by tankers appears to be the most feasible of the water importation options suggested. Marine transport is a proven alternative to land-based pipelines in the oil industry. A Canadian company is now arranging to ship water to China via tankers. The company was granted Alaska's first water-export permit in 1996. When shipping facilities and a bottling plant are built, the company will begin shipping 390 af/yr of Alaskan water to China using tankers, retrofitted to food grade cargo. The water is to be bottled in a plant to be built by the company and the Chinese government. The City of San Diego is considering a marine transport demonstration project, where a private company would transport up to 20 taf/yr of water from British Columbia to the City of San Diego using tankers. The demonstration project, if implemented, could provide cost and technical data on bulk tanker shipping of water. The U.S. Ocean Pollution Act of 1990, which required phasing out single-hulled oil tankers, presented an opportunity to make tankers available for conversion into bulk water carriers at reduced costs. Tanker haulage could provide a flexible delivery system for emergency supply of water for coastal areas in the event of earthquakes or droughts.

Gray Water

Some residential wastewater can be directly reused by homeowners as gray water. Gray water can be used in subsurface systems to irrigate lawns, fruit trees, ornamental trees, and shrubs and flowers (in finite amounts, depending on the plant types being irrigated). Water from the bathroom sink, washing machine, bathtub, or shower is generally safe to reuse. Care must be taken so that people and pets do not come in contact with gray water. Food irrigated by gray water subsurface systems should be rinsed and cooked before being eaten.

Gray water has been used by some homeowners in coastal urban areas during extreme drought to save their landscaping. In the past, health concerns and lack of information limited use of gray water. In 1992, the Legislature amended the Water Code to allow gray water systems in residential buildings subject to appropriate standards and with the approval of local jurisdictions. There appears to be limited interest in exploring gray water as an option beyond listing its use as a potential urban BMP.

Watershed Management on National Forest Lands

National forest lands provide about half of the State's runoff. A Department study of vegetation management found that thinning trees and shrubs from 33,000 acres of foothill watershed above Lake Oroville might increase average annual runoff by 2.5 taf. USFS estimates that if national forest management as practiced during the 1980s had been practiced earlier, the average annual runoff from national forests would have been increased by about 360 taf (an increase of about 1 percent). Without new storage facilities, only a fraction of this amount would contribute to water supply.

Forest management proposals prepared on behalf of the biomass power industry call for removing excess dead material and invasive species from the forest understory and thinning of the trees themselves. Tree thinning would produce fuel for the biomass power industry. These proposals attempt to return forests to their pre-fire exclusion condition, achieving wildfire reduction and wildlife and water supply benefits. From a water supply perspective, extensive areas of land would have to be managed to increase statewide water supplies. The maximum rate of forest evapotranspiration is reached at about 65 percent tree and shrub cover density. To achieve water savings, it would be necessary to thin trees and shrubs to reduce cover to less than 65 percent, requiring detailed evaluation of potential environmental impacts. Watershed management would require ongoing treatment of forest vegetation to prevent loss of water yield due to regrowth of trees and shrubs.

Currently, no local water agencies are actively pursuing forest management as a component of their future supply. The potential environmental impacts and institutional difficulties of establishing a forest management program suggest that it would be carried out as part of a multipurpose program whose main objectives would be timber management or fire suppression rather than water supply.

Long-Range Weather Forecasting

Accurate advance weather information—extending weeks, months, and even seasons ahead—would be invaluable for planning all types of water operations. Had it been known, for instance, that 1976 and 1977 were going to be extremely dry years, or that the drought would end in 1977, water operations could have been planned somewhat differently and the impacts of the drought could have been lessened. The response to the 1987-92 drought could have been modified to store more water in the winter of 1986-87 and to use more of the remaining reserves in 1992, the last year of the drought.

The potential benefits of dependable long-range weather forecasts could be calculated in hundreds of millions of dollars, and their value would be national. Hence, research programs to investigate and develop forecasting capability would most appropriately be conducted at the national level. The National Weather Service routinely issues 30 and 90 day forecasts; the Scripps Institution of Oceanography in San Diego (until recently) and Creighton University in Omaha, Nebraska, make experimental forecasts. The predictions have not been sufficiently reliable for water project operation. Predictions may be improved by research on global weather patterns, including the El Niño Southern Oscillation in the eastern Pacific Ocean.

Summary of Statewide Supply Augmentation Options

The preceding sections evaluated statewide water management options, including demand reduction measures and large-scale water supply augmentation measures that would provide supply to multiple beneficiaries. Demand reduction and water recycling options are shown in the regional option tabulations in Chapters 7–9, since these options would be implemented by individual local agencies in their service areas. Table 6-10 summarizes options likely to be implemented by 2020 to meet statewide needs. Because these statewide options would provide new water, the opportunity exists for the options' effectiveness to be multiplied through regional reapplication. Therefore, the options would provide regional applied water gains that are greater than the gains shown in Table 6-10.

CALFED

Statewide options include actions that could be taken by CALFED to develop new water supplies. The water supply yield shown for the CALFED Bay-Delta program's preferred alternative is necessarily a placeholder, as a final program environmental document for the Bay-Delta solution has not been completed. The CALFED placeholder does not address specifics of which upstream of Delta storage facilities might be selected, or how conjunctive use programs might be operated. The placeholder assumes dual Delta conveyance (Alternative 3) and approximately 3 maf of storage facilities, with 1 maf of this storage dedicated for environmental uses. Project yield and operating criteria were defined by a DWRSIM operations study. The CALFED placeholder used for Bulletin 160-98 quantification of potential CALFED new water supply does not include water use efficiency measures proposed in a technical appendix to CALFED's March 1998 draft

TABLE 6-10

Statewide Supply Augmentation Options Likely to be Implemented by 2020[a]

Options	*Potential Gain (taf)*	
	Average	*Drought*
CALFED Bay-Delta Program	100	175
SWP Improvements		
Interim South Delta Program	125	100
Conjunctive Use Programs	—	55
Water Marketing (Drought Water Bank)	—	250
Multipurpose Reservoir Projects		
Auburn Dam	620	370
Friant Dam Enlargement	90	0
Total	**935**	**950**

[a] Demand reduction options are shown in the regional option tabulations in Chapters 7–9. Demand reduction options would be implemented by individual local agencies in their service areas.

PEIS/PEIR, because the CALFED operations studies used to quantify program water supply benefits did not incorporate those demand reductions.

Other Statewide Options

Other likely statewide options include specific projects to improve SWP water supply reliability, water marketing through the Department's DWB, and two multipurpose reservoirs. A third potential multipurpose reservoir option, an enlarged Shasta Lake, was not included as a likely option because further studies are needed to quantify the water supply and flood control benefits associated with different potential reservoir sizes. Preliminary studies suggest that a 9 maf enlargement of Shasta Lake would yield 760 taf in average years and 940 taf in drought years. Additional evaluation of this option is recommended.

The two multipurpose reservoir projects included as statewide options – Auburn Reservoir and enlarged Millerton Lake (Friant Dam)—were included as likely options to recognize the interrelationship between water supply needs and the Central Valley's flood protection needs. It is recognized that both projects may have controversial aspects and that neither of them is inexpensive. However, both projects offer enough benefits to justify serious consideration. The lead time for planning and implementing any large reservoir project is long, and it would take almost to this Bulletin's 2020 planning horizon for the projects to be constructed.

The identity of the specific entity(ies) that might implement the two multipurpose reservoir projects is uncertain. USBR, as the owner of the existing Friant Dam and as the federal agency having authorization for operating Auburn, would presumably be a participant. The implementing entity could be a partnership of some combination of federal/State/local agencies.

Allocating Options Yield Among Hydrologic Regions

In Tables 6-11 and 6-12, yields from likely statewide supply augmentation options were allocated among potentially participating hydrologic regions to illustrate how the supplies might be used. Potential supply from a Friant Dam enlargement was shown as remaining in the San Joaquin River and Tulare Lake Regions, where existing Friant supplies are used. For Auburn Dam and CALFED, supply was divided among hydrologic regions served by CVP and SWP facilities. Auburn could also provide supplies for foothill communities that are too small to develop projects on their own, as discussed in Chapter 8. (In neither option is it assumed that the CVP or SWP would contract for the supply—only that conveyance facilities exist to make the water available to potential users.) The Bulletin makes no attempt to allocate costs of these projects between flood protection and water supply.

Uncertainties in the Bulletin Planning Process

Planning about the future is subject to uncertainty. In response to public comments, this section briefly analyzes the effects of some uncertainties on the shortage forecasts and potential options presented in Bulletin 160-98.

Water use forecasts rely on assumptions about population growth, urban per-capita water use, land use and

TABLE 6-11

Likely Statewide Supply Augmentation Options by Hydrologic Region
2020 Average Year (taf)

Region	*CALFED*	*ISDP*[a]	*Conjunctive Use*[a,b]	*DWB*[b]	*Auburn Dam*	*Friant Dam*	*Total*
North Coast	—	—	—	—	—	—	—
San Francisco Bay	—	8	—	—	—	—	8
Central Coast	2	1	—	—	2	—	5
South Coast	15	68	—	—	67	—	150
Sacramento River	—	—	—	—	85	—	85
San Joaquin River	—	—	—	—	—	39	39
Tulare Lake	70	35	—	—	310	51	466
North Lahontan	—	—	—	—	—	—	—
South Lahontan	12	10	—	—	152	—	174
Colorado River	1	3	—	—	4	—	8
Total	**100**	**125**	**—**	**—**	**620**	**90**	**935**

[a] SWP Improvements

[b] The options provide only drought year supplies

cropping patterns, and environmental water requirements. Environmental water requirements are the most difficult to forecast, as they are driven by regulatory and legislative processes. Implementation of CVPIA and SWRCB's Bay-Delta Plan, new ESA restrictions, and FERC relicensing/electric utility deregulation are actions that could significantly modify forecasted environmental demands with the Bulletin 160-98 planning period.

In addition to forecasting water demand components, the Bulletin must also characterize future water management options. The CALFED Bay-Delta program and the draft CRB 4.4 Plan are still in development. These programs have been represented by placeholder throughout the Bulletin. Even if final decisions on the programs were made in the near future, both are long-term programs that will be implemented in phases; some phases may extend beyond this Bulletin's planning horizon.

To illustrate the effects of uncertainties on the Bulletin's water budgets, maximum and minimum applied water shortages associated with potential implementation of SWRCB's Bay-Delta water rights proceeding and CALFED are shown in Table 6-13. For comparison, the Bulletin's forecasted 2020 applied water shortages are 2.4 maf in average years and 6.2 af in drought years with existing facilities and programs. As discussed in earlier chapters, there are no data available at this time to quantify site-specific impacts of new ESA listings, FERC relicensing, and electric utility deregulation.

TABLE 6-12

Likely Statewide Supply Augmentation Options by Hydrologic Region
2020 Drought Year (taf)

Region	*CALFED*	*ISDP*[a]	*Conjunctive Use*[a]	*DWB*	*Auburn Dam*	*Friant Dam*	*Total*
North Coast	—	—	—	—	—	—	—
San Francisco Bay	—	7	18	75	—	—	100
Central Coast	4	1	—	51	1	—	57
South Coast	26	54	22	3	39	—	144
Sacramento River	—	—	—	—	51	—	51
San Joaquin River	—	—	—	—	—	—	—
Tulare Lake	123	28	—	51	185	—	387
North Lahontan	—	—	—	—	—	—	—
South Lahontan	21	7	15	70	91	—	204
Colorado River	1	3	—	—	3	—	7
Total	**175**	**100**	**55**	**250**	**370**	**—**	**950**

[a] SWP Improvements

Several large-scale environmental restoration programs are just beginning. These programs may entail significant acquisition of agricultural land and its conversion to habitat uses, as well as extensive water acquisition for environmental purposes. It is too soon to be able to quantify their water use impacts; these are among the uncertainties that must be resolved over time.

Bulletin 160-98 assumes SWRCB's Order WR 95-6 as the prevailing Bay-Delta standard, with the CVP and SWP meeting the standards under the terms of the Bay-Delta Accord. The alternatives contained in SWRCB's draft EIR for the water rights proceeding would broaden the responsibility for meeting standards to include additional Central Valley water users. Doing so can entail different flow regimes in Valley and Delta waterways, resulting in changes in water supplies. To capture the effects of uncertainties of SWRCB's water rights proceeding, flow Alternative 5 in SWRCB's draft EIR was used to determine the maximum shortage; flow Alternative 6 was used to compute the minimum shortage. Under flow Alternative 5, Bay-Delta standards would be met through monthly average flow requirements established for each of the major watersheds tributary to the Delta. Under flow Alternative 6, Bay-Delta standards would be met solely by operation of the CVP and SWP. Flow objectives at Vernalis on the San Joaquin River would be met by the CVP through releases from the Delta-Mendota Canal via the Newman Waterway into the San Joaquin River.

Implementation of any of the future water management options discussed in the Bulletin would be subject to completing appropriate environmental documentation and obtaining the required permits and approvals, including compliance with ESA requirements. The Tipton Kangaroo rat, listed as endangered under both ESA and CESA, is an example of a listed species found in parts of the San Joaquin Valley where groundwater conjunctive use projects might be planned.

TABLE 6-13

Effects of Alternative Assumptions on 2020 Applied Water Shortages (taf)

	Applied Water Shortage Range	
Region	***Average***	***Drought***
North Coast	0	194
San Francisco Bay	0-13	276-295
Central Coast	172-176	270-276
South Coast	944-1,053	1,270-1,441
Sacramento River	0-85	739-989
San Joaquin River	63-122	711-769
Tulare Lake	264-1,027	1,619-2,071
North Lahontan	10	128
South Lahontan	270-285	303-325
Colorado River	147-149	157-162
Total (rounded)	**1,870-2,920**	**5,670-6,650**

For CALFED implementation, the Bulletin's placeholder assumes dual Delta conveyance (Alternative 3) and approximately 3 maf of surface water storage facilities. Project yield and operating criteria were defined by an operations study which assumed that 1 maf of new storage would be operated to meet CALFED's ecosystem restoration program targets. The maximum shortage condition results from assuming that no new water supply is provided by CALFED (no storage facilities are constructed). The minimum shortage results from assuming approximately 6 maf of surface and groundwater storage. (CALFED's assumption for this scenario is that 1.25 maf of new storage would be operated to meet ERP targets.)

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Options for Future Environmental Habitat Enhancement

A number of programs designed to restore and/or enhance environmental resources are in various stages of implementation. These programs vary in scope, geographic region, and objective. Some of these programs provide environmental water supplies; others involve structural measures, such as placing spawning gravel or constructing fish screens. Some of these programs are legislatively driven; others have resulted from collaborative efforts among stakeholders. Table 6-14 illustrates the emphasis now being placed on environmental restoration actions, by identifying a variety of funding sources available for fishery-related environmental restoration actions.

This section identifies and describes programs expected to provide future environmental benefits. This section covers a representative sample, and is not meant to be a comprehensive listing of all possibilities statewide.

Central Valley Project Improvement Act

Some CVPIA environmental restoration actions, such as water acquisition and fish screening, are applicable to the entire Central Valley. Site-specific projects, such as construction of the Shasta Dam TCD, are described in Chapters 7–9.

The May 1997 draft Anadromous Fish Restoration Plan proposed habitat restoration actions such as spawning gravel placement and stream channel restoration, acquisition of land for wildlife habitat, construction of fish screens and facilities to improve passage of migrating anadromous fish, and development of plans to prevent habitat degradation due to sedimentation and urbanization. The plan also included target instream flows for rivers and streams in the Central Valley and the Delta. The three tools available for USBR to meet these flow objectives are reoperation of the CVP, dedication and management of 800 taf of CVP yield annually, and water acquisition. Water acquisition efforts were described in the water marketing section of this chapter. Tools available to meet CVPIA's broad goal of doubling anadromous fish populations in the Central Valley include the many physical habitat restoration actions specified in the act, as well as substantial funding from the CVPIA Restoration Fund and from general congressional appropriations.

USBR and USFWS have contributed funding for local agency and privately owned fish screen installation projects and planning studies as part of the anadromous fish screening program. About 20 grants have been executed to date for screening projects and feasibility studies of screening alternatives. Examples of completed and pending projects are described in Chapter 5. USBR and USFWS have completed two spawning gravel replenishment projects on the Sacramento River below Keswick Dam. Additional projects are being planned for the other rivers authorized in the act. The gravel replenishment actions are analo-

Restoring and enhancing riparian habitat helps sustain healthy populations of the species that rely on this habitat. Beavers are an example of a species dependent on riparian habitat.

TABLE 6-14

Environmental Restoration Funding

Program and Responsible Agencies	*Projects/Program Funded Selection Criteria*	*Authorizing Legislation or Agreement*	*Funding Source*	*Funding Allocation*
Program: CVPIA Anadromous Fish Restoration Program **Responsible Agencies:** USBR and USFWS	**Projects/Program Funded:** This program funds environmental restoration actions contributing to the goal of doubling natural production of anadromous fish in Central Valley rivers and streams. The program gives first priority to measures which protect and restore natural channel and riparian habitat values through habitat restoration actions; augment river and stream flows; and implement supporting measures mandated by CVPIA Section 3406(b). **Selection Criteria:** None specified in statute.	CVPIA	Congressional appropriations from CVPIA Restoration Fund and Energy and Water Development Fund	Varies (actual expenditures: federal FY 1995, $0.8 million; FY 1996 $1.4 million)
Program: CVPIA (State cost-sharing program) **Responsible Agencies:** DWR and DFG, in coordination with USBR and USFWS	**Projects/Program Funded:** This program funds environmental restoration projects with mandatory State cost-sharing under CVPIA Section 3406. Projects include the Shasta Dam temperature control device, Red Bluff Diversion Dam fish passage actions, spawning gravel restoration projects, and fish screens. **Selection Criteria:** Projects must be capital outlay actions with mandatory State cost-sharing under CVPIA. California and the United States have executed a master cost-sharing agreement covering crediting and transferring funds for the restoration actions.	CVPIA Proposition 204 1994 State-federal cost-sharing agreement	General obligation bonds	$93 million
Program: Category III Program **Responsible Agencies:** CALFED agencies	**Projects/Programs Funded:** Nonflow related projects to protect and improve Bay-Delta ecological resources. **Selection Criteria:** Selection is based on RFP process.	Bay-Delta Accord	Proposition 204, local water agency contributions, congressional appropriations	Proposition 204 provided $60 million for State contribution.

TABLE 6-14

Environmental Restoration Funding (continued)

Program and Responsible Agencies	*Projects/Program Funded Selection Criteria*	*Authorizing Legislation or Agreement*	*Funding Source*	*Funding Allocation*
Program: CALFED Ecosystem Restoration Program **Responsible Agencies:** CALFED agencies	**Projects/Program Funded:** To be determined, but could include fish screens, spawning gravel restoration projects, and riparian habitat enhancement projects. The funds are not available until an EIR/EIS and a State-federal cost-sharing agreement are completed. **Selection Criteria:** To be determined.	Proposition 204	General obligation bonds	$390 million
Program: Delta Pumping Plant Fish Protection Agreement (Four-Pumps Agreement) **Responsible Agencies:** DWR and DFG	**Projects/Program Funded:** Fish screens, rearing striped bass, gravel restoration projects, hatchery and other actions to benefit aquatic resources, particularly salmon and striped bass. Geographic scope includes the Central Valley and the Delta. **Selection Criteria:** Actions that benefit aquatic resources, particularly chinook salmon, steelhead, and striped bass. Priority will be given to measures on the San Joaquin River system. The Department and DFG staff review project proposals and submit them to an advisory committee composed of representatives from SWP contractors and the environmental and fishing communities. Recommendations are presented to the directors of the Department and DFG for approval.	Agreement between the Department and DFG to offset direct fish losses in relation to Banks Pumping Plant, dated December 1986	SWP funds administered by the Department	$15 million for fish population recovery program, and additional annual funding to compensate for annual fish losses caused by the Banks Pumping Plant[a]
Program: Tracy Fish Agreement **Responsible Agencies:** USBR and DFG	**Projects/Program Funded:** This agreement between DFG and USBR implements measures to reduce, offset, or replace direct losses of chinook salmon and striped bass in the Delta as a result of Tracy Pumping Plant diversions. **Selection Criteria:** A committee composed of representatives from USBR, DFG, and USFWS screens project proposals. Projects are funded upon recommendation by DFG Director to USBR.	Tracy Fish Agreement between USBR and DFG, dated June 1992	Congressional appropriations for operations and maintenance of CVP, administered by USBR	Approximately $1 million per year. USBR has provided funding totaling $6.5 million during 1992-97

TABLE 6-14

Environmental Restoration Funding (continued)

Program and Responsible Agencies	*Projects/Program Funded Selection Criteria*	*Authorizing Legislation or Agreement*	*Funding Source*	*Funding Allocation*
Program: Commercial Salmon Stamp Account **Responsible Agency:** DFG	**Projects/Program Funded:** Projects to restore salmon populations through habitat restoration and breeding, and projects which provide public education on the importance and biology of salmon. Examples of eligible restoration projects include spawning gravel restoration, bank stabilization, riparian revegetation, fish passage improvement, installation of fish ladders and screens, and short-term salmon breeding. **Selection Criteria:** Projects are evaluated based on benefits to fishery resources, need for work in a particular watershed for target species, and project costs. Project proposals are evaluated and prioritized first by DFG. Projects for salmon habitat restoration and breeding are sent to the Commercial Salmon Trollers Advisory Committee. There are two subaccounts in the program—a commercial salmon stamp dedicated account, and an augmented salmon stamp dedicated account. The commercial salmon stamp dedicated account is statutorily directed to salmon breeding. Expenditures from the other account must meet the recommendations of the advisory committee. Final funding decision is by the Director of DFG.	Fish and Game Code Sections 7860-7863 that impose a stamp fee on commercial salmon fishers, as well as commercial passenger salmon fishing vessel operators	Annual stamp fee which ranges from $85 to $260 depending on salmon landing	Total annual revenue varies from $340,000 to just over $1 million.
Program: California Wildlife, Coastal and Park Land Conservation Initiative (Proposition 70) **Responsible Agency:** DFG	**Projects/Program Funded:** Projects to restore and enhance salmon streams, and wild trout and native steelhead habitat. **Selection Criteria:** Similar to salmon stamp program. Project proposals are initially reviewed by DFG and then sent to the Commercial Salmon Trollers Advisory Committee and to the Proposition 70 subcommittee (a six-member group representing the Commercial Salmon Trollers Advisory Committee and the California Advisory Committee on Salmon and Steelhead Trout) for funding consideration. Final approval for funding is by the Director of DFG.	Proposition 70 of 1988[b]	General obligation bonds	see footnote

[a] Generally, the $15 million funds projects with long-term benefits to fish, while the annual account funds projects to replace fish lost annually at the pumping plant. By 1996, the Department had allocated all of the $15 million and had spent about $6 million in annual mitigation projects.

[b] State FY 1997-98 was the last year of funding under Proposition 70. DFG received $10 million to restore and enhance salmon streams, and $6 million to restore and enhance wild trout and native steelhead habitat and related projects.

gous to an operations and maintenance program, where work would be done periodically on river segments identified as needing more gravel. A monitoring program would be required, both to identify areas that are gravel-limited and to evaluate the effectiveness of the gravel provided.

Category III Program

The Category III funding program was established as part of the 1994 Bay-Delta Accord to address non-flow factors affecting the health of the Bay-Delta ecosystem. A steering committee of agricultural, urban, and environmental stakeholders administered the project selection process

TABLE 6-15

Sample Projects Funded by Category III Program

Project / Program	*Proponent*	*Category III Funds*
Battle Creek Restoration	DFG	$730,000
Durham Mutual Fish Screen and Fish Ladder	Durham Mutual Water Company	up to $416,500
M&T/Parrott Pump Relocation and Fish Screen	Ducks Unlimited, Inc.	$1,550,000
Biologically Integrated Orchard Systems Program	Comm. Alliance w/ Family Farmers Fnd.	$660,000
Sacramento R. Habitat Restoration (Colusa to Verona)	Wildlife Conservation Board	$400,000
Suisun Marsh Screening Project	Suisun Resource Conservation Dist.	up to $950,000
Sacramento River Winter-Run Broodstock Program	Pacific Coast Fed. of Fishermen's Assoc.	$300,000
Western Canal Water District Butte Creek Siphon	WCWD	$2,739,000
Prospect Island Restoration	DWR	up to $2,535,000
Sacramento R. Habitat Restoration (Verona to Collinsville)	DWR/The Reclamation Board	$500,000
Princeton Pumping Plant Fish Screens	Reclamation District 1004	$75,000
Princeton-Codora-Glenn/Provident ID Fish Screen	PCGID/PID	$5,575,000
Cosumnes River Preserve (Valensin Acquisition)	The Nature Conservancy	$1,500,000
Lower Butte Creek Habitat Restoration	The Nature Conservancy	$130,000
Sherman Island Levee Habitat Demonstration	DWR	up to $480,000
Ecological Functions of Restored Wetlands in the Delta	University of Washington	$475,000
Molecular Genetic Identification of Chinook Salmon Runs, Focused on Spring-Run Integrity	Bodega Marine Laboratory	$450,000
Decker Island Tidal Wetland Enhancement	Port of Sacramento	$399,000
Yolo Bypass Habitat Restoration Study	DFG	$226,000
Clear Creek Property Acquisition Assistance	BLM	up to $211,000
Research Program to Address the Introduction of Non-Indigenous Aquatic Species	San Francisco Estuary Institute	$197,000
Sacramento River and Major Tributaries Corridor Mapping	Calif. State University, Chico	$145,200
Fish Screen for Unscreened Diversion on Yuba R.	Browns Valley Irrigation District	$114,750
Effects of Toxics on Central Valley Chinook Salmon	Fox Environmental Management	$110,000
Barrier Intake Screen at Wilkins Slough Diversions	Reclamation District 108	$100,000
San Joaquin River Main Lift Canal Intake Channel Fish Screen Facility	Banta-Carbona Irrigation District	$100,000
Adams Dam Fish Screen and Fish Ladder	Rancho Esquon Partners	up to $100,000
Gorrill Dam Fish Screen and Fish Ladder	Gorrill Land Company	up to $100,000
Fish Screen Testing for Small Unscreened Diversions	Buell and Associates	$90,000
Watershed Management Strategy for Butte Creek	Calif. State University, Chico	$83,000
Establish Battle Creek Watershed Conservancy	Western Shasta Resource Consv. Dist.	$50,000
Inventory of Rearing Habitat for Juvenile Salmon	Calif. State University, Sacramento	$24,500
Total		**$21,515,950**

in 1995 and 1996. During this period, the program funded 32 restoration projects, including land acquisition, fish screening, habitat restoration, and a toxicity study. In 1997, CALFED became the lead agency for implementing the Category III program. Program funding sources include $10 million per year (for 3 years) from water users and $60 million from Proposition 204 funding. The Ecosystem Roundtable, a subcommittee of the Bay-Delta Advisory Council, provides input on selection of Category III projects. Table 6-15 is a sampling of projects funded through 1997. Often, projects that receive part of their funding from the Category III program are also funded in part by CVPIA's AFRP, the 4-Pumps program, or other restoration programs.

The Prospect Island restoration project is an example of a project funded by Category III. Prospect Island, an approximately 1,600-acre tract in the Delta, has a project area of about 1,300 acres in agricultural land use. The project's objectives are to create wetland and shaded riverine aquatic habitat, restore fish and wildlife habitat, and decrease maintenance costs for the Sacramento Deepwater Ship Channel levee. Actions include flooding the interior of the island to create small internal islands, stabilizing existing levees by flattening the slopes, and planting vegetation to provide erosion control. The project is sponsored by USACE (under WRDA Section 1135 authority) and the Department. USBR purchased the project site with CVPIA funds in 1995. After restoration is complete, USFWS will manage the property in conjunction with the nearby Stone Lakes National Wildlife Refuge. Category III has established an endowment fund of $1.25 million for long-term project maintenance.

CALFED Bay-Delta Ecosystem Restoration Program

CALFED's Ecosystem Restoration Program is to provide the foundation for a long-term ecosystem restoration effort that may take several decades to implement. The ERP is included in each of the alternatives being evaluated in the programmatic EIR/EIS. Some proposed actions contained in the plan include:

- Breeching levees for intertidal wetlands.
- Constructing setback levees to increase floodplain and riparian corridors.
- Limiting further subsidence of Delta islands by implementing measures such as restoring wetlands to halt the oxidation of peat soils.
- Controlling introduced species and reducing the probability of additional introductions.
- Acquiring land or water from willing sellers for ecosystem improvements.
- Providing incentives to encourage environmentally friendly agricultural practices.

Congress authorized $430 million over the next three years for the federal share of CALFED programs such as Category III and initial implementation of the ERP, and appropriated $85 million for federal fiscal year 1998. Proposition 204 also included $390 million for implementation of the ERP. This funding will not be available until after CALFED's PEIR/EIS has been completed.

CALFED operations studies, in addition to modeling storage and conveyance elements, also model CALFED's ecosystem restoration common program element through specification of ERP environmental flow targets. In the operations studies, water supplies required to meet ERP flow targets are provided from new storage facilities dedicated to environmental restoration. Water acquisitions from willing sellers are assumed to fully meet flow targets when sufficient flow is unavailable from environmental storage releases.

The ERP outlines several environmental flow objectives to support sustainable populations of plant and animal species in the Bay-Delta. The ERP identifies monthly and 10-day flow event targets for Delta outflow and for many of the river basins within the Bay-Delta watershed. As a simplification, CALFED operations studies focus on flow targets on the Sacramento River at Freeport. (The Freeport flow target is the most significant in terms of total instream flow volume.) Instream flow targets not modeled by the operations studies include: Sacramento River at Knights Landing, Feather River at Gridley, Yuba River at Marysville, American River at Nimbus Dam, Stanislaus River at Goodwin Dam, Tuolumne River at LaGrange, and Merced River at Shaffer Bridge. The additional river flows targeted by the ERP would occur through CVPIA instream flow requirements, releases from new environmental storage created under the CALFED program, and water acquisition from willing sellers.

CALFED operations studies assume that new storage volume is split among the three water using sectors. The placeholder study assumes 3 maf of new surface water storage, with 1 maf dedicated for environmental water uses. Environmental storage is operated to maximize average annual yield by not imposing carryover provisions. Water released from storage to meet ERP flow targets is not diverted at the Delta.

Other Environmental Enhancement Options

SWP's Sherman and Twitchell Islands Wildlife Management Plans

The objective of the management plans is to control subsidence and soil erosion on Twitchell and Sherman Islands, while providing wetland and riparian habitat. The plans also provide recreational opportunities such as walking trails and wildlife viewing. Subsidence would be reduced by minimizing oxidation and erosion of peat soils on the islands and by replacing present agricultural cultivation practices with land use management practices designed to stabilize the soil. Altering land use practices on Twitchell Island could provide up to 3,000 acres of wetland and riparian habitat.

Fish Protection Agreements

USBR and the Department have entered into agreements with DFG to mitigate fish losses at Delta export facilities. Subsequent to execution of USBR's agreement with DFG, CVPIA directed USBR to substantially upgrade Tracy Pumping Plant's fish protection facilities and to construct a new screening facility. Planning studies are now under way for a major upgrade of the existing facility. The Department's 4 Pumps agreement with DFG has funded, or cost-shared in many habitat restoration actions upstream of the Delta, as described previously. Discussions are presently ongoing regarding the possibility of using the remainder of the agreement's capital outlay funds to construct a fish hatchery on the Tuolumne River.

Upper Sacramento River Fisheries and Riparian Habitat Restoration Program

As described in Chapter 2, elements of the 1989 plan prepared under this program were incorporated in CVPIA, or are being considered in forums such as the CALFED program. In 1992, the Resources Agency reconvened the SB 1086 Advisory Council. The council's current charge is two-part: to serve in an advisory capacity to State agencies responsible for actions likely to affect the Upper Sacramento River and adjacent lands, and to complete the council's earlier work on riparian habitat protection and management. The goals for the latter charge include establishing a riparian habitat management area and a governance or management entity for the area. Recommendations are being developed for the boundaries of a riparian habitat conservation area, management objectives by river reach, and the type of governance organization that could most effectively carry out the management plan.

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Financing Local Water Management Options

Implementing and maintaining many of the options discussed in the Bulletin will require a large commitment of funds. When a local agency is confronted with additional expenditures for water management options, it must decide whether the costs of these options will be paid from current or accumulated revenues (pay-as-you-go), or be financed with the proceeds of debt repaid from future revenues. Historically, local water agencies relied on several methods for long-term debt financing, including general obligation bonds, revenue bonds, and assessment bonds. Innovative long-term debt financing strategies, such as bond pools, are being increasingly used.

Financial costs are different from economic costs. Financial costs are the actual expenditures required by a water agency to repay the debt (with interest) incurred to finance the capital costs of an option and to meet operations and maintenance costs. Thus, the objective of financial feasibility studies is to solve cash flow problems. In contrast, economic costs reflect the costs of committing resources needed to construct, operate, and maintain an option for its life, to whomever they may accrue. Economic feasibility studies are used to compare the relative merit of options, to determine the most economically efficient size or configuration of an option, and to allocate costs among beneficiaries. It is possible for options to be financially feasible and economically unjustified, or vice versa. For example, even though an agency can generate the funds to pay for an option, this does not necessarily mean that the option is economically the best of available options. On the other hand, an option may be economically justified but it cannot be financed because of existing debt limitations.

Financial feasibility is becoming an increasingly important consideration in water supply management planning for a number of reasons.

- Future water demands are expected to exceed present supplies. There is thus a need to develop water supply augmentation and demand management programs.
- Compliance with new EPA and DHS drinking water standards is likely to increase capital expenditures by municipal water agencies.
- Some water suppliers have deferred maintenance and/or replacement of aging facilities to the point where increased operation, maintenance, and replacement costs are being incurred.
- Since the 1980s, the federal government has been reducing aid to state and local governments for large-scale water resources projects, a trend which is expected to continue.
- Since the early 1990s, the Legislature has been shifting property tax revenues away from counties and special districts and into the State's general fund.

Sources of Revenues

Whether capital improvements are funded on a pay-as-you-go basis or through debt financing, a water agency must have sufficient revenues to cover capital costs as well as ongoing operation and maintenance costs. The major sources of revenue for publicly-owned systems include water rates charged to customers, property taxes (although use of these has been limited since passage of Proposition 13), and benefit assessments through special improvement districts. (See Chapter 2 for discussion of Proposition 218 and its impacts on assessments.) Because of voter opposition to further tax increases, local governments have increasingly relied upon other revenue sources such as development impact fees from new construction, standby fees, and fees for special services. These alternatives are typically only feasible for agencies with large service areas, so that income from these fees will be significant and reliable. Investor-owned water agencies and mutual water companies are almost exclusively dependent upon water rates to generate revenues. Tables 6-16 and 6-17 show significant sources of revenue for water agencies by type of ownership and by agency size.

Financing Methods

The ability of a public agency to access different financing methods depends upon the enabling legislation under which the agency was formed. Among other things, the enabling legislation will indicate the agency's:

- Authority to issue bonds, the vote required to authorize issuance, and any limitations on the amounts of bonds or on the amount of indebtedness;
- Powers and methods of tax assessments, including whether the assessments are on an ad valorem basis (a tax based on value of property) or are levied according to benefits, and the type of property (land and/or improvements) upon which the assessments may be levied;

TABLE 6-16

Significant Sources of Revenue to Water Agencies by Type of Ownership

Revenue Sources	*Public*	*Investor*	*Mutual*
Water Rates	X	X	X
Property Taxes	X		
Special Improvement District Assessments	X		
Development Impact Fees	X		
Customer Hookup Fees	X		
Special Service Fees	X	X	

TABLE 6-17

Significant Sources of Revenue to Water Agencies by Water Agency Size

Revenue Sources	*Small*	*Intermediate*	*Medium*	*Large*
Water Rates	X	X	X	X
Property Taxes		X	X	X
Special Improvement District Assessments		X	X	X
Development Impact Fees				X
Customer Hookup Fees				X
Special Service Fees				X

- Revenue sources, including charges, rates or tolls for service or commodities, or sales and leases of property; and
- Area over which it can collect taxes and/or sell services or commodities.

Self-Financing

Self-financing is a form of non-debt financing. A water agency can use reserves generated from accumulated revenues and other income to pay for improvements rather than incurring debt. The pay-as-you-go approach generally works best for small or recurring capital expenditures that can be reasonably accommodated in an agency's annual budget. For major capital improvements, a debt financing approach would be more appropriate.

Short-Term Debt Financing

Short-term debt financing typically includes borrowing instruments with maturities of less than 1 year. Short-term borrowing can be used for cash flow borrowing, financing for capital improvements with relatively short lives, and interim financing for long-term capital improvements. Revenue and tax anticipation notes can be used when an agency is experiencing cash flow problems because revenues are occurring unevenly during the fiscal year. Revenue and tax anticipation notes can be used to pay current expenses, with note repayment coming from revenues received later in the fiscal year. Capital items with relatively short lives can be financed through the use of commercial paper—short-term, unsecured promissory notes backed by a line of credit from one or more banks. Short-term financing methods can provide interim financing for the construction of capital improvements which are planned to be financed on a permanent basis at a later date. Examples of interim financing include grant anticipation notes (where the permanent funding could be a grant from another government agency) and bond anticipation notes (where the permanent funding will come through the issuance of long term debt such as bonds).

Conventional Long-Term Debt Financing

Conventional long-term debt financing methods include general obligation bonds, revenue bonds, assessment bonds, and lease or installment sales agreements, all of which are typically used by publicly owned utilities.

General obligation bonds are used to finance improvements benefitting the community as a whole, and are secured by the full faith and credit of the agency. General obligation bonds issued by public water agencies are secured by a pledge of the agency's ad valorem taxing power. Passage of Proposition 13 and its requirement for two-thirds voter approval have limited the ability of agencies to assess additional property taxes which would be needed to fulfill this pledge, reducing the use of these bonds. General obligation bond limits are often established by a water agency's enabling legislation.

Revenue bonds do not require the agency's pledge of full faith and credit. Debt service for these bonds is paid exclusively from a specific revenue source, such as the revenue obtained from the operation of the financed project. Because revenue bonds do not require voter approval, they are now more commonly used than general obligation bonds.

Assessment bonds are issued to finance capital improvements and debt service, are paid through assessments levied upon real property benefitted by such improvements, and are secured by a lien on that property. Under the Mello-Roos Community Facilities Act of 1982, water agencies may establish a community facilities district and levy a special tax upon land within that district. This tax can be used to finance capital improvements (generally distribution systems), new services, or to repay bonds issued for such purposes. Passage of Proposition 218 in 1996 substantially changed the way in which property-related assessments can be imposed by local agencies. In the future, these assessments must be subjected to a vote of the property owners.

Lease or installment revenue bonds have become common as taxpayer resistance and State statutes have limited the taxing and borrowing ability of local agencies, thus reducing use of general obligation bonds. In California, a form of a lease revenue bond is the Certificate of Participation. With a COP, facilities are built or acquired by an agency of the city, and leased to the city, for which the city makes lease payments equal to the principal repayment plus interest. A city, non-profit corporation, or a community redevelopment agency must be used as the intermediary leasing entity, but that agency must give the facilities to the city free and clear without added expense when the indebtedness is repaid.

Innovative Long-term Debt Financing

New long-term debt financing strategies are being developed to assist water agencies in obtaining funding for water system improvements. Bond pools increase access to bond funds for smaller water agencies who might not otherwise be able to obtain funding. Bond pools use a JPA to combine several small bond offerings into a single financial package, minimizing the cost of bond issuance for participating water agencies. The Association of California Water Agencies and the WateReuse Association offer such financial packages.

Privatization occurs when the private sector becomes involved in design, financing, construction, ownership and/or operation of a public facility such as a water system improvement. Privatization can offer advantages. For example, it may provide cheaper or more accessible financing, and it may provide substantial tax advantages to the private sector. Privately arranged financing may be an attractive option when a publicly owned water agency's access to the financial markets is diminished or nonexistent, as is the case for many smaller utilities.

Another potential opportunity for water agencies involves the provision of funds by one agency for water system or on-farm improvements by another agency, in exchange for use of the water conserved. An example is the agreement between MWDSC and IID, where MWDSC is funding IID system improvements in exchange for a 35-year right to use the waters which have been conserved.

Credit Substitution and Enhancement

Although not financing methods, credit substitution and enhancement can assist local agencies in obtaining financing and in lowering the costs of financing. Credit substitution occurs when an agency substitutes its own credit for that of a local agency that is seeking to finance a project. The local agency can improve the quality of its bonds and obtain them at a lower cost. Credit enhancement occurs when an agency guarantees that the debt service obligations will be met, which can be a low-cost and effective way for states to assist local agencies.

TABLE 6-18

Major State and Federal Financial Assistance Programs

Program	*Eligible Projects*	*Administering Agencies*
State		
Safe Drinking Water Bond Laws	Grants/low interest loans for public water system improvements	DWR/DHS
Water Conservation Bond Laws	Low interest loans for water conservation, groundwater recharge, local water supply, and water recycling projects	DWR/SWRCB
Agricultural Drainage Water Management Loan	Low interest loans for agricultural drainage projects	SWRCB
Safe, Clean, Reliable Water Supply Act of 1996 (Proposition 204)	Low interest loans and grants for water conservation, groundwater recharge and water recycling projects	DWR/SWRCB
Federal		
Water and Wastewater Disposal Loans/Grants	Loans and grants to small communities for water and wastewater facilities	Farmers Home Administration
Community Development Block Grants (HUD)	Grants to large communities for water and wastewater facilities	Housing and Urban Development through Department of Housing and Community Development
Small Business Administration Loans	Loans for private water system improvements	Small Business Administration
Federal/State		
Clean Water Act SRF	Low interest loans for water recycling projects	SWRCB
Safe Drinking Water Act SRF	Low interest loans for public water system improvements	DHS

State and Federal Financial Assistance Programs

State and federal financial assistance programs (loans and grants) are available. These programs target varied objectives including safe drinking water, water conservation, water recycling, and water supply development (for example, groundwater recharge projects). Each of these programs has criteria to determine project eligibility and funding. Most of the state and federal programs do not provide funding to investor-owned and mutual companies because this is considered to be adding value to privately owned businesses. The 1996 Safe Drinking Water Act reauthorization may provide about $12 billion from 1997 through 2003 for current and new drinking water programs, including a state revolving fund of $1 billion per year nationally through 2003. Table 6-18 shows some major state and federal financial assistance programs available for water system improvements. Proposition 204 included grants to local agencies for a variety of purposes. For example, the Department is administering two programs to provide loans (and in some cases, grants) to local agencies for water conservation/groundwater recharge facilities ($30 million) and local projects ($25 million). SWRCB is administering loans for water recycling.

Relationship Between Financing and Water Agency Ownership and Size

The types of financing available can vary depending upon the ownership and size of the water agencies. These relationships are discussed below. Table 6-19 summarizes financing methods by type of ownership. Table 6-20 illustrates financing methods typically available to water agencies of different sizes. Table 6-21 summarizes financial assistance programs by ownership type.

Public Water Agencies

In general, public water agencies have access to more financing methods than do investor-owned and mutual water companies. Many financing instruments will be tax-exempt for publicly-owned agencies. The larger public agencies can issue tax-exempt notes and bonds, assess property taxes, issue special assessment bonds, and enter into public/private partnerships to finance capital improvements. A smaller public agency may be unable to secure such financing because either the cost of the method (such as the cost of issuing bonds) or the amount of funds needed to make improvements exceeds the ability of its customers to pay. In these cases, the smaller agencies need to either obtain federal and state assistance, if available, or pursue innovative financing methods. Local public agencies must limit their rates to amounts needed to cover current financing and water costs—they are not allowed to make a profit.

Investor-Owned Water Utilities

Investor-owned utilities can issue equity stock and sell taxable bonds. The California Public Utilities Commission must give authorization prior to the issuance of stocks or bonds by an investor-owned water com-

TABLE 6-19

Financing Methods Available to Water Agencies by Type of Ownership

Method	*Public*	*Investor*	*Mutual*
Self-Financing	X	X	X
Short-Term Financing			
Fixed Rate Notes	X	X[a]	X[a]
Commercial Paper	X	X[a]	X[a]
Floating Rate Demand Notes	X	X[a]	X[a]
Conventional Long-Term Financing			
Equity Shares or Stock		X	X
Bonds (GO and Revenue)	X	X[a]	X[a]
Lease Revenue	X		
Innovative Long-Term Financing			
Bond Pools	X		
Privatization	X		X
Water transfers	X	X	X
Financial Assistance Programs	X	X[b]	X[b]

[a] Taxable instruments.
[b] State and federal loan and grant programs have limited applications for private water agencies.

pany. This method of financing is primarily limited to the larger investor-owned systems. The smaller investor-owned agencies generally do not issue stock and may lack the rate base that would make other financial methods feasible. The CPUC establishes the return on investment that investor-owned utilities are allowed to earn as part of its rate setting authority. Regulated investor-owned utilities are not able to accumulate reserves. Utilities may use short-and long-term taxable bonds and notes.

Mutual Water Companies

A mutual water company is a privately owned company that issues securities in which lot owners are entitled to one share for each lot they own. Mutual water companies have the ability to assess members to raise capital. This does not require approval by either the members or an outside agency. The amount of the assessment may be limited, however, by the ability of the customers to pay. As a requirement of formation of a mutual water company, a sinking fund must be established that provides capital replacement of water facilities at the end of their useful life. Some of the larger mutual companies may be able to use short- and long-term financing instruments such as taxable bonds and notes.

TABLE 6-20

Financing Methods Typically Available to Water Agencies by Water Agency Size

Method	*Small*	*Intermediate*	*Medium*	*Large*
Self-Financing			X	X
Short-Term Financing				
Fixed Rate Notes				X
Commercial Paper				X
Floating Rate Demand Notes				X
Conventional Long-Term Financing				
Equity Shares or Stock			X	X
Bonds (GO and Revenue)				X
Lease Revenue Bonds				X
Innovative Long-Term Financing				
Bond Pools	X	X	X	X
Privatization	X	X	X	X
Water Transfers	X	X	X	X
Financial Assistance Programs	X[a]	X[a]	X[a]	X[a]

[a] State and federal loan and grant programs have limited applications for private water agencies.

TABLE 6-21

Financial Assistance Programs Available to Water Agencies by Type of Ownership

Programs	*Public*	*Investor*	*Mutual*
State			
Safe Drinking Water Bond Laws	X	X[a]	X[a]
Water Conservation Bond Laws	X		
Agricultural Drainage Water Management Loans	X		
Community Development Block Grants	X		
State Revolving Fund for Wastewater	X		
State Revolving Fund for Drinking Water	X	X	X
Federal			
Water and Wastewater Disposal Loans and Grants	X		X
Community Development Block Grants	X		
Small Business Administration Loans		X	

[a] Loans only; grants not provided to privately-owned agencies.

6A

Regional Water Budgets with Existing Facilities and Programs

The following tables show the water budgets for each of the State's ten hydrologic regions with existing facilities and programs. Water use/supply totals and shortages may not sum due to rounding.

TABLE 6A-1

North Coast Region Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	Drought	Average	Drought
Water Use				
Urban	169	177	201	212
Agricultural	894	973	927	1,011
Environmental	19,544	9,518	19,545	9,518
Total	**20,607**	**10,668**	**20,672**	**10,740**
Supplies				
Surface Water	20,331	10,183	20,371	10,212
Groundwater	263	294	288	321
Recycled and Desalted	13	14	13	14
Total	**20,607**	**10,491**	**20,672**	**10,546**
Shortage	**0**	**177**	**0**	**194**

TABLE 6A-2

San Francisco Bay Region Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	Drought	Average	Drought
Water Use				
Urban	1,255	1,358	1,317	1,428
Agricultural	98	108	98	108
Environmental	5,762	4,294	5,762	4,294
Total	**7,115**	**5,760**	**7,176**	**5,830**
Supplies				
Surface Water	7,011	5,285	7,067	5,417
Groundwater	68	92	72	89
Recycled and Desalted	35	35	37	37
Total	**7,115**	**5,412**	**7,176**	**5,543**
Shortage	**0**	**349**	**0**	**287**

TABLE 6A-3

Central Coast Region Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	Drought	Average	Drought
Water Use				
Urban	286	294	379	391
Agricultural	1,192	1,279	1,127	1,223
Environmental	118	37	118	37
Total	**1,595**	**1,610**	**1,624**	**1,652**
Supplies				
Surface Water	318	160	368	180
Groundwater	1,045	1,142	1,041	1,159
Recycled and Desalted	18	26	42	42
Total	**1,381**	**1,328**	**1,452**	**1,381**
Shortage	**214**	**282**	**172**	**270**

TABLE 6A-4

South Coast Region Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	4,340	4,382	5,519	5,612
Agricultural	784	820	462	484
Environmental	100	82	104	86
Total	**5,224**	**5,283**	**6,084**	**6,181**
Supplies				
Surface Water	3,839	3,196	3,625	3,130
Groundwater	1,177	1,371	1,243	1,462
Recycled and Desalted	207	207	273	273
Total	**5,224**	**4,775**	**5,141**	**4,865**
Shortage	**0**	**508**	**944**	**1,317**

TABLE 6A-5

Sacramento River Region Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	766	830	1,139	1,236
Agricultural	8,065	9,054	7,939	8,822
Environmental	5,833	4,223	5,839	4,225
Total	**14,664**	**14,106**	**14,917**	**14,282**
Supplies				
Surface Water	11,881	10,022	12,196	10,012
Groundwater	2,672	3,218	2,636	3,281
Recycled and Desalted	0	0	0	0
Total	**14,553**	**13,239**	**14,832**	**13,293**
Shortage	**111**	**867**	**85**	**989**

TABLE 6A-6

San Joaquin River Region Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	574	583	954	970
Agricultural	7,027	7,244	6,450	6,719
Environmental	3,396	1,904	3,411	1,919
Total	**10,996**	**9,731**	**10,815**	**9,609**
Supplies				
Surface Water	8,562	6,043	8,458	5,986
Groundwater	2,195	2,900	2,295	2,912
Recycled and Desalted	0	0	0	0
Total	**10,757**	**8,943**	**10,753**	**8,898**
Shortage	**239**	**788**	**63**	**711**

TABLE 6A-7

Tulare Lake Region Water Budget with Existing Facilities and Programs (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	690	690	1,099	1,099
Agricultural	10,736	10,026	10,123	9,532
Environmental	1,672	809	1,676	813
Total	**13,098**	**11,525**	**12,897**	**11,443**
Supplies				
Surface Water	7,888	3,693	7,791	3,593
Groundwater	4,340	5,970	4,386	5,999
Recycled and Desalted	0	0	0	0
Total	**12,228**	**9,663**	**12,177**	**9,592**
Shortage	**870**	**1,862**	**720**	**1,851**

TABLE 6A-8

North Lahontan Region Water Budget with Existing Facilities and Programs (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	39	40	50	51
Agricultural	530	584	536	594
Environmental	374	256	374	256
Total	**942**	**880**	**960**	**901**
Supplies				
Surface Water	777	557	759	557
Groundwater	157	187	183	208
Recycled and Desalted	8	8	8	8
Total	**942**	**752**	**950**	**773**
Shortage	**0**	**128**	**10**	**128**

TABLE 6A-9

South Lahontan Region Water Budget with Existing Facilities and Programs (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	238	238	619	619
Agricultural	332	332	257	257
Environmental	107	81	107	81
Total	**676**	**651**	**983**	**957**
Supplies				
Surface Water	322	259	437	326
Groundwater	239	273	248	296
Recycled and Desalted	27	27	27	27
Total	**587**	**559**	**712**	**649**
Shortage	**89**	**92**	**270**	**308**

TABLE 6A-10

Colorado River Region Water Budget with Existing Facilities and Programs (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	418	418	740	740
Agricultural	4,118	4,118	3,583	3,583
Environmental	39	38	44	43
Total	**4,575**	**4,574**	**4,367**	**4,366**
Supplies				
Surface Water	4,154	4,128	3,920	3,909
Groundwater	337	337	285	284
Recycled and Desalted	15	15	15	15
Total	**4,506**	**4,479**	**4,221**	**4,208**
Shortage	**69**	**95**	**147**	**158**

6B

Applied Water Shortages by Hydrologic Region with Existing Facilities and Programs

Tables 6B-1 through 6B-4 show applied water shortages by hydrologic region with existing facilities and programs. Water shortages vary widely from region to region. For example, the North Coast and San Francisco Bay Regions are not expected to experience future shortages during average years, but will see shortages in drought years. Most of the State's remaining regions experience average year and drought year shortages now, and are forecasted to experience increased shortages in 2020.

The largest average year shortages are forecasted for the Tulare Lake and South Coast Regions, areas that rely heavily on imported water supplies. Future average year shortages in the Tulare Lake Region reflect groundwater overdraft. Future average year shortages in the South Coast Region reflect forecasted population growth, plus lower Colorado River supplies as California reduces its use of Colorado River water to the State's basic apportionment.

TABLE 6B-1

Applied Water Shortages by Hydrologic Region (taf), 1995-Level Average Year[a]

Region	*Overdraft*	*Other*	*Total*
North Coast	0	0	0
San Francisco Bay	0	0	0
Central Coast	214	0	214
South Coast	0	0	0
Sacramento River	33	78	111
San Joaquin River	239	0	239
Tulare Lake	820	50	870
North Lahontan	0	0	0
South Lahontan	89	0	89
Colorado River	69	0	69
Total (rounded)	**1,460**	**130**	**1,590**

[a] With existing facilities and programs.

TABLE 6B-2

Applied Water Shortages by Hydrologic Region (taf), 1995-Level Drought Year[a]

Region	*Overdraft*	*Other*	*Total*
North Coast	0	177	177
San Francisco Bay	0	349	349
Central Coast	214	68	282
South Coast	0	508	508
Sacramento River	33	834	867
San Joaquin River	239	549	788
Tulare Lake	820	1,042	1,862
North Lahontan	0	128	128
South Lahontan	89	3	92
Colorado River	69	26	95
Total (rounded)	**1,460**	**3,690**	**5,150**

[a] With existing facilities and programs.

TABLE 6B-3

Applied Water Shortages by Hydrologic Region (taf), 2020-Level Average Year[a]

Region	*Overdraft*	*Other*	*Total*
North Coast	0	0	0
San Francisco Bay	0	0	0
Central Coast	102	70	172
South Coast	0	944	944
Sacramento River	85	0	85
San Joaquin River	63	0	63
Tulare Lake	670	50	720
North Lahontan	0	10	10
South Lahontan	89	181	270
Colorado River	61	86	147
Total (rounded)	**1,070**	**1,340**	**2,410**

[a] With existing facilities and programs.

TABLE 6B-4

Applied Water Shortages by Hydrologic Region (taf), 2020-Level Drought Year[a]

Region	*Overdraft*	*Other*	*Total*
North Coast	0	194	194
San Francisco Bay	0	287	287
Central Coast	102	168	270
South Coast	0	1,317	1,317
Sacramento River	85	904	989
San Joaquin River	63	648	711
Tulare Lake	670	1,181	1,851
North Lahontan	0	128	128
South Lahontan	89	219	308
Colorado River	61	97	158
Total (rounded)	**1,070**	**5,140**	**6,210**

[a] With existing facilities and programs.

6C

Estimating a Water Management Option's Unit Cost

A key consideration in the options evaluation process is the appraisal of costs, both financial and economic. Financial costs are the expenditures required to repay debt (with interest) incurred to finance capital costs of a project and to meet operations, maintenance, and replacement costs. Generally, financial costs are spread over a shorter time period than the life of the project. In comparison, economic costs reflect the costs of resources committed to the construction and operation of a project over its life, which can be 50 years or more for many water resources options. It is possible for options to be economically feasible and financially infeasible, or vice versa.

This appendix focuses upon economic costs. Although economic costs can be expressed in many different ways, a useful statistic is the economic cost per acre-foot of option delivery. The mathematical computation of unit cost is not difficult, but does entail several considerations.

Considerations Common to All Options

Data Availability

Cost estimates require extensive data on an option's costs and its operation under different hydrologic conditions. Costs include capital and annual operations, maintenance, and replacement costs. Capital costs are associated with construction and implementation of an option (including transportation and treatment facilities). Examples of capital costs include expenditures for planning, design, right-of-way, construction, and environmental mitigation. Capital costs also include activation costs (operation and maintenance expenditures prior to operations) and reservoir filling costs. OM&R costs include administration, energy, water purchases, water treatment, and replacement costs incurred during the normal course of project use.

For many options (such as surface water reservoirs and groundwater/conjunctive use projects), hydrology is key to evaluating the option's performance. Some options are designed to provide maximum deliveries during average and wet years and minimal deliveries during drought years; others are designed to provide maximum deliveries during drought years with minimal deliveries during other years. Some options can provide a relatively constant supply regardless of water year type.

Because this Bulletin focuses on local options, cost estimates are dependent upon cost and hydrology data available in existing reports and other documents prepared by water agencies. Some difficulties that arise in using this information include:

- Data are inconsistent among the agencies (different hydrologic time periods were used).
- Data are missing or incomplete (sometimes capital costs are reported, but not operating costs).
- Data may be available, but information about assumptions used in their development is not available (reported total capital costs may or may not include environmental mitigation costs).
- Data were developed at different times (information on some options is relatively new, while other data may be 30 years old).
- Data were developed at different levels of study (appraisal level data are being compared to feasibility level data).

Since the Bulletin's intent is to examine options from a statewide perspective at an appraisal level of detail, the approach used has been to acknowledge that these difficulties exist, but to use the available information. The scope of this Bulletin does not permit development of new information for all of the options for which data were collected. The Bulletin's efforts focused on making costs of the statewide options and larger local options comparable, where possible.

Assumptions

Two analysis periods were used—a 50-year period for capital-intensive options (reservoirs, desalting plants, conjunctive use facilities) and a 25-year period for less capital-intensive options (demand reduction).

The analysis used constant dollars, thus excluding price changes occurring as a result of inflation. The time value of money is represented by a 6 percent discount rate. Dollar values are converted to constant 1995 dollars using USBR's cost index or other cost indices as appropriate. Statewide probabilities for the occurrence of drought years and average years are 20 and 80 percent, respectively.

Method of Analysis

A spreadsheet was developed for cost computations. Table 6C-1 shows the results of a sample cost analysis for four hypothetical water management options using this spreadsheet.

Considerations Specific to Some Options

Conservation

In order to achieve savings from many demand reduction options (landscape retrofits, toilet retrofits), water users rather than water districts must purchase additional equipment. Because of the substantial user costs of some conservation options, they must be addressed in cost estimates. Since the Bulletin 160-98 options evaluation process is focused on costs from the water agency perspective, it is assumed that costs of demand reduction options are funded by water agencies, including reimbursements to water users for costs such as landscape replacement or sprinkler controller installation.

Water Recycling

Costs of water recycling vary with the intended use of the water, due to differences in treatment requirements. Costs of recycling projects are highly site-specific, since costs of associated conveyance and distribution systems may constitute a large percent of the total project cost.

Conjunctive Use Projects

Because conjunctive use projects often involve many types of facilities and are operated according to changes in hydrology, computing cost estimates can be complex. Hydrology is key to the operation of many conjunctive use projects because usually the recharge portion of the project is operated in average years and the extraction portion is operated in drought years. Facilities may not be operated during years where there is insufficient water for recharge, or when conditions are too wet to warrant extractions. Although capital costs of a conjunctive use project are not significantly influenced by hydrology, annual O&M costs are sensitive to hydrology because of pumping costs.

Surface Water Reservoirs

Some reservoirs are operated to maximize water supplies during average years and others are operated

TABLE 6C-1

Sample Cost Computation

Option	*Option Delivery (taf)*		*Probabilities (%)*		*Capital Costs*	*Annual Variable Costs (Million$)*		*Unit Cost ($/af)*
	Average	*Drought*	*Average*	*Drought*	*(Million $)*	*Average*	*Drought*	
Groundwater Recharge/ Conjunctive Use	0	15	80.0	20.0	4.0	0.1	0.6	150
Water Transfers[a]	0	2	80.0	20.0	0.0	0.0	0.5	250
Water Recycling	3	3	80.0	20.0	24.0	0.6	0.6	710
Surface Water Reservoir	10	3	80.0	20.0	80.0	1.0	2.0	730

[a] Using existing facilities.

for drought years or emergency storage purposes. Although the capital cost to construct a reservoir will be the same regardless of its operation, the cost of water supply will differ substantially among these operational modes. A reservoir's O&M costs will vary significantly depending upon whether it provides on-stream or off-stream storage (the latter operation will likely have substantial energy costs associated with reservoir filling). Of supply augmentation options, reservoirs are most likely to provide substantial benefits other than water supply, such as recreation, flood control, and power generation. No attempt is made in this Bulletin to allocate the costs among different purposes, because cost allocation goes beyond the Bulletin's appraisal-level scope of analysis.

Water Marketing

Water transfer costs shown in the Bulletin are generally those reported by local agencies for their proposed marketing arrangements. Costs reported by local agencies are often the contractual prices contained in transfer agreements. Such costs usually do not include environmental mitigation costs or costs relating to third-party impacts.

6D

Calculation of Minimum New Water Needs

Calculations of lower bound, or minimum, new water needs from 2020-level applied water budget shortages are presented by hydrologic region in Tables 6D-1 and 6D-2. In an applied water budget, supply and percent reapplication are defined as:

applied water supply = supply from primary sources + supply from reapplication ... (1)

percent reapplication = (supply from reapplication / supply from primary sources) x 100 ... (2)

In the tables, percent reapplication is calculated for each region from primary supplies and reapplied supplies (both surface water and groundwater) according to equation (2). This calculation is performed only in planning subareas that are forecasted to experience shortages in 2020.

Assuming that new supplies from water management options may be reapplied in the same proportion that existing primary supplies are reapplied, an applied water yield and a percent reapplication for the options may be similarly defined as:

applied water yield = new water supply + reapplication potential ... (3)

percent reapplication = (reapplication potential / new water supply) x 100 ... (4)

By substituting equation (4) into equation (3) and rearranging terms, a regional new water need may be defined as a function of a regional applied water shortage:

new water need = applied water shortage / (1 + [reapplication potential/100]) ... (5)

If the potential to reapply new water supplies does not exist in a region, then according to equation (5), the new water need (maximum) is equal to the region's applied water shortage. If the potential to fully reapply new water supplies exists in a region, then equation (5) defines a minimum new water need. In the tables, the water shortage not due to overdraft ("other" shortage) is adjusted downward by the percent reapplication in accordance with equation (5). This value is summed with the overdraft shortage to arrive at the minimum new water need for the region.

As discussed in Chapter 3, regional supplies generated through groundwater overdraft are excluded from the Bulletin 160-98 water budgets because they do not represent sustainable sources of water supply. Excluding these supplies from the water budgets results in additional regional shortages. However, for clarity of presentation, the regional supplies available through reapplication of overdrafted groundwater supplies are not excluded from the water budgets. Therefore, shortages due to overdraft are not adjusted by the percent reapplication in Tables 6D-1 and 6D-2 to arrive at regional new water needs.

Based on the data presented in Table 6D-1, the minimum new water required to satisfy 2020 average year shortages is approximately 2.2 maf. Similarly, Table 6D-2 shows the minimum new water required to satisfy 2020 drought year shortages is approximately 5.4 maf. As discussed in Chapter 6, not all water management options are created equal in their ability to meet new water needs. Demand reduction options, for example, do not provide new water to a region, and no opportunities exist to multiply their effectiveness through reapplication. Therefore, if a region's options mix includes demand reduction options, the region's new water need will be greater than the minimum need.

TABLE 6D-1

Minimum New Water Needs by Hydrologic Region: 2020 Average Year

Region	*Percent[a] Reapplication*	*Shortage (taf)*		*Minimum New Water Need (taf)*
		Overdraft	*Other*	
North Coast	—	0	0	0
San Francisco Bay	—	0	0	0
Central Coast	24.1	102	70	159
South Coast	12.5	0	944	839
Sacramento River	33.3	85	0	85
San Joaquin River	16.4	63	0	63
Tulare Lake	11.4	670	50	715
North Lahontan	5.4	0	10	9
South Lahontan	35.8	89	181	223
Colorado River	24.6	61	86	130
Total (rounded)	**16.4**	**1,070**	**1,340**	**2,220**

[a] Percent reapplication is computed from supply data for PSAs that are forecasted to experience shortages in 2020.

TABLE 6D-2

Minimum New Water Needs by Hydrologic Region: 2020 Drought Year

Region	*Percent[a] Reapplication*	*Shortage (taf)*		*Minimum New Water Need (taf)*
		Overdraft	*Other*	
North Coast	38.8	0	194	140
San Francisco Bay	0.5	0	287	286
Central Coast	17.8	102	168	245
South Coast	10.4	0	1,317	1,192
Sacramento River	26.3	85	904	801
San Joaquin River	17.4	63	648	615
Tulare Lake	24.0	670	1,181	1,623
North Lahontan	16.5	0	128	110
South Lahontan	34.8	89	219	252
Colorado River	25.3	61	97	138
Total (rounded)	**18.8**	**1,070**	**5,140**	**5,400**

[a] Percent reapplication is computed from supply data for PSAs that are forecasted to experience shortages in 2020.

6E

Net Water Budgets

The following tables show the net water budgets for each of the State's ten hydrologic regions with existing facilities and programs, and then California's net water budget with existing facilities and programs. Water use/supply totals and shortages may not sum due to rounding.

TABLE 6E-1

North Coast Region Net Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Net Water Use				
Urban	169	177	201	212
Agricultural	683	714	699	740
Environmental	19,378	9,393	19,378	9,393
Total	**20,230**	**10,283**	**20,278**	**10,344**
Supplies				
Surface Water	20,003	9,887	20,029	9,911
Groundwater	214	239	236	261
Recycled and Desalted	13	14	13	14
Total	**20,230**	**10,139**	**20,278**	**10,186**
Shortage	**0**	**144**	**0**	**158**

TABLE 6E-2

San Francisco Region Net Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Net Water Use				
Urban	1,255	1,358	1,317	1,428
Agricultural	87	96	87	95
Environmental	1,782	1,284	1,782	1,284
Total	**3,124**	**2,738**	**3,185**	**2,808**
Supplies				
Surface Water	3,024	2,267	3,080	2,400
Groundwater	65	87	69	84
Recycled and Desalted	35	35	37	37
Total	**3,124**	**2,389**	**3,185**	**2,520**
Shortage	**0**	**349**	**0**	**287**

TABLE 6E-3

Central Coast Region Net Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Net Water Use				
Urban	243	253	320	334
Agricultural	912	975	884	947
Environmental	84	22	84	22
Total	**1,238**	**1,250**	**1,288**	**1,303**
Supplies				
Surface Water	252	118	301	140
Groundwater	754	826	772	861
Recycled and Desalted	18	26	42	42
Total	**1,024**	**970**	**1,115**	**1,043**
Shortage	**214**	**280**	**172**	**260**

TABLE 6E-4

South Coast Region Net Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Net Water Use				
Urban	3,973	3,999	4,943	5,009
Agricultural	692	722	421	442
Environmental	27	27	31	31
Total	**4,691**	**4,748**	**5,395**	**5,481**
Supplies				
Surface Water	3,400	2,758	3,184	2,704
Groundwater	1,084	1,274	1,155	1,380
Recycled and Desalted	207	207	273	273
Total	**4,691**	**4,240**	**4,612**	**4,357**
Shortage	**0**	**508**	**783**	**1,125**

TABLE 6E-5

Sacramento River Region Net Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Net Water Use				
Urban	765	829	1,139	1,235
Agricultural	6,529	7,251	6,436	7,041
Environmental	3,845	3,260	3,854	3,263
Total	**11,139**	**11,340**	**11,429**	**11,538**
Supplies				
Surface Water	8,814	7,880	9,159	7,895
Groundwater	2,229	2,699	2,184	2,769
Recycled and Desalted	0	0	0	0
Total	**11,043**	**10,579**	**11,344**	**10,665**
Shortage	**96**	**760**	**85**	**873**

TABLE 6E-6

San Joaquin River Region Net Water Budget with Existing Facilities and Programs (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Net Water Use				
Urban	417	432	673	698
Agricultural	5,818	6,284	5,286	5,784
Environmental	1,249	831	1,263	845
Total	**7,484**	**7,546**	**7,221**	**7,328**
Supplies				
Surface Water	6,190	4,743	6,096	4,696
Groundwater	1,055	2,118	1,063	2,026
Recycled and Desalted	0	0	0	0
Total	**7,245**	**6,861**	**7,159**	**6,722**
Shortage	**239**	**685**	**63**	**606**

TABLE 6E-7

Tulare Lake Region Net Water Budget with Existing Facilities and Programs (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Net Water Use				
Urban	347	358	514	533
Agricultural	7,659	7,817	7,248	7,386
Environmental	37	37	39	39
Total	**8,043**	**8,211**	**7,801**	**7,957**
Supplies				
Surface Water	6,226	2,894	6,129	2,794
Groundwater	957	3,684	962	3,568
Recycled and Desalted	0	0	0	0
Total	**7,183**	**6,578**	**7,091**	**6,361**
Shortage	**860**	**1,634**	**710**	**1,596**

TABLE 6E-8

North Lahontan Region Net Water Budget with Existing Facilities and Programs (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Net Water Use				
Urban	32	33	41	42
Agricultural	470	514	470	516
Environmental	174	136	174	136
Total	**675**	**683**	**685**	**695**
Supplies				
Surface Water	531	384	506	378
Groundwater	136	171	161	190
Recycled and Desalted	8	8	8	8
Total	**675**	**564**	**675**	**576**
Shortage	**0**	**120**	**10**	**119**

TABLE 6E-9

South Lahontan Region Net Water Budget with Existing Facilities and Programs (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Net Water Use				
Urban	160	160	412	412
Agricultural	291	291	230	230
Environmental	107	81	107	81
Total	**558**	**532**	**750**	**724**
Supplies				
Surface Water	244	181	338	234
Groundwater	198	232	201	252
Recycled and Desalted	27	27	27	27
Total	**469**	**440**	**566**	**514**
Shortage	**89**	**92**	**184**	**210**

TABLE 6E-10

Colorado River Region Net Water Budget with Existing Facilities and Programs (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Net Water Use				
Urban	312	312	526	526
Agricultural	3,847	3,847	3,412	3,412
Environmental	39	38	44	43
Total	**4,197**	**4,196**	**3,982**	**3,981**
Supplies				
Surface Water	4,047	4,021	3,809	3,800
Groundwater	66	77	79	79
Recycled and Desalted	15	15	15	15
Total	**4,128**	**4,113**	**3,903**	**3,894**
Shortage	**69**	**83**	**79**	**88**

TABLE 6E-11

California Net Water Budget with Existing Facilities and Programs (maf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Net Water Use				
Urban	7.7	7.9	10.1	10.4
Agricultural	27.0	28.5	25.2	26.6
Environmental	26.7	15.1	26.8	15.1
Total	**61.4**	**51.5**	**62.0**	**52.2**
Supplies				
Surface Water	52.7	35.1	52.6	35.0
Groundwater	6.8	11.4	6.9	11.5
Recycled and Desalted	0.3	0.3	0.4	0.4
Total	**59.8**	**46.9**	**59.9**	**46.8**
Shortage	**1.6**	**4.7**	**2.1**	**5.3**

6F

Land Retirement Analysis in Drainage-Impaired Areas

The San Joaquin Valley Interagency Drainage Program's 1990 report stated that 75,000 acres of land with the worst drainage problems would need to be retired by 2040 unless other actions were taken to improve drainage problems in the area. Assuming that land retirement would occur uniformly over time, the Bulletin's 2020 irrigated acreage forecast includes a reduction of 45,000 acres of land due to impaired drainage, as discussed in Chapter 4. Existing or future programs in which land is purchased and then taken out of irrigated agriculture could increase the acreage taken out of production. Considering the region's chronic agricultural water shortages, it is likely that local water agencies would want to keep the water in the region to improve water supplies for remaining irrigated lands, as is being planned in a pending joint financing arrangement between USBR and WWD.

Bulletin 160-98 does not treat land retirement for drainage purposes as a future demand reduction option. The Bulletin's scope is limited to actions whose primary intent is demand reduction or water supply augmentation. Because land retirement for drainage purposes would affect water use, the following analysis has been provided to quantify water supply impacts. Two land retirement scenarios were evaluated. Scenario 1 assumed that the full 75,000 acres of agricultural lands with the worst drainage problems recommended for retirement by 2040 by the interagency program would be retired by 2020, adding 30,000 acres to the base 45,000 acres included in the Department's 2020 agricultural acreage forecast. Scenario 2 assumed the retirement of up to 85,000 acres over the base 45,000 acres for a total of 130,000 retired acres. This included the 30,000 acres in Scenario 1 plus other lands in the westside of the San Joaquin Valley with a selenium concentration of more than 200 ppb in shallow groundwater. For Scenario 2, the 200 ppb selenium criterion was used to benchmark acreage to be retired because of the interagency report's recommendations. The acreage of land underlain by shallow groundwater has fluctuated over time, reflecting hydrologic conditions and the availability of water supplies in the region. There has been no new regionwide monitoring of selenium in shallow groundwater since publication of the 1990 report, and changes in the extent of lands underlain by high selenium groundwater are unknown. (As described in Chapter 4, the interagency drainage program is in the process of updating its 1990 recommendations based on new information.)

To help put these acreage values into perspective, in 1997 USBR's land retirement program issued its first request for proposals from persons who wished to retire land pursuant to the CVPIA program. USBR received proposals totaling 31,000 acres. Based on its 1998 budget, USBR expects to retire about 12,000 acres of the lands proposed, with additional lands expected to be retired in future budget years. In 1998, USBR released an environmental assessment and finding of no significant impact for a demonstration project on about 1,890 acres of lands acquired or planned to be acquired under the land retirement program. The demonstration program would evaluate wildlife habitat management actions on the retired lands. Under a separate agreement with WWD, the agricultural water supplies associated with the lands would remain within WWD, and part of the supplies would be used to irrigate wildlife habitat. Water used for habitat irri-

TABLE 6F-1

Agricultural Depletion Reductions Due to Land Retirement

Crops	*Scenario 1* Land Retired (acres)	*Scenario 1* Depletions (af/yr)	*Scenario 2* Land Retired (acres)	*Scenario 2* Depletions (af/yr)
Alfalfa	2,370	8,560	4,740	17,290
Irrigated Pasture	60	220	160	580
Barley	3,080	3,880	9,160	11,540
Wheat	5,850	8,660	14,980	22,170
Cotton	12,830	33,490	41,600	108,580
Safflower	4,390	4,430	9,690	9,790
Sugar Beets	60	170	350	990
Dry Beans	470	900	1,470	2,820
Dry Onions	190	500	520	1,370
Tomatoes (processing)	480	1,280	1,730	4,600
Almonds	110	360	220	690
Pistachios	10	20	80	240
Wine Grapes	100	220	250	550
Total (rounded)	**30,000**	**62,700**	**85,000**	**181,200**

gation would be limited to 0.6 af/acre, to avoid deep percolation of applied water.

Table 6F-1 displays the crops calculated to be retired for both scenarios along with the expected reductions in depletions. Field crops are the primary types of crops calculated to be retired, based on Central Valley Production Model results, with barley, wheat, cotton, and safflower comprising almost 90 percent of total retired acreage for each option.

The costs of land retirement scenarios are measured by the estimated costs to purchase farmland and remove it from irrigated agricultural production. Table 6F-2 shows land retirement costs for either permanently taking the farmland out of agricultural production or for taking it out of irrigated agricultural production.

Implementing land retirement programs can be controversial because of concerns about third-party impacts to those who do not benefit from sale of the land or its associated water supply. (Direct farm income losses to growers should be recovered through land purchase costs.) To illustrate the magnitude of potential third-party impacts, Tables 6F-3 and 6F-4 show economic effects of the land retirement scenarios. These effects would need to be addressed in environmental documentation for land retirement programs. Environmental documentation prepared to date for land retirement activities has not proposed specific mitigation measures for third-party economic impacts. There has thus been no basis for allocating costs in addition to the land purchase price to the costs shown in this analysis. Third-party impacts associated with managed land retirement programs on the westside of the San Joaquin Valley would be of particular concern to city and county governments in the area, because agricultural activities provide the dominant source of employment in many of the small rural communities on the westside.

TABLE 6F-2

Costs of Land Retirement (1995 Dollars)

Land Retirement Assumptions	*Scenario 1* Total Cost Per Acre	*Scenario 1* Annualized Cost Per Acre[a]	*Scenario 1* Cost Per af of Depletions	*Scenario 2* Total Cost Per Acre	*Scenario 2* Annualized Cost Per Acre[a]	*Scenario 2* Cost Per af of Depletions
With No Alternative Uses	1,550	121	55	1,760	138	63
With Grazing	1,420	111	51	1,640	128	59

[a] For a 25 year period and 6% discount rate.

TABLE 6F-3

Land Retirement Analysis—Scenario 1 Economic Impacts (1995 Dollars)

		Direct, Indirect, Induced Effects			
		Value of Production		*Employment*	
Crops	*Acres Retired*	*Regional[a] ($1,000)*	*Statewide ($1,000)*	*Regional[a] (person years)*	*Statewide (person years)*
Alfalfa	2,370	3,980	4,190	56	58
Irrigated Pasture	60	50	50	1	1
Barley	3,080	1,730	1,960	29	30
Wheat	5,850	5,180	5,510	73	77
Cotton	12,830	32,480	34,650	535	541
Safflower	4,390	3,670	4,000	59	61
Sugar Beets	60	120	120	2	2
Dry Beans	470	750	850	10	10
Dry Onions	190	500	540	7	7
Tomatoes (processing)	480	1,590	1,740	22	23
Almonds	110	710	770	14	14
Pistachios	10	70	70	1	1
Wine Grapes	100	500	560	10	10
Totals (rounded)	**30,000**	**51,300**	**55,000**	**820**	**830**

[a] Includes Fresno, Kern, and Kings Counties.

TABLE 6F-4

Land Retirement Analysis—Scenario 2 Economic Impacts (1995 Dollars)

		Direct, Indirect, Induced Effects			
		Value of Production		*Employment*	
Crops	*Acres Retired*	*Regional[a] ($1,000)*	*Statewide ($1,000)*	*Regional[a] (person years)*	*Statewide (person years)*
Alfalfa	4,790	8,050	8,460	114	118
Irrigated Pasture	160	120	130	2	2
Barley	9,160	5,140	5,840	86	88
Wheat	14,980	13,240	14,100	187	196
Cotton	41,600	105,300	112,350	1,735	1,756
Safflower	9,690	8,090	8,830	129	134
Sugar Beets	350	680	720	11	12
Dry Beans	1,470	1,920	2,180	32	33
Dry Onions	520	1,360	1,490	19	19
Tomatoes (processing)	1,730	5,740	6,280	80	81
Almonds	220	1,380	1,510	26	27
Pistachios	80	770	840	15	15
Wine Grapes	250	1,250	1,410	24	24
Totals (rounded)	**85,000**	**153,000**	**164,100**	**2,460**	**2,510**

[a] Includes Fresno, Kern, and Kings Counties.

6G

Review and Evaluation of Statewide-Level Storage Facilities That Could Be Included in CAL-FED Alternatives

Evaluation of Onstream Storage Options Upstream of the Delta

The initial screening of storage options included the 34 reservoir sites shown in Table 6G-1. These sites have been investigated, so information was available to support a preliminary assessment. After the initial screening, 15 remaining options were examined in detail. This appraisal relied on previous studies covering traditional project formulation, engineering feasibility, cost, and environmental aspects. The older studies were supplemented by a cursory reexamination of environmental aspects that reflected the most recent information on critical habitat, wetlands, endangered species, and cultural resources. Because past studies were limited, these environmental reexaminations generated few conclusive findings. The larger reservoirs on major waterways tend to have the most potential environmental consequences. And, there is a definite correlation between the intensity of prior studies and the number of known potential environmental problem issues. The potential environmental issues at the 15 retained options are shown in Table 6G-2.

The appraisal process confirmed that larger projects tend to have the potential to produce less costly and more reliable water supply, but have greater potential impacts on the environment. There is no one accepted method to compare options, particularly those of vastly differing size, but clear conclusions emerged from assessing options within similar groups.

Very Large Onstream Reservoirs (Over 1.0 maf)

With the potential to provide up to 10 maf of additional storage, an enlarged Lake Shasta is in a class apart; at large sizes, it could provide new storage at a favorable unit cost, but with substantial financial and environmental consequences. In the 1.0-2.5 maf range, Auburn Reservoir ranks high, but is burdened with well-publicized environmental controversies. As discussed in Chapter 3, there is an urgent need for greater flood protection on the American River, and a dam at Auburn has been identified by the Reclamation Board as the best flood control alternative. A Thomes-Newville development in the Stony Creek basin remains a possibility, provided it is sized to match its limited water supply; the site also has potential for offstream storage of adjacent basin or Sacramento River water.

The Trinity enlargement option involves a new concept that has not been investigated in detail. The fundamental premise is sound: divert surplus water directly from Lake Shasta to an enlarged Trinity Lake on the Trinity River. This would reap some benefits of enlarging Lake Shasta without the associated major disruptions or relocation costs. The less attractive aspects include a 13-mile tunnel, a 1,500-foot pump lift, and substantial energy costs. This option appears to be more costly than enlarging Lake Shasta, but within the range of consideration. More information on environmental aspects would be needed for a better assessment. Experience has shown large projects at this stage often harbor unexpected environmental drawbacks. Currently, enlarging Trinity Lake is characterized as a future possibility, but not yet thoroughly explored.

TABLE 6G-1

Onstream Storage Options Upstream of the Delta

Stream	*Reservoir*	*Retain or Defer*	*Reason for Deferral*
Cache Creek	Wilson Valley	Defer	Defer due to environmental impacts and conflicts with federal land management policies.
	Kennedy Flats	Defer	Defer due to environmental impacts and conflicts with federal land management policies.
	Blue Ridge	Defer	Defer due to environmental impacts and conflicts with federal land management policies.
Stony Creek	Newville (Part of Thomes-Newville Complex)	Retain	
Thomes Creek	Thomes Division (Part of Thomes-Newville Complex)	Retain	
	Paskenta	Defer	Defer in favor of alternate site in same general area.
Elder Creek	Gallatin	Defer	Limited water supply to support significant amount of storage.
Red Bank Creek	Schoenfield (Part of Red Bank Project)	Retain	
S.F. Cottonwood Creek	Dippingvat (Part of Red Bank Project)	Retain	
	Rosewood (Dry Creek)	Defer	Limited water supply to support significant amount of storage.
	Tehama	Retain	
M.F. Cottonwood Creek	Fiddlers	Retain	
Cottonwood Creek	Dutch Gulch	Retain	
N.F. Cottonwood Creek	Hulen	Retain	
Lake Shasta Tributaries	Shasta Enlargement	Retain	
	Enlarged Trinity	Retain	
	Squaw Valley (Squaw Valley Cr.)	Defer	Defer due to high costs and substantial environmental impacts.
	Kosk (Pit River)	Retain	
	Allen Camp (Pit River)	Defer	Primarily a local project, not well suited for statewide supply augmentation.
Little Cow Creek	Bella Vista	Defer	Defer due to high costs and substantial environmental impacts.
South Cow Creek	Millville	Retain	
Inks Creek	Wing	Retain	

TABLE 6G-1

Onstream Storage Options Upstream of the Delta (continued)

Stream	*Reservoir*	*Retain or Defer*	*Reason for Deferral*
Deer Creek	Deer Creek Meadows	Defer	Primarily a local project, not well suited for statewide supply augmentation. Also doubtful environmental feasibility.
Upper Feather River	Abbey Bridge (Red Clover Creek)	Defer	Primarily a local project, not well suited for statewide supply augmentation. Also doubtful environmental feasibility.
	Dixie Refuge (Last Chance Creek)	Defer	Primarily a local project, not well suited for statewide supply augmentation. Also doubtful environmental feasibility.
Yuba River	Marysville/Narrows	Defer	Defer due to high costs and substantial environmental impacts.
M.F. Yuba River	Freemans Crossing	Defer	Limited water supply to support significant amount of storage and doubtful environmental feasibility.
Bear River	Garden Bar	Defer	Primarily a local project.
N.F. American River	Auburn	Retain	
American River	Folsom Enlargement	Retain	
S.F. American River	Coloma/Salmon Falls	Defer	Defer due to environmental and social/third party impacts.
Cosumnes River	Nashville	Retain	
Mokelumne River	Pardee Enlargement	Defer	Primarily a local project.
San Joaquin River	Millerton Enlargement	Retain	

Large Onstream Reservoirs (0.5 to 1.0 maf)

Tehama and Dutch Gulch reservoirs in the Cottonwood Creek Basin clearly warrant further consideration, possibly at smaller sizes than the 0.7 and 0.9 maf considered in the 1983 USACE feasibility study. As an alternative to Dutch Gulch the upstream Fiddlers Reservoir site has promise, but its optimum size may be smaller than 0.5 maf.

Raising Friant Dam on the San Joaquin River by 120 to 140 feet could more than double the current 520 taf capacity of Millerton Lake. While the expansion would be expensive, it is the only San Joaquin Valley surface storage option that appears to offer potential for statewide supply augmentation. Enlarging Friant Dam also would provide flood control benefits.

Kosk Reservoir on the Pit River and Nashville Reservoir on the Cosumnes River appear to offer some promise for storage in this size range, but scant current information is available on their cost, water supply efficacy, or environmental impacts. Reconnaissance reappraisals could fully assess the practicability of these sites. The Nashville site appears to have significant environmental issues associated with its construction.

Coloma Reservoir on the South Fork American River could provide storage within this size range, but any size over 0.2 maf would inundate the town of Coloma and the Marshall Gold Discovery State Historic Park (which would require legislative authorization under Water Code Section 10001.5). Coloma and the nearby Salmon Falls alternative are unpromising and are deferred from further consideration. Marysville and Narrows sites on the Yuba River also are deferred from further consideration because local interests are evaluating a small facility at a nearby site as a local project.

TABLE 6G-2

Retained Onstream Storage Options and Environmental Issues

Reservoir	*Storage[a] Volume (maf)*	*Potential Environmental Issues*
Very Large Reservoirs		
Shasta Enlargement	up to 14.5	stream/river habitat; wild and scenic rivers; trout fisheries; downstream salmon; downstream seepage and erosion impact; deer; numerous listed and candidate species; cultural resources; disruption of established development
Trinity Enlargement	7.2	stream habitat; wetlands/marshes; sensitive plants; eagles; spotted owls; anadromous fish (Trinity and Sacramento Rivers)
Auburn	0.85 - 2.3	stream habitat; wetlands; wildlife; trout; listed amphibian, insect, and plant species; cultural resources; recreation impacts
Thomes-Newville	1.4 - 1.9	deer; stream habitat; cultural resources; possible minor salmon/steelhead runs
Large Reservoirs		
Tehama	0.5 - 0.7	riparian habitat; salmon/steelhead; deer; upland game; bald eagles; cultural resources; various listed species possible
Dutch Gulch	0.7 - 0.9	riparian habitat; salmon/steelhead; deer; upland game; bald eagles; cultural resources; various listed species possible
Kosk	0.8	stream habitat; deer; elk; bear; upland game; eagles; spotted owls; trout; Big Bend Indian Rancheria
Nashville	0.9	wetland/marsh habitat; stream habitat; deer; upland game
Millerton Enlargement	1.0 - 1.4	stream and upland habitat; disruption of established development
Small to Medium Reservoirs		
Wing	0.25 - 0.5	salmon/steelhead (Battle Creek); deer; several listed bird, amphibian, insect, plant species
Red Bank Project	0.35	stream habitat; California red-legged frog; spring-run salmon
Millville	0.1 - 0.25	stream habitat; salmon
Hulen	0.2 - 0.3	fossils; stream habitat
Folsom Enlargement	1.3	stream and upland habitat; eagles; several listed plant species; cultural resources; disruption of established development
Fiddlers	0.2 - 0.5	stream habitat

[a] Volume shown is total storage volume, including, where applicable, the existing storage capacity of reservoirs to be enlarged.

Small-to-Medium-Sized Onstream Reservoirs (0.1 to 0.5 maf)

Options within this range selected for analysis included three sites on upper Sacramento Valley tributaries that appear to offer acceptable combinations of water supply capability, cost, and environmental compatibility. The largest of these, Wing Reservoir on Inks Creek with a diversion from Battle Creek, could provide over 0.4 maf of storage. The other apparently viable options, both near the lower limit of this size range, are the Red Bank Project on South Fork Cottonwood and Red Bank Creeks, and Millville Reservoir on South Cow Creek. One of the two on-stream reservoirs developed by the Red Bank Project would be used primarily as an offstream storage facility. Hulen Reservoir on North Fork Cottonwood Creek would be high on the list except it would inundate a premier deposit of Cretaceous fossils. (Medium-sized projects involving Cottonwood Creek water, such as the Fiddlers site, are alternatives, not adjuncts, to the larger downstream Tehama and Dutch Gulch storage sites.)

Enlargement of Folsom Lake was among the options considered to provide additional flood control along the lower American River. If that enlargement were practicable, it could provide a valuable increment of water supply storage (depending on the flood operating criteria). That storage would be expensive, so it is unlikely except as an element of a comprehensive flood control package.

The remaining two medium-sized options are Bella Vista Reservoir on Little Cow Creek near Redding and Squaw Valley Reservoir on Squaw Valley Creek near McCloud. These projects appear more expensive and more environmentally disruptive than the competing options. Therefore, they are not considered promising prospects for future development and are deferred from further evaluation.

Evaluation of Offstream Storage Options Upstream of the Delta

The initial screening of upstream of Delta offstream storage options included the 14 proposals in Table 6G-3. The initial screening indicated that eight of those warranted further examination, including a review of past studies and a cursory reexamination of the latest available environmental information. The potential environmental issues identified with the retained options are shown in Table 6G-4. Offstream storage has an inherent environmental advantage because the reservoirs tend to be on minor tributaries, which reduces impacts on live streams and riparian habitat. For most of the larger offstream options, that advantage must be balanced against the potentially severe environmental impacts with diversions from major nearby streams. Evaluating the retained options from that perspective leads to the following general conclusions.

Very Large Offstream Reservoirs (Over 1.0 maf)

Two of the five very large reservoir options have the potential to provide more than 4 maf of new storage, but not without some considerable environmental effects. The existing 1.6 maf Lake Berryessa could be enlarged to provide massive amounts of storage for surplus flows pumped from the lower reaches of the Sacramento River. Past studies have shown the unit cost of storage in the large project sizes would be attractive, though a 31-mile conveyance facility with a 700-foot pump lift would be required. The financial and energy costs of this conveyance would be enormous, as would the environmental consequences. Diversion of around 12,000 cfs from the lower river could prove challenging. Under current conditions, offstream storage of Sacramento River water in an enlarged Lake Berryessa does not appear to hold much promise in the foreseeable future.

TABLE 6G-3

Offstream Storage Options Upstream of the Delta

Watershed	*Reservoir*	*Retain or Defer*	*Reason for Deferral*
Putah Creek	Berryessa Enlargement	Retain	
Various	Sites	Retain	
Various	Colusa	Retain	
Stony Creek	Thomes-Newville	Retain	
Stony Creek	Glenn	Retain	
S.F. Cottonwood Creek	Red Bank Project	Retain	
Inks Creek	Tuscan Buttes	Defer	Defer due to substantial environmental impacts.
Bear River	Waldo	Defer	Being actively pursued by Yuba County Water Agency; not considered for statewide supply.
Deer Creek	County Line	Defer	Defer in favor of alternate site in same general area.
Deer Creek	Deer Creek	Retain	
Laguna Creek	Clay Station	Retain	
Calaveras River	Duck Creek	Defer	Defer due to extraordinarily high costs.
Calaveras River	South Gulch	Defer	Primarily a local project, not well suited for statewide supply augmentation.
Littlejohns Creek	Farmington Enlargement	Defer	Primarily a local project, not well suited for statewide supply augmentation.

TABLE 6G-4

Retained Offstream Storage Options and Environmental Issues

Reservoir	*Storage Volume (maf)*	*Potential Environmental Issues*
Very Large Reservoirs		
Berryessa Enlargement	up to 11.5 additional	stream habitat; wetlands; deer and upland game; Putah Creek trout fishery; Sacramento River anadromous fish; listed/sensitive plant species; cultural resources; disruption of established agriculture and recreation; population displacement
Thomes-Newville	1.4 -1.9	deer; stream habitat; cultural resources; possible minor salmon/ steelhead runs
Glenn	6.7 - 8.7	stream habitat; wetlands/vernal pools; deer and upland game; deer winter range; Sacramento River anadromous fish; eagles; cultural resources; population displacement
Sites	1.2 - 1.8	Sacramento River anadromous fish
Colusa	3.0	Sacramento River anadromous fish
Large Reservoirs		
Deer Creek	0.6	vernal pools; meadow/marsh habitat; listed bird, invertebrate, insect, and plant species; cultural resources
Small to Medium Reservoirs		
Red Bank	0.35	stream habitat; California red-legged frog; spring-run salmon
Clay Station	0.2	stream habitat; wetlands; meadow/marsh habitat; listed bird, invertebrate, insect, and plant species

Similarly, a Glenn Reservoir, a combination of Thomes-Newville Reservoir on the North Fork Stony Creek and Rancheria Reservoir on the mainstem of Stony Creek would provide over 8 maf of storage for surplus water of the upper Sacramento River. The two-compartment Glenn Reservoir was conceived as terminal storage for exports from the North Coast rivers. Following passage of the Wild and Scenic Rivers Act of 1972, it was reformulated for offstream storage of water diverted from the Sacramento River. The unit cost of storage appeared reasonable, but controversy over diversions to the Tehama-Colusa Canal cast doubt on the environmental feasibility of diverting large flows to support the large-scale Glenn Reservoir. At this time, a large Glenn Reservoir does not appear to be a likely candidate for early construction. The smaller Thomes-Newville Reservoir (1.4 to 1.9 maf) operated as an offstream storage reservoir remains a possibility.

The other very large offstream storage options, Sites and Colusa Reservoirs, are related, in that the 3 maf Colusa Reservoir represents a northward expansion of the 1.2 to 1.8 maf Sites Reservoir into the Hunter and Logan Creek Basins. Either version of the reservoir would involve minimal environmental impacts within the area of inundation. The drawback is diverting surplus water from the Sacramento River for storage. Past proposals have focused on off-season use of the existing Tehama-Colusa Canal diversion facilities at Red Bluff Diversion Dam and the Glenn-Colusa Irrigation District pumping plant near Hamilton City. Alternative Sites/Colusa conveyance facilities are now being examined. Although the alternative conveyance facilities would likely raise costs, the Sites and Colusa offstream storage options remain the most promising.

Large Offstream Reservoirs (0.5 to 1.0 maf)

Deer Creek Reservoir in northeastern Sacramento County is the only upstream of Delta offstream storage option within this size range. Past investigators have examined a 0.6 maf Deer Creek Reservoir to store surplus water from the American River, delivered from an enlargement of the existing northern reaches of the Folsom South Canal. Another version of the project was considered for flood control, incorporating a gravity diversion direct from Folsom Lake via a new outlet at Mormon Island Dike. Major offstream storage in the Deer Creek area would be ideally suited to develop some of the abundant surplus flow of the American

River without the difficulties associated with Auburn Dam. Also, by diverting directly from Folsom Lake or Lake Natoma, this project would avoid the principal conflicts with anadromous fish. Initial studies indicate a Deer Creek offstream storage project would be expensive—with a unit storage cost several times that of the lower-cost options.

Small to Medium Offstream Reservoirs (0.1 to 0.5 maf)

Two options fall into this range, the Red Bank Project and Clay Station Reservoir. The Red Bank Project would consist of a 100 taf Dippingvat Reservoir and a 250 taf Schoenfield Reservoir. Dippingvat Reservoir would store water from the South Fork of Cottonwood Creek. Water would be diverted from Dippingvat to Schoenfield Reservoir where it would later be released down Red Bank Creek to the Sacramento River. Water could also be released via a new conveyance facility to the Corning Canal or the Tehama-Colusa Canal.

The Clay Station Reservoir is a smaller version of Deer Creek Reservoir, but 8 miles south. Its storage cost would be similar to Deer Creek's (very high). With its small size and high cost, Clay Station Reservoir offers little promise as a statewide water supply option.

Likely Storage Options Upstream of the Delta

Figure 6G-1 shows the location of likely surface storage options upstream of the Delta. This reappraisal of surface reservoir options identified several that appear to offer the best prospects. Foremost in this group, in order of size, are:

- Colusa Reservoir, 3.0 maf offstream
- Thomes-Newville Reservoir, 1.4 to 1.9 maf offstream
- Sites Reservoir, 1.2 to 1.8 maf offstream
- Dutch Gulch Reservoir, 0.7 to 0.9 maf onstream (or its upstream alternative, Fiddlers Reservoir, 0.2 to 0.5 maf)
- Tehama Reservoir, 0.5 to 0.7 maf onstream
- Wing Reservoir, 0.25 to 0.5 maf onstream (with Battle Creek diversion)
- Red Bank Project, 0.35 maf onstream and offstream
- Millville Reservoir, 0.1 to 0.25 maf onstream

A second tier of options offers substantial water supply potential, but with greater environmental impacts and/or economic costs that create some uncertainty about their implementability. From a flood control standpoint, enlarged Shasta, Auburn, and enlarged Millerton would provide important benefits. In order of size, these sites are:

- Enlarged Lake Berryessa, up to 11.5 maf additional offstream
- Enlarged Lake Shasta, up to 10 maf additional onstream
- Glenn Reservoir, 6.7 to 8.7 maf offstream
- Auburn Reservoir, 0.85 to 2.3 maf onstream
- Thomes-Newville Reservoir, 1.4 to 1.9 maf onstream
- Enlarged Millerton Lake, 0.5 to 0.9 maf additional onstream
- Enlarged Folsom Lake, 0.37 maf additional onstream

A third group of options includes one that may be a viable alternative, but for which limited information is available. This site might be characterized as "worthy of a second look" in the future:

- Kosk Reservoir, 0.8 maf onstream

Operation of Storage Upstream of the Delta

Additional surface storage upstream of the Delta would be effective if operated with major water supply reservoirs in the basin, principally Shasta, Oroville, and Folsom. Under California's water rights hierarchy, new facilities may store surplus water that is not needed to meet preexisting rights. Since virtually no surplus water is available during the irrigation season, storage in new projects will be limited to late fall, winter, and early spring. Most storable flow occurs during periods of flood runoff. But, under certain conditions, coordinated operation with other reservoirs may allow occasional storage of fall releases made to achieve mandatory flood reservations.

A Sites Reservoir offstream storage facility provides a good example of how a Sacramento Valley surface project could be operated in coordination with other facilities. A large Sites Reservoir would provide 1.8 maf of storage in the foothills west of Maxwell. The large Sites Reservoir would be formed by constructing two main dams on Stone Corral and Funks Creeks and several smaller saddle dams along the low divide be-

FIGURE 6G-1

Likely Reservoir Sites Upstream of the Delta

tween Funks and Hunters Creeks. A larger Colusa Reservoir, providing 3.0 maf of storage, would be formed by extending the large Sites Reservoir north into the Hunters and Logan Creek drainages.

In this configuration, water would be delivered to the reservoirs by winter use of the existing Tehama-Colusa Canal (which diverts from the river near Red Bluff), and by diversion to the Glenn-Colusa Canal at its pumping site near Hamilton City. A new pumped intertie would deliver Glenn-Colusa Canal water to the Tehama-Colusa Canal, from which it would be lifted a maximum of about 320 feet to Sites/Colusa Reservoirs. In a recently conceived alternative, use of the existing diversions would give way in favor of a single pumping facility south of Chico Landing.

Most of the water available for storage in Sites/Colusa Reservoirs occurs from December through April. Whenever water and energy were available, operators would make maximum effort to fill Sites/Colusa Reservoirs. As seasonal water demands increased, water would be withdrawn from system reservoirs to meet needs. Since water would have to be pumped to Sites/Colusa Reservoirs, the optimum operation would favor making the initial withdrawals from onstream reservoirs with higher ratios of inflow to storage (which are more likely to refill in the subsequent wet season). At some point, depending on the dryness of the year and the storage status of other facilities, withdrawals would be made from Sites/Colusa Reservoirs. To minimize potential impacts of the existing diversions on the Sacramento River fisheries, Sites/Colusa Reservoirs would release water back into the two canals in exchange for reduced diversions from the river. Sites/Colusa Reservoirs would be drawn to minimum pool only in a prolonged series of drought years. In wetter periods, they would operate within a narrow range near full.

Evaluation of Off-Aqueduct Storage Options South of the Delta

In the Department's recent alternative South of Delta offstream reservoir reconnaissance study, all geographically possible off-aqueduct reservoir sites on the west side of the San Joaquin Valley were identified. Alternatives on the east side of the valley were not considered due to the excessive cost of conveyance connections to the California Aqueduct. Ninety-seven dam sites in 46 watersheds were evaluated (Table 6G-5) for their potential to economically improve SWP water supply reliability with minimal environmental and social impacts. For each potential reservoir site, the capital cost and the potential environmental impacts were evaluated and rated at a general level to determine the sites that should be studied in more detail.

The Department's study examined a wide range of storage volumes to evaluate potentially feasible projects based on the future long-term availability of exports from the Delta and the level of SWP contractor participation. Multiple reservoir sizes were considered for each alternative dam site. Volumes from 0.1 to 2 maf of storage were classified into four categories (Table 6G-6).

All sites were evaluated using the same level of detail for each of the screening criteria. To evaluate and compare engineering characteristics, site information was gathered and construction costs were estimated for each alternative. For this purpose, a basic design configuration was selected. The storage capacity and water surface area of each reservoir option were calculated. The embankment volumes of each main dam and associated saddle dams were calculated.

The capital costs of all reservoir options were based on previous cost estimates developed for LBG facilities. Sixteen categories of cost, including mitigation costs, were calculated. A rating of the alternatives was performed based on estimated capital costs per acre-foot of storage. A unit storage cost of above $3,000/af was deemed impractical and was used as a threshold for deferring alternative sites. After deferring alternatives with unit storage costs above the practical threshold, 34 dam sites in 18 watersheds were retained for further consideration. The unit storage cost for each of these options was translated to a 100 point system, with 0 points assigned to a unit cost of $3,000/af of storage and 100 points to a unit cost of $0/af of storage. Unit costs and scores were developed for several reservoir sizes at each site to cover the potential range of storage volume available at each dam site. The unit costs and scores for the reservoir sizes evaluated at each dam site were plotted versus volume. Curves were drawn through the points associated with each dam site to allow interpolation of this information for the entire range of storage volumes available at each dam site.

Environmental criteria were developed by the Department and DFG. Factors affecting the degree of environmental sensitivity of each alternative reservoir site were identified by the Department and DFG, and were reviewed by USFWS. Six environmental screen-

TABLE 6G-5

Watersheds Identified for South of the Delta Storage Options

Watershed	*County*	*Watershed*	*County*
Arroyo Ciervo	Fresno	Los Banos Creek	Merced
Arroyo Hondo	Fresno	Los Gatos Creek	Fresno
Bitter Creek	Kern	Los Vaqueros	Contra Costa
Bitterwater Valley	Kern/San Luis Obispo	McKittrick Valley	Kern
Broad Creek	Kern	Moreno Gulch	Fresno
Buena Vista Creek	Kern	Mustang Creek	Merced
Buena Vista Lake Bed	Kern	Orestimba Creek	Stanislaus
Cantua Creek	Fresno	Ortigalita Creek	Merced
Capita Canyon	Fresno	Oso Creek	Stanislaus
Castac Valley	Kern/Los Angeles	Packwood Creek	Kern
Deep Gulch	San Joaquin	Panoche Hills	Fresno
Del Puerto Canyon	Stanislaus	Panoche/Silver Creek	Fresno/San Benito
Garzas Creek	Stanislaus	Pleito Creek	Kern
Hospital Creek	San Joaquin/Stanislaus	Quinto Creek	Merced/Stanislaus
Ingram Canyon	Stanislaus	Romero Creek	Merced
Ingram/Kern Canyon	Stanislaus	Salado Creek	Merced
Kellogg/Marsh Creek	Contra Costa	Salt Creek	Fresno/Kern/Merced
Kern Canyon	Stanislaus	San Emigdio Creek	Kern
Kettleman Plain	Kings	San Luis Creek	Merced
Laguna Seca Creek	Merced	Sandy Creek	Kern
Little Panoche Creek	Fresno	Santiago Creek	Kern
Little Salado/Crow Creek	Stanislaus	Sunflower	Kings/Kern
Lone Tree Creek	San Joaquin	Wildcat Canyon	Merced/Fresno

ing criteria were developed. The environmental resources information varied among the sites. To ensure that all the options were evaluated equally, all sites used the same level of detail for each of the screening criteria. In evaluating wetland resources, USFWS National Wetland Inventory Maps were used to determine wetland abundance and types at each site. USGS national aerial photographic project maps were used to determine vegetation community abundance and type, and to obtain additional habitat and land use information. Listed and candidate animal and plant species that could potentially be found at the alternative sites were identified by searching the 1995 DFG Natural Diversity Data Base, the fifth edition of the California Native Plant Society's inventory of rare and endangered vascular plants of California, and DFG Wildlife Habitat Relationships System publications.

Economic and environmental sensitivity scores were given equal weight and combined to develop a score for each alternative reservoir site ranging from 0 to 100 points. Table 6G-7 shows the combined ranking of each alternative reservoir site, sorted by the four storage volume categories. Alternative reservoir sites with the highest scores were selected for each storage volume category. A minimum of 4 and a maximum of 10 alternative reservoir sites were chosen for each size category to provide a reasonable variety of alternatives for further evaluation. Using the previously defined categories, alternative reservoir sites were selected for further evaluation. Many of the alternative reservoir sites were selected in more than one size category. As shown in Table 6G-8, a total of 19 reservoir sites in 10 watersheds were retained for more analysis after the initial evaluation. These sites are shown in Figure 6G-2.

Likely Off-Aqueduct Storage Options South of the Delta

After a general evaluation, five sites appeared most favorable: Garzas Creek, Ingram Canyon, Los Banos

TABLE 6G-6

South of the Delta Off-Aqueduct Storage Size Categories

Category	*Storage (maf)*
Small	0.1 - 0.25
Medium	0.25 - 0.5
Large	0.5 - 1.0
Very Large	1.0 - 2.0

TABLE 6G-7

Ranking of Off-Aqueduct Storage Options South of the Delta

Dam Site	*Potential Range of Storage (taf)*	*Unit Cost ($/af)*	*Cost Ranking (0-100)*	*Environmental Sensitivity Ranking (0-100)*	*Combined Ranking (0-100)*
Very Large Reservoirs (1.0 to 2.0 maf)					
LBG/Los Banos Creek (Dam 181)	1,000-2,000	730-550	76-82	31-31	53-56
Garzas Creek (Dam 104)	1,000-1,750	1,600-1,310	47-56	53-52	50-54
Panoche/Silver Creek (Dam 114)	1,000-2,000	1,370-1,210	54-60	47-45	51-52
Orestimba Creek (Dam 171)	1,000-1,140	1,670-1,600	44-47	46-46	45-46
Large Reservoirs (0.5 to 1.0 maf)					
LBG/Los Banos Creek (Dam 181)	500-1,000	1,000-730	67-76	33-31	50-53
Panoche/Silver Creek (Dam 112)	500-1,000	1,620-1,320	46-56	49-47	48-52
Panoche/Silver Creek (Dam 114)	500-1,000	1,830-1,370	39-54	48-47	44-51
Ingram Canyon (Dam 37)	500-980	1,950-1,400	35-53	48-48	42-51
Orestimba Creek (Dam 170)	500-900	1,890-1,410	37-53	49-46	43-50
Garzas Creek (Dam 104)	500-1,000	2,090-1,600	30-47	54-53	42-50
Garzas Creek (Dam 105)	500-630	1,910-1,660	36-45	54-54	45-49
Panoche/Silver Creek (Dam 45)	500-990	2,300-1,920	23-36	59-57	41-47
Garzas Creek (Dam 109)	500-940	2,250-1,730	25-42	54-52	40-47
Orestimba Creek (Dam 171)	500-1,000	1,930-1,670	36-44	48-46	42-45
Medium Reservoirs (0.25 to 0.5 maf)					
LBG/Los Banos Creek (Dam 181)	250-500	1,660-1,000	45-67	35-33	40-50
Panoche/Silver Creek (Dam 112)	250-500	2,250-1,620	25-46	49-49	37-48
Sunflower Valley (Dam 177)	250-500	2,490-1,460	17-51	46-44	31-48
Garzas Creek (Dam 106)	250-310	2,050-1,820	32-39	54-54	43-47
Garzas Creek (Dam 105)	290-500	2,400-1,910	20-36	54-54	37-45
Panoche/Silver Creek (Dam 114)	250-500	2,050-1,830	32-39	49-48	40-44
Orestimba Creek (Dam 170)	250-500	2,630-1,890	12-37	50-49	31-43
Garzas Creek (Dam 104)	250-500	2,950-2,090	2-30	55-54	28-42
Orestimba Creek (Dam 171)	250-500	3,000-1,930	0-36	49-48	24-42
Ingram Canyon (Dam 37)	250-500	3,120-1,950	N/A-35	49-48	N/A-42
Small Reservoirs (0.10 to 0.25 maf)					
Kettleman Plain (Dam 99)	100-250	2,990-1,620	0-46	61-59	30-53
Garzas Creek (Dam 106)	100-250	3,300-2,050	N/A-32	56-54	N/A-43
Garzas Creek (Dam 107)	100-250	3,300-2,020	N/A-33	56-54	N/A-43
Panoche/Silver Creek (Dam 111)	100-240	3,480-2,020	N/A-33	51-49	N/A-41
LBG/Los Banos Creek (Dam 181)	100-250	3,350-1,660	N/A-45	37-35	N/A-40
Panoche/Silver Creek (Dam 114)	100-250	3,560-2,050	N/A-32	51-49	N/A-40
Little Salado/Crow Creek (Dam 63)	100-130	2,810-2,310	6-23	49-48	28-36
Quinto Creek (Dam 54)	110-250	3,120-2,370	N/A-21	50-49	N/A-35
Romero Creek (Dam 56)	100-180	3,410-2,560	N/A-15	53-53	N/A-34
Garzas Creek (Dam 108)	100-250	4,010-2,870	N/A-4	56-55	N/A-30

Creek, Orestimba Creek, and Panoche/Silver Creek. As all past studies have shown, Los Banos Creek is the most cost-effective reservoir option considered for size categories above 250 taf. The next least costly reservoir option ranges from about 50 percent more expensive for the medium size category up to about 100 percent more expensive for the very large category. In the environmental analysis, however, the Los Banos Creek option received the lowest environmental sensitivity rating (or had the most potential impacts) of all alternative sites. This could be because there is a greater level of knowledge about this reservoir site. Los Banos Creek was the highest ranked reservoir option based on total combined rating for reservoir sizes above 250 taf.

A reservoir at Little Salado-Crow Creek would have a high surface area to storage volume ratio. There would be high evaporation losses, making the site unfavorable. Sunflower Reservoir site lies 10 miles west of the California Aqueduct and would require an extended conveyance system. Significant seepage rates would also be expected at this site. These two sites (in addition to Romero Creek, Kettleman Plain, and Quinto Creek) have small storage capacities. Preliminary modeling results indicate that the range of additional surface storage south of the Delta should be around 500 to 2,000 taf. The cumulative environmental impacts of several small to medium reservoirs needed to attain the storage capacity would probably be greater than one larger reservoir. Therefore, the small to medium size reservoir options were deferred.

Enlarging San Luis Reservoir has been considered for additional storage, but because of engineering and economic criteria, this has been deferred. The integrity of an enlarged San Luis Dam has been questioned, and the cost would be high.

TABLE 6G-8

Retained Off-Aqueduct Storage Options
South of the Delta

Watershed	*Dam Site*	*Reservoir Size Category*			
		Small	*Medium*	*Large*	*Very Large*
Garzas Creek	104		X	X	X
	105		X	X	
	106	X	X		
	107	X			
	108	X			
	109			X	
Ingram Canyon	37		X	X	
Kettleman Plain	99	X			
LBG/Los Banos Creek	181	X	X	X	X
Little Salado/Crow Creek	63	X			
Orestimba	170		X	X	
	171		X	X	X
Panoche/Silver Creek	111	X			
	112		X	X	
	114	X	X	X	X
	45			X	
Quinto Creek	54	X			
Romero Creek	56	X			
Sunflower	177		X		

FIGURE 6G-2.
Off-Aqueduct South of the Delta Watershed Sites

Operation of Off-Aqueduct Storage South of the Delta

To illustrate how south of Delta offstream storage would operate, LBG Reservoir is used as a model. This example treats LBG as an SWP facility. To meet CVP service area needs, USBR could participate with the Department in this project.

LBG would be located on Los Banos Creek 6 miles west of the California Aqueduct in the Los Banos Valley area. The main damsite would be about 80 miles south of the Delta. Facilities would consist of a storage reservoir with associated pump-generating plants and conveyance channels. Delta winter flows would be conveyed through the California Aqueduct and pumped into LBG for storage. Operation of the reservoir would be similar to that of San Luis Reservoir, except that LBG would retain about one half to two-thirds of its storage in average years to improve drought year water supply reliability of the SWP.

During periods of low Delta inflow, LBG would provide water supplies south of the Delta to reduce the demand for Delta exports. Added flexibility could permit the SWP to take advantage of seasonal and short-term water quality improvements to enhance the quality of delivered supplies. The 1.73 maf LBG Reservoir examined in the 1990 feasibility study would operate through a range of about 550 to 750 taf each year, filling in the early spring and releasing water to the California Aqueduct between May and September.

7

Options for Meeting Future Water Needs in Coastal Regions of California

This chapter covers the coastal hydrologic regions of the State: the North Coast, San Francisco Bay, Central Coast, and South Coast (Figure 7-1). These four regions make up 29 percent of the State's land area and were home to 78 percent of the State's population in 1995.

FIGURE 7-1
Coastal Hydrologic Regions

FIGURE 7-1
Coastal Hydrologic Regions

The Pulgas Water Temple, owned by the City and County of San Francisco.

FIGURE 7-2

North Coast Hydrologic Region

North Coast Hydrologic Region

. . .

Description of the Area

The North Coast Region comprises the Pacific Ocean coastline from Tomales Bay to the Oregon border, extending inland to the crest of coastal watersheds. The region includes all or large portions of Modoc, Siskiyou, Del Norte, Trinity, Humboldt, Mendocino, Lake, and Sonoma Counties. Small areas of Shasta, Tehama, Glenn, Colusa, and Marin Counties are also within the North Coast Region (Figure 7-2).

Most of the region is comprised of rugged mountains; the dominant topographic features are the Klamath Mountains and the Coast Range. Mountain elevations range from 5,000 feet along the coast to more than 8,000 feet in the Klamath River watershed. Valley areas include the high plateau of the Klamath River Basin in Modoc County, the Eureka/Arcata area, Hoopa Valley in Humboldt County, Anderson Valley, the Ukiah area, Alexander Valley, and the Santa Rosa Plain.

Precipitation in the region varies depending on location and elevation. In the Modoc Plateau of the Klamath River Basin, annual precipitation averages 10 inches, while higher elevation lands of the Smith River Basin in Del Norte County average more than 100 inches of rain per year. The southern portion of the region is drier; Santa Rosa averages about 29 inches of rain annually.

Most land area in the North Coast Region is forest or range land. Irrigated agriculture is concentrated in narrow river valleys such as the Russian River Valley in Sonoma County, and on the high plateau of the Klamath River Basin. The primary crops are pasture, grain, alfalfa, wine grapes, truck crops, and nursery stock. Principal cities in the region include Crescent City, Yreka, Eureka, Fort Bragg, Ukiah, Santa Rosa, and Rohnert Park. Table 7-1 shows the 1995 population and irrigated crop acreage in the region and 2020 forecasts.

Water Demands and Supplies

Because of the water dedicated to the North Coast's wild and scenic rivers, environmental water use comprises the majority of the total water demand in the North Coast Region. Water shortages are expected to occur only under drought conditions, as shown in Table 7-2. These water shortages will be mostly in the USBR's Klamath Project's service area and in some small coastal communities.

Three existing projects provide much of the North Coast's developed surface water supply—USBR's Klamath Project, Humboldt Bay Municipal Water District's Ruth Lake, and USACE's Russian River Project. The primary water storage facilities of USBR's Klamath Project are Upper Klamath Lake, Clear Lake, and Gerber Reservoir. This project was authorized by the Secretary of the Interior in 1905, and is one of the West's earliest reclamation projects. The project's primary purpose is to store and divert water for agricultural use. The project service area includes more than 230,000 acres of irrigable lands in Oregon and

TABLE 7-1

Population and Crop Acreage

	Population (thousands)	*Irrigated Crop Acreage (thousands of acres)*
1995	606	323
2020	835	335

TABLE 7-2
North Coast Region Water Budget (taf)[a]

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	169	177	201	212
Agricultural	894	973	927	1,011
Environmental	19,544	9,518	19,545	9,518
Total	**20,607**	**10,668**	**20,672**	**10,740**
Supplies				
Surface Water	20,331	10,183	20,371	10,212
Groundwater	263	294	288	321
Recycled and Desalted	13	14	13	14
Total	**20,607**	**10,491**	**20,672**	**10,546**
Shortage	**0**	**177**	**0**	**194**

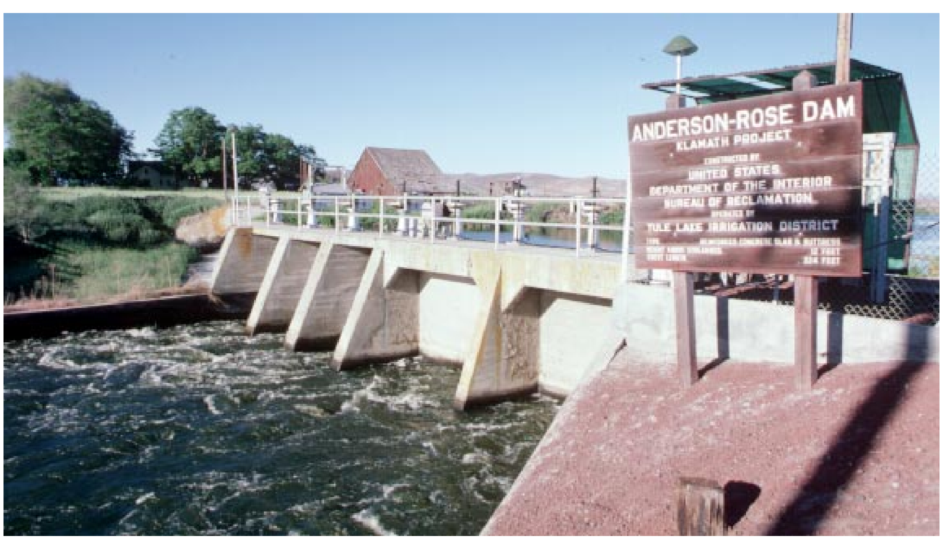
[a] Water use/supply totals and shortages may not sum due to rounding.

California. The project also serves four national wildlife areas—the Lower Klamath, Tule Lake, Clear Lake, and Upper Klamath Refuges.

The 48 taf Ruth Lake is Humboldt Bay Municipal Water District's water storage facility on the Mad River. Downstream Ranney collector wells capture water released from Ruth Lake for distribution in the Eureka-Arcata-McKinleyville area. Humboldt Bay MWD is a water wholesaler with seven municipal, two industrial, and about 200 miscellaneous water customers.

The Trinity River Division of the CVP develops supply for export to the Central Valley and does not deliver water in the North Coast Region. USBR constructed Trinity River facilities in the early 1960s to augment CVP water supplies in the Central Valley. The principal features of the Trinity Division are Trinity Dam and the 2.4 maf Trinity Lake on the upper Trinity River, Lewiston Dam, the 10.7-mile Clear Creek Tunnel that begins at Lewiston Dam and ends at Whiskeytown Lake in the Sacramento River Basin, Spring Creek Tunnel, and Spring Creek Powerplant.

Exports from the Trinity River to the Sacramento River Basin began in 1963. From 1980 through 1995, Trinity River exports averaged 825 taf annually. In 1981, the Secretary of the Interior increased instream flow requirements in the Trinity River from 120 taf to 287 taf in drought years, and 340 taf in wet years. In 1991, the Secretary of the Interior amended the 1981 decision, directing that at least 340 taf be released into the Trinity River for water years 1992 to 1996, pending completion of a USFWS instream flow study. In 1992, CVPIA mandated that the secretarial decision remain in place until the instream flow study was com-



USBR's Anderson-Rose Dam is located on the Lost River in Oregon, just north of the stateline. This Klamath Project facility diverts water to serve irrigation needs on the bed of the former Tule Lake in California and Oregon.

Courtesy of USBR

Trinity Dam and Trinity Lake. Releases from the reservoir are reregulated at Lewiston Dam, 7 miles downstream on the Trinity River. At Lewiston, water is either released back to the Trinity River or diverted through the Clear Creek Tunnel into the Sacramento River Basin.

Courtesy of USBR

pleted, at which time the study's recommendations would be implemented. Currently, a draft Trinity River flow evaluation report recommends that 815 taf, 701 taf, 636 taf, 453 taf, and 369 taf be released in the Trinity River during extremely wet, wet, normal, dry, and critically dry years, respectively. The water year types are based on Trinity Lake inflow.

Lake Mendocino on the East Fork Russian River near Ukiah and Lake Sonoma on Dry Creek near Geyserville are the water storage facilities of USACE's Russian River Project. Sonoma County WA receives most of the water from this project and delivers about 29 taf/yr to Santa Rosa, Rohnert Park, Cotati, and Forestville in the North Coast Region, and another 25 taf/yr to Novato, Petaluma, the Valley of the Moon, and Sonoma in the San Francisco Bay Region. The Russian River Project also regulates flow in the Russian River for agricultural, municipal, and instream uses within Mendocino and Sonoma Counties, and municipal uses in Marin County. Water is diverted from the Eel River into Lake Mendocino through PG&E's Potter Valley Project.

Local Water Resources Management Issues

Klamath River Fishery Issues

The primary water management issue in the Klamath River Basin is the restoration of fish populations that include listed species such as the Lost River and shortnose suckers, coho salmon, and steelhead trout. The Lost River sucker is native to Upper Klamath Lake and its tributaries, and the shortnose sucker is found in the Lost River, Clear Lake, Tule Lake, and Upper Klamath Lake. Both species spawn during the spring. Higher water levels in Upper Klamath Lake have been identified as an aid to recovery of these fisheries. Coho and steelhead were recently listed, and water supply implications will not be known until management plans are completed and recovery goals are established.

To address the need for greater certainty in project operations, USBR began preparing a long-term Klamath Project operations plan in 1995. Difficult and complex issues have delayed completion of the long-term plan. USBR has issued an annual operations plan each year since 1995 as it continues the development of the long-term plan. The Klamath River Compact Commission is facilitating discussions on water management alternatives to address ESA and water supply needs. This three-member commission was established by an interstate compact ratified by Congress in 1957 to facilitate integrated management of interstate water resources and to promote intergovernmental cooperation on water allocation issues. Members include a representative from the Department, the Director of the Oregon Water Resources Department, and a presidentially-appointed federal representative.

Trinity River Fish and Wildlife Management Program

Following completion of the Trinity River Division, fish populations in the Trinity River Basin declined dramatically. The Resources Agency established a statewide task force in 1967 to develop a program to improve the fishery. One of the most significant problems identified was sedimentation from Grass Valley Creek. In 1980, PL 96-335 authorized construction of Buckhorn Mountain Debris Dam on Grass Valley Creek, as well as sediment dredging in the Trinity River below Grass Valley Creek. In 1984, PL 98-541 authorized the Trinity River fish and wildlife management program, providing $57 million (excluding Buckhorn Mountain Debris Dam and sediment dredging costs) to implement actions to restore fish and wildlife populations in the Trinity River Basin to pre-project levels. Congress authorized an additional $15 million in 1993 for purchase of 17,000 acres of the Grass Valley Creek watershed and its restoration. PL 104-143 in 1996 extended the program three years to October 1, 1998, to allow expenditure of funds previously authorized, but not yet appropriated. Reauthorization of the program is currently under consideration. A draft EIS/EIR is being prepared to address proposed streamflow changes and mainstem Trinity River restoration actions.

Water Supplies of Small Coastal Communities

The town of Klamath in Del Norte County obtains its water supply from two wells adjacent to the Klamath River. During the recent drought, seawater intrusion forced the Klamath Community Services District to use an upstream private well in the Hoopa Creek drainage area. All of Klamath's water supply in 1995 was obtained from the private well, and no water was pumped from Klamath CSD's wells. In 1996, Klamath CSD pumped adequate supplies from its two wells, but seawater intrusion during dry years remains a problem. Although the Hoopa Creek drainage area has adequate groundwater supplies, Klamath CSD does not have funding to construct an additional well.

The town of Smith River, 13 miles north of Crescent City, takes its water supply from wells along Rowdy Creek. Water demands in the town of Smith River are expected to exceed the capacity of the town's delivery system if projected growth occurs. (Growth from Brookings, a popular Oregon retirement and resort community about 7 miles north of the stateline, is affecting Smith River.) There are no plans to upgrade Smith River's water system.

Growth in the Crescent City area is creating the need to expand the city's water distribution system, which consists of a Ranney collector well on the Smith River and a 50,000 gallon storage tank. The Ranney collector can produce about 7.8 taf/yr, but the capacity of the existing transmission and storage system is only about 4.5 taf/yr. Crescent City is planning to add new mains, a new pump station, one additional booster pump, and a 4 mg storage tank. The upgraded system will produce 5.9 taf/yr. The estimated cost is $6.7 million. A second phase will make additional distribution system improvements. These new conveyance facilities should meet the city's demands through 2007.

The Weaverville Community Services District in Trinity County serves about 1,370 metered connections. In average water years, demands within the district are met with existing supplies from East and West Weaver Creeks. During drought years, water rationing and building moratoria were needed to reduce demands. In response to drought year demands, a new diversion of up to 3 cfs from the Trinity River was constructed. The Weaverville area is expected to have adequate water supplies to meet demands over the next 30 years.

Trinity County Water Works District #1 is investigating a wastewater treatment and reuse project for the Hayfork area. The project would treat wastewater from individual septic systems, and would eliminate septic tank seepage into local streams. The district's feasibility study identified a gravity collection system with an oxidation pond and two marsh areas as the best alternative for wastewater treatment. The project would treat 160 af annually, and could reuse the treated water to irrigate agricultural lands or landscaping. The estimated cost for this project is $8.9 million.

The City of Rio Dell obtains its water from a well on property owned by the Eel River Sawmill. Pentachlorophenol has been detected in groundwater on the sawmill's property, although not in the city's well water. Rio Dell is planning to find an alternate water supply. The most likely alternative will be treated surface water from the Eel River.

The City of Fort Bragg experiences water shortages during drought years. The water sources for the city are direct diversions from surface water sources. During average rainfall years, water rights from these sources are enough to meet the city's demands to the year 2020. Supplies are inadequate to meet the city's needs during drought years and to maintain instream flows required by DFG. DHS issued an order in 1991 prohibiting new demands on the water system until adequate water supplies were developed. The city has been investigating alternate sources of supply and has implemented water conservation measures and improved existing system capacity. As a result of these corrective measures DHS lifted its order in 1993 and allowed the city to begin issuing building permits, subject to restrictions including no net increase in consumption and implementation of a conservation and retrofit program.

Groundwater use is constrained by limitations in aquifer storage capacity in some coastal communities. Wells on low terraces near the ocean are potentially vulnerable to seawater intrusion. The town of Mendocino is completely dependent on individual wells. A local survey conducted in 1986 showed that about 10 percent of the wells go dry every year and 40 percent go dry during drought years. In 1986, water was trucked in during summer and fall to help reduce shortages. The Mendocino Community Services District investigated new water supply sources, including wells in the Big River aquifer and desalting. To date, no acceptable water source has been identified. In 1990, town residents approved developing a public water system if an adequate water source could be found. The district is currently collecting hydrogeological data on the groundwater basin.

Russian River Environmental Restoration Actions

Water quality issues and barriers to fish migration are of concern in the Russian River Basin. No future water supply shortages are forecasted for the basin, although actions taken to protect recently listed salmonids may affect existing or future diversions. A Russian River Action Plan, prepared by Sonoma County WA in 1997, provides a regional assessment of needs in the watershed and identifies fishery habitat restoration projects in need of funding. The SWRCB is promoting a coordinated Russian River fishery restoration plan.

In 1997, NMFS listed coho salmon and steelhead trout as threatened along part of the Central California coast that includes the Russian River Basin. SCWA, USACE, and NMFS signed an agreement to establish a framework for consultation under Section 7 of the ESA. Under the agreement, USACE and SCWA will jointly review information on their respective Russian river activities to determine impacts to critical habitat.

The Eel-Russian River Commission, composed of county supervisors from Humboldt, Mendocino, Sonoma, and Lake Counties, provides a regional forum for agencies and groups to stay informed about projects and issues affecting the Eel and Russian Rivers. The Commission, formed in 1978 under a joint powers agreement among the counties, was to aid in implementing an Eel-Russian River watershed conservation and development plan. A regional issue currently being addressed by the Commission is the review of a

Currently, the main water issues in the Russian River Basin are related to watershed management and environmental restoration programs.

draft 10-year fishery study by PG&E for its Potter Valley Project, required as a condition of a 1983 FERC license.

A proposed SCWA project would allow fish passage through a flood control structure on Matanzas Creek in downtown Santa Rosa. The original structure, constructed in the early 1960s, does not permit fish passage. SCWA also proposes to install a fish ladder at Healdsburg Dam on the Russian River, a small flashboard dam used in the summer to create a recreational pool.

City of Santa Rosa Long-Term Wastewater Project

In early 1998 the City of Santa Rosa selected an alternative that would recharge depleted geothermal fields in the Geysers area with treated wastewater as part of its long-term wastewater recycling program. Under this alternative, the Santa Rosa Subregional Sewerage System will pump about 11 mgd of treated wastewater to the Geysers for injection into the steamfields. This amount is a little less than half the flow the treatment system is expected to produce at buildout. The project is intended to eliminate weather-related problems of the city's current disposal system and minimize treated wastewater discharges into the Russian River. The project consists of pipeline transmission and distribution systems and is scheduled to be completed by 2001.

SCWA Water Supply and Transmission Project

Sonoma County WA is preparing an EIR to develop additional water supply as well as to expand its existing water transmission system. The project will be implemented under an agreement among SCWA and its water contractors. Components of the project include water conservation, increased use of the Russian River Project, and expansion and revised operation of the water transmission system. Water conservation is planned to provide additional savings of 6.6 taf. The Russian River component will allow for increasing diversions from 75 to 101 taf from the Russian River. This increased use of the Russian River Project water will require construction of additional diversion and conveyance facilities, including new diversion locations. The project will continue to meet existing instream flow requirements associated with the SWRCB's Decision 1610 and will require new water rights applications to SWRCB. The transmission system component has two elements—facilities to divert and treat Russian River Project water, and transmission system improvements allowing for delivery of up to 167 taf/yr. The final EIR is scheduled for late 1998.

Potter Valley Project

PG&E's Potter Valley Project diverts water from the Eel River to the East Fork of the Russian River for power generation and downstream agricultural and municipal water use. The project consists of Scott Dam and Lake Pillsbury, Van Arsdale Diversion Dam and tunnel, and the Potter Valley Powerplant. The project diverts about 159 taf of water and generates about 60 million kWh of energy annually. Releases are limited by required minimum flows on the Eel River and by requirements to maintain reservoir levels in Lake Pillsbury during the summer recreation season. Under the FERC relicensing process, PG&E has been meeting with State and federal agencies to develop instream flow recommendations for the Eel River. Diversions from the Eel River are being evaluated in light of ongoing efforts to restore Eel River fisheries. PG&E is also trying to secure additional operating revenue from the project and, if unsuccessful, may sell or abandon the project. Local agencies have expressed interest in acquiring the project if it were to be sold.

Water Management Options for the North Coast Region

Table 7-3 shows a list of options for the region, and the results of an initial screening of the options. The retained options were evaluated (Table 7A-1 in Appendix 7A) based on a set of fixed criteria discussed in Chapter 6.

Water Conservation

Urban. Urban water demand forecasts for 2020 assume that BMPs are in place; consequently, only those urban conservation efforts which exceed BMPs are considered as options. All urban conservation options were retained. Reducing outdoor water use to 0.8 ET_o in new development would attain about 1 taf /yr of depletion reductions, while extending this measure to include existing development would reduce depletions by about 6 taf/yr. Reducing residential indoor water use to 60 and 55 gpcd would reduce depletions by 3 and 6 taf/yr, respectively. Reducing commercial, institutional, and industrial water use an additional 3 and 5 percent would attain 1 and 2 taf/yr of depletion reductions, respectively. Reducing distribution system losses to 7 and 5 percent would reduce depletions by 6 and 9 taf/yr.

TABLE 7-3

North Coast Region List of Water Management Options

Option	*Retain or Defer*	*Reason for Deferral*
Conservation		
Urban		
Outdoor Water Use to 0.8 ET_o	Retain	
Indoor Water Use	Retain	
Interior CII Water Use	Retain	
Distribution System Losses	Retain	
Agricultural		
Seasonal Application Efficiency Improvements	Defer	No significant depletion reductions attainable.
Flexible Water Delivery	Defer	No significant depletion reductions attainable.
Canal Lining and Piping	Defer	No significant depletion reductions attainable.
Tailwater Recovery	Defer	No significant depletion reductions attainable.
Modify Existing Reservoirs/Operations		
Ewing Reservoir Enlargement	Defer	No demand for additional supply.
New Reservoirs/Conveyance Facilities		
Boundary Reservoir - Lost River, Oregon	Defer	Low yields, high cost.
Beatty Reservoir - Sprague River, Oregon	Defer	High cost, archaeological resources, and sucker habitat.
Chiloquin Narrows Reservoir - Sprague River, Oregon	Defer	High cost, archaeological resources, and sucker habitat.
Montague Reservoir - Shasta River	Defer	Low yields, high cost.
Grenada Ranch Reservoir - Little Shasta River	Defer	Low yields, poor dam site and reservoir geology, high cost.
Table Rock Reservoir - Little Shasta River	Defer	No surplus water, no local interest.
Highland Reservoir - Moffett Creek	Defer	Low yields, high cost.
Callahan Reservoir - Scott River	Defer	Low yields, high cost, no local interest.
Grouse Creek Reservoir - E.F. Scott River	Defer	Reservoir seepage, high cost, no local interest.
Etna Reservoir - French Creek	Defer	Low yields, high cost, no local interest.
Mugginsville Reservoir - Mill Creek	Defer	Low yields, excessive cost.
Various sites in Noyo/Navarro River Basins	Defer	No local interest in offstream storage; unfavorable environmental conditions.
Long/Round/Aspen Valley Reservoirs - Klamath River	Defer	Excessive capital cost, questionable reservoir geology.
Georgia-Pacific Wood Waste Disposal Site	Defer	Site not available.
Georgia-Pacific Replacement Site	Defer	Unfavorable geotechnical conditions.
Georgia-Pacific Site No. 3	Defer	Unfavorable geotechnical conditions.
Newman Gulch Site	Defer	Unfavorable geotechnical conditions.
Large reservoir at Boddy Property Site	Defer	Excessive capital cost.
Smaller reservoir (at Boddy property site or alternate location)	Defer	Excessive capital cost.
Waterfall Gulch Intake Improvement	Defer	Biological, instream flow concerns.
South Basin (City of Fort Bragg)	Defer	Water rights issues.

TABLE 7-3

North Coast Region List of Water Management Options (continued)

Option	*Retain or Defer*	*Reason for Deferral*
Groundwater/Conjunctive Use		
New wells	Retain	
Water Marketing		
—	—	—
Water Recycling		
City of Fort Bragg	Defer	Unfavorable costs due to lack of potential users within a reasonable distance.
Desalting		
Brackish Groundwater		
City of Fort Bragg Project	Retain	
Seawater		
City of Fort Bragg Project	Defer	Excessive cost.
Other Local Options		
—	—	—
Statewide Options		
—	—	See Chapter 6.

Agricultural. The 2020 agricultural water demand forecasts assume that EWMPs are in place. As with the urban water management options, only those agricultural conservation efforts which exceed EWMPs are considered as options. Agricultural conservation options were deferred from evaluation for this region because they provide little potential to create new water (reduce depletions).

Modifying Existing Reservoirs or Operations

Trinity County Water Works District #1 has considered raising Ewing Dam, which was designed to be raised up to 12 feet to meet future water supply needs. Raising the dam 12 feet to increase reservoir capacity from 800 af to 1.45 taf and modifying the spillway and outlet works would cost $1.5 million. Plans to enlarge the reservoir were halted when Hayfork's primary employer (a lumber mill) closed, reducing the district's customer base by about 10 percent.

New Reservoirs and Conveyance Facilities

Onstream Storage. Eleven onstream reservoirs in the Klamath River Basin were evaluated and deferred, mainly because of high costs and relatively low yields. Cursory investigations of these projects were completed by USBR, the Department, or the Oregon Water Resources Department. Recent studies completed by the City of Fort Bragg identified potential onstream reservoir sites in the Noyo River watershed; however, these sites were deferred due to environmental and economic concerns.

Offstream Storage. USBR investigated three offstream reservoirs in Oregon's Long, Aspen, and Round Valleys adjacent to Upper Klamath Lake. These offstream storage plans were deferred due to high costs.

In 1993, the City of Fort Bragg moved forward with preliminary plans and work on an environmental impact report on what was then its preferred long-term project, which included a 1.5 taf offstream reservoir. Several promising locations were investigated, but geotechnical investigations indicated that all except one of the sites was unsuitable. Further detailed investigations and cost estimates for the most favorable site indicated the site was infeasible due to excessive costs. A smaller reservoir (about 1 taf) was evaluated, but was also not feasible.

Groundwater Development or Conjunctive Use

Surface water sources meet most of the water needs in the coastal regions. Communities with water shortage problems continue to look for possible groundwater sources and well locations to provide adequate supplies at reasonable cost. Although groundwater quality is generally good, supplies are limited by aquifer storage capacity. For example, Fort Bragg began a test program in 1994 to identify possible well sites, but no significant groundwater supply was found. The city has drilled test wells along the Noyo River about two miles upstream of its mouth, and is studying the potential development of a small production well. It appears that the product water may be brackish.

Water Recycling

The City of Fort Bragg had considered a water recycling project which involved using tertiary treated wastewater to replace potable water used at a lumber processing plant. However, water conservation efforts by the plant reduced its water demand by more than 50 percent, rendering this option uneconomical. Other water recycling projects planned in the region would not generate a source of new supply from a statewide perspective. There are several projects planned which would produce about 15 taf of recycled water annually to serve local water management needs for agricultural, environmental, and for landscape irrigation purposes.

Desalting

Interest in desalting for Fort Bragg increased when feasibility studies showed it was economically competitive with storage alternatives. The city evaluated two reverse osmosis alternatives—one involving seawater and one involving brackish water. Both plant designs would produce about 1 taf of potable water in drought years. Major cost components for the seawater plant would include the ocean intake structure, feedwater pipeline to the plant, and plant equipment. The brackish groundwater plant would require wells, well field collection piping, and a feedwater pipeline into the plant. The city is conducting more detailed studies to identify the location of brackish water sources and brine disposal options.

Other Local Options

Fort Bragg has investigated other alternatives that have not proven to be feasible. These alternatives include improving the city's diversion from Waterfall Gulch and new surface water sources in the South Basin. Lowering the intake structure at Waterfall Gulch would capture an additional 110 af/yr, but presents biological and instream flow concerns. New surface water sources have been identified, but these sources had water rights issues.

Options Likely to be Implemented in North Coast Region

Water supplies are not available to meet all of the region's 2020 water demands in drought years. Drought year applied water shortages are forecasted to be 194 taf. No average year shortages are forecasted for 2020. Ranking of retained water management options for the North Coast Region is summarized in Table 7-4. Table 7-5 summarizes options that can likely be implemented by 2020 to relieve the shortages.

The majority of shortages in the region are agricultural and are expected to occur in the Klamath Project area. The economics of crop production have a major influence on the extent to which growers can afford drought year water supply improvements. Additional groundwater development is a possibility in some areas of the Klamath Project, but there are little data available to evaluate this option. The ability to change cropping patterns in the northern part of the region is limited by the area's climatic conditions. There are no quantifiable options available to meet agricultural shortages.

Urban water conservation options could provide 18 taf/yr in water savings. Small communities along the coast generally do not have the financial resources to construct major water supply projects, and therefore will continue to investigate new groundwater supplies.

TABLE 7-4

Options Ranking for North Coast Region

Option[a]	*Rank*	*Cost ($/af)*	*Potential Gain (taf)*	
			Average	*Drought*
Conservation				
Urban				
Outdoor Water Use to 0.8 ET_o - New Development	M	750	1	1
Outdoor Water Use to 0.8 ET_o -New and Existing Development	M	[b]	6	6
Indoor Water Use (60 gpcd)	M	400	3	3
Indoor Water Use (55 gpcd)	M	600	6	6
Interior CII Water Use (3%)	M	500	1	1
Interior CII Water Use (5%)	M	750	2	2
Distribution System Losses (7%)	M	200	6	6
Distribution System Losses (5%)	M	300	9	9
Groundwater/Conjunctive Use				
New wells - Fort Bragg and other small coastal communities	H	150	[c]	[c]
Agricultural Groundwater Development	M	[b]	[b]	[b]
Desalting				
Brackish Groundwater				
City of Fort Bragg Project	L	770	1	1

[a] All or parts of the amounts shown for highlighted options have been included in Table 7-5.
[b] Data not available to quantify.
[c] Less than 1 taf.

TABLE 7-5

Options Likely to be Implemented by 2020 (taf)
North Coast Region

	Average	*Drought*
Applied Water Shortage[a]	**0**	**194**
Options Likely to be Implemented by 2020		
Conservation	—	18
Modify Existing Reservoirs/Operations	—	—
New Reservoirs/Conveyance Facilities	—	—
Groundwater/Conjunctive Use	—	—
Water Marketing	—	—
Recycling	—	—
Desalting	—	—
Other Local Options	—	—
Statewide Options	—	—
Expected Reapplication	—	—
Total Potential Gain	**—**	**18**
Remaining Applied Water Shortage	**0**	**176**

[a] Majority of shortages in this region are agricultural. Most agricultural shortages in this region are expected to occur in the Klamath Project area.

FIGURE 7-3.

San Francisco Bay Hydrologic Region

San Francisco Bay Hydrologic Region

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Description of the Area

The San Francisco Bay Region (Figure 7-3) extends from southern San Mateo County north to Tomales Bay in Marin County, and inland to the confluence of the Sacramento and San Joaquin Rivers near Collinsville. The eastern boundary follows the crest of the Coast Range. The region includes all of San Francisco and portions of Marin, Sonoma, Napa, Solano, San Mateo, Santa Clara, Contra Costa, and Alameda Counties. The San Francisco Bay Region is divided into the North Bay and South Bay planning subareas. Geographic features include the Marin and San Francisco Peninsulas; San Francisco, Suisun, and San Pablo Bays; and the Santa Cruz Mountains, Diablo Range, Bolinas Ridge, and Vaca Mountains of the Coast Range. Streams flow into the bays or to the Pacific Ocean.

The climate within the region varies significantly from west to east. The coastal areas are typically cool and often foggy. The inland valleys and interior portions of San Francisco Bay are warmer, with a Mediterranean-like climate. The average annual precipitation in the region is 31 inches, ranging from 13 inches in Pittsburg to 48 inches at Kentfield, northeast of Mount Tamalpais in Marin County.

The region is highly urbanized and includes the San Francisco, Oakland, and San Jose metropolitan areas. Agricultural acreage is mostly in the north, with the predominant crop being grapes. In the south, more than half of the irrigated acres are in high-value specialty crops, such as artichokes or flowers. Table 7-6 summarizes the population and irrigated crop acreage for the region.

TABLE 7-6

Population and Crop Acreage

	Population (thousands)	*Irrigated Crop Acreage (thousands of acres)*
1995	5,780	65
2020	7,025	65

Water Demands and Supplies

Table 7-7 shows the water budget for the San Francisco Bay Region. Environmental water demands, primarily Bay-Delta outflow, account for most of the San Francisco Bay Region's water use. Water demands for Suisun Marsh are also included in environmental water needs. As shown in the table, water shortages are forecast only for drought years.

North Bay

Municipal and industrial water use will continue to grow as the population in the North Bay grows. The fastest growing communities have been municipalities in southwestern Solano County, such as Fairfield and Benicia. Growth in the larger communities of Sonoma and Napa Counties, such as Petaluma and Napa, has also been fairly rapid (more than 20 percent during the 1980s). Growth in Marin County has been slow, initially because of a water connection moratorium administered by Marin Municipal WD in the 1970s, and more recently because of the lack of land available for development. Marin MWD imposed a second moratorium on water service connections during the 1987-92 drought. It was lifted in 1993 with the adoption of an integrated water supply program

TABLE 7-7
San Francisco Bay Region Water Budget (taf)[a]

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	1,255	1,358	1,317	1,428
Agricultural	98	108	98	108
Environmental	5,762	4,294	5,762	4,294
Total	**7,115**	**5,760**	**7,176**	**5,830**
Supplies				
Surface Water	7,011	5,285	7,067	5,417
Groundwater	68	92	72	89
Recycled and Desalted	35	35	37	37
Total	**7,115**	**5,412**	**7,176**	**5,543**
Shortage	**0**	**349**	**0**	**287**

[a] Water use/supply totals and shortages may not sum due to rounding.

and the signing of a new Russian River water supply contract.

The Suisun Marsh is the only managed wetland in the North Bay that requires deliveries of fresh water. Its annual applied water demand is expected to remain constant at 150 taf. Other environmental demands include instream flows in Walker and Lagunitas Creeks in Marin County.

Table 7-8 lists major water suppliers within the North Bay, along with their primary sources of supply. Each of these agencies serves a number of municipalities or water retailers. Groundwater and small locally developed supplies serve the remainder of the water users in the area. Table 7-9 lists local agency water supply reservoirs (with capacity greater than 10 taf) serving the North Bay.

- Sonoma County WA, which wholesales water throughout Sonoma and Marin Counties, is forecasting no water shortages through 2020, and is not looking at water supply reliability enhancement options.
- Marin MWD was once one of the most vulnerable water suppliers in the State. The district has negotiated a supplemental water supply contract with Sonoma County WA for 10 taf and now expects to have a more reliable supply as it develops infrastructure to import additional Russian River water.
- Napa County Flood Control and Water Conservation District has a contract for SWP water with a maximum entitlement of 25 taf/yr. The City and County of Napa are examining water supply en-

Vineyard acreage in the Napa and Sonoma Valleys is among the State's most expensive agricultural real estate. Grapes—wine grapes, table grapes, and raisin grapes—are one of California's top dollar value crops.

TABLE 7-8

Major North Bay Water Suppliers

Agency	*Primary Source of Supply*
Sonoma County WA	Russian River Project
Marin MWD	Local surface and Sonoma County WA contract
Napa County FC&WCD	Local surface and SWP
Solano County WA	Solano Project and SWP

hancement options to ensure future supply reliability.

- Solano County WA anticipates a water supply deficiency as municipalities in the western part of the county urbanize rapidly without developing additional water supply sources. Solano County WA's 1995 SWP supply was about 21 taf. The agency's annual SWP entitlement is 42 taf. Benicia is the most vulnerable of the agency's service areas to drought conditions because it is entirely dependent on SWP water. Fairfield also is forecasting future drought year shortages. Vallejo has its own supply from the Delta, which is now conveyed through North Bay Aqueduct facilities.

South Bay

The South Bay is highly urbanized—about 16 percent of the State's population lives in 2 percent of the State's land area. A minor portion of South Bay water use is for agriculture. Hayward Marsh is the only identified environmental water use within the South Bay. The marsh, part of the Hayward Regional Shoreline, has an annual freshwater use of approximately 10 taf of reclaimed wastewater from Union Sanitation District. Industrial water use for cooling is primarily associated with independently produced industrial supplies along the Carquinez Strait.

Table 7-10 lists the major water suppliers in the South Bay and their primary sources of supply. Those areas not served by the listed suppliers get their water from groundwater and from small locally developed surface supplies. Alameda County Water District, Zone

The SWP's North Bay Aqueduct terminates at the Napa Turnout Reservoir, a 22 af storage tank. Napa County Flood Control and Water Conservation District is the contractor for this water supply.

TABLE 7-9

Local Agency Reservoirs Serving the North Bay

Agency	*Reservoir*	*Capacity (taf)*	*Year Constructed*	*Region*
USACE/Sonoma CWA[a]	Mendocino	119	1922	North Coast
USACE/Sonoma CWA[a]	Sonoma	381	1982	North Coast
Pacific Gas & Electric	Pillsbury	73	1921	North Coast
Marin MWD	Kent	33	1953/1982[b]	San Francisco Bay
Marin MWD	Nicasio	22	1960	San Francisco Bay
Marin MWD	Soulajule	11	1979	San Francisco Bay
City of Napa	Hennessey	31	1946	San Francisco Bay
City of Vallejo	Curry	11	1926	San Francisco Bay

[a] USACE built Lake Mendocino and Lake Sonoma primarily for flood control. Sonoma County WA operates the facilities for water supply and holds water rights for the supply.

[b] A 16.5 taf reservoir was initially constructed in 1953. The dam was raised in 1982, nearly doubling the capacity.

TABLE 7-10

Major South Bay Water Suppliers

Agency	*Primary Source of Supply*
San Francisco PUC	Hetch Hetchy project and local surface
Santa Clara Valley WD	Local surface, groundwater, CVP, and SWP
Alameda County WD	Local surface, groundwater, SWP, and Hetch Hetchy project
Zone 7 WA	Local surface, groundwater, and SWP
East Bay MUD	Mokelumne River project and local surface
Contra Costa WD	CVP and local surface

7 Water Agency, and Santa Clara Valley Water District recharge and store local and imported surface water in local groundwater basins. Each of the major water agencies supplies several municipalities or water retailers. Table 7-11 lists local agency water supply reservoirs (with capacity greater than 10 taf) serving the South Bay.

- SFPUC provides water to more than 2.3 million people in San Francisco, San Mateo, Santa Clara, and Alameda Counties, and is forecasting drought year shortages through 2020. In 1990 and 1991, wholesale and retail customers received 25 percent supply reductions (based on historical use). In 1991, SFPUC adopted, but did not implement, a 45 percent rationing plan. Recently revised instream flow requirements in the Tuolumne River Basin have reduced the available Hetch Hetchy supply. The city's studies indicate that the annual yield of the Hetch Hetchy system has dropped from 336 taf to 271 taf.
- SCVWD, which supplies water to about 1.7 million people, provides water to 16 municipal and industrial retailers as well as to agricultural users in Santa Clara County. A number of these retailers also contract with SFPUC for water from Hetch Hetchy. The district possesses one of the most diverse supplies in the State, with imported state project and federal project water, locally developed surface supplies, and extensive groundwater recharge programs. Some of the retail agencies in

TABLE 7-11

Local Surface Reservoirs Serving the South Bay

Agency	*Reservoir*	*Capacity (taf)*	*Year Constructed*	*Region*
San Francisco PUC	Lloyd	273	1956	San Joaquin River
San Francisco PUC	Eleanor	27	1918	San Joaquin River
San Francisco PUC	Hetch Hetchy	341	1923	San Joaquin River
San Francisco PUC	Calaveras	97	1925	San Francisco Bay
San Francisco PUC	Crystal Springs	58	1888	San Francisco Bay
San Francisco PUC	San Andreas	19	1870	San Francisco Bay
San Francisco PUC	San Antonio	50	1964	San Francisco Bay
East Bay MUD	Camanche	417	1963	San Joaquin River
East Bay MUD	Pardee	198	1929	San Joaquin River
East Bay MUD	San Pablo	39	1920	San Francisco Bay
East Bay MUD	Briones	61	1964	San Francisco Bay
East Bay MUD	Chabot	10	1892	San Francisco Bay
East Bay MUD	Upper San Leandro	41	1977	San Francisco Bay
Contra Costa WD	Los Vaqueros[a]	100	1998	San Joaquin River
Santa Clara Valley WD	Calero	10	1935	San Francisco Bay
Santa Clara Valley WD	Coyote	23	1936	San Francisco Bay
Santa Clara Valley WD	Leroy Anderson	89	1950	San Francisco Bay
Santa Clara Valley WD	Lexington	20	1953	San Francisco Bay

[a] Reservoir provides emergency storage and water quality regulation. Does not develop local supply.

State Highway 280 parallels San Francisco's Upper and Lower Crystal Springs Reservoirs in San Mateo County. The reservoirs are located on the San Andreas fault zone.

the district are vulnerable to drought deficiencies imposed by the SWP, CVP, and Hetch Hetchy Project. These deficiencies may be intensified by diminished local runoff during drought conditions.

- ACWD serves a population of 292,000 in southwestern Alameda County, adjacent to San Francisco Bay. ACWD's Niles Cone groundwater basin supply is augmented by SWP and Hetch Hetchy supplies. The district is vulnerable to drought deficiencies imposed by SWP or SFPUC.
- Zone 7 WA delivers water in the Livermore-Almaden Valley in eastern Alameda County, serving communities such as Dublin, Livermore, and Pleasanton, as well as agricultural and industrial customers. Z7WA has an annual SWP entitlement of 46 taf.
- EBMUD provides water to 1.2 million people in the remainder of northern Alameda County, and part of western Contra Costa County. Virtually all of the water used by EBMUD comes from the 577-square-mile watershed of the Mokelumne River, which collects runoff from Alpine, Amador, and Calaveras Counties, on the west slope of the Sierra Nevada. EBMUD has water rights for up to 364 taf/yr from the Mokelumne River. In average years, district reservoirs in the East Bay capture an additional 30 taf from local watershed runoff. In drought years, evaporation and other reservoir losses may exceed local runoff.
- CCWD delivers municipal and industrial water throughout central and eastern Contra Costa County. Deliveries from CCWD go up during droughts as industrial diverters stop diverting with their own Delta water rights (because of water quality constraints) and use CCWD's CVP supplies instead. CCWD's 195 taf/yr CVP contract was recently renegotiated to include operation of Los Vaqueros Reservoir, completed in 1998. Under its new CVP contract CCWD will receive 75 percent of the contract amount, or 85 percent

Santa Clara Valley Water District operates an extensive system of groundwater recharge facilities, some of which are incorporated into a regional system of recreational walking/ biking trails.

CCWD's Los Vaqueros Dam under construction. The reservoir, completed in 1998, does not provide new water supply, but provides terminal storage for CCWD's existing supply and improves service area water quality.

of historical use, during drought periods. Under severe drought conditions, the CVP supply may be reduced to 75 percent of historical use. CCWD has a smaller locally developed source at Mallard Slough, with an associated right to take up to 26.7 taf/yr. Diversions from Mallard Slough are unreliable due to poor water quality. The average annual diversion from this source over the past 20 years was only 5.6 taf.

Small independent water systems, such as those along the San Mateo coast, also suffer water supply reliability problems during droughts. These systems often rely on a single source, such as groundwater, and do not have connections to the larger systems in the Bay Area.

Local Water Resources Management Issues

Bay-Delta Estuary

The CALFED Bay-Delta Program and the 1995 SWRCB Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary are discussed in Chapters 2, 4, and 6. CALFED's ecosystem restoration program could restore wetlands and riparian habitats in the Delta. Other ERP actions in the region could include protection and enhancement of agricultural lands for wildlife, focusing on agricultural land and water management practices that would increase wildlife habitat value, and discouraging development of ecologically important agricultural lands for urban or industrial uses in the Delta, Suisun Marsh, and north San Francisco Bay.

Suisun Marsh

In 1995, USBR, DWR, DFG, and the Suisun Resource Conservation District began negotiations to update the Suisun Marsh Preservation Agreement. In 1996, the negotiators agreed in principle to 10 joint actions designed to lower soil salinity on Suisun Marsh managed wetlands (especially in the Marsh's western half) and to use water more efficiently. SWRCB will review western Suisun Marsh water quality objectives and water rights issues as part of its Bay-Delta water rights proceeding. More information on the Suisun Marsh can be found in Chapters 2, 4, and 6.

Local Water Agency Issues

North Bay. The primary water supply source for Sonoma County Water Agency, the Russian River, is in the North Coast Hydrologic Region. Issues related to SCWA and the Russian River are discussed in the North Coast Region portion of this chapter. Issues facing other major water suppliers in the North Bay are discussed below.

In 1995, SWRCB issued Decision WR 95-17, establishing instream flow requirements in Lagunitas Creek watershed. Marin MWD estimates that the decision will diminish its supply by 3 taf annually during drought years. In the past, Marin MWD examined desalting as an option to augment its water supply, studying construction of a 10 mgd reverse osmosis desalting plant near the western end of the San Rafael Bridge. The plant's annual yield would be approximately 10 taf at a cost of $1,900/af. The desalting project was included in a 1991 bond measure that was not approved by the voters. The following year, a bond measure for new facilities to bring more Russian River water to Marin County passed, and Marin MWD's need for the desalting option diminished. The new Marin MWD Russian River facilities will be on line by 2020. Since the district has all the necessary permits, this water source is not listed as a future option but is included in the district's base supply.

Napa County voters approved a local ordinance in 1998 which established a 0.5 percent sales tax to

Although lands in the Suisun Marsh are managed primarily to provide waterfowl habitat, a variety of mammals are found there as well.

fund a Napa County flood protection and watershed improvement expenditure plan. The goal of the plan was to "provide flood protection, save lives, protect property, restore the Napa River, Napa Creek, and other tributaries, maintain economic vitality, and enhance riparian environments". The Napa River and Napa Creek Project, a cooperative effort with USACE, is designed to provide 100-year flood protection for the City of Napa and environmental restoration. These objectives will be achieved by creating a flood bypass channel and wetlands; removal, redesign and replacement of floodway obstructions; elevation and relocation of homes; and construction of set-back levees and floodwalls. The design is intended to provide flood protection while allowing the river to meander through wide riparian zones. In other actions, funds would be provided for flood protection, environmental enhancement, and water supply reliability improvements for other communities and unincorporated areas of the County.

USBR and Solano County Water Agency have been involved in water rights actions on Putah Creek upstream and downstream of USBR's Solano Project facilities. In 1995, a settlement agreement was reached with water users in Lake and Napa Counties upstream of Lake Berryessa. The agreement establishes limits on future water development in the Lake Berryessa watershed and allocates water for the upstream users. A court-appointed watermaster will monitor water uses and enforce the terms of the settlement agreement.

Downstream of the Solano Project, disputes center around environmental water use and riparian water rights. The Putah Creek Council brought suit in 1990 against Solano Project water users to increase flows in the lower reaches of the creek. In 1996, the Sacramento County Superior Court ruled on instream flow requirements for Putah Creek downstream from Solano Diversion Dam, where water is diverted to Putah South Canal for delivery to agricultural lands and to communities in Solano County. The judgment cited the public trust doctrine as well as California Fish and Game code requirements and required higher (and year-round) flows from the creek into the Yolo Bypass. SCWA estimates the additional requirements are approximately 10 taf during an average year and 20 taf during a dry year. Solano County interests are appealing the judgment, which has been stayed until the appeal is heard. USBR is seeking an out-of-court settlement of the case. Under the Superior Court judgment, Solano County water users would be responsible for meeting the instream flow requirements in the downstream portion of the creek. Solano County water users have asked SWRCB to participate in the settlement process so that regulation of riparian diversions can be included in the final instream flow requirements for the creek.

SCWA's contract with USBR for Solano Project water supply will expire in 1999. The contract is renewable, but the terms and conditions of the contract will be renegotiated. SCWA will then need to renegotiate its contracts with Solano Project member entities.

SCWA has entered into a multi-year banking and exchange agreement with Mojave Water Agency in the South Lahontan and Colorado River regions. During wet years, SCWA can bank up to 10 taf of its annual SWP entitlement in MWA's groundwater basin. During dry years, SCWA can take part of MWA's SWP entitlement in exchange (up to half the banked amount with a maximum of 10 taf/yr). SCWA pays for part of the transportation cost to convey the water to MWA.

Solano County water agencies are monitoring use of groundwater from the Putah Fan/Tehama Formation groundwater basin because of concerns about the condition of the shared basin. The City of Vacaville, Solano Irrigation District, Maine Prairie Water District, and Reclamation District 2068 have implemented AB 3030 groundwater management plans. SCWA has initiated a groundwater monitoring and data collection program. Vacaville, SID, Dixon, and Solano County developed a 1995 agreement to cooperatively mitigate any adverse conditions related to the basin.

South Bay. San Francisco Public Utility Commission and the Bay Area Water Users Association (SFPUC Bay Area Water contractors) are cooperatively developing a water supply master plan for the PUC's retail and wholesale service areas. Phase 1 of the three-phase plan was recently completed. The preliminary list of water supply options to be considered in Phase 2 includes:

- Short- and long-term Central Valley water transfers.
- Conjunctive use / groundwater banking within the Hetch Hetchy system (Tuolumne River Basin and areas adjacent to the aqueduct).
- Transfers within the Hetch Hetchy system.
- Additional surface storage within the Hetch Hetchy system.
- Conjunctive use / groundwater banking within the Bay Area system.
- Transfers within the Bay Area system.
- Additional surface storage within the Bay Area system.
- Desalting.
- Other local projects.

Phase 2 will ultimately produce a master plan for the PUC system and is scheduled for completion in 1999. Phase 3, the implementation phase of the master plan, will include environmental review, design, and construction of plan elements. Construction is anticipated to begin as early as 2001.

Without improvements to its water supply reliability, SCVWD is forecasted to face the largest drought year shortages in the San Francisco Bay Region. The district released an integrated water resources plan in December 1996 to address water supply reliability through 2020. The primary components of the preferred strategy include water banking, water transfers, water recycling, and water conservation. Components are scheduled to be phased into operation as necessary to meet increasing demands. Implementation of specific components is designed to be flexible, with a list of contingency strategies to meet changing conditions. The plan is to be updated every three to five years.

Alameda County Water District is continuing to monitor and manage saline water intrusion in its bayside aquifers. The district depends upon the Niles Cone groundwater basin, which includes at least three distinct aquifers, for district supplies. The district recharges locally developed water and imported surface water to the basin and extracts recharged supplies. Prior to ACWD's import of surface supplies in the 1960s, the upper two aquifers were overpumped, causing saline intrusion into the basin. In 1974, ACWD began its aquifer reclamation program, which includes nine wells designed to extract and discharge saline groundwater from the basin. Because of further intrusion of saline water during the recent drought, operations have been modified to pump and dispose of greater quantities of saline water. In 1992, a reconnaissance level study was conducted to evaluate the feasibility of desalting water pumped from extraction wells, and blending it with groundwater and imported surface water. This desalting option is discussed in the following section.

ACWD is developing a groundwater model to simulate the effectiveness of its aquifer reclamation program, movement of saline water, and remediation of the basin. Because runoff from the Alameda Creek watershed is used to recharge the groundwater basin, ACWD is working with upstream agencies and the RWQCB to ensure that water quality in Alameda Creek is not compromised due to development or other activities in the watershed.

Zone 7 WA has initiated a water supply master plan program EIR to meet projected water needs. Preliminary estimates indicate a need for 40 to 50 taf of additional water supply by 2020. The water supply program will include imported surface water transfers, conservation, water recycling, and purchase of the South Bay Aqueduct's currently unused conveyance capacity.

In a separate planning effort, Z7WA has been working with local developers on a water transfer agreement to provide water to 9,500 new homes in Dougherty Valley, in southern Contra Costa County. A small portion of the Dougherty Valley development is within EBMUD's existing service area. After Contra Costa County approved the development in 1992, EBMUD indicated that it could not reliably provide water service to all 11,000 new customers. Ultimately, EBMUD agreed to provide service to Dougherty Valley over a lengthy development period, with the condition that developers try to find another source of water. The developers negotiated with Berrenda Mesa Water District, a member agency of Kern County WA, to purchase 7 taf of currently unused SWP entitlement water. Dublin San Ramon Services District agreed to be the water retailer and Z7WA, a wholesaler of SWP water, will treat and deliver water from the South Bay Aqueduct. In addition to paying for the entitlement water and connection fees from Z7WA and DSRSD, developers have agreed to pay Z7WA an additional $18 million for the wholesale service. DSRSD and Z7WA anticipate that the arrangement will result in lower water costs to existing customers and improved reliability. Another condition of the agreement stated that the project could not use existing local Z7WA storage space (primarily the Livermore Valley groundwater basin). Z7WA completed an agreement with Semitropic Water Storage District for 43 taf of groundwater storage, which is also being purchased by the developers. In wet years, excess water from Berrenda Mesa WD will be delivered to SWSD and stored in the groundwater basin. In drought years, Z7WA would receive SWP water in exchange through the SBA.

After the Z7WA / Dougherty Valley arrangement was finalized, the City of Livermore and environmental interests sued Z7WA in an effort to stop similar future arrangements. (The city is one of Z7WA's primary contractors.) A major concern of the plaintiffs is that Z7WA's water supply reliability will be diminished.

EBMUD's board approved a water supply action plan in 1995 to meet the objectives of its 1993 water supply management program EIR for improving supply reliability in its service area. The action plan's recommendation was to construct a Folsom South Canal connection to EBMUD's Mokelumne Aqueduct, to allow the district to use its CVP contract for up to 150 taf/yr of American River water. The project would be designed to operate in accordance with the Alameda County Superior Court's 1990 Hodge Decision, which confirmed the district's right to divert its contract amount subject to the court's physical solution for instream flow requirements in the Lower American River.

In November 1997, EBMUD and USBR released a draft EIR/EIS with two alignment alternatives for conveying American River water and one no project alternative. One alternative incorporates a concept developed by Sacramento County, the City of Sacramento, and EBMUD to construct a joint diversion facility near the American River's confluence with the Sacramento River. American River water would be diverted near the confluence and would be pumped back to the City of Sacramento's Fairbairn Water Treatment Plant. A portion of this water would continue on to the Folsom South Canal where it would be conveyed to the Mokelumne Aqueduct via a pipeline extension from the end of the canal. Water for Sacramento County would be treated at the Fairbairn Water Treatment Plant and conveyed to local water users.

In 1997, San Joaquin County interests proposed a groundwater storage project that would allow EBMUD to store surface water in San Joaquin County aquifers and would provide significant benefits to San Joaquin County water users. A joint powers authority of San Joaquin County water agencies hopes to initiate a pilot project to help assess the feasibility of this conjunctive use proposal. EBMUD has agreed to provide water for the project and is retaining this alternative for consideration to provide more out-of-service area storage and improved supply reliability during droughts. However, a conjunctive use alternative was not included in EBMUD's draft EIR for conveyance of its CVP contract supply.

EBMUD has also been involved in negotiations related to instream flows in the Mokelumne River. EBMUD's 1981 FERC license for operation of hydropower facilities at Pardee and Camanche Reservoirs incorporated an existing instream flow agreement between the district and the DFG. During the 1987-92 drought, poor fishery conditions on the Mokelumne River and fish losses at the district's Camanche fish hatchery prompted FERC to evaluate fishery flows. FERC issued a final EIS in November 1993, which was opposed by all the involved parties. Subsequent negotiations led to preparation of a settlement agreement by EBMUD, DFG, and USFWS which was submitted to FERC for review in June 1997. EBMUD has already implemented the agreement's flows which significantly impact the district's water supply. EBMUD estimates that its 2020 shortage with the new agreement flows would increase from 130 taf to 185 taf. The district will continue to pursue reliability enhancement options to meet the expected increased shortage.

Contra Costa Water District is facing several issues with its CVP supply, which is its primary supply source. CCWD's CVP contract is scheduled to expire in 2010, but CVPIA established financial penalties for not committing to review by 1997. The district is weighing the potential loss of supply associated with renewal against the financial penalties, and expects that the reliability of its 195 taf contractual supply will be reduced due to CVPIA implementation.

Bay Area Regional Water Recycling Program

With passage of Title 16 of PL 102-575 in 1992, USBR joined with Bay Area water and wastewater agencies to fund a study of regional water recycling potential. The Bay Area regional water recycling program (formerly Central California regional water recycling program) was established in 1993 to develop a regional partnership for maximizing Bay Area water recycling. The program is sponsored jointly by USBR, the Department, and 13 Bay Area water and wastewater agencies. During the first phase of the program, completed in April 1996, participating agencies explored potential uses for water recycled from Bay Area wastewater treatment plants. The feasibility study showed that a regional approach would be productive.

A major component of the 1996 feasibility study was assessment of potential recycled water use in the Central Valley and other locations outside the Bay Area. The study determined that marketing the recycled water for agricultural use in the Central Valley was not feasible. A regional water recycling master plan, now in preparation, will focus on recycled water markets in the Bay Area. A limited assessment of agricultural uses immediately south of Santa Clara County will be made, but no further assessment of Central Valley uses will be included. Another major component of the feasibility study was the assessment of options to improve recycled water quality with respect to salinity. Two options originally assessed will not be included in the master plan—on-site agricultural salt management and management of agricultural drainage.

Water quality, especially salinity levels, will need to be managed to ensure the feasibility of Bay Area water recycling. The master plan will consider methods to control salt at the point of origin, including controlling infiltration of saline groundwater into agencies' pipelines. Other salt control methods to be considered include regulation of water softeners, control of industrial discharges, and treatment.

Water Management Options for the San Francisco Bay Region

Table 7-12 shows a list of options for the region, and the results of an initial screening of the options. The retained options were evaluated (Table 7A-2 in Appendix 7A) based on a set of fixed criteria discussed in Chapter 6.

Conservation

Urban. Urban water demand forecasts for 2020 assume that BMPs are in place; consequently, only those urban conservation efforts which exceed the BMPs are considered as options. All urban conservation options were retained. Reducing outdoor water use to 0.8 ET_o in new development would attain about 2 taf/yr of depletion reductions, while extending this measure to include existing development would reduce depletions by about 52 taf/yr. Reducing residential indoor water use to 60 and 55 gpcd would attain depletion reductions of 38 and 77 taf/yr, respectively. Reducing commercial, institutional, and industrial water use by an additional 3 percent and 5 percent would attain 11 and 18 taf/yr of depletion reductions, respectively. About 13 taf/yr of depletion reductions would be attained by reducing distribution system losses to 5 percent.

Agricultural. As with urban demand forecasts, agricultural water demand forecasts for 2020 assume that EWMPs are in place and only those efforts which exceed the EWMPs are considered as options. Due to the relatively small amount of irrigated acreage in the region and the high SAE attained on average throughout the region, no significant depletion reductions would accrue.

Modify Existing Reservoirs/Operations

Napa County Flood Control and Water Conservation District has considered reservoir enlargement options which would provide additional offstream storage for Napa River flows. In the South Bay, SCVWD has evaluated enlarging Leroy Anderson Reservoir, which could increase SCVWD's annual supply by about 25 taf. EBMUD has had several proposals to enlarge both of its Mokelumne River reservoirs. The

TABLE 7-12

San Francisco Bay Region List of Water Management Options

Option	*Retain or Defer*	*Reason for Deferral*
Conservation		
Urban		
Outdoor Water Use to $0.8ET_o$	Retain	
Indoor Water Use	Retain	
Interior CII Water Use	Retain	
Distribution System Losses	Retain	
Agricultural		
Seasonal Application Efficiency Improvements	Defer	No significant depletion reductions attainable.
Flexible Water Delivery	Defer	No significant depletion reductions attainable.
Canal Lining and Piping	Defer	No significant depletion reductions attainable.
Tailwater Recovery	Defer	No significant depletion reductions attainable.
Modify Existing Reservoirs/Operations		
Enlarge Lake Hennessey / Napa River Diversion	Retain	
Enlarge Bell Canyon Reservoir	Retain	
Enlarge Bell Canyon Reservoir/ Napa River Diversion	Retain	
Enlarge Pardee Reservoir	Retain	
Enlarge Camanche Reservoir	Retain	
Enlarge Briones Reservoir	Defer	Geologic hazards.
Enlarge Chabot Reservoir	Defer	Substantial residential development.
Enlarge Leroy Anderson Reservoir	Retain	
Upgrade Milliken Treatment Plant	Retain	
Reoperate Rector Reservoir	Retain	
New Reservoirs/Conveyance Facilities		
Chiles Creek Reservoir Project/ Napa River Diversion	Retain	
Enlarge Lake Hennessey /Chiles Creek Project / Napa River Diversion	Retain	
Carneros Creek Reservoir / Napa River Diversion	Retain	
Upper Del Valle Reservoir	Retain	
Buckhorn Dam and Reservoir	Retain	
Upper Kaiser Reservoir	Retain	
Upper Buckhorn Reservoir	Retain	
Middle Bar Reservoir (Amador & Calaveras Counties)	Retain	
Duck Creek Offstream Reservoir	Retain	
Devils Nose Project (Amador County)	Retain	
Clay Station Reservoir (Sacramento County)	Defer	Wetlands, endangered species.
Alamo Creek Reservoir	Defer	Substantial residential development.
Bolinger Reservoir	Defer	Substantial residential development.
Cull Canyon Dam	Defer	Substantial residential development.
Canada del Cierbo Reservoir	Defer	Storage cost too high ($16,000/af).
Curry Canyon Reservoir	Defer	Substantial residential development.

TABLE 7-12

San Francisco Bay Region List of Water Management Options (continued)

Option	*Retain or Defer*	*Reason for Deferral*
Lower Kaiser Reservoir	Defer	Storage cost too high ($9,000/af).
Bailey Road Reservoir	Defer	Storage cost too high ($21,000/af).
EBMUD American River Supply	Retain	
Groundwater/Conjunctive Use		
EBMUD/San Joaquin County Conjunctive Use	Defer	Under discussion; not yet defined.
Milliken Creek Conjunctive Use	Retain	
Lake Hennessey /Conn Creek Conjunctive Use	Retain	
Recharge Dumbarton Quarry Pits	Defer	Unsuitable geologic conditions.
Sunol Valley Groundwater Recharge	Defer	Limited aquifer production.
Water Marketing		
Napa/Solano County WA Exchange	Defer	SCWA is not interested in exchange.
Solano County WA	Defer	No proposals identified at this time.
Contra Costa WD	Defer	No proposals identified at this time.
Zone 7 WA/Kern County WA	Retain	
Santa Clara Valley WD/SLDMWA	Retain	
Water Recycling		
Bel Marin Keys Golf Course - North Marin Water District	Retain	
Black Point Golf Links - North Marin Water District	Retain	
Central Marin Water Recycling Project - Marin MWD	Retain	
Golf Course Irrigation, City Park Irrigation - North San Mateo CSD	Retain	
Hercules/Franklin Canyon WRP-Phase 2 - EBMUD	Retain	
Industrial Use - Central Contra Costa Sanitary District	Retain	
Lamorinda - Central Contra Costa Sanitary District	Retain	
Nonpotable Wastewater Reuse Master Plan - Union Sanitation District	Retain	
Phase 1 Water Reclamation Program - Alameda County WD	Retain	
Phase 2 Water Reclamation Program - Alameda County WD	Retain	
San Francisco Water Recycling Master Plan	Retain	
San Ramon Valley Recycled Water Program - DSRSD/EBMUD	Retain	
San Ramon Valley Water Recycling Project - EBMUD	Retain	
South Bay Water Recycling Project - City of Santa Clara	Retain	
South Bay Water Recycling Project - San Jose	Retain	
Zone 1 - Central Contra Costa Sanitary District	Retain	

TABLE 7-12
San Francisco Bay Region List of Water Management Options (continued)

Option	*Retain or Defer*	*Reason for Deferral*
Desalting		
Brackish Groundwater		
Alameda County WD Aquifer Recovery Project	Retain	
Seawater		
Marin Municipal WD Desalting Project	Retain	
Other Local Options		
New Surface Water Diversion from Sacramento River by Cities of Benicia, Fairfield, & Vacaville	Retain	
Statewide Options		
—	—	See Chapter 6.

improvement of system yields associated with these projects has not been determined.

Reoperating Rector Reservoir in Napa County would provide an increase of approximately 1.2 taf/yr in system yield. NCFC&WCD is also considering a modification of its Milliken Water Treatment Plant, which would generate a small increase (450 af) in its annual water supply.

New Reservoirs and Conveyance Facilities

Ten new reservoirs were evaluated for Bay Area water agencies. NCFC&WCD investigated several diversion and storage projects, including Chiles Creek Reservoir Project and Carneros Creek Reservoir Project. The viability of these offstream storage projects depends upon the district's ability to make Napa River diversions. (SWRCB has declared the Napa River to

USBR's Folsom South Canal was designed to convey water from the American River below Nimbus Dam to central San Joaquin County. Only part of the canal was actually constructed, and the canal now terminates in southeastern Sacramento County.

Courtesy of USBR

be fully appropriated during parts of the year.) Some agencies, including ACWD, have examined an Upper Del Valle Reservoir Project. EBMUD has considered three new storage reservoirs in its service area and two new reservoirs in the Mokelumne Basin (Middle Bar and Devils Nose projects). These storage options have been inactive since EBMUD's focus on its supplemental water supply project.

As discussed previously, EBMUD and USBR released a draft EIR/EIS in 1997 for EBMUD's diversion of its American River CVP supply. EBMUD estimates that it would receive 112 taf and 70 taf in average and droughts years, respectively. (The draft EIR/EIS evaluates alternatives for conveyance of the water. Project yield remains the same in either of the conveyance alternatives.)

Groundwater Development or Conjunctive Use

EBMUD is continuing discussions with San Joaquin County interests for a joint groundwater storage/conjunctive use project. EBMUD's CVP contract water could be stored in San Joaquin County groundwater basins prior to being diverted into EBMUD's Mokelumne River Aqueduct in northeast San Joaquin County. This option was considered in EBMUD's 1995 Water Supply Action Plan, but not included in EBMUD's draft EIR for conveyance of its CVP contract supply. The yield is currently undefined.

Only two groundwater or conjunctive use options in Table 7-12 were retained for further evaluation. NCFC&WCD has two proposals to construct conjunctive use facilities adjacent to existing surface water facilities. The proposed Milliken Creek conjunctive use project would allow the City of Napa and the Silverado Country Club to share surface and groundwater supplies, and would provide an additional drought year yield of 1.9 taf. The proposed Lake Hennessey/Conn Creek conjunctive use project would make the City of Napa's surface water available to agricultural users in exchange for rights to pump groundwater during droughts. This option would provide an estimated 5 taf during drought years.

Water Marketing

Agencies throughout the Bay Area are proposing to negotiate for new or additional water imports into the region. Most of these proposals are preliminary. Water transfer proposals by SCWA, CCWD, and Z7WA all include transfers from as-yet-unnamed Sacramento Valley water users. The actual amount of water available through these proposals is unknown and the competition for transfers will certainly impact both price and availability. A likely option for Z7WA is the permanent transfer of 7 taf of SWP entitlement from KCWA, as provided for in SWP's Monterey Amendments.

Several agencies in the region already have banking and exchange agreements with agencies in the Tulare Lake, South Lahontan, and Colorado River regions. These agreements among SWP contractors involve exchanges of SWP entitlement. ACWD, Z7WA, and SCVWD are participating in SWSD's groundwater banking program and have long-term contracts for 50, 43, and 350 taf of storage, respectively. SWP entitlement would be delivered to SWSD for groundwater recharge in wet years and SWSD, a member agency of KCWA, would forego a portion of its entitlement in dry years in exchange. SCWA has a similar agreement with MWA in San Bernardino County for up to 10 taf.

SCVWD has also entered into a three-way transfer agreement with the San Luis Delta-Mendota Water Authority and USBR. Under this option, participating member agencies of SLDMWA may receive some of SCVWD's CVP water allocation in normal and above-normal water years, in exchange for committing to make available a share of their CVP allocation during drought years. This option would provide SCVWD with up to 14 taf in drought years and is discussed in more detail in Chapter 6.

Water Recycling

The 1995 water recycling survey identified 16 water recycling options in the San Francisco Bay Region, with a total potential 2020 yield of 101 taf. The average price of recycled water from these options would be just over $500/af, with a range from $100 to over $2,000/af. The most common use for recycled water would be for landscape irrigation. A few options were proposed for industrial or agricultural use.

One consideration in evaluating water recycling proposals is that a number of options may be proposed for the same wastewater treatment plant. These options depend upon different distribution systems and are therefore considered separately for this report. Some of the larger projects with their associated 2020 yield include the South Bay water recycling program (31 taf), the Central Contra Costa Sanitary District industrial use project (20 taf), the San Francisco water recycling management plan (12 taf), and the San

Ramon Valley recycled water project (10 taf). Most of the remaining water recycling options have 2020 yields in the range of 1 to 4 taf.

Desalting

Alameda County WD has evaluated the potential for desalting brackish water to allow increased use of groundwater. Water pumped from the district's aquifer recovery project wells would be desalted and blended with groundwater and Hetch Hetchy water to provide a quality consistent with other sources of supply. The plant would produce 9 taf/yr at a cost of about $500/af.

In the past, Marin MWD examined seawater desalting as an option to augment its water supply. The district studied constructing a 10 mgd reverse osmosis desalting plant. The plant's annual production would be approximately 10 taf at a cost of $1,900/af.

Other Local Options

Solano County WA and its member agencies have been examining several surface water management projects to improve their water supply reliability. One proposal is to apply for additional water rights from the Sacramento River. The Cities of Benicia, Fairfield, and Vacaville have filed an application with the SWRCB to divert an additional 31 taf/yr. The water would be conveyed to the cities via the North Bay Aqueduct. (Vacaville is in the Sacramento River Region and its share is 8.5 taf/yr).

Statewide Options

Statewide water supply augmentation options are discussed and quantified in Chapter 6.

Options Likely to be Implemented in San Francisco Bay Region

Water supplies are not available to meet all of the region's 2020 water demands in drought years. Applied water shortages are forecasted to be 287 taf. No average year water shortages are forecasted for 2020. Ranking of retained water management options for the San Francisco Bay Region is summarized in Table 7-13. Table 7-14 summarizes options that can likely be implemented by 2020 to relieve the shortages.

Implementation of BMPs will continue through 2020 and is reflected in the base demand levels for urban water use. Urban conservation options likely to be implemented, based on costs and feasibility, would provide an estimated 57 taf/yr in water savings in the region.

Agencies throughout the region have ambitious plans for water recycling as a future water supply option. These options could provide an additional 24 taf/yr to the region by 2020. EBMUD's American River supply would augment drought year supplies by 70 taf. Water marketing agreements being negotiated with Central Valley agencies will likely add 19 taf/yr in the near future. Statewide options including SWP improvements and drought water bank would likely augment drought supplies by 100 taf.

Many South Bay water purveyors' systems are interconnected, reflecting a common reliance on the SWP, CVP, and Hetch Hetchy facilities for their water supplies. CCWD and SCVWD are connected to the Delta via CVP facilities. In addition, piping to facilitate connections between EBMUD and CCWD and the City of Hayward is in place for emergency transfers. (These connections are of limited capacity to allow for transfers in a catastrophic event.) SCVWD, ACWD, and Z7WA are connected by the SWP's South Bay Aqueduct. SFPUC now has a permanent connection to the SWP, to allow it to take delivery of water transfers wheeled by the SWP. These interconnections facilitate water transfers and are positive factors in water resources management in the South Bay.

TABLE 7-13

Options Ranking for San Francisco Bay Region

Option[a]	*Rank*	*Cost ($/af)*	*Potential Gain (taf)*	
			Average	*Drought*
Conservation				
Urban				
Outdoor Water Use to 0.8 ET_o- New Development	M	750	2	2
Outdoor Water Use to 0.8 ET_o-New and Existing Development	L	b	52	52
Indoor Water Use (60 gpcd)	M	400	38	38
Indoor Water Use (55 gpcd)	M	600	77	77
Interior CII Water Use (3%)	M	500	11	11
Interior CII Water Use (5%)	M	750	18	18
Distribution System Losses (5%)	M	300	13	13
Modify Existing Reservoirs/Operations				
Enlarge Lake Hennessey /Napa River Diversion	M	630	12	-
Enlarge Bell Canyon Reservoir	M	b	b	2
Enlarge Bell Canyon Reservoir/Napa River Diversion	M	b	b	4
Enlarge Pardee Reservoir	M	b	b	30
Enlarge Camanche Reservoir	M	b	b	15
Enlarge Leroy Anderson Reservoir	M	4,400	b	25
Upgrade Milliken Treatment Plant	M	1,770	1	1
Reoperate Rector Reservoir	M	800	-	1
New Reservoirs/Conveyance Facilities				
Chiles Creek Reservoir Project/Napa River Diversion	L	1,170	12	-
Enlarge Lake Hennessey/Chiles Creek Project/ Napa River Diversion	L	1,030	15	-
Carneros Creek Reservoir/Napa River Diversion	L	2,100	12	-
Upper Del Valle Reservoir	M	1,600	5	2
Buckhorn Dam and Reservoir	M	b	b	23
Upper Kaiser Reservoir	M	b	b	6
Upper Buckhorn Reservoir	L	b	b	3
Middle Bar Reservoir	L	b	b	15
Duck Creek Offstream Reservoir	L	b	b	15
Devils Nose Project	L	b	b	23
EBMUD American River Supply	M	850	112	70
Groundwater/Conjunctive Use				
Milliken Creek Conjunctive Use	H	150	-	2
Lake Hennessey/Conn Creek Conjunctive Use	H	280	-	5
Water Marketing				
Z7WA/KCWA (7 taf entitlement)	H	b	7	5
SCVWD/SLDMWA	H	b	-	14

TABLE 7-13

Options Ranking for San Francisco Bay Region (continued)

Option[a]	*Rank*	*Cost ($/af)*	*Potential Gain (taf)*	
			Average	*Drought*
Water Recycling				
Group 1 (Cost < $500/af)	H	500	24	24
Group 2 (Cost $500/af - $1,000/af)	M	1,000	20	20
Group 3 (Cost > $1,000/af)	M	1,500	46	46
Desalting				
Brackish Groundwater				
Alameda County Water District Aquifer Recovery Project	H	510	9	9
Seawater				
Marin Municipal Water District Desalting Project	L	1,900	10	10
Other Local Options				
New Surface Water Diversion from Sacramento River by Cities of Benicia, Fairfield, & Vacaville[c]	M	[b]	22	22
Statewide Options				
See Chapter 6.				

[a] All or parts of the amounts shown for the highlighted options have been included in Table 7-14.
[b] Data not available to quantify.
[c] The three cities have applied for 31 taf/yr of supplemental water, part of which would be used in the Sacramento River Region.

TABLE 7-14

Options Likely to be Implemented by 2020 (taf)
San Francisco Bay Region[a]

	Average	*Drought*
Applied Water Shortage	**0**	**287**
Options Likely to be Implemented by 2020		
Conservation	-	57
Modify Existing Reservoirs/Operations	-	-
New Reservoirs/Conveyance Facilities	-	70
Groundwater/Conjunctive Use	-	7
Water Marketing	-	19
Recycling	-	24
Desalting	-	9
Other Local Options	-	-
Statewide Options	-	100
Expected Reapplication	-	1
Total Potential Gain	**-**	**287**
Remaining Applied Water Shortage	**0**	**0**

[a] Implementing options to reduce drought year shortages would provide more water than is needed to meet average year needs. In average years, this water could be available for transfer to other regions, or some options could be operated at less than their full capacity.

FIGURE 7-4.
Central Coast Hydrologic Region

Central Coast Hydrologic Region

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Description of the Area

The Central Coast Region (Figure 7-4) extends from southern San Mateo County in the north to Santa Barbara County in the south. The region includes the southern tip of San Mateo County, part of Santa Clara County, most of San Benito County, all of Santa Cruz, Monterey, San Luis Obispo and Santa Barbara Counties, and the northwestern tip of Ventura County. The major topographic features include Monterey and Morro Bays; the Pajaro, Salinas, Carmel, Santa Maria, Santa Ynez and Cuyama Valleys; the Coast Range, and the coastal plain of Santa Barbara County. The region is divided into two planning subareas: Northern (including all counties except San Luis Obispo and Santa Barbara) and Southern (San Luis Obispo and Santa Barbara Counties). Summer temperatures are cool along the coastline and warmer inland. In the winter, temperatures remain cool along the coast but become cooler inland. Annual precipitation ranges from about 10 inches on valley floors at the south end of the region to as much as 50 inches on some of the highest peaks. The year-round frost-free climate of the coastal valleys makes them ideal for production of specialty crops such as strawberries and artichokes.

The principal population centers in the region are Santa Cruz, Hollister, Salinas, Monterey, Paso Robles, San Luis Obispo, Santa Maria, Goleta, and Santa Barbara. Intensive agriculture is found in the Salinas and Pajaro Valleys in the north and the Santa Maria and lower Santa Ynez Valleys in the south. Agricultural acreage has remained fairly stable during recent years, although urban development is encroaching on some valley agricultural lands. In the Pajaro and Salinas Valleys, the major crops include vegetables, specialty crops, and cut flowers. Wine grape acreage has increased in the upper Salinas Valley. The flower seed industry in Lompoc Valley is thriving and attracts many tourists each year. Parts of the upper Salinas Valley and Carrizo Plain are dry-farmed to produce grains. Table 7-15 shows the region's population and crop acreage for 1995 and 2020.

Major economic activities include tourism, agricultural-related processing, and government and

The Pajaro and Salinas Valleys are known for their production of specialty crops. Castroville is sometimes called the artichoke capital of the world.

TABLE 7-15

Population and Crop Acreage

	Population (thousands)	*Irrigated Crop Acreage (thousands of acres)*
1995	1,347	572
2020	1,946	570

service sector employment. Oil production and transportation sites onshore and offshore are important to the economies of Santa Barbara and San Luis Obispo Counties. San Luis Obispo County has major thermal powerplants at Diablo Canyon and Morro Bay. Military facilities include Hunter-Liggett Military Reservation, Vandenberg Air Force Base, and Camp San Luis Obispo.

Water Demands and Supplies

The water budget for the Central Coast Region is shown in Table 7-16. Groundwater is the primary source of water supply in the region, followed by local surface water. CVP water supply is delivered to the northern part of the region from San Luis Reservoir. SWP Coastal Branch deliveries to the southern part of the region began in 1997. Most of the water shortage in the region is due to groundwater overdraft, although the overdraft is expected to lessen with SWP water deliveries and decreased agricultural demands.

Northern PSA

This planning subarea includes Santa Cruz County, Pajaro Valley, the Monterey Peninsula, and Salinas Valley. Water agencies include Monterey County Water Resources Agency, Monterey Peninsula Water Management District, Marina Coast Water District, California-American Water Company (Carmel), Pajaro Valley Water Management Agency, City of Santa Cruz, and San Benito County Flood Control and Water Conservation District.

The Northern PSA is comprised of a number of medium-to-small independent watersheds. There is limited infrastructure for water transfers among the watersheds and from outside the region. The only water import from outside the region comes from CVP's San Felipe Unit, which imports 53 taf/yr into southern Santa Clara and San Benito Counties.

Groundwater is the primary water source for the subarea. Groundwater recharge is provided by the Pajaro, Salinas, and Carmel Rivers, and by Arroyo Seco. San Clemente and Los Padres Dams on the Carmel River (Monterey County), San Antonio Dam on the San Antonio River (Monterey County), and Nacimiento Dam on the Nacimiento River (San Luis Obispo County) are the region's main surface water storage facilities. Water impounded in these reservoirs is managed to provide groundwater recharge.

Southern PSA

The largest water agencies in the southern PSA are two countywide agencies—the San Luis Obispo County Flood Control and Water Conservation District and the Santa Barbara County Flood Control and Water Conservation District. The Central Coast Water Authority was formed in 1991 to construct, manage, and operate Santa Barbara County's 42 mile portion

TABLE 7- 16

Central Coast Region Water Budget (taf)[a]

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	286	294	379	391
Agricultural	1,192	1,279	1,127	1,223
Environmental	118	37	118	37
Total	**1,595**	**1,610**	**1,624**	**1,652**
Supplies				
Surface Water	318	160	368	180
Groundwater	1,045	1,142	1,041	1,159
Recycled and Desalted	18	26	42	42
Total	**1,381**	**1,328**	**1,452**	**1,381**
Shortage	**214**	**282**	**172**	**270**

[a] Water use/supply totals and shortages may not sum due to rounding.

of the Coastal Aqueduct. Many small retail agencies and small municipalities provide their own water supplies.

The major source of water in the two counties is coastal groundwater basins. SLOCFC&WCD and SBCFC&WCD contract with the Department for SWP water. The two agencies have contractual entitlements totaling 70.5 taf/yr. Due to the 1987-92 drought, three seawater desalting plants were constructed in the region. The City of Morro Bay's plant has an annual capacity of 670 af and is used when groundwater supplies are limited during dry periods. The City of Santa Barbara's plant has an annual capacity of 7.5 taf and is on standby. (Although the Santa Barbara plant only operated briefly in 1992, it is considered in the base water budget as a drought year supply under 1995 level of development, and as an average and drought year supply in 2020.) The plant at San Simeon Beach State Park has minimal capacity (45 af) and is also on standby.

There are two USBR projects in the subarea. The Cachuma Project provides Santa Ynez River water to the Santa Barbara area; main project facilities are the 205 taf Cachuma Reservoir (Bradbury Dam) and the South Coast Conduit. The Santa Maria Project provides Cuyama River water for irrigation use in the Santa Maria area; main project facilities are Twitchell Dam and Reservoir (240 taf). Another federal reservoir, USACE's 26 taf Santa Margarita Lake (Salinas Dam) provides supply for the City of San Luis Obispo.

Local Water Resources Management Issues

Seawater Intrusion

With Central Coast's limited surface supply and few surface water storage facilities, the growing demand for water is causing an increased dependence on the region's groundwater resources. Because groundwater extractions have exceeded groundwater replenishment, seawater has advanced into some coastal freshwater aquifers, degrading water quality. Seawater intrusion is a major concern in the region.

Several decades of over-pumping groundwater have caused seawater intrusion in the aquifers that supply the Salinas Valley with nearly 100 percent of its fresh water. Seawater has intruded almost 6 miles inland into the 180-foot aquifer and two miles inland into the 400-foot deep aquifer. This intrusion has rendered the groundwater too salty for either municipal or agricultural use. Replenishment of groundwater occurs primarily from percolation of surface water from the Salinas River and its tributaries. The construction of Nacimiento and San Antonio Dams in 1957 and 1965, respectively, has increased replenishment but has

DWR's extension of the Coastal Branch to serve San Luis Obispo and Santa Barbara Counties provides an imported surface water supply that can help reduce overdraft of coastal groundwater basins.

not stopped seawater intrusion. In 1994, SWRCB began investigating the Salinas Valley. The SWRCB suggested that adjudication may be necessary if the local agencies could not halt the seawater intrusion.

In 1998, the MCWRA and the MRWPCA jointly completed a $78 million Salinas Valley reclamation project and Castroville seawater intrusion project. These projects consist of a 19.5 taf/yr tertiary treatment plant and a distribution system that will provide recycled water to 12,000 acres of Castroville area farms. During the low irrigation demand periods in winter, early spring and late fall, recycled water will supply most of the water needed for irrigation. During late spring, summer, and early fall, growers will receive a blend of recycled water and groundwater. The projects will reduce groundwater pumping in the project area, thus reducing seawater intrusion. Additionally, the projects will reduce the amount of secondary-treated wastewater discharged to the Monterey Bay National Marine Sanctuary. The sanctuary is a federally-protected aquatic ecosystem extending from Point Reyes to San Luis Obispo with abundant marine resources including kelp forests, marine mammals, and sea and shore birds.

MCWRA is preparing an EIR and preliminary design for a Salinas Valley water project to solve seawater intrusion and nitrate contamination. Major components of the project include dam modifications and reservoir reoperation, river conveyance and diversion facilities, groundwater recharge, storage for recycled water, distribution systems, and conservation. The project also will include management strategies to address nitrate contamination problems.

Seawater intrusion is also a problem facing the Pajaro Valley. Pajaro Valley Water Management Agency is preparing environmental documents to address water management issues facing the valley, following adoption of a basin management plan in 1993. The plan includes projects to develop local supplies, recharge groundwater, import new water, and adopt conservation measures to help solve groundwater overdraft and attendant seawater intrusion problems. Failing to implement the plan could result in intervention by SWRCB, potentially resulting in basin adjudication and restrictions on extractions. PVWMA is working closely with SWRCB to address groundwater overdraft problems, and SWRCB has reserved $5 million in low interest loan money from the Proposition 204 Seawater Intrusion Control Fund to help assist PVWMA in implementing its basin management plan.

Local Water Agency Issues

Santa Cruz County relies mostly on surface water diversions. Drought years pose a threat of water rationing and shortages because of the lack of adequate storage facilities. Seawater intrusion is a concern for groundwater users. For example after years of stable conditions, groundwater quality in municipal wells in the Soquel-Aptos area began to degrade in 1993-94. Soquel Creek Water District, the largest purveyor in this part of the county, relies primarily on groundwater. As measured in monitoring wells along the Monterey Bay coastline, groundwater quality degraded noticeably in less than 4 years, with chloride concentrations increasing from 20 to 40 mg/L to about 250 to 2,500 mg/L. These conditions occurred despite the district's managing its extractions to maintain coastal groundwater levels above sea level and decreasing its pumping.

Between urban growth and growth in tourism, the Monterey Peninsula is expected to experience more frequent shortages in drought years. Water supply for the area comes from the Carmel River, which has relatively little developed storage. In its Monterey Peninsula water supply project final EIR/EIS, MPWMD chose the 24 taf New Los Padres Reservoir on the Carmel River as its preferred alternative for meeting future water needs. The proposed reservoir would expand the Peninsula's water supply and help protect and restore natural resources on the Carmel River, by providing instream flows. However, voters defeated bonds for the project in a 1995 election. MPWMD staff prepared a water supply alternatives plan in 1996 which included recommendations for expanded groundwater production, additional recycled water use, desalting, and additional conservation programs.

In 1995, SWRCB determined that Cal-Am was diverting approximately 10.7 taf/yr out of the Carmel River Basin without valid water rights. SWRCB ordered that diversions from the river be reduced, and that sources outside of the basin be developed. One of these sources could be additional groundwater production from the Seaside Basin, but use of this basin as a replacement for diversions from the Carmel River is being challenged in litigation. SWRCB indicated that New Los Padres Reservoir should be reconsidered to enhance Carmel River habitat values and to provide for Cal-Am's water supply. In 1996, Cal-Am decided to proceed with the New Los Padres Reservoir, but with a reduced urban yield of 10.7 taf to support only existing water needs, without providing supplies for

The Monterey Bay National Marine Sanctuary is home to a variety of species.

future growth. The remainder of the reservoir's supply would be used for instream flow enhancement.

The City of San Luis Obispo has been pursuing a Salinas Reservoir expansion project to supplement its water supply. The existing reservoir is owned by USACE and is managed by SLOCFC&WCD. The expansion project involves installing spillway gates to expand the storage capacity from about 24 taf to 42 taf. The proposed project would increase the city's annual water supply by about 1.6 taf, but would supply only a portion of the city's expected future water demands. An initial draft EIR was issued in late 1993. A revised draft EIR was issued in May 1997.

Seawater Desalting

Current municipal seawater desalting capacity in the Central Coast Region is almost entirely based on the City of Santa Barbara's desalting plant (7.5 taf/yr). The remainder of the plants are small, less than 750 af/yr in capacity. During the 1987-92 drought, a number of seawater desalting projects were anticipated, but the return of average water years put most of these plants on hold. Only Santa Barbara, Morro Bay, and the San Simeon Beach State Park installed plants because of the drought. Proposed bonds for a 3 mgd seawater desalting plant for Monterey Peninsula Water Management District were rejected by voters in 1992. The plants in Santa Barbara and San Simeon are on standby. The plant at Morro Bay is used only during dry periods when groundwater supplies are limited.

In response to seawater intrusion in its groundwater basin, the Marina Coast Water District completed a 300,000 gpd (340 af/yr) seawater desalting plant in 1997. The plant produces about 14 percent of the district's water supply.

Water Management Options for the Central Coast Region

Table 7-17 shows a list of options for the region, and the results of an initial screening of the options.

The Cuyama River has its headwaters in northwestern Ventura County and flows onto the Cuyama Valley floor in San Luis Obispo and Santa Barbara Counties. As suggested by this photo, the river's flow is ephemeral. Valley agriculture is supported by groundwater.

TABLE 7-17

Central Coast Region List of Water Management Options

Option	*Retain or Defer*	*Reason for Deferral*
Conservation		
Urban		
Outdoor Water Use to $0.8ET_o$	Retain	
Indoor Water Use	Retain	
Interior CII Water Use	Retain	
Distribution System Losses	Retain	
Agricultural		
Seasonal Application Efficiency Improvements	Defer	No significant depletion reductions attainable.
Flexible Water Delivery	Defer	No significant depletion reductions attainable.
Canal Lining and Piping	Defer	No significant depletion reductions attainable.
Tailwater Recovery	Defer	No significant depletion reductions attainable.
Modify Existing Reservoirs/Operations		
Modify Nacimiento Spillway	Retain	
Inter-Lake Tunnel - Nacimiento/San Antonio Reservoirs	Defer	Alternative to preferred Nacimiento spillway modification.
Enlargement of Salinas Reservoir	Retain	
Enlargement of Cachuma Reservoir	Retain	
Enlargement of Lopez Reservoir	Defer	Excessive unit cost.
New Reservoirs/Conveyance Facilities		
College Lake	Retain	
Bolsa De San Cayetano Reservoir	Defer	Fishery and foundation issues; excessive cost.
Corncob Canyon Reservoir	Defer	High level of housing development in canyon.
Pescadero Reservoir	Defer	Fishery and foundation issues; excessive cost.
Gabilan Creek Dam	Defer	Questionable water supply.
Feeder Streams (Various Sites)	Retain	
Chalone Canyon Dam	Defer	Questionable water supply.
Vaqueros Canyon Dam	Defer	Questionable water supply.
New Los Padres Reservoir	Retain	
Nacimiento Pipeline	Retain	
Arroyo Seco Dam	Defer	Impacts to environment, residential and commercial development.
Barloy Dam	Defer	Questionable water supply.
Mathews Dam	Defer	Questionable water supply.
Jerret Dam	Defer	Questionable water supply.
New San Clemente Reservoir	Defer	Strong regulatory agency objections.
San Clemente Creek Reservoir	Defer	High probability of inundating spotted owl habitat.
Cachagua Reservoir	Defer	Questionable supply and located outside MPWMD boundaries.
Canada Reservoir	Defer	Questionable geological conditions at dam site.
Klondike Dam	Defer	Located near active faults; inundation of residential development.
Chupines Creek Reservoir	Defer	Questionable supply and located outside MPWMD boundaries.
Pine Creek	Defer	Potential impacts to environmentally sensitive areas.

TABLE 7-17

Central Coast Region List of Water Management Options (continued)

Option	*Retain or Defer*	*Reason for Deferral*
Buckeye Creek	Defer	Located near active faults; unsuitable dam foundation.
Lower Jack	Defer	Environmental impacts; riparian oak grassland.
Santa Rita	Defer	Environmental impacts; riparian oak grassland.
Camuesa and Salsipuedes Reservoirs	Defer	Environmental impacts; presence of endangered species.
Hot Springs, New Gilbraltar, and Round Corral Reservoirs	Defer	Insufficient yield, high unit cost of water.
Groundwater/Conjunctive Use		
College Lake Injection/Extraction Wells	Retain	
Increase Groundwater Development in Seaside Basin	Retain	
Seaside Conjunctive Use	Defer	Insufficient yield.
Salinas River Well System	Defer	Will not produce supply without implementing other new supply component.
Storage and Infiltration Basins/Recharge	Defer	Questionable water supply.
Upper/Lower Carmel Valley Well Development	Defer	Questionable water supply.
Water Marketing		
CVP (San Felipe Project Extension)	Retain	
SWP (Coastal Branch/Salinas River/Nacimiento transfer)	Defer	No current local interest.
Water Recycling		
Aquifer Storage/Recovery - Monterey County Water Resources Agency	Retain	
Castroville Seawater Intrusion Project expansion	Retain	
Santa Cruz Water Reuse Project - Pajaro Valley WMA	Retain	
SSLOCSD Reclamation Project - City of Arroyo Grande	Retain	
SVWD Recycled Water Plant - Scotts Valley Water District	Retain	
Urban Reuse Project - Monterey Regional Water Pollution Control Agency	Retain	
Watsonville Water Resue Project - Pajaro Valley WMA	Retain	
Injected Treated Water/Carmel River Mouth	Defer	Health concerns.
Desalting		
Brackish Groundwater		
City of Santa Cruz	Retain	
Seawater		
Monterey Peninsula Water Management District	Retain	

TABLE 7-17

Central Coast Region List of Water Management Options (continued)

Option	*Retain or Defer*	*Reason for Deferral*
Other Local Options		
Weather modification	Defer	Difficult to quantify.
Salinas River Diversion and Distribution Project	Retain	
Statewide Options		
—	—	See Chapter 6.

The retained options were evaluated (Table 7A-3 in Appendix 7A) based on a set of fixed criteria discussed in Chapter 6.

Water Conservation

Urban. Urban water demand forecasts for 2020 assume that BMPs are in place; consequently, only those urban conservation efforts which exceed BMPs are considered as options. Reducing outdoor water use to 0.8 ET_o in new development would attain about 4 taf/yr of depletion reductions, while extending this measure to include existing development would reduce depletions by about 13 taf/yr. Reducing residential indoor water use to 60 and 55 gpcd would reduce depletions by 8 and 17 taf/yr, respectively. Reducing CII water use by an additional 3 and 5 percent would attain 2 taf and 3 taf of depletion reductions per year, respectively. Reducing distribution system losses to 7 and 5 percent would save 3 and 8 taf/yr.

Agricultural. The 2020 agricultural water demand forecasts assume that EWMPs are in place. As with the urban water management options, only those agricultural conservation efforts which exceed EWMPs are considered as options. Agricultural conservation options were deferred for this region, because no significant depletion reductions would be achieved. Excess applied irrigation water recharges aquifers in the major agricultural areas.

Modify Existing Reservoirs or Operations

In the Northern PSA, most of these options involve Nacimiento and San Antonio Reservoirs. The options include raising and widening the spillway at Nacimiento Reservoir, constructing a tunnel or pipeline between the two reservoirs, and changing reservoir operation rules. Any combination of these reservoir modification options would likely be combined with other options (such as improved conveyance facilities or groundwater recharge projects). Some of these options are estimated to cost about \$100/af—raising and widening the spillway at Nacimiento Reservoir is one such option. Sediment removal may provide a very small amount of additional supply, and MPWMD is studying the effectiveness of sediment removal from its existing reservoirs (Los Padres and San Clemente).

There are two proposals for reservoir enlargements in the Southern PSA. The Salinas Reservoir enlargement project would install a radial gate to raise the spillway height 19 feet above its existing elevation, increasing the reservoir's storage capacity by about 18 taf, and the City of San Luis Obispo's annual yield by almost 2 taf. In Santa Barbara County raising USBR's Bradbury Dam (Cachuma Reservoir) 50 feet for additional water supply plus an additional 40 feet for flood surcharge storage could result in an additional annual yield of 17 taf at a cost of about \$1,200/af. The reservoir would serve coastal areas and the Santa Ynez Valley.

New Reservoirs and Conveyance Facilities

In the Pajaro Valley, constructing a 27-foot high dam at the existing College Lake drainage pump house would create a 10 taf reservoir. The reservoir could be supplied with natural runoff and a supplemental 25 cfs diversion from Corralitos Creek during the winter. Its annual yield of 3.4 taf could be supplied to the coastal or inland distribution systems through a 5-mile, 30-inch diameter pipeline. The cost of this option is estimated to be under \$400/af. Other reservoir options include Corncob Canyon and Pescadero Creek, both of which could store up to 10 taf; new water supplies produced by either of these options are estimated to cost about \$600/af. Bolsa De San Cayetano (estimated to cost \$640/af) could store up to 4 taf. These latter three options were deferred, as shown in Table 7-17.

A dam on Arroyo Seco was removed from further consideration as a water supply project, although

MCWRA may evaluate it as a flood control project. The Monterey Peninsula could receive up to 24 taf/yr from the proposed New Los Padres Reservoir, at a cost of about $400/af. This new reservoir would inundate the existing Los Padres Dam on the Carmel River. Although bonds to fund this option were rejected in a 1995 election, Cal-Am announced its intentions to proceed with a reformulated version of the project with 11 taf of annual yield at a cost of $800/af. SWRCB's requirements that Cal-Am provide a new firm supply for existing uses and improve fishery habitat in the Carmel River make New Los Padres a likely future project.

SLOCFC&WCD has an annual 17.5 taf entitlement from Nacimiento Reservoir, only about 1.3 taf of which is now used. A pipeline would be needed to distribute the remaining 16.2 taf to 18 water purveyors. The preferred pipeline alignment would go through the communities of Paso Robles, Templeton, Atascadero, Santa Margarita, and San Luis Obispo and terminate near Avila Beach. This option is not affected by reservoir modifications under consideration by MCWRA.

There are opportunities to import purchased water wheeled through the CVP or SWP into the Northern PSA. In the Pajaro Valley, an option involves connecting a pipeline to USBR's San Felipe Unit, which serves CVP water from San Luis Reservoir to Santa Clara and San Benito Counties. PVWMA could connect to the San Felipe Unit by constructing a 22-mile pipeline from the Watsonville Turnout. This 42-inch diameter pipeline with a capacity of 75 cfs would be able to deliver a maximum of 20 taf/yr. PVWMA does not have a CVP water service contract. CVPIA banned execution of new water service contracts for an indefinite period of time. The average annual yield of a connection to the San Felipe system is estimated to be 13 taf, if a source of purchased water could be found. Northern Monterey County could also benefit from a San Felipe extension because of its close proximity to the Pajaro Valley.

Groundwater Development and Conjunctive Use

Because groundwater is the primary water source for the Central Coast Region, many options have a groundwater recharge component alone or in combination with surface water development projects. In the Pajaro Valley, options include the Pajaro recharge canal (1.5 taf annually) and the College Lake injection/extraction wells (seven wells to inject diverted surface runoff currently captured in College Lake). These wells would be used to extract groundwater during drought years when deliveries of San Felipe water are reduced. On the Monterey Peninsula, the Seaside groundwater basin has the potential to produce an additional 1 taf/yr. This option may be pursued if legal challenges are resolved, because of SWRCB's order which encourages the maximum use of supplies from Seaside to reduce diversions from the Carmel River. Another option would be to retrofit existing wells in the Seaside Basin to accomplish both injection and extraction, to increase storage and to use Carmel River and other supplies more efficiently. This option would include a series of new wells and a pipeline system from inland areas (Fort Ord) to the Monterey Peninsula. The system would be operated primarily for drought year supply. Yields and costs of this option are unknown at present.

In Santa Cruz County, options include several new wells and deep brackish groundwater wells (with reverse osmosis treatment facilities) in the northern coast area. The new wells would provide an additional water supply of about 3 taf while the brackish wells would be used for drought contingency. The groundwater resources of the north county could be increased by developing small local recharge projects, such as retention basins. However, the incremental yield of these projects would be small since the soils in the area are sandy and runoff is already minimal. There are no physical facilities available for artificial recharge in the Southern PSA, but there are some potential sites along coastal streams in San Luis Obispo County where additional runoff could be used for recharging groundwater basins.

Water Marketing

In the Salinas Valley, SWP water from the Coastal Branch could be purchased and either traded with San Luis Obispo County for that county's existing entitlement to Nacimiento reservoir water or delivered directly through a pipeline constructed at the aqueduct's crossing of the Salinas River. There are presently no local agencies seeking water marketing arrangements using this approach.

PVWMA is evaluating options for assignment of CVP water from project agricultural water contractors and opportunities for participation with SCVWD and San Benito County Flood Control and Water Conservation District (existing CVP San Felipe Division contractors) in water marketing arrangements.

Water Recycling

For the Northern PSA, water recycling options include an aquifer storage and recovery program which would use injection wells to store recycled water produced during the winter, and then would extract this water for irrigation in the Castroville area during the summer months. This program has an estimated annual yield of up to 8.3 taf.

In the Pajaro Valley, a 12 or 18 mgd recycling plant would be constructed adjacent to the existing Watsonville Wastewater Treatment Plant. The 12 mgd plant (about 13.4 taf annually) would treat water from the Watsonville area; the 18 mgd plant (about 20.1 taf annually) would treat water from both Watsonville and Santa Cruz. The 18 mgd option would require constructing a pipeline from Santa Cruz to Watsonville to transport treatment plant effluent.

On the Monterey Peninsula, the Carmel Area Wastewater District/Pebble Beach Community Services District treatment plant could be expanded to provide more recycled water (up to 100 af annually) for use on golf courses, open space, or cemeteries. In 1992, local water agencies studied potential markets for recycled water produced by the regional recycling plant near Marina. Potential uses of recycled water in Fort Ord, Seaside, and other Monterey Peninsula communities having a potential annual demand of up to 1 taf were identified, but the uses were deemed economically infeasible at that time. This study is currently being updated to reflect the conversion of Fort Ord to civilian use.

For the Southern PSA, recycled water projects have been proposed in conjunction with construction of new or expanded municipal wastewater treatment plants. In coastal areas—such as San Luis Obispo Bay, Estero, and south San Luis Obispo County—treated wastewater is discharged to the ocean, and reusing the wastewater would help reduce water supply shortages. (In the City of San Luis Obispo and in communities along the Salinas River, the wastewater recharges the groundwater basin.)

Planned recycling projects in Santa Barbara County include the Santa Barbara regional water reuse project, which would provide 1.6 taf of recycled water annually for landscape irrigation within the City of Santa Barbara, Montecito Water District, and Summerland County Water District. This project would replace potable water being used for irrigation. Other potential projects involve expanding Lompoc's secondary treatment facilities and Santa Barbara's tertiary treatment facilities for an additional annual yield of 2 taf by the year 2000.

Desalting

Several coastal cities in the region have identified desalting options for additional water supply. The City of Santa Cruz is conducting a feasibility study on a 4.5 taf/yr brackish groundwater desalting plant to supplement local water supplies. The Cambria and San Simeon community services districts had plans, recently put on hold, to jointly construct a 320 af/yr (with ultimate capacity of 1.3 taf annually) seawater desalting plant. Monterey Peninsula Water Management District's plans for a 3.4 taf/yr seawater desalting plant were defeated by voters in the 1992 election.

Other Local Options

In the Salinas Valley, a Salinas River diversion and distribution project is being planned to transfer up to 35 taf/yr to northern Salinas Valley to halt seawater intrusion. In the Northern PSA, MCWRA has a weather modification program which targets the watersheds of the Nacimiento and San Antonio Rivers and the Arroyo Seco. MCWRA estimates that increased annual flows into reservoirs ranged from about 8 taf to 68 taf between 1990 to 1994. San Luis Obispo began a 3-year cloud seeding program in January 1991 to produce more runoff in the Salinas and Lopez Watersheds. Although this program has ended, future programs may be a possibility. Future weather modification options are difficult to quantify and are not evaluated in this Bulletin. Weather modification programs are often operated on a year-to-year basis by water agencies, and usually not reliable supply sources in drought years due to a lack of storm systems to seed.

Statewide Options

Statewide water supply augmentation options are discussed and quantified in Chapter 6.

Options Likely to be Implemented in Central Coast Region

Water supplies are not available to meet all of the region's 2020 water demands in average or drought years. Applied water shortages are forecasted to be 172 taf and 270 taf in average and drought years, respectively. Ranking of retained water management options for the Central Coast Region is summarized in Table 7-18. Table 7-19 summarizes options that can likely be implemented by 2020 to relieve the shortages.

TABLE 7-18

Options Ranking for Central Coast Region

Option[a]	*Rank*	*Cost ($/af)*	*Potential Gain (taf)*	
			Average	*Drought*
Conservation				
Urban				
Outdoor Water Use to $0.8ET_o$ - New Development	M	750	4	4
Outdoor Water Use to $0.8ET_o$ - New and Existing Development	M	[b]	13	13
Indoor Water Use (60 gpcd)	M	400	8	8
Indoor Water Use (55 gpcd)	M	600	17	17
Interior CII Water Use (3%)	M	500	2	2
Interior CII Water Use (5%)	M	750	3	3
Distribution System Losses (7%)	M	200	3	3
Distribution System Losses (5%)	M	300	8	8
Modify Existing Reservoirs/Operations				
Modify Nacimiento Spillway	H	120	20	[b]
Enlargement of Salinas Reservoir	M	400	2	[b]
Enlargement of Cachuma Reservoir	L	1,200	17	[b]
New Reservoirs/Conveyance Facilities				
College Lake	M	350	3	-
Feeder Streams (Various Sites)	M	400	[b]	[b]
New Los Padres Reservoir	M	800	11	11
Nacimiento Pipeline	M	950	16	16
Groundwater/Conjunctive Use				
College Lake Injection/Extraction Wells	M	130	2	2
Increase Groundwater Development in Seaside Basin	L	410	1	1
Water Marketing				
CVP (San Felipe Project Extension)	M	580	13	2
Water Recycling				
Group 1 (Cost < $500/af)	H	500	29	29
Group 2 (Cost $500/af - $1,000/af)	M	1,000	8	8
Desalting				
Brackish Groundwater				
City of Santa Cruz	L	1,100	5	5
Seawater				
Monterey Peninsula WMD	L	1,700	3	3
Other Local Options				
Salinas River Diversion and Distribution Project	M	[b]	35	[b]
Statewide Options				
See Chapter 6.				

[a] All or parts of the amounts shown for highlighted options have been included in Table 7-19.
[b] Data not available to quantify.

The urban water conservation options beyond BMPs that would likely be implemented would add 32 taf/yr in depletion reductions in the region. Additional reliance on water recycling will be likely in the future to alleviate shortages. Additional water recycling in the region could produce 29 taf/yr of new water supply. Recycled water would be used for landscaping, direct agricultural application, and groundwater recharge.

In the Pajaro Valley, options that would likely be implemented by 2020 would include a pipeline to connect to the CVP's San Felipe Unit to provide an opportunity for water transfers.

Modifying existing reservoirs or constructing new reservoirs are likely options for the region. One likely option to augment water supplies in the Salinas Valley would be to modify Nacimiento's spillway. Raising the spillway 6.5 feet would increase storage capacity by 34 taf, increasing the reservoir's yield by about 20 taf. Other spillway modifications are also being evaluated to allow more water to be released throughout the year for recharge. A long-term water management plan for the Monterey Peninsula would likely include construction of the proposed New Los Padres Dam, which could augment supplies by 11 taf/yr.

In San Luis Obispo County, current planning focuses on the Nacimiento pipeline, which would convey a portion of the county's entitlement of 17.5 taf/yr from Lake Nacimiento in northern San Luis Obispo County. Communities potentially receiving supplies from this option include the City of San Luis Obispo and Cayucos (through an exchange of water from Nacimiento and Whale Rock Reservoirs). In addition, the communities of Paso Robles, Templeton, and Atascadero may also receive supplies for groundwater recharge.

If implemented, the identified options would still leave remaining shortages in drought years of 100 taf.

TABLE 7-19

Options Likely to be Implemented by 2020 (taf)
Central Coast Region

	Average	*Drought*
Applied Water Shortage	**172**	**270**
Options Likely to be Implemented by 2020		
Conservation	32	32
Modify Existing Reservoirs/Operations	22	[a]
New Reservoirs/Conveyance Facilities	27	27
Groundwater/Conjunctive Use	2	2
Water Marketing	13	2
Recycling	29	29
Desalting	–	–
Other Local Options	35	[a]
Statewide Options	5	57
Expected Reapplication	7	21
Total Potential Gain	**172**	**170**
Remaining Applied Water Shortage	**0**	**100**

[a] Data not available to quantify.

FIGURE 7-5

South Coast Hydrologic Region

South Coast Hydrologic Region

. . .

Description of the Area

The South Coast is California's most urbanized hydrologic region (Figure 7-5). Although it covers only about 7 percent of the State's total land area, it is home to roughly 54 percent of the State's population. Extending eastward from the Pacific Ocean, the region is bounded by the Santa Barbara-Ventura County line and the San Gabriel and San Bernardino Mountains on the north, and a combination of the San Jacinto Mountains and low-elevation mountain ranges in central San Diego County on the east, and the Mexican border on the south. Topographically, the region is comprised of a series of broad coastal plains, gently sloping interior valleys, and mountain ranges of moderate elevations. The largest mountain ranges in the region are the San Gabriel, San Bernardino, San Jacinto, Santa Rosa, and Laguna Mountains. Peak elevations are generally between 5,000 and 8,000 feet above sea level; however, some peaks are nearly 11,000 feet high.

The climate of the region is Mediterranean-like, with warm dry summers followed by mild winters. In the warmer interior, maximum temperatures during the summer can be over 90°F. The moderating influence of the ocean results in lower temperatures along the coast. During winter, temperatures rarely descend to freezing except in the mountains and some interior valley locations.

About 80 percent of the precipitation occurs during the four-month period from December through March. Average annual rainfall can range from 10 to 15 inches on the coastal plains and 20 to 45 inches in the mountains. Precipitation in the highest mountains commonly occurs as snow. In most years, snowfall is sufficient to support winter sports in the San Bernardino and San Gabriel Mountains.

There are several prominent rivers in the region, including the Santa Clara, Los Angeles, San Gabriel, Santa Ana, Santa Margarita, and San Luis Rey. Some segments of these rivers have been intensely modified for flood control. Natural runoff of the region's streams and rivers averages around 1.2 maf annually.

The largest cities in the region are Los Angeles, San Diego, Long Beach, Santa Ana, and Anaheim. Although highly urbanized, about one-third of the region's land is publicly owned. About 2.3 million acres is public land, of which 75 percent is national forest. Irrigated crop acreage accounts for a small percent of land use. Table 7-20 shows the region's population and crop acreage for 1995 and 2020.

Water Demands and Supplies

Since the turn of the century, extensive water development has been carried out in the South Coast Region. Steady expansion of population and of the economy led to the demands and financial resources to build large water supply projects for importing water to the region. In 1913, the Los Angeles Aqueduct began importing water from the Owens Valley to the South Coast Region. Los Angeles diversions from the

TABLE 7-20
Population and Crop Acreage

	Population (thousands)	*Irrigated Crop Acreage (thousands of acres)*
1995	17,299	313
2020	24,327	190

Although the South Coast Region has been extensively urbanized, some species of wildlife have learned to coexist with suburban development. The region's remaining riparian areas still support such common mammals as skunks and raccoons.

Mono Basin began in 1940 when the LAA was extended by about 11 miles (a second conduit was added in 1970). In 1941, MWDSC completed its Colorado River Aqueduct, which now provides about 25 percent of the region's supply. SWP began delivering water from the Delta to the South Coast Region in 1972. Table 7-21 shows the water budget for the region.

Los Angeles Aqueduct

The Los Angeles Department of Water and Power owns and operates the LAA which diverts both surface and groundwater from the Owens Valley and surface water from the Mono Basin. The combined carrying capacity of the aqueduct system is about 760 cfs, or about 550 taf/yr. An average of 400 taf/yr of water is delivered through the LAA with a record 534 taf in 1983. Court-ordered restrictions on diversions from the Mono Basin and Owens Valley have reduced the amount of water the City of Los Angeles can divert (see South Lahontan Region).

Colorado River Aqueduct

MWDSC was created in 1928 to construct and operate the Colorado River Aqueduct to deliver Colorado River water to Southern California. MWDSC wholesales water supplies from the Colorado River and the SWP to water agencies throughout Southern California.

MWDSC and its 27 member agencies (Table 7-22) serve 95 percent of the South Coast Region. Some agencies rely solely on MWDSC for their water supply, while many, like the City of Los Angeles, rely on MWDSC to supplement existing supplies. Between its fiscal years 1970 and 1994, the City of Los Angeles

TABLE 7-21

South Coast Region Water Budget (taf)[a]

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	4,340	4,382	5,519	5,612
Agricultural	784	820	462	484
Environmental	100	82	104	86
Total	**5,224**	**5,283**	**6,084**	**6,181**
Supplies				
Surface Water	3,839	3,196	3,625	3,130
Groundwater	1,177	1,371	1,243	1,462
Recycled and Desalted	207	207	273	273
Total	**5,224**	**4,775**	**5,141**	**4,865**
Shortage	**0**	**508**	**944**	**1,317**

[a] Water use/supply totals and shortages may not sum due to rounding.

For much of its length, LADWP's aqueduct skirts the eastern flank of the Sierra Nevada.

purchased an average of 130 taf/yr from MWDSC, about 20 percent of the City's total water supply. In 1996, almost 90 percent (447 taf) of San Diego County Water Authority's total water supply was purchased from MWDSC.

MWDSC has received Colorado River water since 1941 under contracts with USBR. These contracts have allowed the diversion of 1.21 maf/yr, as well as 180 taf/yr of surplus water when available. (The maximum capacity of the CRA is 1.3 maf/yr.) California's basic apportionment of Colorado River water is 4.4 maf/yr plus one-half of any surplus water, when available. In the past, California was able to use hydrologic surpluses and the amount apportioned to, but not used by, Nevada and Arizona. With completion of the Central Arizona Project and Arizona's 1996 enactment of a state groundwater banking act, Arizona's use has reached it basic apportionment. California's reduction of Colorado River use from current levels to 4.4 maf / yr has significant implications for the South Coast Region. (See the issues section below and the Colorado River Region in Chapter 9). California's Colorado River use reached a high of 5.4 maf in 1974, and has varied from 4.5 maf to 5.3 maf annually over the past 10 years.

State Water Project

Local agencies contracting with the SWP for part of their supplies are shown in Table 7-23.

MWDSC is the largest SWP contractor, with an annual entitlement of more than 2 maf. In 1992, Castaic Lake Water Agency assumed the SWP contract of Devil's Den Water District in the Tulare Lake

TABLE 7-22

Metropolitan Water District of Southern California Member Agencies

Cities	*Municipal Water Districts*	*Water Authority*
Anaheim	Calleguas	San Diego County
Beverly Hills	Central Basin	
Burbank	Chino Basin	
Compton	Coastal	
Fullerton	Eastern	
Glendale	Foothill	
Long Beach	Las Virgenes	
Los Angeles	Orange County	
Pasadena	Three Valleys	
San Fernando	West Basin	
San Marino	Upper San Gabriel Valley	
Santa Ana	Western of Riverside County	
Santa Monica		
Torrance		

TABLE 7-23

State Water Project Contractors in the South Coast Region

Agency	*Contract Entitlement (taf)*	*SWP Deliveries in 1995 (taf)*
Castaic Lake WA	54.2	27.2
San Bernardino Valley MWD	102.6	0.7
San Gabriel Valley MWD	28.8	12.9
San Gorgonio Pass WA	17.3	0
MWDSC	2,011.5	436.0
Ventura County FCD	20.0[a]	0

[a] Ventura County FCD subleases 1.85 taf/yr to MWDSC.

Region, increasing Castaic's entitlement to 54.2 taf. Within the San Bernardino Valley Municipal Water District service area, groundwater is the major water source, and hence the district has used little of its SWP water. Ventura County Flood Control District also relies mostly on groundwater and has taken delivery of SWP supply only twice, during the drought in 1990 and 1991. San Gorgonio Pass Water Agency (which also serves a portion of the Colorado River Region) lacks the facilities to take delivery of SWP water, and to date has received no supply from the SWP.

The Department is working with the SGPWA and SBVMWD to extend the East Branch of the California Aqueduct to SGPWA, which serves the Banning Pass area of Riverside County (including the communities of Banning and Beaumont), and to provide system improvements to SBVMWD. The Notice of Determination for the final supplemental EIR was filed in March 1998. The project will be constructed in two phases. Phase I construction is scheduled to begin in late 1998 and to be completed by late 2000. A second phase will be constructed to serve the Mentone area if demand increases.

The Department's A.D. Edmonston Pumping Plant lifts California Aqueduct water 1,926 feet across the Tehachapi Mountains to serve Southern California. The maximum plant capacity is 4,480 cfs.

Local Surface Water Supplies

Table 7-24 lists major local storage reservoirs in the region. Most of the larger reservoirs in the region have water supply as their primary purpose. However, several of the larger water supply reservoirs do not develop local supply—they are the terminal facilities of the major conveyance facilities that import water to the region.

Table 7-25 lists local water supply reservoirs in MWDSC's service area with at least 10 taf storage capacity.

About 96 percent of San Diego County's population resides within SDCWA's service area. SDCWA, a wholesale water agency, purchases imported water from MWDSC and delivers the water to its 23 member agencies (Table 7-26) in the western third of San Diego County through two aqueduct systems. SDCWA's maximum annual delivery was 647 taf in 1990. Most of San Diego's in-county water supplies are from local agencies' surface reservoirs. Twenty-four surface reservoirs are located within its service area, with a combined capacity of approximately 569 taf. Some reservoirs are connected to SDCWA's aqueduct system and can receive imported water in addition to surface runoff. In 1995, local water sources provided 118 taf, or 23 percent of the water used in SDCWA's service area. (Since 1980, local surface water supplies have ranged from 33 taf to 174 taf annually.)

TABLE 7-24

Major Reservoirs in the South Coast Region[a]

Reservoir	*Owner*	*Capacity (taf)*	*Primary Purpose*
Casitas	USBR	254	Water Supply
Lake Piru	United WCD	88	Water Supply
Pyramid	DWR	171	Water Supply
Castaic	DWR	324	Water Supply
Big Bear Lake	Big Bear MWD	73	Water Supply
Perris	DWR	132	Water Supply
Mathews	MWDSC	182	Water Supply
Vail	Rancho California WD	51	Water Supply
Henshaw	Vista ID	52	Water Supply
San Vicente	City of San Diego	90	Water Supply
El Capitan	City of San Diego	113	Water Supply
Morena	City of San Diego	50	Water Supply
Whittier Narrows	USACE	67	Flood Control
Prado[b]	USACE	188	Flood Control
Seven Oaks (under construction)	USACE	146	Flood Control
Eastside (under construction)	MWDSC	800	Water Supply

[a] Reservoirs with capacity greater than 50 taf.

[b] 26 taf of storage capacity is used for water supply purposes, for downstream groundwater recharge.

TABLE 7-25

Reservoirs Owned by Water Retailers in MWDSC's Service Area[a]

Reservoir	*Agency*	*Capacity (taf)*
Bard	Calleguas MWD	10
Vail	Rancho California	51
Hemet	Lake Hemet MWD	14
Westlake	Las Virgenes MWD	10
Los Angeles	City of Los Angeles	10
Stone Canyon	City of Los Angeles	11
Santiago	Irvine Ranch WD & Serrano ID	25
Henshaw	Vista ID	52
Barrett	City of San Diego	38
El Capitan	City of San Diego	113
Lake Hodges	City of San Diego	34
Morena	City of San Diego	50
Lower Otay	City of San Diego	50
San Vicente	City of San Diego	90
Sutherland	City of San Diego	30
Loveland	South Bay ID	25
Sweetwater	South Bay ID	28
Railroad Canyon	Temescal Water Company	12

[a] Reservoirs with capacity of at least 10 taf.

The City of San Diego's Murray Dam, shown under construction in 1917, is a multiple arch concrete dam impounding a 6 taf reservoir. The wooden stave pipeline below conveyed supplies for the Cuyamaca Water Company.

Courtesy of Water Resources Center Archives, University of California, Berkeley

Groundwater Supplies

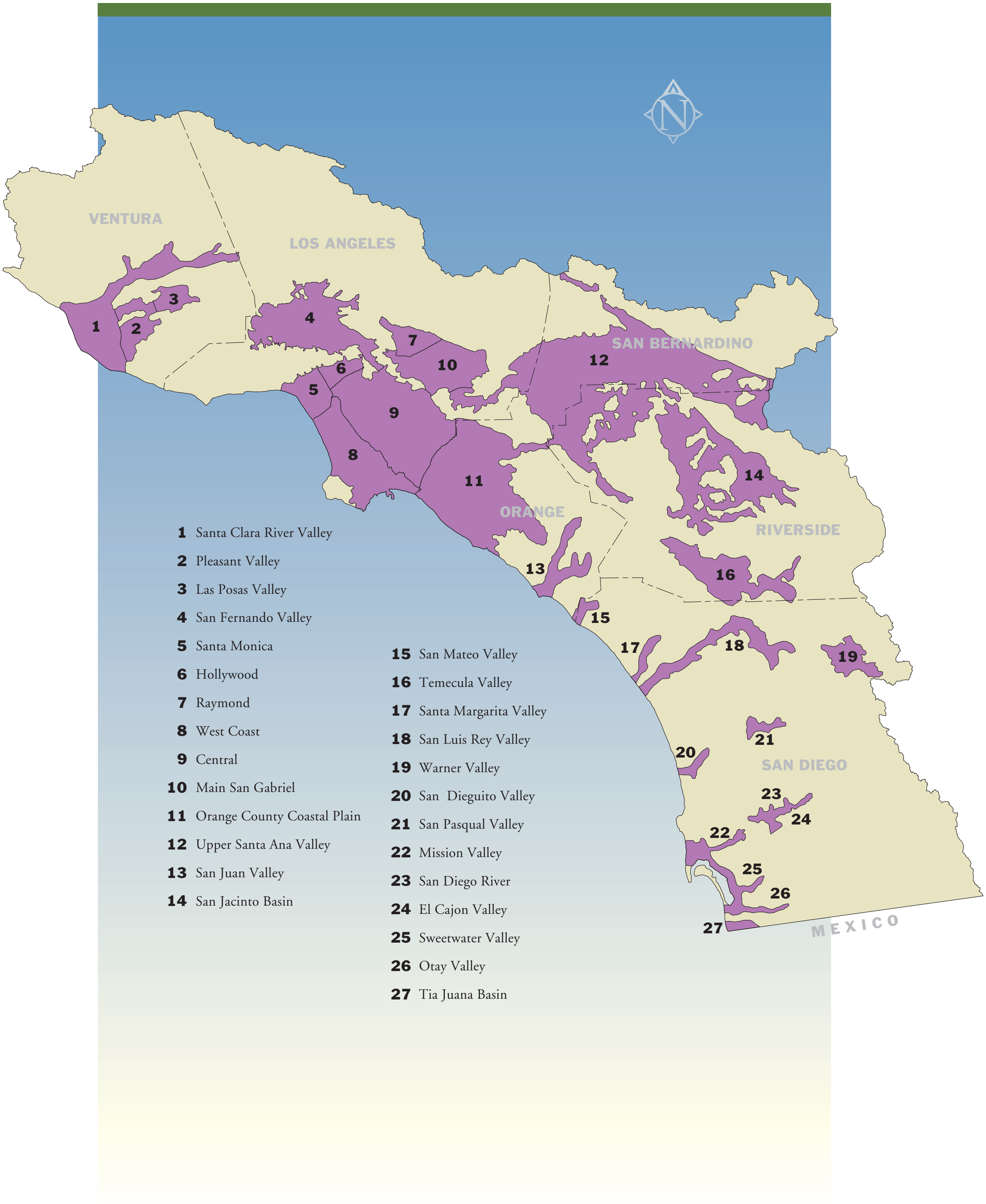
Groundwater is a major local supply source in the remaining counties in MWDSC's service area. For example local supplies developed by individual retail agencies, primarily groundwater, presently account for about 50 percent of Orange County's water use. There are numerous groundwater basins (Figure 7-6) along the coast and inland valleys of the region. Many of these basins are actively managed by public agencies or have been adjudicated by the courts. Some groundwater basins are as large as several hundred square miles in area and have a capacity exceeding 10 maf. The South Coast's current estimated annual groundwater use is about 1.2 maf. Recharge occurs from natural infiltration along river valleys, but in many cases facilities have been constructed to recharge local, imported, or recycled supplies. For example, in average years the Los Angeles Department of Public Works intention-

TABLE 7-26

San Diego County Water Authority Member Agencies

Cities	Municipal Water Districts	Irrigation Districts
Del Mar	Carlsbad	Santa Fe
Escondido	Olivenhain	South Bay
National City	Padre Dam	Vista
Oceanside	Rainbow	***Public Utility District***
Poway	Ramona	Fallbrook
San Diego	Rincon Del Diablo	***Reservation***
Water Districts	Valley Center	Pendleton Military
Helix	Yuima	***Ex-Officio Member***
Otay		San Diego County
San Dieguito		
Vallecitos		

FIGURE 7-6
South Coast Groundwater Basins



ally recharges 230 taf of local flows, 60 taf of imported water, and 50 taf of recycled water. These surface supplies not only replenish groundwater basins, but can be banked for later use. Programs are in place to bank imported water, when available in wetter periods, to increase groundwater production during the summer season and in drought years. At a 1995 level of development, about 100 taf is banked in average years. This water is included as an average year urban water demand in Bulletin 160-98 water budgets for the South Coast.

Table 7-27 shows adjudicated groundwater basins in the South Coast Region. In the adjudicated groundwater basins, the court appoints watermasters to oversee the court judgement. The court judgement limits the amount of groundwater that can be extracted by parties to the judgement.

Local Water Resources Management Issues

Water Supply Reliability

Since local supplies are insufficient to meet water demands, the region imports more than 60 percent of its supply. A natural disaster or other emergency that would curtail or limit imports to the region would be detrimental. Water supply reliability is a critical issue for the region and water agencies are seeking to ensure a more reliable and adequate supply in case of emergencies.

Eastside Reservoir. MWDSC provides about 60 percent of the water used by the nearly 16 million people living on the coastal plain between Ventura County and the Mexican border. MWDSC is constructing Eastside Reservoir to better manage its water supplies between wet and dry years. The 800 taf reservoir, located near Hemet in southwestern Riverside County, will nearly double the region's existing surface storage capacity and will provide increased terminal storage for SWP and Colorado River supplies. When completed, Eastside Reservoir would provide the entire region with a six-month emergency supply after an earthquake or other disaster. It would also provide water supply for drought protection and peak summer demands.

Under construction in the Domenigoni and Diamond Valleys, the $2 billion project consists of two embankments to block the east and west ends of the valleys, and a saddle dam located along a low point in the hills which form the northern boundary of the reservoir. The reservoir includes a forebay and pumping plant, and the 8-mile, 12-foot diameter Eastside Pipeline. After reservoir completion in 1999, up to four years will be needed to fill the reservoir with imported water. Water from the Colorado River Aqueduct will be delivered through the San Diego Aqueduct to the reservoir forebay and pumped into the reservoir. SWP water will either be delivered from the Santa Ana Valley Pipeline and bypassed around Lake Perris, or taken from Lake Perris and conveyed through MWDSC's system into the reservoir forebay.

The Inland Feeder is a new conveyance facility to deliver SWP water made available by enlargement of the East Branch of the California Aqueduct. Upon its completion in 2004, the Inland Feeder will deliver

Plans to construct a San Diego emergency storage project reflect the area's vulnerability to natural disasters such as earthquakes. Much of the area's supplies are imported through the Colorado River Aqueduct. This photo shows an early example of local conveyance projects—a wooden trestle carrying a flume across the Sweetwater River.

Courtesy of Water Resources Center Archives, University of California, Berkeley

TABLE 7-27

Adjudicated Groundwater Basins in the South Coast Region

Court Name	*Filed in Court*	*Final Decision*	*Watermaster*	*Basin Name, County*
Upper Los Angeles River Area	1955	1979	Superior Court appointee	San Fernando Valley Basin (entire watershed), Los Angeles County
Raymond Basin	1937	1944	Raymond Basin Management Board	Northwest part of San Gabriel Valley Basin, Los Angeles County
Main San Gabriel Basin	1968	1973	9-Member Board appointed by the Los Angeles County Superior Court	San Gabriel Valley Basin, excluding Raymond Basin, Los Angeles County
Central Basin	1962	1965	DWR	Northeast part of Coastal Plain of Los Angeles County Basin, Los Angeles County
West Coast Basin	1946	1961	DWR	Southwest part of Coastal Plain of Los Angeles County Basin, Los Angeles County
Puente	1985	1985	Two consultants, one representing the Walnut Valley WD and Rowland WD; and one for the City of Industry and Industry Urban Development Agency; and a third neutral party	Southwest part of San Gabriel Valley Basin, Los Angeles County
Santa Margarita River Watershed	1951	1966	U.S. District Court appointee	The entire Santa Margarita River watershed, including Santa Margarita Coastal, Murrieta-Temecula and Anza-Cahuilla groundwater basins, San Diego and Riverside Counties
Santa Paula Basin	1991	1996	3 person Technical Advisory Committee from United Water Conservation District, City of Ventura, and Santa Paula Basin Pumpers Association	Sub-basin of Santa Clara River, Ventura County
Chino Basin	1978	1978	9-Member Board	Chino Basin, northwest part of Upper Santa Ana Valley Basin, San Bernardino and Riverside Counties
Cucamonga Basin	N/A	1958	Cucamonga County WD and San Antonio Water Company	Cucamonga Basin, north-central part of Upper Santa Ana Valley Basin, San Bernardino County
San Bernardino Basin Area	1963	1969	One representative each from Western Municipal Water District and San Bernardino Valley Municipal Water District	Northeast part of Upper Santa Ana Basin, San Bernardino and Riverside Counties

water by gravity to Eastside Reservoir via 43.7 miles of tunnels and pipeline that start at Devil Canyon and tie into the CRA and Eastside Pipeline. The Inland Feeder will provide system reliability by linking together the SWP and Colorado River systems, and will improve water quality by allowing greater blending of SWP and Colorado River waters.

San Diego Emergency Water Storage Project. SDCWA does not own or operate treatment or storage facilities. It has a contractual agreement with the City of San Diego to store up to 40 taf of water in San Vicente and Lower Otay Reservoirs. To increase local supplies that would be available during times of emergency, SDCWA has proposed an emergency storage project that could increase the county's total water storage by 90 taf. Use of the project would be limited to emergency situations, such as prolonged drought or catastrophic failure of the San Diego Aqueduct during an earthquake. Although not a water supply development project, the emergency water storage project would provide incidental local supply benefits by allowing capture of additional winter runoff.

Four project alternatives were evaluated. All involved increased surface storage and new distribution systems. Three alternatives additionally involved reservoir reoperation.

- San Vicente stand-alone. Expand San Vicente Reservoir by raising the dam 83 feet to contain 90.1 taf of emergency storage.
- Moosa Canyon construction/Lake Hodges reoperation. Construct a new dam at Moosa Canyon to hold 68 taf and reoperate Lake Hodges to provide 22 taf.
- San Vicente expansion and reoperation. Raise the dam by 65 feet, adding 68 taf of emergency storage and reoperate the reservoir to provide an additional 22 taf.
- Olivenhain construction, Lake Hodges reoperation, and San Vicente expansion. Build a new 320-foot high dam at the Olivenhain site to create 18 taf of emergency storage (24 taf total capacity, with 4 taf reserved for Olivenhain MWD). Reoperate Lake Hodges to provide an additional 20 taf and raise San Vicente Dam by 54 feet to hold an additional 52 taf.

The preferred alternative is the Olivenhain-Hodges-San Vicente project. A new reservoir would be constructed about 1 mile northwest of Lake Hodges in conjunction with Olivenhain Municipal Water District. Olivenhain Reservoir, which would also serve as operational storage for Olivenhain MWD, would be connected to Lake Hodges by a 1.5-mile pipeline. San Vicente Dam would be raised from 234 feet to 288 feet. The Olivenhain-Hodges-San Vicente project would add 90 taf of emergency storage capacity. The final EIR was certified in 1996. In 1997, USACE issued a record of decision on the final EIS and a permit for the project under Section 404 of the federal Clean Water Act. Construction of the $550 million project is scheduled to begin in 1999 and be completed by 2011. SDCWA has agreements with the City of San Diego regarding joint use of San Vicente Reservoir and Lake Hodges, and with Olivenhain MWD concerning joint use of the Olivenhain Reservoir. (Olivenhain MWD had planned to construct a 5 to 8 taf reservoir at the site for its own use if SDCWA did not go forward with a joint project.) Olivenhain MWD would construct a 20 mgd water treatment plant (to be expanded to 80 mgd ultimately) in conjunction with storage at Olivenhain reservoir.

Management of California's Colorado River Water

A major water management issue facing the South Coast Region is California's use of Colorado River water in excess of its basic annual apportionment of 4.4 maf. In the past, Arizona and Nevada were not using the full amount of their annual apportionments, and California was able to use the amount apportioned to, but not used by, Nevada and Arizona, and to use wet year surplus flows. As described in more detail in Chapter 9, the Colorado River Board's draft 4.4 Plan describes how California would reduce its use of river water over time.

The draft CRB 4.4 Plan includes actions that would be taken in two phases. The first phase, extending from the present to 2010 or 2015, would comprise those actions that are now in some stage of planning and implementation. These programs are intended to reduce California's annual use of Colorado River water to about 4.6 to 4.7 maf. The second phase would comprise actions that have not yet been formulated and quantified. Examples of phase one actions include the SDCWA/IID transfer, lining of parts of the All-American and Coachella Canals, and groundwater banking projects associated with surplus Colorado River water that could be conveyed in MWDSC's aqueduct. Examples of potential phase two actions include proposals to desalt water in Salton Sea tributaries and to convey the treated water to the South

Coast Region. (Actions such as agricultural water conservation programs or desalting proposals that would reduce the amount of fresh water inflow to the Salton Sea are subject to environmental review to ensure that they will not significantly affect the sea. A description of the Salton Sea and its environmental resources is provided in Chapter 9.)

The draft CRB 4.4 Plan would in essence reduce California's use of Colorado River water in agricultural areas in the Colorado River Region, transfer conserved Colorado River water to the South Coast Region for urban use, and define how water from wet year surpluses (and the unused apportionments of other states, when available) could be used to help keep the Colorado River Aqueduct full. When California is limited to its basic apportionment of 4.4 maf, MWDSC would only be able to exercise its fourth priority right to 550 taf, as compared to maximum aqueduct capacity of 1.3 maf.

Mono Basin

The City of Los Angeles' water diversions from Mono Basin lowered Mono Lake's water level by more than 40 feet since 1941 and also increased the lake's salinity. (See the South Lahontan Region in Chapter 9 for more detailed discussion of Mono Lake issue.) In 1994, SWRCB adopted Water Right Decision 1631 amending the city's water rights for diverting water from Mono Basin. The decision restricts diversions from the basin to increase and maintain Mono Lake's level to 6,391 feet above sea level. During the period of Mono Lake's transition to the 6,391-foot level (estimated to take about 20 years), the maximum amount of water that Los Angeles can divert from the basin is 16 taf/yr. Long-term Los Angeles diversions from the Mono Basin are projected to be about 31 taf/yr after Mono Lake has reached the 6,391-foot level, or one-third of the city's historical diversions from the Mono Basin.

Restoration of Coastal Wetlands and Estuaries

Ballona Wetlands Preserve. Although the majority of California's wetlands habitat is found in the Central Valley and San Francisco Bay area, there are significant wetlands in the South Coast, as described below. The Ballona wetlands is one of the more well-known South Coast wetlands.

The Ballona Wetlands Preserve, located in Los Angeles County near Marina Del Rey, is one of the few tidal marshes in Southern California. It is a complex of estuary, lagoon, salt marsh, freshwater marsh, and dune habitats. It provides nesting grounds for migrating waterfowl, supports a variety of plant, fish, and animal life, and is home to two endangered species—Belding's Savannah sparrow and the California least tern. The present Ballona wetlands is a small remnant of what existed in the early 1800s, when the wetlands comprised more than 2,000 acres. At the present time, it has been reduced to a little more than 180 acres.

The Ballona Wetlands Preserve was the subject of a long-running debate among private property owners and environmental groups that began in 1984 when the California Coastal Commission approved a land use plan to develop the wetlands. In the years that followed, the parties negotiated a settlement to litigation over the development. The settlement provides for:

- Restoration of 190 acres of salt marsh habitat. Plans are underway to provide the eastern portion of the salt marsh with full tidal flow and expanded habitat for sub-tidal and mudflat organisms. The western portion would be provided with muted tidal flow to protect and enhance existing salt marsh habitat for pickleweed and the Belding's Savannah sparrow.
- A 34-acre freshwater marsh.
- A 25-acre corridor of riparian habitat along Centinela Creek. This area will potentially provide appropriate vegetation for the least Bell's vireo and a wide variety of other birds which nest in riparian trees.
- Restoration of 48 acres of upland, bluff edge, and coastal strand habitat.

When completed, the Ballona Wetlands Preserve will be one of the largest wildlife sanctuaries in any major U.S. city.

Santa Monica Bay. Santa Monica Bay extends about 50 miles from Point Hume to Palos Verdes Point. A coordinated effort to improve the Santa Monica Bay ecosystem began with establishment of the Santa Monica Bay restoration project. SMBRP was included in the Clean Water Act's National Estuary Program in 1988, and was charged with assessing the bay's problems and with producing a bay restoration plan. Implementation of the plan, approved by the Governor in 1994, and by the Administrator of EPA in 1995, is currently under way.

Prado Wetlands Project. OCWD owns 2,150 acres behind Prado Dam in Riverside County where the district operates constructed freshwater wet-

An aerial view of the constructed wetlands behind Prado Dam.

Courtesy of Orange County Water District

lands to reduce the nitrogen concentration of river water. USACE's Prado Flood Control Basin is operated primarily for flood control. Under an agreement with USACE and USFWS, OCWD uses 25.75 taf of the reservoir's capacity for water supply. OCWD diverts Santa Ana River water through 465 acres of constructed wetlands for biochemical nitrogen removal. Because Santa Ana River water provides much of the recharge for Orange County's coastal plain groundwater basin, nitrogen removal is important to improving water quality.

The Prado wetlands are home to several rare and endangered bird and waterfowl species. As part of the three party agreement, OCWD set aside more than 226 acres as habitat for the endangered least Bell's vireo and southwestern willow flycatcher.

Flood Control

As noted earlier, groundwater constitutes most of the local water supply in the region. Local surface water resources are relatively limited. In the Los Angeles-Orange County coastal strip, most of the rivers and streams that drain to the Pacific Ocean have been developed primarily for flood control purposes, rather than for surface water supply. (Some of these reservoirs are operated to provide surface flows for groundwater recharge.) A few of the existing flood control reservoirs are now being evaluated for their potential to provide some, albeit small, water supply benefits, usually by reoperation of the facilities to enhance groundwater recharge and provide limited year-round storage. Several of these facilities are discussed in the water management options section. Below are a few examples of flood control-related water management issues in the region.

Los Angeles River. USACE, in cooperation with Los Angeles County, has constructed an extensive network of flood control facilities on the Los Angeles River, which passes through one of the most intensively urbanized areas in the South Coast Region. (In fact, discussions on transportation issues in the region sometimes mention converting the existing concrete channel into a freeway or high-occupancy-vehicle transit route.) USACE's flood control facilities on the Los Angeles River and its tributaries include 5 major dams, 22 debris basins, and 470 miles of channel modifications.

Flood control operations in coastal Southern California and their interaction with reservoir operations for water supply typically differ from those in Northern California. The Sierran reservoirs in the Central Valley that provide most of California's developed surface water supply are, as a broad generalization, operated from a water supply standpoint to manage snowmelt runoff that occurs over a period of several months, and to hold large volumes of carryover storage throughout the year. Flood control reservoirs in coastal Southern California are operated to provide short-term detention (days to weeks) of peak flows from rainfloods. Many of these reservoirs impound ephemeral streams, or streams whose runoff is so small that little water supply benefit is available.

USACE's facilities on the Los Angeles River were designed to provide temporary detention of peak flows, allowing the floodflows to be released to the Pacific Ocean without exceeding downstream channel capacities. Continually increasing water demands in the South Coast Region have prompted reevaluting operations of some of the larger facilities, to determine if their operations could be modified to provide limited additional water supply. One example is a 67 taf flood control detention basin impounded by Whittier Narrows Dam on Rio Hondo, a Los Angeles River tributary, described in the water management options section.

Santa Ana River. The Santa Ana River has been channelized for almost its entire length throughout the highly urbanized part of Orange County, from the river's mouth near Costa Mesa upstream to the vicinity of Yorba Linda. Prado Dam, located in the Corona area between the Chino Hills and the Santa Ana Mountains, impounds a large flood control detention basin. USACE has constructed several flood control features of the Santa Ana mainstem project, with the most recent facility of that project being Seven Oaks Dam. The 550-foot high Seven Oaks Dam is under construction about 35 miles upstream from Prado Dam and will have a gross storage capacity of about 146 taf.

The existing 134-foot high earthfill Prado Dam has a storage capacity of 188 taf. OCWD manages the water supply provided by the dam for groundwater recharge. Future plans entail enlarging Prado's capacity to 363 taf for flood control and water supply storage. After Prado Dam is enlarged, OCWD would propose to raise the reservoir's minimum pool level to increase water supply benefits. Enlargement would be accompanied by development of a new flood forecasting system for the reservoir. The district is currently undertaking a feasibility study with USACE to evaluate potential water supply gains from Prado's enlargement. Modifying flood control operations would provide an additional 3 to 5 taf of annual supply for groundwater recharge.

Salinity Management Actions

Imported Colorado River water is a significant source of supply for the South Coast Region. The total dissolved solids concentration in imported water has water management implications for the region, affecting the feasibility of water recycling and groundwater recharge programs. Because residential use of water increases TDS concentration, water recycled from a moderately high TDS source water can result in unacceptably high TDS concentrations. Groundwater recharge potential may be restricted because the RWQCB has established TDS requirements for recharge water in some groundwater basins, to protect existing basin water quality.

In 1996, USBR and MWDSC began a joint salinity management study to develop information to support adoption of regional salinity management policies by MWDSC and to coordinate interagency action to solve salinity problems. The study's initial phase focused on identifying problems and salinity management needs in MWDSC's service area.

Phase I identified the average TDS concentration of MWDSC's Colorado River water in 1996 as being about 700 mg/L, and average TDS of MWDSC's SWP supplies as being about 300 mg/L. The City of Los Angeles' water supply from the eastern Sierra Nevada had significantly lower TDS concentration, typically about 160 mg/L. TDS levels in local groundwater supplies in the South Coast Region vary considerably, ranging from 200 mg/L (Cucamonga Basin near Upland) to more than 1,000 mg/L (Arlington Basin near Corona). Table 7-28 shows groundwater supplies by salinity.

Local sources of salinity also contribute significantly. Municipal and industrial use of water add between 250 to 500 mg/L of TDS to wastewater. Key sources of local salts include water softeners (typically contributing from 5 to 10 percent of the salt load) and industrial processes.

The long-term salt balance of South Coast groundwater basins is an important management problem. Smaller basins like the Arlington and Mission groundwater basins were abandoned for municipal supply because of high salinity levels. These basins have only recently been restored through construction of desalting projects. Blending SWP and Colorado River supplies or using the SWP's relatively low TDS supplies for groundwater replenishment has been a goal in some areas. However, without an ocean outfall or stream discharge, some inland agencies that reuse wastewater have salt accumulation problems in their groundwater basins. Some inland agencies have access to a brine line for exporting salt and concentrated wastes to a coastal treatment plant and ocean outfall, while others have not found construction of a brine line economical.

During droughts when use of recycled water projects and marginal quality groundwater are most important, some local supplies may be constrained by water quality problems. Concerns about wastewater TDS have grown with the expansion of water recy-

TABLE 7-28

Salinity of South Coast Region Groundwater Supplies

Annual Production (maf)	*TDS (mg/L)*	*Percent*
<500	1.06	78
500 to 1,000	0.15	11
>1,000	0.15	11
Total	**1.36**	**100**

cling programs. In general, TDS more than 1,000 mg/L is a quality problem for irrigation and industrial reuse customers.

The MWDSC/USBR study's second phase will evaluate regional applications of four TDS management options: local water service control, imported water source control, desalting, and blending.

Groundwater Issues

San Gabriel and San Fernando Valleys. Groundwater contamination in the San Gabriel Valley and San Fernando Valley Basins has come from many sources dating back to the 1940s. Each basin has four areas on EPA's Superfund list.

More than 30 square miles of groundwater under the San Gabriel Valley Basin may be contaminated. Contamination from volatile organic compounds was first detected in 1979 when Aerojet Electrosystems in Azusa sampled nearby wells in Valley County Water District. Subsequently, DHS initiated a well sampling program to assess the extent of contamination. By 1984, 59 wells were found to be contaminated with high levels of VOCs. The most prevalent contaminants were trichloroethene, perchloroethylene, and carbon tetrachloride.

The San Gabriel Basin Water Quality Authority was created by the Legislature in 1993 to be the agency responsible for remediating groundwater contamination in San Gabriel Valley. The authority's mission is to plan and implement groundwater quality management programs and to protect the basin from future contamination. The SGBWQA is governed by a 5-member board, comprised of one member from each of the overlying municipal water districts, one from a city with prescriptive water pumping rights and one from a city without prescriptive water pumping rights. (The three municipal water districts are San Gabriel Valley MWD, Three Valleys MWD, and Upper San Gabriel Valley MWD.)

Currently, four areas of the basin are of concern: Whittier Narrows, Puente Basin, Baldwin Park/Azusa, and El Monte/South El Monte. The SGBWQA is involved in groundwater cleanup projects in these areas. The Whittier Narrows and Puente Basins are also being managed by EPA under its Superfund program. Another concern is that contamination in the South El Monte area might migrate from the San Gabriel Basin through Whittier Narrows and into the Central Basin.

The Arrow Well Treatment Plant in Baldwin Park was the first project implemented by SGBWQA, with a $1.3 million construction grant from SWRCB. The project, completed in 1992, extracts about 3 taf/yr of contaminated groundwater, treats the water, and distributes it to customers. The Big Dalton Well Treatment Project was the second in a series of projects focusing on contamination problems in the Baldwin Park area. The facility, designed to extract and treat approximately 4 taf/yr of contaminated groundwater, is part of a three-well barrier to stop migration of contaminated groundwater. The Monrovia Wells project currently treats approximately 4.6 taf/yr of contaminated groundwater with airstripping, giving the City of Monrovia the ability to use water from contaminated aquifers while preventing the spread of contamination to adjacent clean aquifers. In 1996, legislation was enacted extending SGBWQA's authority to remediate groundwater contamination in the San Gabriel Basin through July 1, 2002.

About 50 percent of the water supply wells in the eastern portion of the San Fernando Valley Basin were found to be contaminated with volatile organic compounds. Many of the wells have been shut down. The RWQCB is investigating area-wide sources of groundwater contamination for four Superfund sites in the San Fernando Valley Basin. Interim clean-up measures include groundwater pumping and treatment.

Actions taken to address groundwater contamination included a basin-wide Superfund investigation, completed in 1992. The study included installation of 87 monitoring wells, development of a basin-wide groundwater flow model, and evaluation of the extent of contamination. Presently, two large-scale plants are in operation—the North Hollywood Treatment Plant (2,000 gpm) which uses aeration with GAC scrubbing and the Burbank Operable Unit (9,000 gpm) which uses aeration with GAC scrubbing and liquid-phase GAC polishing units. The Pollock Wells Treatment Plant (3,000 gpm) is under construction with a start-up date in 1998, and two additional plants, the 5,000 gpm Glendale Operable Unit and the 13,500 gpm Headworks Wells Treatment Plant, are in the planning/preliminary design phase. These plants will collectively treat over 48 taf/yr of San Fernando Basin's groundwater supply. The basin provides urban water supply for Los Angeles, Burbank, Glendale, and La Crescenta.

San Bernardino Valley. As late as the 1940s, the lowest portion of San Bernardino Valley was largely marshlands with abundant springs. Downtown San Bernardino is located over a confined aquifer which experiences high groundwater levels. Buildings have experienced seepage of water into basements or ground floors. High groundwater conditions increase soil liquefaction potential in an area that could be affected by movement along the Cucamonga, San Jacinto, or San Andreas Faults. The presence of unreinforced masonry buildings above the confined aquifer increases the risk of damage in the event of liquefaction.

The Bunker Hill Basin groundwater extraction project involves extracting groundwater from the basin to lower groundwater levels, thereby reducing seismic risks. The water could potentially be sold to help offset project costs. Groundwater extraction for this project will not exceed the perennial yield of the San Bernardino Basin (which includes both Bunker Hill and Lytle Creek Basins). The ultimate goal of the extraction project is to reduce the unacceptably high groundwater levels in the basin. A suggested minimum depth target of 30 feet below ground surface in the confined zone would minimize the risk of liquefaction and other adverse impacts associated with high groundwater. One plan being considered is for San Bernardino Valley Municipal Water District to pump between 20 taf/yr and 70 taf/yr, with larger volumes being extracted as necessary after exceptionally wet seasons.

Ventura County. Groundwater is the main water supply for agricultural and urban use in much of the coastal plain of Ventura County, including Oxnard Plain. Seawater intrusion was initially observed in the late 1940s, following the widespread development of agriculture and food processing in the Oxnard Plain. Increasing water demands in the 1940s led to overdraft of groundwater aquifers underlying the plain.

In the 1990s demand has decreased due to agricultural and urban water conservation measures. Recent estimates show an approximate balance between extractions and recharge because of increased artificial recharge and a reduction in groundwater extraction required by Fox Canyon Groundwater Management Agency. The agency adopted ordinances requiring meter installation on wells extracting more than 50 af/yr, and restricting drilling of new wells in some areas.

In 1991, United Water Conservation District completed construction of the Freeman Diversion improvement project on Santa Clara River. This project increased average annual diversions from the river from 40 taf to 60 taf. The diverted water is used for groundwater recharge and irrigation, reducing agricultural demand for groundwater.

Southern California Comprehensive Water Reclamation and Reuse Study

In 1993 USBR, seven local agencies and the Department began evaluating the feasibility of regional water recycling in Southern California. The seven participating local agencies are: Central and West Basin Municipal Water Districts, City of Los Angeles, City of San Diego, MWDSC, SDCWA, Santa Ana Water Project Authority, and South Orange County Reclamation Authority. Regional planning would take advantage of potential surpluses of recycled water which could serve needs in areas throughout Southern California. The plan of study called for a three-part, six-year comprehensive effort to identify a regional recycling system and develop potential projects.

The study has identified regional and area-wide water recycling potential for 20 and 50 year planning horizons. An economic distribution model will be used to maximize the allocation of recycled water at minimum cost throughout the region.

Water Marketing

The highly urbanized South Coast Region relies substantially on imported water. Water wholesalers serving the region expect to acquire part of their future supplies from water marketing arrangements, using the Colorado River Aqueduct and California Aqueduct to convey the acquired water.

A difficulty associated with future supply from water marketing arrangements—as opposed to from fixed facilities such as reservoirs or water recycling plants—is the greater uncertainty involved in forecasting future contractual arrangements for transfers. For example, SDCWA recently released a request for proposals for entities interested in selling water both on a short-term or long-term basis. Details of marketing arrangements developed would depend on specific terms and conditions negotiated for each arrangement. An urban agency may plan to acquire water from agricultural users in the Central Valley or the Colorado River Region, but terms and conditions of the transfers are subject to negotiation with potential sellers and the availability of conveyance. There are many ways to structure marketing arrangements—long-term agreements for base year transfers that occur every year regardless of hydrology, drought year transfers tied to specific hydrologic criteria, or transfer options that may be exercised based on negotiated criteria. Marketing may also be accomplished through short-term (one year or less) agreements on the spot market. Of note in the South Coast Region, local agencies are now planning to use water transfers for part of their base supplies, a change from past years when marketing arrangements were viewed as primarily drought year supplies.

An example of a base year transfer is the SDCWA/IID transfer described in Chapter 9. The two agencies executed an agreement in 1998 for a long-term transfer that would build up over time to 200 taf/yr. SDCWA would need to use MWDSC's Colorado River Aqueduct to convey the transferred water to the South Coast Region. SDCWA and MWDSC have negotiated an initial wheeling agreement.

New Conveyance Facilities from Colorado River Region to South Coast Region

SDCWA has been studying the feasibility of constructing a new aqueduct from the Imperial Valley to its service area. Two alternatives have been considered—an aqueduct on the U.S. side of the international border that would be used to convey Colorado River water acquired through marketing arrangements with water users in the Colorado River Region, and a joint aqueduct on the Mexican side of the border with the City of Tijuana. SDCWA has completed the first phase of a feasibility study for the U.S. alignment; Proposition 204 authorizes funding for further feasibility-level study of conveyance alternatives. In addition to the usual engineering and environmental considerations associated with large-scale conveyance projects, the ability to implement this project would be affected by the other Colorado River Basin states' concerns about a new California diversion on the river, and by international considerations involved in financing and constructing a project with the Mexican government.

Water marketing arrangements established through the draft CRB 4.4 Plan would be a source of water for a new conveyance facility. Other sources could result from responses to SDCWA's 1998 request for proposals for short-term and long-term marketing arrangements. While new conveyance may be a possible option for the South Coast Region in the long term, the time required to implement such a large scale project and the schedule presently contemplated for implementing the draft CRB 4.4 Plan suggest that a facility would not be constructed within the Bulletin 160-98 planning horizon.

Mexican Border Environmental Quality Issues

Tijuana's excess sewage has plagued San Diego area beaches since the 1930s. During frequent failures of Tijuana's inadequate, antiquated sewage treatment system, millions of gallons of raw sewage have been carried across the border through the Tijuana River to its estuary in San Diego County. San Diego's first attempt to alleviate this problem was in 1965, when the city agreed to treat Tijuana's wastewater on an emergency basis. In 1983, the United States and Mexico signed an agreement stating that Mexico would modernize and expand Tijuana's sewage and water supply system and build a 34 mgd sewage treatment plant. Mexico received a grant for $46.4 million from the Inter-American Development Bank to help finance the expansion and was to spend an additional $11 million to build a wastewater treatment plant 5 miles south of the border. The plant became fully operational in 1988.

In 1990, the United States and Mexico, through the International Boundary and Water Commission, agreed to construct international wastewater treatment facilities in the United States to solve continuing border sanitation problem. Facilities included a 25 mgd secondary treatment plant at a site just north of the international border and a 3.5 mile ocean outfall. Construction of the first phase of the international plant, a 25 mgd advanced primary treatment plant is being completed. Construction of the secondary phase of the international plant is on hold pending the completion of a supplemental environmental impact statement on alternative methods of secondary treatment. The second phase is expected to be complete by December 2000.

EPA and IBWC have completed a supplemental EIS on interim options for discharge of effluent from the international plant prior to completion of the ocean outfall and the secondary treatment component of the plant. The preferred option is a combination of discharging the effluent to the City of San Diego's metropolitan sewerage system and constructing a detention basin to hold flows for discharge during off-peak hours.

Water Management Options for South Coast Region

Southern California's challenge in managing its water resources is driven by one of the most fundamental realities of the West—it is an arid region. The major water agencies in the South Coast Region are extensively involved in water resources management planning. A mixture of water management options will be needed to replace California's reduced supply from the Colorado River and to offer long-term reliability to the region. Table 7-29 shows a list of options for the region, and the results of an initial screening of the options. The retained options were evaluated (Table 7A-4 in Appendix 7A) based on a set of fixed criteria discussed in Chapter 6.

Water Conservation

Urban. Urban water demand forecasts for 2020 assume that BMPs are in place; consequently, only those urban conservation efforts which exceed BMPs are considered as options. Reducing outdoor water use to 0.8 ET_o in new development would attain 67 taf/yr of depletion reductions, while extending this measure to include existing development would reduce depletions by 246 taf/yr. Reducing residential indoor water use to 60 and 55 gpcd would reduce depletions by 110 and 220 taf/yr, respectively. Reducing commercial, institutional, and industrial water use by an additional 3 percent and 5 percent would attain 30 taf/yr and 49 taf/yr of depletion reductions, respectively. Reducing system losses to 5 percent would reduce depletions by 84 taf/yr.

Agricultural. The 2020 agricultural water demand forecasts assume that EWMPs are in place. As with the urban water management options, only those agricultural conservation efforts which exceed EWMPs are considered as options. Agricultural water conservation options are limited in the region because of the relatively high SAEs that currently exist, the reliance on high cost, pressurized potable water or groundwater, and the limited agricultural acreage. Improving irrigation management to raise SAEs to 76, 78, and 80 percent in the South Coast would reduce depletions by 4, 7, and 10 taf/yr, respectively. Flexible water deliveries are deferred because most of the water applied for agriculture is delivered on-demand in the region. Canal lining and piping are deferred because of the absence of open canal systems in the region. The spill recovery and tailwater systems option is deferred because of the relatively small acreage under furrow or border irrigation in the region.

Modify Existing Reservoirs or Operations

USACE operates flood control reservoirs in the Los Angeles and San Gabriel River Basins of Los Angeles County. Water conservation benefits could be realized if storage was established in these reservoirs for temporarily impounding storm flows for later release to downstream recharge facilities. The Los Angeles County Department of Public Works and USACE are evaluating the potential for reoperating USACE flood control reservoirs. Preliminary studies have indicated that an additional 17 taf of conservation storage is possible, and USACE is currently performing a feasibility study expected to conclude in 1998.

Prado Dam. As discussed in the water management issues section, construction of Seven Oaks Dam on the Santa Ana River and pending enlargement of the existing Prado Dam create an opportunity to increase water supply storage in Prado Reservoir for recharging Orange County groundwater basins. Modifying Prado Reservoir's flood control operation would provide an additional 3 to 5 taf of annual supply for groundwater recharge.

Hansen and Lopez Dams. Hansen Dam on Tujunga Wash and Lopez Dam on Pacoima Wash are small USACE flood control detention reservoirs (essentially debris basins) located on adjoining drainages in Los Angeles County, in the San Gabriel Mountains above Pacoima. The combined storage capacity of the two reservoirs is about 25 taf. Los Angeles County has cooperated with USACE in completion of a reconnaissance study (1994) and preparation of a feasibility-level study to evaluate possible water supply benefits from reoperating the reservoirs for limited water supply storage. The feasibility study is scheduled to be completed in 1998.

Santa Fe and Whittier Narrows Dams. Santa Fe Dam (32 taf storage capacity) on the San Gabriel River and Whittier Narrows Dam (67 taf storage capacity) on Rio Hondo are USACE dams that impound flood control detention basins in Los Angeles County. The county cooperated with USACE in a 1994 reconnaissance study and feasibility-level evaluation of possible water supply benefits from reoperating the reservoirs to provide limited water supply storage. The feasibility study, scheduled to be completed in 1998, is examining allowing a permanent water conservation pool to be maintained at Santa Fe Dam and expanding the existing conservation storage pool at Whittier Narrows.

New Reservoirs

In an average year, about 200 taf of storm runoff from the Los Angeles River flows to the ocean. A proposed freshwater reservoir project in Long Beach would include an inflatable weir across the Los Angeles River

TABLE 7-29

South Coast Region List of Water Management Options

Option	*Retain or Defer*	*Reason for Deferral*
Conservation		
Urban		
Outdoor Water Use to 0.8ET_o	Retain	
Indoor Water Use	Retain	
Interior CII Water Use	Retain	
Distribution System Losses	Retain	
Agricultural		
Seasonal Application Efficiency Improvements	Retain	
Flexible Water Delivery	Defer	No significant depletion reductions attainable.
Canal Lining and Piping	Defer	No significant depletion reductions attainable.
Tailwater Recovery	Defer	No significant depletion reductions attainable.
Modify Existing Reservoirs/Operations		
Reoperate Prado Dam	Retain	
Reoperate Hansen and Lopez Dams	Retain	
Reoperate Santa Fe and Whittier Narrows Dams	Retain	
New Reservoirs/Conveyance Facilities		
Freshwater Reservoir in Long Beach Harbor	Retain	
New Aqueduct from Imperial Valley to San Diego	Defer	Interstate issues.
Groundwater/Conjunctive Use		
Local Groundwater Banking/Conjunctive Use	Retain	
Water Marketing		
Castaic Lake Water Agency	Retain	
Water Recycling		
Alamitos Barrier - Los Angeles County Sanitation Districts	Retain	
Alamitos Barrier Recycled Water Project - Water Replenishment District	Retain	
Carlsbad Water Reclamation Plan - Encina Basin - P2 - Carlsbad MWD	Retain	
Castaic Lake Water Agency Reclaimed Water Master Plan - LACSD	Retain	
Central City/Elysian Park Water Recycling Project - LADWP	Retain	
City of Escondido Regional Water Recycling Program	Retain	
City of Poway - Escondido Expansion	Retain	
City of Poway - S.D. Expansion	Retain	
City of West Covina - LACSD	Retain	
Dominguez Gap Barrier Recycled Water Project - Water Replenishment District	Retain	

TABLE 7-29

South Coast Region List of Water Management Options (continued)

Option	*Retain or Defer*	*Reason for Deferral*
E. Thornton Ibbetson Century Recycled Water Project - City of Downey	Retain	
East Valley Water Recycling Project Expansion - LADWP	Retain	
El Toro Water District Reclamation	Retain	
Esteban Torres Water Recycling Project - Central Basin MWD	Retain	
Green Acres-Phase 2 - Orange County WD	Retain	
Headworks Water Recycling Project - LADWP	Retain	
Irvine Ranch Water District	Retain	
Los Angeles Harbor Water Recycling Project - LADWP	Retain	
Montebello Forebay Advanced Treatment Plant - Water Replenishment District	Retain	
Non-domestic Irrigation System - Capistrano Valley Water District	Retain	
North City Reclamation Plant - Poway Resources Expansion - City of Poway	Retain	
North San Diego County Reclamation Project Phase 2 - Leucadia County WD	Retain	
OCR Project - CSDOC - Orange County Sanitation District	Retain	
Orange County Regional Reclamation Project - Orange County Water District	Retain	
Puente Hills/Rose Hills Reclaimed Water District System - LACSD	Retain	
San Elijo Joint Powers Authority - Santa Fe Irrigation District	Retain	
San Elijo Joint Powers Authority WRF	Retain	
San Gabriel Valley Groundwater Recharge Demonstration - LACSD	Retain	
San Pasqual Groundwater Management Program - City of San Diego	Retain	
Sepulveda Basin Water Recycling Project - LADWP	Retain	
South Bay Water Reclamation Project - City of San Diego	Retain	
Verdugo-Scholl-Brand Project - City of Glendale	Retain	
Water Repurification Project - City of San Diego	Retain	
West Basin Recycling Project-Phase 2 - West Basin MWD	Retain	
West Los Angeles Extension Expansion - West Basin MWD	Retain	
Westside Water Recycling Project - LADWP	Retain	
Whittier Narrows Recreation Area - Los Angeles County Sanitation Districts	Retain	

TABLE 7-29

South Coast Region List of Water Management Options (continued)

Option	*Retain or Defer*	*Reason for Deferral*
Desalting		
Brackish Groundwater		
Capistrano Beach Desalter	Retain	
Huntington Beach Colored Water	Retain	
IRWD Colored Water Treatment Project	Retain	
Laguna Beach GW Treatment Project	Retain	
Mesa Colored Water Project	Retain	
Oceanside Desalter No. 2	Retain	
OCWD Undetermined Colored Water Projects	Retain	
Corona/Temescal Basin Desalter	Retain	
Otay/Sweetwater Desalter	Retain	
Perris Basin Desalter	Retain	
Rubidoux/Western Desalter	Retain	
San Dieguito Basin Desalter	Retain	
San Juan Basin Desalter No. 2	Retain	
San Pasqual Basin Desalter	Retain	
Santee/El Monte Basin Desalter	Retain	
Sweetwater Desalter No.2	Retain	
Tijuana River Valley Desalter	Retain	
Torrance Elm Ave. Facility	Retain	
West Basin Desalter No. 2	Retain	
West Basin Desalter No. 3	Retain	
Western/Bunker Basin Treatment Project	Retain	
Winchester/Hemet Desalter	Retain	
Seawater		
Reverse Osmosis Facilities at South Bay Powerplant	Retain	
Reverse Osmosis Facilities at Encina Powerplant	Retain	
Reverse Osmosis Facilities at Alamitos Powerplant	Retain	
Multiple-effect Distillation Process	Retain	
Other Local Options		
Draft CRB 4.4 Plan	Retain	
Multipurpose Flood Control Basins	Retain	
Statewide Options		
—	—	See Chapter 6.

near its mouth, to direct some of the storm flows into intakes along existing river levees. From the intakes, the storm flow would be pumped or flow by gravity via culverts or tunnels to an offshore reservoir. The reservoir site would be in the vicinity of the existing Long Beach Breakwater in San Pedro Bay. Reservoir dikes would be constructed in the bay with a diaphragm wall constructed through the dikes to prevent leakage of fresh water through the walls of the dam. A bulb of fresh water would be maintained at the bottom of the reservoir to repel seawater. The reservoir could be sized to store 100 taf to 300 taf of storm water during the wet season. This captured storm water could subsequently be distributed for a number of uses, with the most likely use being groundwater recharge. A final feasibility report was issued in March 1998.

The option analyzed consisted of a 100 taf reservoir sited within San Pedro Bay supplying the Montebello Forebay spreading grounds with 71 to 129 taf/yr. The annual cost of the water would be about $1,700/af at 71 taf of supply, decreasing to $1,000/af at 129 taf of supply. Expansion of the project to use additional captured storm water runoff would maximize the reservoir yield at 172 taf/yr, decreasing the annual cost to $800/af.

Groundwater Development and Conjunctive Use

As a result of MWDSC's seasonal storage service pricing program, local agencies are storing imported water in groundwater basins and increasing their groundwater use during the summer and during drought years. It is estimated that an average of 100 taf/yr of groundwater supply is now produced as a result of MWDSC's discount pricing for winter season deliveries. The program provides imported water at an average discount of $125/af during the winter.

MWDSC had identified the potential for 200 taf of additional groundwater production during drought years. To accomplish this additional drought year production, about 600 taf of dedicated storage capacity within the local basins may be required. The cost of the water would be about $350/af. MWDSC is working with Calleguas Municipal Water District on a Las Posas Basin aquifer storage and recovery project. CMWD would develop up to 300 taf of storage in the lower aquifer system of the Las Posas groundwater basin. The project currently provides 70 taf of water supply in drought years, which has been included as 2020 supply in the water budget. MWDSC is pursuing an additional 130 taf/yr of groundwater production in the region.

Water Marketing

Water from the Colorado River Region. Several water marketing arrangements are being planned or implemented as part of the draft CRB 4.4 Plan. These arrangements are described in the section on implementing the draft CRB 4.4 Plan.

Water from the Central Valley. More than half of California's agricultural water use is in the Central Valley. The California Aqueduct could be used for voluntary transfers of some of this water to the South Coast. It is estimated that potential future marketing arrangements from the Central Valley to the South Coast Region could be about 200 taf/yr. Voluntary marketing arrangements would be developed through option agreements, storage programs, and purchases of water through the drought water bank or other similar spot markets.

MWDSC is currently banking water with Semitropic Water Storage District under a long-term transfer agreement to store up to 350 taf. The agreement allows MWDSC to deliver available SWP water in wetter years to SWSD for in-lieu groundwater recharge. In drought years SWSD would release its SWP allocation to MWDSC, and if necessary pump groundwater back into the California Aqueduct to meet its obligations. The drought year yield would be about 60 taf/yr.

A long-term agreement has been completed between MWDSC and Arvin-Edison Water Storage District to store up to 350 taf of water for MWDSC in Arvin-Edison's groundwater basin. Water banked in this program would be provided by both MWDSC and AEWSD. MWDSC would withdraw about 60 taf in drought years under this program.

As specified in the Monterey Amendment, agricultural contractors will make available up to 130 taf of annual SWP entitlement for permanent transfer to urban contractors, on a voluntary basis. Berrenda-Mesa Water District has already completed the transfer of 25 taf of entitlement to MWA. Similar permanent transfers could be negotiated in the South Coast Region. Castaic Lake Water Agency is preparing an EIR for the proposed transfer of 40 taf of SWP entitlement from Wheeler Ridge-Maricopa Water Storage District, a member agency of KCWA. The CLWA service area includes the Santa Clarita Valley in northwestern Los Angeles County and extends into eastern Ventura County.

Implementing the CRB's Draft 4.4 Plan

The draft CRB 4.4 Plan would reduce California's use of Colorado River to the State's basic apportionment while using marketing arrangements and other options to keep a full Colorado River Aqueduct for the South Coast. Phase one elements of the draft CRB 4.4 Plan that have been quantified and would provide water supplies for the South Coast are described below. More detail on the draft plan and its elements is provided in Chapter 9. Chapter 9 also presents an overview of how the use of Colorado River water is apportioned among the basin states and among California entities.

Bulletin 160-98 water budgets assume that the South Coast Region's 2020 base supply from the Colorado River will be limited to MWDSC's fourth priority right of 550 taf, plus any marketing arrangements that have already been implemented (i.e., 107 taf from the MWDSC/IID agreement described in Chapter 3). Actions taken as part of the draft CRB 4.4 Plan to fill the CRA's remaining capacity are treated as future options in the water budgets. As described in Chapter 9 (and shown in Table 9-25), the base water demand forecasts for Bulletin 160-98 include implementation of EWMPs. This conserved water would be another source of water for Colorado River/South Coast marketing arrangements, in addition to those actions that Bulletin 160-98 categorizes as water management options.

Water management options contained in phase one of the draft CRB 4.4 Plan include the SDCWA/IID water transfer, MWDSC intrastate groundwater banking programs, interstate groundwater banking in Arizona, drought year land fallowing programs (such as an MWDSC/PVID program), lining parts of the All American and Coachella Canals, and agricultural water conservation beyond EWMP implementation. As described in Chapter 9, potential South Coast supplies from these options are assumed to be made available for the region after shortages due to groundwater overdraft in the Colorado River Region have been balanced out.

The draft CRB 4.4 Plan further proposes criteria for reoperating Colorado River system reservoirs. The Colorado River has a high ratio of storage capacity to average annual runoff. Projections of consumptive use for the upper basin states suggest that those states will not attain full use of their Compact apportionments until 2060. USBR's surplus declarations to date have not adversely impacted the other states' use of their apportionments—reservoir flood control releases were made in 1997 and 1998. The more significant impediment to implementing revised operating guidelines would be concerns of the other basin states about impacts of an extended period of reoperation on the ability to avoid future shortages. Reservoir reoperation is not numerically evaluated in Bulletin 160-98, because implementing new operations criteria would require agreement of USBR and the remaining basin states, and there is presently no generally accepted proposal available for quantification.

Water management options in phase two of the draft CRB 4.4 Plan have not yet been quantified; implementation of some may extend beyond the Bulletin 160-98 planning horizon. Examples of phase two actions include desalting tributary inflows to the Salton Sea or weather modification programs. For example, USBR had developed a 1993 proposed pilot program to evaluate cloud seeding potential in the upper basin, but had not implemented the program because of opposition from the upper basin states. Large-scale weather modification programs are typically difficult to implement due to institutional and third-party concerns.

Water Recycling

Since the 1970s, Southern California has been a leader in developing water recycling projects. Recycled water is currently used for applications that include groundwater recharge, hydraulic barriers to seawater intrusion, landscape and agricultural irrigation, and direct use in industry. Currently some 80 local recycling projects are producing about 210 taf/yr of new water supply. It is estimated that these existing projects will provide an additional 70 taf /yr of water supply by year 2020.

Almost 40 new water recycling projects were evaluated as future water supply augmentation options for the region. Water recycling could potentially increase by 639 taf by 2020, yielding about 527 taf of new water. The price of recycled water from these options ranges from $180/af to more than $2,500/af. This large range is due to the individual characteristics of proposed projects—some entail major capital costs for construction of new treatment plants while others may involve only distribution systems from an existing plant. For example, projects designed for groundwater recharge are often located near the treatment plant—reducing the costs for distribution. As another example, projects that are designed for landscape irrigation or direct industrial uses will generally be higher in cost because of the extensive distribution system needed for delivery.

In an effort to broaden the potential application of recycled water to include indirect potable use, the City of San Diego has conducted research into advanced treatment and ultimate use of recycled water as a supplement to potable water supplies. This indirect potable reuse concept has been termed repurification by San Diego. The City of San Diego is currently working on a water repurification project (described in Chapter 5) that would produce about 16 taf/yr of repurified water to augment local supplies. The repurified water would be stored in the San Vicente Reservoir and blended with local runoff and imported water.

To evaluate and compare recycling options with other water management options, the water recycling options were grouped by cost into three groups. Group I included those options which cost under $500/af; Group II included those options which cost between $500 and $1,000/af; and Group III included those options which cost more than $1,000/af. The costs used to group these projects are based on the costs reported by local agencies in the Department's 1995 water recycling survey. (These costs are not likely to have all been calculated on the same basis by the local project sponsors.) The local agencies' costs were used to judge the order of magnitude of proposed projects' costs.

A proposed Orange County regional water recycling project is being developed jointly by the Orange County Water District and County Sanitation Districts of Orange County. Wastewater currently discharged into the Pacific Ocean would be recycled to supplement Orange County's potable supplies. The treated wastewater would be used to recharge an aquifer along the Santa Ana River, in lieu of using imported water provided by MWDSC. A plant to treat second-

San Diego Area Water Reclamation Programs

The San Diego County Water Authority and its member agencies are engaged in a long-term effort to reduce regional reliance on imported water supplies. Water recycling is critical to the success of that effort. Two major programs are currently underway.

The San Diego Area water reclamation program is a system of interconnected reclamation facilities designed to serve southern and central San Diego County. When completed, the program will serve an area of more than 700 square miles and add more than 60 taf/yr to the San Diego region's local water supply. Summarized below are the eight participating agencies and each agency's planned reuse. Facilities to be constructed include up to ten new or expanded water recycling plants, a water repurification facility, and hundreds of miles of recycled water delivery pipelines.

Agency	New Water Supply (taf/yr)
City of Escondido	3.2
City of Poway	2.3
City of San Diego	26.9
City of San Diego/San Diego County Water Authority	15.0
Otay Water District	2.9
Padre Dam Municipal Water District	1.9
Sweetwater Authority	7.2
Tia Juana Valley County Water District	2.2
Total	**61.6**

Padre Dam MWD has completed construction of its treatment facility, and has begun delivery of recycled water. The City of San Diego's North City water recycling plant and distribution system have also been completed and are delivering recycled water.

The North San Diego County Area water recycling project will provide more than 15 taf/yr of recycled water to northern coastal and inland San Diego County. The project is a cooperative effort of Carlsbad and Olivenhain MWDs, the Leucadia County Water District and the San Elijo JPA. When completed, the system of interconnected recycling facilities will serve an area of more than 100 square miles, from the coastal communities of Carlsbad, Encinitas and Solana Beach inland to the San Dieguito River Valley. Facilities to be constructed include three new or expanded water recycling facilities, about 65 miles of recycled water delivery pipeline and associated pump stations and storage facilities, and new groundwater recharge and extraction facilities.

ary effluent produced by an existing wastewater treatment plant would be constructed, with a transmission pipeline to convey the recycled water to existing spreading basins located in the Orange County Forebay in Anaheim. Some recycled water would also be injected into a seawater intrusion barrier in Fountain Valley. Another benefit would be that water recycling would decrease the total wastewater treatment discharge to the ocean, which would eliminate or delay the need for a new or expanded ocean outfall. Phase I is planned to produce 50 taf/yr of recycled water by 2002. Phases II and III would produce an additional 50 taf/yr by 2020, reducing Orange County's dependence on imported water.

Desalting

Groundwater. Recovery of mineralized groundwater supplies is an important resource strategy for Southern California. This resource option is usually expensive—because it involves sophisticated technologies and high energy costs. Some groundwater recovery projects serve the dual purpose of managing migration of plumes to prevent further contamination of usable aquifers.

Groundwater desalting plants currently operating include Santa Ana Watershed Project Authority's Arlington Desalter (6.7 taf), the City of Oceanside's Oceanside Desalter No.1 (2.2 taf), and West Basin MWD's West Basin Desalter No.1 (1.7 taf). Construction of Sweetwater Authority's groundwater demineralization plant (3.6 taf) in the Sweetwater River Valley began in 1998. Plans are to expand the plant to produce an additional 4 taf. Additional plants and plant expansions are being planned or constructed throughout the coastal areas of the Los Angeles Basin, with an estimated total installed capacity of 33 taf/yr by 2000. The estimated total net groundwater recovery potential in the South Coast is about 150 taf/yr.

The Santa Ana Watershed Project Authority was formed in 1972 to plan and operate facilities to protect water quality in the Santa Ana River's watershed. The authority is a joint powers agency composed of the five larger water districts that share the watershed—Chino Basin Municipal Water District, Eastern Municipal Water District, Orange County Water District, San Bernardino Valley Municipal Water District, and Western Municipal Water District. SAWPA operates a brine disposal line which facilitates disposal of waste brine from regional desalting plants and operates the Arlington Desalter.

While increases in groundwater recovery are technically feasible, they are challenged by the need for development of new brine lines (or alternative brine disposal options) for inland projects as well as requirements for replenishment in certain groundwater basins. Approximately 20 potential groundwater recovery projects were evaluated with a net yield of 95 taf/yr. Supply costs range from $300/af to $900/af. The groundwater recovery projects are grouped by cost into two groups, those projects less than $500/af and those more than $500/af.

Seawater. Seawater desalting is sometimes described as the ultimate solution to Southern California's water supply shortfall. Although there is often public support for this resource, seawater desalting is currently limited by high costs, environmental impacts of brine disposal, and siting considerations. Based on current technology, the costs for desalting seawater for potable use ranges from about $1,000 to $2,000/af depending on the type of treatment and the distribution system that would be required to deliver the water. Although high costs may currently limit this resource, seawater desalting may prove to be an important strategy in the future. MWDSC, with joint funding from the U.S. Government and Israel Science and Technology Foundation, recently embarked on a demonstration project

Brackish Water Reclamation Demonstration Facility

The Port Hueneme Water Agency was formed to develop and operate a brackish water desalting demonstration facility for its member agencies, all of whom are located in Ventura County. The BWRDF is the cornerstone of the program to improve water quality and reliability and reduce groundwater extractions and seawater intrusion in the Oxnard Plain. BWRDF will provide a full-scale demonstration of side-by-side operation of three brackish water desalting technologies (reverse osmosis, nanofiltration, and electrodialysis reversal). The feasibility of using desalting concentrate for wetlands enhancement is also being studied. Construction of the project has begun and is expected to be completed in 1998. The total capital costs are estimated to be $15.2 million.

using a multiple-effect distillation process, as described in Chapter 5.

In the past, SDCWA has evaluated the possibility of constructing two reverse osmosis desalting facilities in conjunction with the proposed repowering of the San Diego Gas and Electric South Bay Powerplant and the Encina Powerplant. The capacity of the two plants would total 20 taf/yr. The City of Long Beach and the Central Basin MWD are also collaborating on a study of a reverse osmosis plant with 5.6 taf annual capacity to be located at Southern California Edison's Alamitos Powerplant.

Other Local Options

Chino Basin Water Conservation District has prepared a scoping report on the construction and operation of multipurpose storm water detention and groundwater recharge basins. The proposed project involves San Bernardino County Flood Control District's plans for additional flood control facilities in the City of Ontario. SBCFCD plans to construct a storm water conduit to convey water to existing multipurpose flood control and groundwater recharge basins and to develop a new flood control detention basin. Converting the proposed single-purpose basin into a flood control and groundwater recharge basin could provide additional water supply benefits for the Chino Basin. Although the volume of water to be conserved and developed by these projects is relatively small (about 1 taf), the projects meet specific local needs.

Statewide Options

Statewide water supply augmentation options are discussed and quantified in Chapter 6.

Options Likely to be Implemented in South Coast Region

Water supplies are not available to meet all of the region's 2020 water demands in average or drought years. Applied water shortages are forecasted to be 944 and 1,317 taf in average and drought years, respectively. Ranking of retained water management options for the South Coast Region is summarized in Table 7-30. Table 7-31 summarizes options that can likely be implemented by 2020 to relieve the shortages. These shortages are primarily attributed to increased urban demands and reduced Colorado River supplies.

To meet the water shortages, water agencies in the South Coast Region are planning to implement additional conservation programs, water recycling, and groundwater recovery, as well as water marketing and other water supply augmentation options. Demand reduction options such as urban conservation are currently an important program for all water agencies in the South Coast. Supply augmentation options to be implemented would include the draft CRB 4.4 Plan and a combination of local and statewide options.

Implementation of BMPs and EWMPs will continue through 2020 and is reflected in the base demand levels for urban and agricultural water use. Additional conservation options likely to be implemented, based on costs and feasibility, would provide 91 taf/yr in depletion reduction.

The South Coast Region will increase its reliance on water marketing as Colorado River supplies are reduced. Options in the first phase of the draft CRB 4.4 Plan could make available up to 172 taf in average years and 410 taf in drought years for transfer to the South Coast Region. Additional banking and marketing arrangements, as well as permanent transfer of SWP entitlement, are likely options for the region, amounting to 37 taf and 27 taf in average and drought years, respectively.

Local groundwater conjunctive use programs will likely add 130 taf of production in drought years. Water recycling will continue to be a source of water supply for Southern California. New projects could provide an additional 367 taf/yr by 2020. Groundwater desalting projects could provide an additional 27 taf/yr.

TABLE 7-30

Options Ranking for South Coast Region

Option[a]	*Rank*	*Cost ($/af)*	*Potential Gain (taf)*	
			Average	*Drought*
Conservation				
Urban				
Outdoor Water Use to 0.8 ET_o - New Development	M	750	67	67
Outdoor Water Use to 0.8 ET_o -New and Existing Development	L	[b]	246	246
Indoor Water Use (60 gpcd)	M	400	110	110
Indoor Water Use (55 gpcd)	M	600	220	220
Interior CII Water Use (3%)	M	500	30	30
Interior CII Water Use (5%)	M	750	49	49
Distribution System Losses (5%)	M	300	84	84
Agricultural				
Seasonal Application Efficiency Improvements (76%)	H	100	4	4
Seasonal Application Efficiency Improvements (78%)	M	250	7	7
Seasonal Application Efficiency Improvements (80%)	M	450	10	10
Modify Existing Reservoirs/Operations				
Reoperate Prado Dam	H	60	5	5
Reoperate Hansen and Lopez Dams	M	[b]	[b]	[b]
Reoperate Santa Fe and Whittier Narrows Dams	M	[b]	[b]	[b]
New Reservoirs/Conveyance Facilities				
Freshwater Reservoir in Long Beach Harbor	L	1,000	172	—
Groundwater/Conjunctive Use				
Local Groundwater Banking/Conjunctive Use	H	350	—	130
Water Marketing				
Castaic Lake WA/Kern County WA (40 taf entitlement)	H	—	37	27
Water Recycling				
Group 1 (Cost < $500/af)	H	500	391	391
Group 2 (Cost $500/af- $1,000/af)	M	1,000	75	75
Group 3 (Cost > $1,000/af)	M	1,500	61	61
Desalting				
Brackish Groundwater				
Group 1 (Cost < $500/af)	M	500	27	27
Group 2 (Cost $500/af- $1,000/af)	M	1,000	68	68
Seawater				
Reverse Osmosis Facilities at South Bay Powerplant	L	920	5	5
Reverse Osmosis Facilities at Encina Powerplant	L	1,220	15	15
Reverse Osmosis Facilities at Alamitos Powerplant	L	1,700	6	6
Multiple-Effect Distillation Process	L	<1000	85	85
Other Local Options				
Multipurpose Flood Control Basins	H	[b]	[c]	[c]
Draft Colorado River Board 4.4 Plan	H	230	172	410
Statewide Options				
See Chapter 6.				

[a] All or parts of the amounts shown for highlighted options have been included in Table 7-31.
[b] Data not available to quantify.
[c] Less than 1 taf.

TABLE 7-31

Options Likely to be Implemented by 2020 (taf)

South Coast Region

	Average	*Drought*
Applied Water Shortage	**944**	**1,317**
Options Likely to be Implemented by 2020		
Conservation	91	91
Modify Existing Reservoirs/Operations	5	5
New Reservoirs/Conveyance Facilities	-	-
Groundwater/Conjunctive Use	-	130
Water Marketing	37	27
Recycling	367	367
Desalting	27	27
Colorado River Board's Draft 4.4 Plan	172	410
Statewide Options	150	144
Expected Reapplication	95	116
Total Potential Gain	**944**	**1,317**
Remaining Applied Water Shortage	**0**	**0**

7A

Options Evaluations for Coastal Regions

TABLE 7A-1

Options Evaluation North Coast Region

Option	*Evaluation Scores*							*Rank*
	Engineering	*Economics*	*Environ-mental*	*Institutional/ Legal*	*Social/ Third Party*	*Other Benefits*	*Overall Score*	
Conservation								
Urban								
Outdoor Water Use - New Development	3	2	4	2	2	1	**14**	**M**
Outdoor Water Use - New and Existing Development	3	1	4	2	2	1	**13**	**M**
Indoor Water Use (60 gpcd)	3	3	4	2	2	1	**15**	**M**
Indoor Water Use (55 gpcd)	2	2	4	2	2	1	**13**	**M**
Interior CII Water Use (3%)	3	3	4	2	2	1	**15**	**M**
Interior CII Water Use (5%)	3	2	4	1	2	1	**13**	**M**
Distribution System Losses (7%)	3	4	4	2	2	1	**16**	**M**
Distribution System Losses (5%)	2	3	4	2	2	1	**14**	**M**
Groundwater/Conjunctive Use								
New wells - Fort Bragg and other small coastal communities	3	4	4	4	3	0	**18**	**H**
Agricultural Groundwater Development	3	1	3	3	3	0	**13**	**M**
Desalting								
Brackish Groundwater								
City of Fort Bragg project	3	1	3	2	2	0	**11**	**L**

TABLE 7A-2

Options Evaluation San Francisco Bay Region

Option	*Evaluation Scores*							*Rank*
	Engineering	*Economics*	*Environ-mental*	*Institutional/ Legal*	*Social/ Third Party*	*Other Benefits*	*Overall Score*	
Conservation								
Urban								
Outdoor Water Use - New Development	3	2	4	2	2	1	**14**	**M**
Outdoor Water Use - New and Existing Development	3	1	4	1	2	1	**12**	**L**
Indoor Water Use (60 gpcd)	3	3	4	2	2	1	**15**	**M**
Indoor Water Use (55 gpcd)	2	2	4	2	2	1	**13**	**M**
Interior CII Water Use (3%)	3	3	4	2	2	1	**15**	**M**
Interior CII Water Use (5%)	3	2	4	1	2	1	**13**	**M**
Distribution System Losses (5%)	2	3	4	2	2	1	**14**	**M**
Modify Existing Reservoirs/Operations								
Enlarge Lake Hennessey / Napa River Diversion	3	2	2	3	3	1	**14**	**M**
Enlarge Bell Canyon Reservoir	3	2	2	2	3	2	**14**	**M**
Enlarge Bell Canyon Reservoir / Napa River Diversion	3	1	2	3	3	1	**13**	**M**
Enlarge Pardee Dam	3	2	2	2	2	3	**14**	**M**
Enlarge Camanche Dam	3	2	2	2	2	3	**14**	**M**
Enlarge Leroy Anderson Reservoir	3	0	2	3	3	2	**13**	**M**
Upgrade Milliken Treatment Plant	3	0	3	4	4	1	**15**	**M**
Reoperate Rector Reservoir	3	1	3	3	4	1	**15**	**M**
New Reservoirs/Conveyance Facilities								
Chiles Creek Reservoir Project / Napa River Diversion	3	0	2	3	3	1	**12**	**L**
Enlarge Lake Hennessey / Chiles Creek Project / Napa River Diversion	3	0	2	2	3	1	**11**	**L**
Carneros Creek Reservoir / Napa River Diversion	3	0	1	2	3	1	**10**	**L**
Upper Del Valle Reservoir	3	0	2	3	3	2	**13**	**M**
Buckhorn Dam and Reservoir	3	1	1	2	3	3	**13**	**M**
Upper Kaiser Reservoir	3	1	1	3	3	3	**14**	**M**

TABLE 7A-2

Options Evaluation San Francisco Bay Region (continued)

Option	*Evaluation Scores*							*Rank*
	Engineering	*Economics*	*Environ-mental*	*Institutional/ Legal*	*Social/ Third Party*	*Other Benefits*	*Overall Score*	
New Reservoirs/Conveyance Facilities (continued)								
Upper Buckhorn Reservoir	3	1	1	1	2	3	**11**	**L**
Middle Bar Reservoir	3	1	1	2	2	2	**11**	**L**
Duck Creek Offstream Reservoir	3	1	1	2	2	3	**12**	**L**
Devils Nose Project	3	1	1	2	2	1	**10**	**L**
EBMUD American River Supply	4	1	3	3	3	2	**16**	**M**
Groundwater/Conjunctive Use								
Milliken Creek Conjunctive Use	3	4	3	3	4	1	**18**	**H**
Lake Hennessey / Conn Creek Conjunctive Use	4	3	4	3	4	1	**19**	**H**
Water Marketing								
Zone 7 WA/KCWA	4	4	4	4	3	0	**19**	**H**
SCVWD/SLDMWA	4	4	4	4	3	0	**19**	**H**
Water Recycling								
Group 1 (Cost < $500/af)	4	3	3	3	3	1	**17**	**H**
Group 2 (Cost $500/af - $1,000/af)	4	2	3	3	3	1	**16**	**M**
Group 3 (Cost > $1,000/af)	4	0	3	3	3	1	**14**	**M**
Desalting								
Brackish Groundwater								
Alameda County WD Aquifer Recovery Project	4	2	3	3	3	2	**17**	**H**
Seawater								
Marin Municipal WD Desalting Project	3	0	2	0	3	1	**9**	**L**
Other Local Options								
New Surface Water Diversion from Sacramento River by Cities of Benicia, Fairfield, & Vacaville	3	3	2	2	3	0	**13**	**M**
Statewide Options								
See Chapter 6.								

TABLE 7A-3

Options Evaluation Central Coast Region

Option	*Evaluation Scores*							*Rank*
	Engineering	*Economics*	*Environ-mental*	*Institutional/ Legal*	*Social/ Third Party*	*Other Benefits*	*Overall Score*	
Conservation								
Urban								
Outdoor Water Use - New Development	3	2	4	2	2	1	**14**	**M**
Outdoor Water Use - New and Existing Development	3	1	4	2	2	1	**13**	**M**
Indoor Water Use (60 gpcd)	3	3	4	2	2	1	**15**	**M**
Indoor Water Use (55 gpcd)	2	2	4	2	2	1	**13**	**M**
Interior CII Water Use (3%)	3	3	4	2	2	1	**15**	**M**
Interior CII Water Use (5%)	3	2	4	1	2	1	**13**	**M**
Distribution System Losses (7%)	3	4	4	2	2	1	**16**	**M**
Distribution System Losses (5%)	2	3	4	2	2	1	**14**	**M**
Modify Existing Reservoirs/Operations								
Modify Nacimiento Spillway	3	4	4	4	4	0	**19**	**H**
Enlarge Salinas Reservoir	3	3	3	3	3	0	**15**	**M**
Enlarge Cachuma Reservoir	2	0	3	3	3	0	**11**	**L**
New Reservoirs/Conveyance Facilities								
College Lake	2	3	2	1	3	2	**13**	**M**
Feeder Streams (Various Sites)	2	3	3	2	3	0	**13**	**M**
New Los Padres Reservoir	3	1	3	2	3	3	**15**	**M**
Nacimiento Pipeline	4	1	3	3	3	0	**14**	**M**
Groundwater/Conjunctive Use								
College Lake Injection/Extraction Wells	3	4	3	3	3	0	**16**	**M**
Increase Groundwater Development in Seaside Basin	3	3	2	1	2	0	**11**	**L**
Water Marketing								
CVP (San Felipe Project Extension)	3	2	3	2	3	1	**14**	**M**

TABLE 7A-3

Options Evaluation Central Coast Region (continued)

Option	*Evaluation Scores*							
	Engineering	*Economics*	*Environ-mental*	*Institutional/ Legal*	*Social/ Third Party*	*Other Benefits*	*Overall Score*	*Rank*
Water Recycling								
Group 1 (Cost < $500/af)	4	3	3	3	3	1	**17**	**H**
Group 2 (Cost $500/af - $1,000/af)	4	2	3	3	3	1	**16**	**M**
Desalting								
Brackish Groundwater								
City of Santa Cruz	3	0	3	2	3	0	**11**	**L**
Seawater								
Monterey Peninsula Water Management District	3	0	3	1	2	0	**9**	**L**
Other Local Options								
Salinas River Diversion and Distribution Project	3	2	3	3	2	2	**15**	**M**
Statewide Options								
See Chapter 6.								

TABLE 7A-4

Options Evaluation South Coast Region

Option	*Evaluation Scores*							*Rank*
	Engineering	*Economics*	*Environ-mental*	*Institutional/ Legal*	*Social/ Third Party*	*Other Benefits*	*Overall Score*	
Conservation								
Urban								
Outdoor Water Use - New Development	3	2	4	2	2	1	**14**	**M**
Outdoor Water Use - New and Existing Development	3	1	4	1	2	1	**12**	**L**
Indoor Water Use (60 gpcd)	3	3	4	2	2	1	**15**	**M**
Indoor Water Use (55 gpcd)	2	2	4	2	2	1	**13**	**M**
Interior CII Water Use (3%)	3	3	4	2	2	1	**15**	**M**
Interior CII Water Use (5%)	3	2	4	1	2	1	**13**	**M**
Distribution System Losses (5%)	2	3	4	2	2	1	**14**	**M**
Agricultural								
SAE Improvements (76%)	3	4	3	4	3	1	**18**	**H**
SAE Improvements (78%)	3	3	3	3	2	1	**15**	**M**
SAE Improvements (80%)	2	3	3	2	2	1	**13**	**M**
Modify Existing Reservoirs/Operations								
Reoperate Prado Dam	3	4	4	3	3	0	**17**	**H**
Reoperate Hansen and Lopez Dams	3	3	3	2	3	0	**14**	**M**
Reoperate Santa Fe and Whittier Narrows Dams	3	3	3	2	3	1	**15**	**M**
New Reservoirs/Conveyance Facilities								
Freshwater Reservoir in Long Beach Harbor	2	1	2	2	3	0	**10**	**L**
Groundwater/Conjunctive Use								
Local Groundwater Banking/Conjunctive Use	4	3	4	3	4	0	**18**	**H**
Water Marketing								
Castaic Lake Water Agency	4	4	4	4	3	0	**19**	**H**
Water Recycling								
Group 1 (Cost < $500/af)	4	3	3	3	3	1	**17**	**H**
Group 2 (Cost $500/af - $1,000/af)	4	2	3	3	3	1	**16**	**M**
Group 3 (Cost > $1,000/af)	4	0	3	3	3	1	**14**	**M**

TABLE 7A-4

Options Evaluation South Coast Region (continued)

Option	*Evaluation Scores*							*Rank*
	Engineering	*Economics*	*Environ-mental*	*Institutional/ Legal*	*Social/ Third Party*	*Other Benefits*	*Overall Score*	
Desalting								
Brackish Groundwater								
Group 1 (Cost < $500/af)	3	3	3	3	3	1	**16**	**M**
Group 2 (Cost $500/af - $1,000/af)	3	2	3	3	3	1	**15**	**M**
Seawater								
Reverse Osmosis Facilities at South Bay Powerplant	2	1	2	3	3	0	**11**	**L**
Reverse Osmosis Facilities at Encina Powerplant	2	0	2	3	3	0	**10**	**L**
Reverse Osmosis Facilities at Alamitos Powerplant	2	0	2	3	3	0	**10**	**L**
Multiple-effect Distillation Process	1	1	2	3	3	0	**10**	**L**
Other Local Options								
Draft CRB 4.4 Plan	4	4	3	3	3	3	**20**	**H**
Multipurpose Flood Control Basins	3	3	3	3	3	3	**18**	**H**
Statewide Options								
See Chapter 6.								

8

Options for Meeting Future Water Needs in Interior Regions of California

This chapter covers the interior regions of the State: the Sacramento River, San Joaquin River, and Tulare Lake Hydrologic Regions (Figure 8-1). These regions constitute the Central Valley, which makes up about 38 percent of the State's land area and almost 80 percent of the State's irrigated acres.

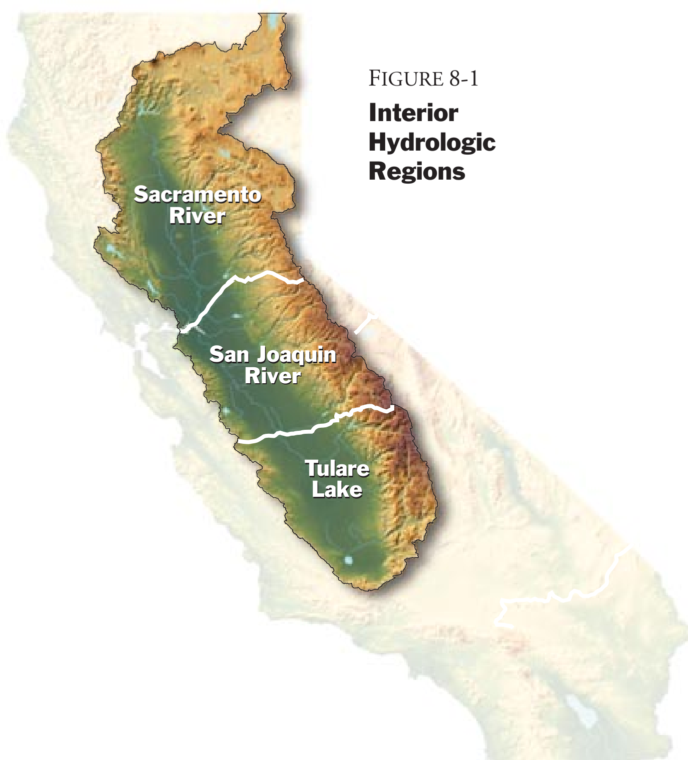


FIGURE 8-1
Interior Hydrologic Regions

The SWP's California Aqueduct.

FIGURE 8-2
Sacramento River Hydrologic Region

Sacramento River Hydrologic Region

. . .

Description of the Area

The Sacramento River Region, the drainage area of the Sacramento River and its tributaries, extends 300 miles from the Oregon border south to Collinsville in the Delta (Figure 8-2). The crest of the Sierra Nevada forms the eastern border of the Sacramento River Region, while the western side is defined by the crest of the Coast Range. The southern portion includes the American River watershed and the northern Delta. The Sacramento River Region includes all or large portions of Modoc, Siskiyou, Lassen, Shasta, Tehama, Glenn, Plumas, Butte, Colusa, Sutter, Yuba, Sierra, Nevada, Placer, Sacramento El Dorado, Yolo, Solano, Lake, and Napa Counties. Small areas of Amador and Alpine Counties are also within the Sacramento River Region. The State's largest river, the Sacramento, flows the length of the valley before entering the Delta. The Sacramento Valley is comprised of eight planning subareas, all of which are hydrologically connected by the Sacramento River.

The region is defined by two distinct features—the foothill and mountain areas of the Sierra Nevada, Cascade, and Coast Ranges, and the valley floor. Mountain elevations range from 5,000 feet along the coast to more than 10,000 feet in the Sierra Nevada. The elevation of the valley floor gradually decreases from 500 feet in the Redding area to just below sea level in the Delta.

Precipitation in the region varies substantially depending on location and elevation. In the foothill and higher mountain areas, precipitation ranges from 40 to more than 80 inches annually. The valley receives less rainfall, with average annual rainfall for Redding and Sacramento being 35 inches and 18 inches, respectively. The mountain areas have cold, wet winters with snow contributing runoff for summer water supply. The valley has mild winters and dry, hot summers.

Base year and future population and crop acreage for the region are provided in Table 8-1. Most of the region's population growth is expected to occur in the southern part of the region in Sacramento, Placer, El Dorado, Sutter, Yolo, and Solano Counties. The Sacramento metropolitan area and surrounding communities are expected to experience significant population growth, as is the Yuba City-Marysville area in Sutter and Yuba Counties. The region includes extensive irrigated agricultural acreage. Rice, irrigated pasture, alfalfa, grain, fruits, nuts, and tomatoes account for about 80 percent of the irrigated crop acreage. Irrigated acreage in the region is expected to change little during the planning period.

Water Demands and Supplies

Water shortages are expected to occur under average and drought conditions, as shown in Table 8-2. The 1995-level average year shortage reflects that groundwater overdraft is not treated as a source of supply. Most of the drought year water shortage is

TABLE 8-1

Population and Crop Acreage

	Population (thousands)	*Irrigated Crop Acreage (thousands of acres)*
1995	2,372	2,139
2020	3,813	2,150

The 3.5 maf Lake Oroville is the largest of the SWP's storage facilities.

associated with agricultural water use, primarily on the valley floor area north of Sacramento.

Excluding supplies dedicated to environmental purposes, surface water accounts for about 70 percent of the region's average year water supply. Groundwater provides the remaining supply. During drought years, additional groundwater is pumped to compensate for reduced surface water supplies. The region has 43 major reservoirs, with a combined storage capacity of almost 16 maf. About half of this surface capacity is contained in the CVP's Shasta Lake and the SWP's Lake Oroville.

CVP Water Supply

Most of the water delivered by CVP facilities in the Sacramento River Region is for agricultural use. Sacramento and Redding receive part of their water supply from CVP facilities.

The Tehama-Colusa and Corning Canals, supplied from Red Bluff Diversion Dam on the Sacramento River, deliver CVP water to agricultural users and to wildlife refuges. The Tehama-Colusa Canal extends 110 miles south of RBDD, terminating south of Dunnigan in Yolo County. The Corning Canal extends 25 miles south of RBDD, terminating near Corning. Together, the canals serve about 160,000 acres of land in Tehama, Glenn, Colusa, and Yolo Counties. CVP contractors and water rights settlement users also make direct diversions from the Sacramento River. Some of the larger water agencies receiving CVP supplies are listed in Table 8-3. The supplies shown include, where applicable, both project water and water rights settlement (base supply) water.

Releases from Folsom Reservoir on the American River serve Delta and CVP export needs, as well as providing supplies to agencies in the Sacramento metropolitan area. The City of Sacramento is the largest water rights contractor on the American River, with a contract for almost 300 taf/yr. Placer County Water Agency, one of the largest American River project water contractors, also holds a water rights settlement contract for 120 taf/yr. EBMUD holds the largest contract for project water on the American River system (150 taf/yr), which it had originally planned to receive via an extension of the existing Folsom South Canal. (EBMUD's American River supply is described in

TABLE 8-2

Sacramento River Region Water Budget (taf)[a]

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	766	830	1,139	1,236
Agricultural	8,065	9,054	7,939	8,822
Environmental	5,833	4,223	5,839	4,225
Total	**14,664**	**14,106**	**14,917**	**14,282**
Supplies				
Surface Water	11,881	10,022	12,196	10,012
Groundwater	2,672	3,218	2,636	3,281
Recycled and Desalted	0	0	0	0
Total	**14,553**	**13,239**	**14,832**	**13,293**
Shortage	**111**	**867**	**85**	**989**

[a] Water use/supply totals and shortages may not sum due to rounding.

Monticello Dam, impounding Lake Berryessa, is the principal feature of USBR's Solano Project. Solano Irrigation District was formed in 1948 to sponsor construction of a reclamation project to serve Solano County.

Chapter 7.) Jenkinson Lake (Sly Park Dam) and Sugar Pine Reservoir serve communities in the foothills east of Sacramento.

Supply from Other Federal Water Projects

Monticello Dam in Napa County impounds Putah Creek to form Lake Berryessa, the principal water storage facility of USBR's Solano Project. The project provides urban and agricultural water supply to Solano County (partly in the Sacramento River Region and partly in the San Francisco Bay Region) and agricultural water supply to the University of California at Davis in Yolo County. Napa County uses about 1 percent of the supply for developments around Lake Berryessa.

Solano County Water Agency is the regional water contractor for both the federal Solano Project and the SWP. Within the Sacramento River Region, SCWA member entities with contracts for Solano Project water include the City of Vacaville (which also receives SWP water and uses groundwater), Solano Irrigation District and Maine Prairie Water District. (The Cities of Fairfield, Vallejo, and Suisun City in the San Francisco Bay Region have SCWA contracts for Solano Project water, as discussed in Chapter 7.) SID contracts for 141 taf/yr of Solano Project water from SCWA and delivers it to agricultural users in Solano County.

TABLE 8-3

Major Sacramento River CVP Water Users

Agency	*Total Supplies from CVP Facilities (taf)*
Anderson-Cottonwood ID	175.0
Glenn-Colusa ID	825.0
Natomas Central MWC	120.2
Princeton-Codora-Glenn ID	67.8
Reclamation District 108	232.0
Reclamation District 1004	71.4
Sutter Mutual WC	268.0

SWP Water Supply

Lake Davis, Frenchman Lake, and Antelope Lake are located on Feather River tributaries in Plumas County and are used primarily for recreation, but also provide water supply to the City of Portola and to local agencies having water rights agreements with the Department. Lake Oroville and Thermalito Afterbay also provide supply within the region. Local agencies that receive water rights water delivered through Thermalito Afterbay include Western Canal Water District, Richvale Irrigation District, Biggs-West Gridley Water District, Butte Water District, and Sutter Extension Water District. Agencies in the region holding long-term contracts for SWP supply are Plumas County Flood Control and Water Conservation District, Butte County, Yuba City, and SCWA. SCWA receives its SWP supply from the Delta through the North Bay Aqueduct.

Local Surface Water Supply

Water stored and released from Clear Lake and Indian Valley Reservoir into Cache Creek is diverted

Cache Creek, with Capay Diversion Dam in foreground. Clear Lake and Mount Konocti are in the background.

by the Yolo County Flood Control and Water Conservation District for irrigation in Yolo County. Since 1950, the district has diverted an average of 130 taf annually at Capay Diversion Dam on lower Cache Creek. No water supply from these sources was available during the 1977 and 1990 drought years.

In Sutter County and in western Placer County, agricultural water is supplied by South Sutter Water District from Camp Far West Reservoir on the lower Bear River. SSWD also purchases surface water from Nevada Irrigation District to supplement irrigators' groundwater supplies. NID's supplies come from its reservoirs on the Yuba-Bear River system. Yuba River supplies have also been developed by Yuba County Water Agency, which owns the 966 taf New Bullards Bar Reservoir, the river's largest reservoir.

The Sacramento metropolitan area, served by more than 20 water purveyors, is the largest urban area in the Sacramento Region and is also the largest urban surface water user. Within Sacramento County, the City of Sacramento relies primarily on surface water (approximately 80 to 90 percent); water purveyors in unincorporated areas use both surface water and groundwater. The City of Sacramento diverts its CVP water supply from the American River at H Street, and also diverts from the confluence of the American and Sacramento Rivers. The City of Folsom takes surface water from Folsom Lake.

Groundwater Supply

Most groundwater used in the region comes from alluvial aquifers on the valley floor. The Sacramento Valley is a major groundwater basin, with an estimated 114 maf of water in storage at depths of up to 600 feet. (Only a portion of this amount can be economically used, however.) Well yields in alluvial areas vary significantly depending on location; pumping rates typically range from 100 to 4,000 gpm. Foothill communities using groundwater generally rely on fractured rock sources having yields lower than those found in valley floor alluvium.

Redding supplements its CVP surface water supply with groundwater. Smaller communities in the northern and central Sacramento Valley, such as Anderson, Red Bluff, Marysville, Olivehurst, Wheatland, Willows, Corning, and Williams, rely almost entirely on groundwater and have adequate supplies to meet local demands for the foreseeable future. Woodland, Davis, and Dixon are completely dependent on groundwater. Most residents in unincorporated areas rely on groundwater.

In the Sacramento metropolitan area, groundwater is used by the Cities of Sacramento and Galt, Sacramento County, and local water agencies. Two areas of overdraft exist in Sacramento County, one near McClellan Air Force Base and the other in the Elk Grove area.

Local Water Resources Management Issues

Sierra Nevada Foothills Water Supply

Urbanization of agricultural lands in the Central Valley is an issue currently attracting public attention. An alternative to urban development on valley floor agricultural lands is increasing development on nonarable lands in the adjoining Sierra Nevada foothills. However, the foothill areas also have land use and water supply concerns associated with development pressure, particularly for communities within commuting distance of the valley's major population centers.

Historically the rural foothill counties have had economies based on natural resource development (ranching and logging). Tourism is becoming increasingly important. Although individual foothill communities have experienced relatively high growth rates, the area's overall population is small, and future development is constrained by the high percentage of federal lands managed by the USFS and the National Park Service.

Although extensive development of large-scale water projects has occurred in the foothills, that development serves downstream urban and agricultural water users. The foothills' local water supply infrastructure is limited, with some water users still being served by open ditch and flume systems dating back to gold rush-era mining operations. The area's development pattern of small, geographically dispersed population centers and its lack of a financial base for major capital improvement projects constrains the ability to interconnect individual water systems and to develop centralized sources of water supplies, limiting options for water marketing. The area's small population translates into high per capita costs for water supply improvements. Many individual residences and subdivision developments rely on self-supplied groundwater from wells tapping fractured rock aquifers. Groundwater resources from fractured rock sources are highly variable in terms of water quantity and quality, and are an uncertain source for large-scale residential development.

Management of existing water supplies, especially meeting increasingly stringent drinking water quality requirements, is a challenge for some foothill water systems. As with water supply, interconnections for water treatment purposes are difficult due to geographic and topographic constraints. System consolidations are also complicated by the relatively large percentage of the foothill population living in unincorporated areas, and the correspondingly high number of small, independent water systems. Historically, many isolated developments relying on groundwater as a source of supply also used septic tank systems for waste disposal. Eventually, some of these systems experience groundwater contamination problems, requiring a new water supply or connection to a regional wastewater system, if one exists.

Conveyance system reliability is a concern in foothill areas where sources of surface supply are often limited. Conveyance facilities are vulnerable to localized flooding and earthquake or landslide damage. After the 1997 floods, a landslide destroyed a 30-foot section of Georgetown Divide Public Utility District's canal which supplied water to 9,000 customers in six towns in rural El Dorado County. Nearby, El Dorado Irrigation District also lost the use of a flume diverting from the American River due to another landslide. The district is currently developing alternatives to repair or replace the flume. EID has released a draft EIR for the project, and is proposing to make temporary canal repairs to allow for 40 cfs summer deliveries until permanent repairs can be made.

The communities of Cohasset and Forest Ranch in Butte County are considering building a pipeline to convey part of Butte County's SWP supply to urban users east of Chico. During extended drought conditions some of the wells serving the area have gone dry, requiring that water be hauled by truck. Also in Butte County, the Department's Division of Safety of Dams reduced the allowable operating capacity of Paradise Irrigation District's Magalia Reservoir because of seismic safety concerns. The 2.9 taf capacity reservoir is impounded by a hydraulic fill dam built in 1918. Restoring the 1.5 taf reduction in storage capacity is estimated to cost about $10 million.

Through 2020, no average year water shortages are anticipated in the entire Sierra foothill area stretching from Modoc County on the north to Kern County on the south and including adjacent parts of the Cascade Range foothills. Drought year shortages in 2020 are forecast to be 220 taf, over 60 percent of which are associated with agricultural water use. The area's limited payment capacity and its need for drought year supplies suggests that participation in regional water supply projects with larger water agencies is a viable option. Although local agencies have evaluated a number of new reservoir projects in the past (see water management options section), these projects have not gone forward.

Foothill Area Water Supply from American River Basin

El Dorado County water agencies have made several attempts to develop local supplies in the American River Basin, in anticipation of their service area's future water needs. Originally, USBR's multipurpose Auburn Dam was to provide local supply. When Auburn Dam did not go forward, EID and El Dorado County Water Agency proposed a joint water supply and hydropower project in the late 1970s. The South Fork American River project would have included a large dam at the Alder Creek site, Texas Hill Reservoir on Weber Creek, two diversion dams, and several powerplants. When the SOFAR project did not prove to be financially feasible, a small Alder Creek Reservoir project with a storage capacity of 31 taf was investigated. In 1993, EDCWA released a final EIR for water supply development in EID's service area.

Many foothill areas are served by conveyance systems that had their origins in gold rush-era mining systems. Another reminder of the region's mining history is the ringtail, also known as the "miner's cat". Some early settlers kept ringtails as pets, to control mice. The ringtail lives in rocky and wooded areas in the foothills and in valley riparian areas.

Alternatives included a 7.5 taf/yr CVP water service contract for deliveries from Folsom Reservoir (authorized in PL 101-514), the El Dorado project, Texas Hill Reservoir, Small Alder Reservoir, and the White Rock project. The preferred alternative was identified as a combination of the water service contract, the El Dorado project, and the White Rock project.

EDCWA subsequently executed the CVP water service contract and EID sought to implement the El Dorado project, a proposal to acquire rights to consumptively use water that had been developed by PG&E for hydropower generation. In 1996, SWRCB's Decision 1635 approved EID's water rights filing for 17 taf/yr of consumptive use from PG&E's Caples, Aloha, and Silver Lakes on the South Fork of the American River and its tributaries, based in part on a PG&E agreement to sell facilities of the hydropower project to EID. Several other water right holders petitioned SWRCB to reconsider its decision. EID and PG&E subsequently went to litigation over the sale of the facilities, and EID's EIR for the El Dorado project was found inadequate by a Superior Court judge. The project is currently on hold.

EID's White Rock project is a diversion and conveyance project that would build about 4.5 miles of pipeline, connecting a proposed treatment plant with an existing Sacramento Municipal Utility District penstock. The project would allow more efficient use of El Dorado project water, but would not provide additional water supply.

Alternatives to meeting GDPUD's future water needs were identified in a 1992 planning report that examined a potential reservoir project on Canyon Creek. The reservoir project was found to be unaffordable for the service area. The most promising option to meet future water demands in GDPUD's service area is to divert and convey CVP water from the American River (as part of EDCWA's CVP water service contract authorized by PL 101-514). The additional supplies would be 7.5 and 5.6 taf for average and drought years, respectively.

In the 1990s, USBR conducted an American River water resources investigation to evaluate local area water supply options that would replace the water supply that was to have been provided by the original multipurpose Auburn Dam. The study proposed two alternatives for meeting municipal and agricultural water supply needs in portions of Sacramento, San Joaquin, El Dorado, Placer, and Sutter Counties through 2030—a conjunctive use alternative and an Auburn Dam alternative. Three alternative Auburn Reservoir sizes were studied: 430 taf, 900 taf, and 1,200 taf. The final EIS for this investigation was completed in 1997. In May 1998, USBR issued a record of decision to not proceed with federal actions to meet future water needs in the study area.

Sacramento Area Water Forum

The Sacramento Area Water Forum was formed in 1993 to discuss ways to accommodate two co-equal objectives, providing water supply for the area's planned development and preserving fishery, wildlife, recreational, and aesthetic values of the lower American River. Forum membership includes the Cities of Sacramento, Galt, and Folsom; County of Sacramento; more than twenty urban and agricultural water agencies; several environmental groups; and representatives from the business community and other community groups. In 1995 the forum began meeting jointly with water interests in Placer and El Dorado Counties.

Working together, they developed proposed draft recommendations for their objectives, releasing a *Draft Recommendations for a Water Forum Agreement* in 1997. The proposed solution included seven elements:

- Increased surface water diversions
- Actions to meet customers' needs while reducing diversion impacts on the Lower American River in drier years
- Support for an improved pattern of fishery flow releases from Folsom Reservoir
- Lower American River habitat management
- Water conservation
- Groundwater management
- Water Forum successor effort

Generally, water interests would increase their diversions from the American River in average and wet years and decrease diversions in drought years. PCWA would release stored water from its reservoirs on the Middle Fork of the American River for many of the participating water agencies during drought years as replacement water for their decreased American River diversions. PCWA's participation in these agreements is dependent upon SWRCB approval for changes to conditions of its existing water rights.

The proposal calls for conjunctively managing surface and groundwater supplies to help control declining groundwater levels in parts of Sacramento County, and for implementing water conservation measures. An example of the regional cooperation for stabilizing groundwater levels is a joint pipeline project being carried out by San Juan Water District and Northridge Water District. SJWD has completed the first phase and NWD has completed the second phase of a joint pipeline project which will provide surface water to northern Sacramento County water purveyors. Phase III would extend the pipeline to the Rio Linda WD, McClellan AFB, the westerly Citizen's Utilities service area, and Natomas Central Mutual Water Company area. By providing surface water supplies, the retail purveyors along the pipeline route can reduce their dependence on groundwater, allowing the groundwater basin to recharge.

Colusa Basin Drainage District

A 1995 study by the Colusa Basin Drainage District identified projects to meet six objectives: protect against flood and drainage damages, preserve and enhance agricultural production, capture surface or storm water for increased water supplies, facilitate groundwater recharge to help reduce overdraft and land subsidence, improve and enhance wetland and riparian habitat, and improve water quality. Some projects selected for feasibility and preliminary design studies have potential water supply benefits—two small onstream reservoirs and one groundwater recharge project. These projects are described in the discussion of water management options. Much of the present supply for agricultural water users in the Colusa Basin comes from return flows from CVP water contractors. These irrigation return flows have become an increasingly unreliable supply for Colusa Basin Drain diverters as a result of increased water conservation measures by upstream water users.

Groundwater Management Actions

The Sierra Valley Groundwater Management District adopted an ordinance in 1980 limiting the amount of groundwater extraction in Sierra Valley. A legal challenge led to a repeal of the ordinance by the SVGMD. The district has since focused its efforts on monitoring the basin's groundwater levels and requesting voluntary reductions in extractions.

In 1992, the Tehama County Board of Supervisors amended its county code to enact urgency ordinances prohibiting groundwater mining within the county and extraction of groundwater for export without a permit from the board. In 1996, the Tehama County Flood Control and Water Conservation District adopted a resolution of intent to develop a countywide AB 3030 plan and prepared a draft plan to serve as the basis for developing agreements with groundwater users.

Butte County has enacted two ordinances regulating groundwater extraction. The purpose of one ordinance was to "attempt to reduce potential well interference problems to existing wells and potential adverse impacts to the environment which could be caused by the construction of new wells or the repair or deepening of existing wells. . . ." The ordinance limited pumping rates to 50 gpm per acre. The ordinance also established well spacing requirements based on well pumping capacity; spacing requirements range from 450 feet for a 1,000 gpm well to 2,600 feet for a 5,000 gpm well. The other ordinance was approved by voters in 1996 and regulated export of groundwater out of the county and substitution of groundwater for surface water when surface water is sold. The ordinance gave the Butte County Water Commission permitting authority over groundwater export or groundwater substitution.

Glenn County enacted a groundwater ordinance in 1977. This ordinance required a permit to export groundwater outside the county. A permit can be issued only if it is found that export will not result in overdraft, adverse impacts to water levels, or water quality degradation. The Board of Supervisors may impose permit conditions. Glenn County is preparing an AB 3030 groundwater management plan that is expected to be completed in 1998.

American River Flood Protection

Following the floods of February 1986, USACE reanalyzed American River basin hydrology and concluded that Folsom Dam did not provide an adequate level of flood protection to the downstream Sacramento area, significantly less than the 250-year protection estimated in the late 1940s when Folsom Dam was designed. Local, State, and federal agencies worked together to identify ways to provide additional flood protection for the American River Basin. In December 1991, an American River watershed investigation feasibility report and EIR/EIS were completed, presenting flood protection alternatives. The report recommended a flood control detention dam near Auburn. In 1992, Congress directed USACE to perform additional flood control studies. Three main alternatives were evaluated. Two of the alternatives would increase flood control storage in Folsom Lake, modify the dam's spillway and outlet works, and improve downstream levees. The third alternative would construct a detention dam at Auburn, with downstream levee improvements. USACE studies identified the detention dam as the plan that maximized national economic benefits. The State Reclamation Board endorsed the detention dam as the best long-term solution to reliably provide greater than 1-in-200 year flood protection. In 1996, USACE recommended deferring a decision on long-term solutions and proceeding with the levee improvements common to all three alternatives. Congress authorized $57 million in 1996 for construction of the levee improvements.

The Central Valley's January 1997 flood disaster prompted another examination of American River hydrology. Based on that hydrologic review, the 1986 and 1997 floods are now considered to be about 60-year events. The 1997 flooding also triggered payback provisions of the Sacramento Area Flood Control Agency's agreement with USBR, under which USBR sets aside up to 270 taf of additional winter flood control space in Folsom Lake. (This additional flood control space in the reservoir raises Sacramento's level of protection to about a 77-year event level.) Because the January 1997 flood event was followed by an unusually dry spring, reoperation of Folsom Lake for additional flood control resulted in a loss of supply to USBR. The federal government and SAFCA purchased 100 taf to offset the loss of supply—50 taf from YCWA, 35 taf from PCWA, and 15 taf from GCID.

In its Resolution No. 98-04, the Reclamation Board restated its conclusion that the best long-term engineering solution to reliably provide greater than 1-in-200 year flood protection is to develop additional flood detention storage at Auburn. As an incremental measure to increase the level of flood protection, the Board also voted to support SAFCA's Folsom Modification Plan, described in SAFCA's February 1998 report *Next Steps for Flood Control along the American River.* This plan, costing $75 to $140 million, would

Sacramento River Flood Control Project

Congress authorized the Sacramento River Flood Control Project in 1917 after a series of major Sacramento Valley floods in the late 1800s and early 1900s. The project was built with local, State, and federal funding. The project includes levees, overflow weirs, bypass channels, and channel enlargements. Overflow weirs allow excess water in the main river channel to flow into bypasses in the Sutter Basin and Yolo Basin. The bypass system was designed to carry 600,000 cfs of floodwater past Sacramento—110,000 cfs in the Sacramento River through downtown Sacramento and West Sacramento, and the remainder in the Yolo Bypass. The system has worked exceedingly well over the years.

The capability of the SRFCP was improved upon completion of Shasta Dam in 1945 and Folsom Dam in 1956. The Feather and Yuba River systems did not share in the SRFCP's flood control benefits; however, supplemental protection was provided by the completion of Oroville Dam on the Feather River in 1968 and New Bullards Bar Dam on the Yuba River in 1970. These are large multipurpose reservoirs in which flood control functions share space with water supply functions.

The City of Sacramento experienced several major floods during its early years. The following description of the floods of 1862 is taken from the journal of William Brewer, a member of the California State Geological Survey. "Such a desolate scene I hope never to see again. Most of the city is still under water, and has been for three months. ... Not a road leading from the city is passable, business is at a dead standstill, everything looks forlorn and wretched. Many houses have partially toppled over... some have been carried from their foundations, several streets (now avenues of water) are blocked up with houses that have floated in them, dead animals lie about here and there. . . ."

Courtesy of California State Library

increase flood protection to approximately a 1-in-110 year level. In addition, the Board strongly urged SAFCA to advocate federal flood insurance for all residents and businesses in the Sacramento area having less than a 1-in-200 year level of flood protection. As of July 1998, SAFCA was seeking congressional authorization for USACE participation in Folsom Dam modifications and downstream levee enlargements. The Board currently does not support raising and strengthening the levees downstream from the dam, and would not support State cost-sharing in this effort. Two competing flood control bills, HR 4111 and HR 3698, are pending before Congress. HR 4111 would authorize construction of a small flood control dam, while HR 3698 would rely mostly on levee improvements for flood protection for the Sacramento area.

Yuba River Flood Protection

The Marysville-Yuba City area, located at the confluence of the Feather and Yuba Rivers, relies on levees for much of its flood protection. New Bullards Bar Reservoir on the Yuba River, the only Yuba River Basin reservoir with dedicated flood control storage, regulates less than half the river's runoff. The middle and south forks of the Yuba River, and Deer Creek, have no dedicated flood storage. A large reservoir site (the former Marysville project, and similar sites near the Yuba River Narrows) was studied by USACE, YCWA, the Department, and others at various times in the 1950s and through the 1980s for both water supply and flood control purposes.

USACE, in cooperation with the State Reclamation Board and YCWA, conducted a feasibility study of water resources problems and opportunities in the Yuba River Basin in 1991, after a 1990 reconnaissance study identified a significant flood threat. Preliminary alternatives included modifying existing levees, implementing nonstructural measures, constructing a large or small bypass, reregulating existing flood storage at Oroville and New Bullards Bar Reservoirs, providing new flood storage at Englebright Reservoir, raising Englebright Dam and reregulating flood storage at Englebright and New Bullards Bar Reservoirs, and constructing a single purpose or multipurpose reservoir at the Parks Bar or Narrows damsites. The recommended plan in USACE's 1998 Yuba River Ba-

Flooding on the American River in 1986 and again in 1997 severely tested levee system capabilities. Releases from Folsom Dam in 1986 actually exceeded design capacity of the levee system. In 1997, voluntary evacuation advisories were issued for some parts of the Sacramento metropolitan area. This photo shows the American River at the H Street bridge.

sin Investigation final feasibility report and EIR/EIS was to modify existing levees along the Yuba and Feather Rivers. In response to the significant flood problems experienced in the Marysville-Yuba City area during the January 1997 flood, YCWA began a new investigation of flood control alternatives. The multi-year study will examine a range of alternatives, including storage facilities such as the Parks Bar site. During the 1997 flood event, 35,000 people were evacuated from the Marysville area and 75,000 people were evacuated downstream in Sutter County.

Sacramento River Mainstem Flood Protection and Water Supply

Enlargement of Shasta Reservoir has been examined in the past by USBR and the Department as a water supply option. Reservoir enlargement would also provide additional flood protection on the Sacramento River mainstem. When the project was last reviewed in the 1980s (at a cursory level of detail), its financial costs were high, reflecting the project's magnitude (up to 10 maf of additional storage capacity). Railroad and highway relocations were a substantial cost item. In the wake of the January 1997 flooding, there was renewed interest in reexamining Shasta's enlargement, and in considering a range of potential reservoir sizes. USBR conducted a preliminary study for the CALFED program, reviewing three options. One option would raise the dam 6 feet to add 300 taf of storage at a cost of $123 million. Raising the dam 100 feet would add 4 maf of storage and cost $3.9 billion. Raising the dam 200 feet would add 9.3 maf of storage and cost $5.8 billion. Enlarging Shasta as a statewide water management option could provide the opportunity for local agencies in the region to participate in the project, especially smaller agencies that lack the resources to develop new local projects themselves.

Putah Creek Adjudication

USBR's Solano Project stores and diverts water from Putah Creek. Solano Project operations are subject to a condition reserving water for users upstream of Monticello Dam in Lake Berryessa. In 1990, two project water users (SID and SCWA) commenced an action in Solano County Superior Court to determine all rights to the use of water from Putah Creek and its tributaries. Among other issues, the action required a determination of how rights can be exercised among USBR and upstream water users. An agreement was negotiated among SID, SCWA, USBR, and upstream water users. In 1996, the SWRCB adopted Order WR 96-2, amending appropriative water rights in the upper Putah Creek watershed to be consistent with the negotiated agreement.

Fish Passage at Red Bluff Diversion Dam

USBR's Red Bluff Diversion Dam, completed in 1966, spans the Sacramento River. The dam diverts river water into the Tehama-Colusa and Corning Canals, supplying irrigation and wildlife refuge water. Severe fishery declines in the upper river during the 1970s and 1980s, were partly attributed to the dam and the canal intake screens. The dam delayed upstream passage of migrating adult salmon and steelhead and disoriented downstream migrating juveniles, which made them vulnerable to predation by squawfish. The original fish screens also permitted passage of many juvenile fish into the canals.

In 1986, USBR began raising the gates of the dam between December and March to allow unimpeded fish passage. The gates-up period has been expanded in response to ESA requirements for winter-run chinook salmon; the current objective is to raise the gates for eight consecutive months (September 15 to May 15) each year to allow unimpeded fish passage. New drum fish screens and bypasses were installed at the canal headworks in 1991 and are now operating successfully. As discussed in Chapter 2, USBR and USFWS are operating a research pumping plant at the dam to evaluate the effects of different pump types on fish. The plant supplies a limited amount of water to the canals during the eight months when the dam gates are raised.

Glenn-Colusa Irrigation District Fish Screen

The 175,000 acre Glenn-Colusa Irrigation District has the largest diversion on the mainstem Sacramento River, with a maximum capacity of 3,000 cfs. GCID may divert up to 825 taf from April through October for irrigation supply. GCID also conveys CVP water to three national wildlife refuges—Sacramento, Delevan, and Colusa.

GCID's pumping plant is located on a river side channel upstream of Hamilton City, near Chico. DFG constructed a 40-drum rotary screen fish barrier at the plant's intake in 1982, to prevent entrainment of juvenile fish. The fish barrier did not perform as intended, resulting in an unacceptably high rate of juvenile fish mortality. ESA listing of the winter-run chinook salmon resulted in a 1991 court order restricting GCID's pumping and requiring installation of a new fish screen. CVPIA required DOI to improve fish passage at the pumping plant. GCID installed a temporary flat-plate screen in 1993 while a permanent solution was being developed. An environmental document identifying a preferred fish passage alternative—a new flat-plate screen with a river gradient control facility in the main channel of the Sacramento River—was released in 1997. Construction of the new screen began in 1998.

Fish and Wildlife Restoration Activities in the Sacramento Valley

Many fishery restoration actions or projects are ongoing in the Sacramento Valley. Some of the larger projects are described below.

Mill and Deer Creeks support spring-run chinook salmon, a candidate species under the California ESA. In 1995, State legislation restricted future water development on the creeks, to protect salmon habitat. In addition, local landowners formed the Mill and Deer Creek Watershed Conservancies. The conservancies

USBR's Red Bluff Diversion Dam, with gates raised. The dam was designed to divert Sacramento River water into the Tehama-Colusa Canal. The intake channel for the Corning Canal Pumping Plant connects to the Tehama-Colusa Canal.

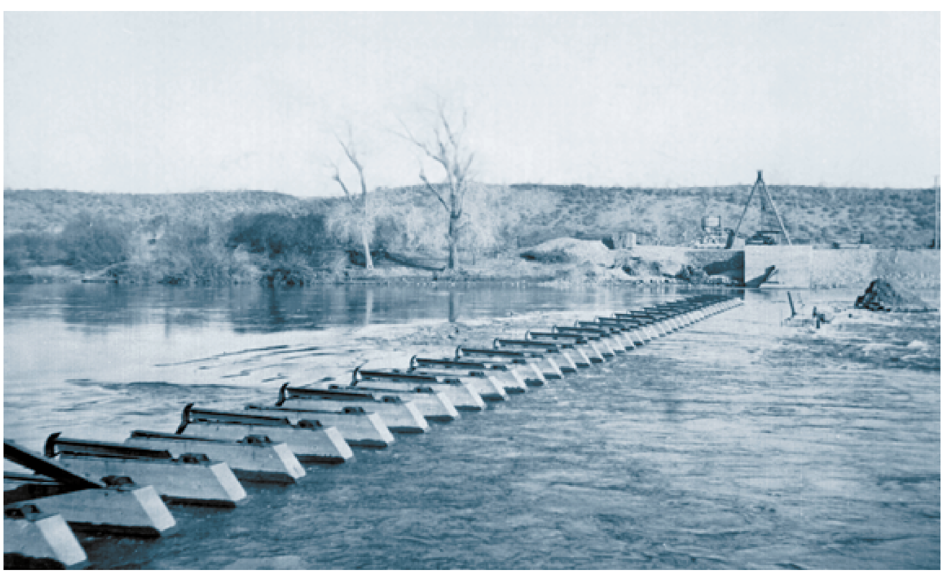
Local agencies have made extensive efforts to improve Butte Creek fish passage, in response to declines in the population of spring-run chinook salmon.

have begun a watershed planning and management process, with funding assistance from an EPA grant. The Department has participated with Mill Creek landowners in a test project to construct wells to provide groundwater supplies in lieu of creek diversions for irrigation during spring fish migration periods. A similar project is being negotiated with Deer Creek water users.

Big Chico Creek supports a small population of spring-run salmon, and some fall-run salmon. M&T Chico Ranch and Parrott Ranch pumps were relocated from the creek to the Sacramento River in 1996 to eliminate reverse flows at the mouth of the creek. Other fishery improvement actions—modification of small temporary dams and a permanent fish ladder, revegetation of Lindo Channel, and development of a fishery management plan—are being investigated.

Butte Creek is presently receiving considerable fishery restoration attention. The creek has a large spring-run salmon population and also supports a small fall run. Recent fishery restoration efforts on Butte Creek began in 1993 when Western Canal Water District and private landowners agreed to remove the Point Four Diversion Dam near Nelson. M&T Chico Ranch and DFG agreed to install a new fish ladder and fish screens at the Parrott-Phelan Dam in 1995. M&T Chico Ranch also dedicated 40 cfs of instream flow for fishery needs on Butte Creek. WCWD installed a siphon under Butte Creek in 1998, allowing removal of its two main dams and two smaller downstream dams from the creek. The siphon separates WCWD's canal system from Butte Creek and eliminates fish losses previously caused by creek diversion. Work began in 1998 on fishery facility modifications to Durham Mutual, Adams, and Gorrill Dams. The Nature Conservancy and California Waterfowl Association are evaluating diversion dams in the Butte Slough and Sutter Bypass for potential fish passage improvements.

Pelger Mutual Water Company and Maxwell Irrigation District installed fish screens on their Sacramento River diversions in 1994. Princeton-Codora-Glenn Irrigation District and Provident



A 1917 construction photo of Anderson-Cottonwood Irrigation District's diversion dam on the Sacramento River. Flashboards are installed during the irrigation season to raise the river's water level for diversions to ACID's main canal. ACID's diversion is one of many Sacramento River Basin sites under study for fish passage Improvements.

Courtesy of Water Resources Center Archives, University of California, Berkeley

Irrigation District started construction on a new screened pumping plant on the Sacramento River, which is expected to be operational in 1998. Reclamation District 108 started building its new fish screen at its Wilkins Slough Diversion on the Sacramento River in 1997. The new screen is expected to be operational in 1999. Reclamation District 1004 is completing final design and will begin construction on its new fish screen and pumping facility in 1998. Natomas Central Mutual Water Company will soon begin feasibility studies for a large screening project on the lower Sacramento River. On the Yuba River, Browns Valley Irrigation District will install a fish screen in 1998.

Clear Creek is another location in the Sacramento River Basin where fishery restoration work has been performed. Additional planned work includes fish passage around McCormick-Saeltzer Dam, gravel placement, and sediment control. Much of the riparian land along Clear Creek below Whiskeytown Reservoir has been acquired by BLM and the Wildlife Conservation Board to preserve its habitat values.

Other Sacramento River Region streams with environmental restoration studies underway are Battle Creek and Lower Stony Creek. Potential restoration work at Battle Creek includes studies of fish passage, instream flows, screened diversions, and hatchery modernization. Glenn County is seeking funding for planning of a Lower Stony Creek watershed restoration program.

Water Needs for Rice Field Flooding

Sacramento Valley rice fields provide overwintering areas for about one-third of all migrating waterfowl in California. Historically, many farmers in the Sacramento Valley have flooded harvested rice fields to attract waterfowl for hunting. Additional rice acreage is now being flooded for rice straw decomposition, due to air quality restrictions on burning rice straw. Most flooding of harvested rice lands begins in mid-October and continues into November. Flooded conditions are usually maintained through March. In 1994-95, the Department studied three Sacramento Valley planning subareas (Northwest Valley, Central Basin West, and Central Basin East) to evaluate fall and winter water use. The study area included approximately 123,000 acres of flooded rice land. The estimated applied water requirement was 260 taf or about 2 af/acre; the estimated ETAW was 107 taf. Fields used for waterfowl hunting have higher water demands than those used for rice straw decomposition. Water demands for flooding to decompose rice straw may decrease in the future if growers are able to find commercial uses for rice straw.

Water Management Options for the Sacramento River Region

Water management options in the Sacramento River Region have been extensively investigated by federal, State and local governments over the last 70 years. Many of the federal and State options were explored for their potential to augment CVP or SWP water supplies. Some projects, once studied as statewide options, are now being reconsidered for meeting future local water supply and flood control needs in the Sacramento River Region. Most large onstream and offstream reservoirs are beyond the development capacity of local water agencies, and are being considered as CALFED options, described in Chapter 6.

Table 8-4 shows a list of options for the region, and the results of an initial screening of the options. The retained options were evaluated (Table 8A-1 in Appendix 8A) based on a set of fixed criteria discussed in Chapter 6.

Water Conservation

Urban. Urban water demand forecasts for 2020 assume that BMPs are in place; consequently, only those urban conservation efforts which exceed BMPs are considered as options. Urban conservation options were deferred from detailed evaluation because they provide little cost-effective potential to create new water through depletion reductions in the Sacramento River Region.

Agricultural. The 2020 agricultural water demand forecasts assume that EWMPs are in place. As with the urban water management options, only those agricultural conservation efforts which exceed EWMPs are considered as options. Agricultural conservation options were deferred. Water that is not consumed by evapotranspiration is recoverable either as surface or groundwater for reapplication downstream.

Modify Existing Reservoirs/Operations

Two reservoir enlargement options were deferred in initial screening. Enlargement of Camp Far West Reservoir was deferred based on economic criteria. A Lower Bear River expansion project that would increase the storage of Lower Bear Reservoir by more than 26 taf was deferred because of several uncertainties includ-

TABLE 8-4

Sacramento River Region List of Water Management Options

Option	*Retain or Defer*	*Reason for Deferral*
Conservation		
Urban		
Outdoor Water Use to 0.8 ET_o	Defer	No significant depletion reductions attainable.
Indoor Water Use	Defer	No significant depletion reductions attainable.
Interior CII Water Use	Defer	No significant depletion reductions attainable.
Distribution System Losses	Defer	No significant depletion reductions attainable.
Agricultural		
Seasonal Application Efficiency Improvements	Defer	No significant depletion reductions attainable.
Flexible Water Delivery	Defer	No significant depletion reductions attainable.
Canal Lining and Piping	Defer	No significant depletion reductions attainable.
Tailwater Recovery	Defer	No significant depletion reductions attainable.
Modify Existing Reservoirs/Operations		
Enlarge Camp Far West Reservoir	Defer	Economics.
Lower Bear River Expansion Project	Defer	Uncertainties with water rights issues.
Reoperate Caples, Aloha, and Silver Lakes	Retain	
New Reservoirs/Conveyance Facilities		
Wilson Creek Reservoir (Glenn County)	Defer	Undetermined yields; primarily flood control project.
Golden Gate Reservoir (Funks Creek, Colusa County)	Defer	Undetermined yields; primarily flood control project.
Dry Creek Reservoir (Lake County)	Retain	
Bear Creek Reservoir (Colusa County)	Defer	Environmental concerns. Conflicts with federal land management policies.
Wilson Valley Reservoir (Lake County)	Defer	Environmental concerns. Conflicts with federal land management policies.
Garden Bar Reservoir (Placer and Nevada Counties)	Defer	Economics.
Long Bar Reservoir (Yuba County)	Defer	Undetermined yields; primarily hydropower project.
Wambo Bar Reservoir (Yuba County)	Defer	Undetermined yields; primarily hydropower project.
Marysville Dam (Yuba County)	Defer	Undetermined yields; economics.
Blue Ridge Reservoir (Yolo County)	Defer	Environmental concerns. Conflicts with federal land management policies.
Thurston Lake Pump-Storage Project (Lake County)	Retain	
Parks Bar Reservoir (Yuba County)	Retain	
Waldo Reservoir (Yuba County)	Retain	
White Rock Project (El Dorado County)	Defer	Reoperation of existing supply; would not provide new water supply.
Texas Hill Reservoir (El Dorado County)	Retain	
Small Alder Reservoir (El Dorado County)	Retain	
Canyon Creek Reservoir (Georgetown)	Defer	Excessive costs.
GDPUD Diversion from American River	Retain	

TABLE 8-4

Sacramento River Region List of Water Management Options (continued)

Option	*Retain or Defer*	*Reason for Deferral*
Groundwater/Conjunctive Use		
New Wells (Redding, Butte, and Colusa Basins)	Retain	
USBR/Ducks Unlimited Conjunctive Use	Defer	Would not create new water supply.
Big Valley Conjunctive Use (Lake County)	Retain	
Orland-Artois Groundwater Recharge Basin	Defer	Lack of project data, no yields determined.
Adobe Creek Detention Structure (Lake County)	Defer	Negative environmental impacts.
Water Recycling		
Water recycling options	Defer	Water recycling options would not generate new water supply.
Desalting		
Brackish Groundwater		
—	—	—
Seawater		
—	—	—
Other Local Options		
New Surface Water Diversion from Sacramento River and Cache Creek by YCFC&WCD	Retain	
New Surface Water Diversion from Sacramento River by Cities of Benicia, Fairfield, and Vacaville	Retain	
Statewide Options		
—	—	See Chapter 6.

ing water rights issues, coordination with PG&E (the reservoir's owner), and lack of definitive estimates of the project's drought year supply.

The water management issues section described several projects for EID's service area. The El Dorado Project would offer an annual yield of 17 taf for EID through consumptive use of water developed for hydropower at PG&E facilities (Caples, Aloha, and Silver Lakes). No new diversion facilities would be required for the project. Implementation of the El Dorado Project is currently on hold pending negotiations with project opponents.

New Reservoirs

An extensive reevaluation of onstream and offstream Sacramento Valley reservoir sites is being conducted by the CALFED Bay-Delta program. Chapter 6 discusses reservoir sites (such as the offstream Sites Reservoir) being evaluated as statewide water supply options for CALFED.

Onstream Storage. Local efforts to develop American River Basin water supply for rapidly growing foothill communities were described previously. Most recently, EID and EDCWA considered the Texas Hill and Small Alder Reservoir sites, but EDCWA did not include them as preferred alternatives in its plan for EID's service area. The drought year yields from these reservoirs have been estimated at 9.4 taf and 11.3 taf, respectively. If implementation of EDCWA's preferred alternative does not proceed, these options may still be viable. GDPUD has examined a reservoir project on Canyon Creek. The 17 taf reservoir site, located between the Middle and South Forks of the American River, would have an estimated drought year yield of 6 taf. This project was not cost-competitive with other options available to GDPUD.

The Colusa Basin Drainage District has investigated two small reservoirs as part of its integrated watershed management project—a 2.2 taf Wilson Creek Reservoir west of Orland in Glenn County, and

Sites Reservoir (described in Chapter 6 as a CALFED option) could provide some local supply for the region, depending on the project's formulation. This photo shows the dam site area.

a 16.9 taf Golden Gate Reservoir on Funks Creek near Maxwell in Colusa County. The estimated average annual runoff at the Wilson Creek site is 2.4 taf. The construction cost is estimated at $3.3 million. The primary purpose of the proposed reservoir would be flood control, although it offers limited water supply benefits. Golden Gate Reservoir would be formed by a 76-foot high earthfill dam; this dam site is also a component of the Sites/Colusa Reservoir, a CALFED storage option presented in Chapter 6. The estimated average annual runoff at the Golden Gate Dam site is 8.6 taf and the construction cost estimate for the dam and reservoir is $2.5 million. Neither of these projects is included in the Bulletin's detailed options evaluation because potential yields are undetermined. These reservoirs are too small to provide enough carryover storage to significantly increase local drought year water supply reliability.

The Department investigated the Dry Creek Project in Lake County near Middletown in 1965. The project was designed to irrigate 5,700 acres of agricultural lands in the Collayomi and Long Valleys in Lake County. The main project feature would be a 129-foot-high earthfill dam on Dry Creek (a Putah Creek tributary) forming a 6.6 taf reservoir. Updated cost estimates range from $150 to $250/af, assuming a maximum annual yield of 6.6 taf. USACE is conducting a reconnaissance study for a similar facility, scheduled for completion in 1998.

In 1988, YCFC&WCD studied alternative water supply projects in the Cache Creek watershed. The study identified three onstream storage projects—Bear Creek Reservoir in Colusa County and Wilson Valley Reservoir in Lake County, with annual yields of 30 taf each, and Blue Ridge Reservoir in Yolo County, with an annual yield of 100 taf. None of these sites are under active consideration now. Parts of the Cache Creek drainage basin that could be impacted by these projects are managed by BLM and DFG for wildlife habitat and recreational purposes, and a segment of Cache Creek is under study for potential federal designation as a wild and scenic river.

South Sutter Water District had looked at a potential Garden Bar Reservoir on the Bear River, upstream of Camp Far West Reservoir and had determined that the project was not economically feasible.

Many potential Yuba River reservoir sites have been studied to meet basin flood protection and water supply needs. Recent local interest has focused on the Parks Bar Reservoir site on the lower Yuba River (below Englebright Dam) and on Waldo Reservoir, an offstream storage option discussed in the next section. The potential multipurpose Parks Bar Reservoir would have a 640 taf capacity and could provide up to 160 taf of drought year yield. Parks Bar Dam is a flood control alternative previously rejected by the USACE in favor of levee improvements. YCWA is starting a new three-year study to evaluate all basin flood control and water supply options. The study will reevaluate levee improvements, new flood control channels, new storage (including Parks Bar), and reoperation of existing reservoirs.

Offstream Storage. In 1996, YCWA completed a reconnaissance evaluation of the proposed 300 taf offstream Waldo Reservoir. Waldo Dam would be located on Dry Creek, east of Beale Air Force Base in Yuba County. Water would be diverted from the Yuba River by gravity through a tunnel from Englebright Reservoir. The dam would provide flood control benefits on Dry Creek for the City of Wheatland, but would have no direct flood control benefits on the Yuba River. Waldo Reservoir could provide offsetting storage for increased flood control reservation at New Bullards Bar Reservoir and Lake Oroville if YCWA negotiates agreements with the reservoir owners for supply from Waldo Reservoir in exchange for the flood control storage.

Phase I of a feasibility investigation was conducted in 1997 to determine reservoir yield, develop cost estimates, and evaluate environmental issues. The reservoir's average and drought year yields for YCWA's service area would be about 145 and 109 taf, respectively. The cost of water if served in the area of origin would be about $110/af. Phase II of the study began in 1998 and includes analyses of alternatives. Preparation of environmental documentation would begin in 2000 if the project appeared feasible. Environmental issues include flooding of a portion of the Spenceville Wildlife and Recreation Area, remediation of an abandoned copper mine, and instream flows. (The preliminary cost estimates include removal of mine tailings and site remediation in accordance with regulatory requirements.)

A 1988 YCFC&WCD study investigated a potential offstream storage project at Thurston Lake, a natural lake in the Clear Lake watershed. The Thurston Lake pump-storage project was to develop a new water supply and reduce flooding at Clear Lake communities. The project would provide storage of up to 300 taf and yield 60 taf/yr. Water would be pumped from Clear Lake into Thurston Lake during periods of high runoff, reducing downstream flood flows. Preliminary investigations suggest that substantial leakage at the site would occur and that potential water quality problems could result from high boron levels in Thurston Lake.

New Conveyance Facilities

The White Rock conveyance project would divert and convey South Fork American River water from SMUD's White Rock Penstock to EID's proposed Bray Water Treatment Plant near Diamond Springs. The diversion could be made under a 1957 contract and a 1961 supplemental agreement with SMUD, if water rights were granted by SWRCB to EDCWA and EID. The maximum quantity of water that could be diverted annually is about 40 taf. The project would not generate new water.

Groundwater Development or Conjunctive Use

Groundwater is expected to be the primary local option for increasing valley floor water supplies north of Sacramento within this Bulletin's planning horizon. Where supplies are plentiful and of adequate quality, groundwater has a cost advantage over new reservoirs. Groundwater can be developed incrementally by individual farms and domestic users, or by water purveyors. Data are not available to quantify the availability of additional groundwater development.

USBR, in cooperation with Ducks Unlimited, studied a conjunctive use project within GCID to provide long-term groundwater supply to supplement available surface water for rice straw decomposition and waterfowl habitat. In wet years, surplus Sacramento River water would be pumped into GCID's conveyance system for delivery to recharge areas. The study concluded that the project would not provide new water supply.

The Lake County Flood Control and Water Conservation District is investigating a small conjunctive use project in Big Valley near Kelseyville. This project would modify the primary spillway structure of Highland Creek Reservoir to increase storage. The conserved water would be released downstream during the spring and fall for groundwater recharge. Current estimates indicate a project yield of 400 af/yr at a cost of about $30/af. Because the yield would be less than 1 taf/yr, the project was not shown in the list of options likely to be implemented for the region.

The Colusa Basin Drainage District is investigating the Orland-Artois groundwater recharge project in southern Glenn County. Water would be delivered to an abandoned quarry via the Tehama-Colusa Canal during periods of high Sacramento River flows. Preliminary designs for this project estimate groundwater recharge capacity of 1.5 taf per season. The estimated cost of construction ranges from about $363,000 to $513,000. Evaluation of this option was deferred until project yields are determined.

Water Marketing

Intra- and inter-district water transfers have been common among CVP water rights settlement contractors on the Sacramento River. Year-to-year transfers among CVP water users in the region are not considered as new projects for Bulletin 160-98.

Water Recycling

As with conservation, recycling is not a source of new supply in the Sacramento River Region from a statewide perspective. Recycling is a potentially important water source for local purposes, but does not create new water. Several small water recycling projects serve local water needs for agricultural, environmental, and landscape irrigation purposes. In the 1995 base year, about 12.5 taf of wastewater was recycled in the region, an amount expected to increase to 14.5 taf by 2020.

Other Local Options

YCFC&WCD has filed water right applications for supplemental water from the Sacramento River for

Davis, Woodland, and Winters, and for agricultural and fishery uses at UC Davis. YCFC&WCD also filed an application to divert water from Cache Creek for groundwater recharge and to replace groundwater currently being used for irrigation. About 95 taf has been requested under the two applications.

SCWA and its member agencies are examining several surface water management projects. One potential project is an intertie connecting a Solano Irrigation District irrigation canal with the SWP's North Bay Aqueduct. Another potential SCWA project involves permanent or long-term water transfers. The Cities of Fairfield and Benicia in the San Francisco Bay Region and Vacaville in the Sacramento River Region have filed a water right application for supplemental water from the Sacramento River, seeking 12, 10.5, and 8.5 taf/yr, respectively.

Statewide Options

Statewide water supply augmentation options are discussed and quantified in Chapter 6.

Options Likely to be Implemented in the Sacramento River Region

Water supplies are not available to meet all of the region's 2020 water demands in average or drought years. Applied water shortages are forecasted to be 85 taf and 989 taf in average and drought years, respectively. Ranking of retained water management options for the Sacramento River Region is summarized in Table 8-5. Table 8-6 summarizes options that can likely be implemented by 2020 to relieve the shortages.

Costs of new reservoir projects are often prohibitive for agricultural water users, especially when the

TABLE 8-5

Options Ranking for Sacramento River Region

Option[a]	*Rank*	*Cost ($/af)*	*Potential Gain (taf)*	
			Average	*Drought*
Modify Existing Reservoirs/Operations				
Reoperate PG&E Reservoirs	L	[b]	[b]	17
New Reservoirs/Conveyance Facilities				
Dry Creek Reservoir (Lake County)	L	200	7	[b]
Thurston Lake Pump-Storage Project	M	390	[b]	60
Parks Bar Reservoir (Yuba County)	H	[b]	[b]	160
Waldo Reservoir (Yuba County)	H	110	145	109
Texas Hill Reservoir (El Dorado County)	L	[b]	[b]	9
Small Alder Reservoir (El Dorado County)	L	[b]	[b]	11
GDPUD Diversion from American River	M	[b]	8	6
Groundwater/Conjunctive Use				
New Wells (Redding, Butte, and Colusa Basins)	H	[b]	[b]	[b]
Big Valley Conjunctive Use	H	30	—	[c]
Other Local Options				
New Surface Water Diversion from Sacramento River and Cache Creek by YCFC&WCD	M	[b]	95	95
New Surface Water Diversion from Sacramento River by cities of Benicia, Fairfield, and Vacaville	M	[b]	8	8

[a] All or parts of the amounts shown for highlighted options have been included in Table 8-6.
[b] Data not available to quantify.
[c] Less than 1 taf.

supplies are needed primarily for drought year shortages. However, Yuba River onstream storage at the Parks Bar site or offstream storage at Waldo Reservoir are promising options. Parks Bar in particular could reduce the flood threat to the Yuba City-Marysville area and downstream levee systems on the Feather and Sacramento Rivers. Parks Bar could provide a drought year yield of 160 taf. Likewise, a 2.3 maf Auburn Dam would provide the Sacramento metropolitan area with substantial flood protection as well as augment the region's average year and drought year supplies by 85 taf and 51 taf, respectively. If options shown in Table 8-6 are implemented, average water year needs of the region would be fully met, although a drought year shortage would remain.

TABLE 8-6

Options Likely to be Implemented by 2020 (taf)
Sacramento River Region

	Average	*Drought*
Applied Water Shortage	**85**	**989**
Options Likely to be Implemented by 2020		
Conservation	—	—
Modify Existing Reservoirs/Operations	—	—
New Reservoirs/Conveyance Facilities[a]	—	160
Groundwater/Conjunctive Use	—	—
Water Marketing	—	—
Recycling	—	—
Desalting	—	—
Other Local Options	—	—
Statewide Options	85	51
Expected Reapplication	—	56
Total Potential Gain[b]	**85**	**267**
Remaining Applied Water Shortage	**0**	**722**

[a] Average year yield of Parks Bar Reservoir has not been quantified.
[b] With construction of Parks Bar Reservoir, average water year needs of region would be exceeded, although there is a substantial drought year shortage. In average water years, the surplus water could be available for use in other regions.

FIGURE 8-3

San Joaquin River Hydrologic Region

San Joaquin River Hydrologic Region

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Description of the Area

The San Joaquin River Region is bordered on the east by the crest of the Sierra Nevada and on the west by the coastal mountains of the Diablo Range (Figure 8-3). It extends from the Delta and the Cosumnes River watershed to the San Joaquin River watershed near Fresno. All or portions of counties within the study area include Alameda, Alpine, Amador, Calaveras, Contra Costa, El Dorado, Fresno, Madera, Mariposa, Merced, Sacramento, San Benito, San Joaquin, Stanislaus, and Tuolumne.

Summer temperatures are usually hot in the valley, and slightly cooler in the Delta and upland areas. In the winter, temperatures are usually moderate in the valley and cool in the Delta and upland areas. Annual precipitation on the valley floor ranges from about 17 inches in the north to 9 inches in the south.

TABLE 8-7

Population and Crop Acreage

	Population (thousands)	*Irrigated Crop Acreage (thousands of acres)*
1995	1,592	2,005
2020	3,025	1,935

The principal population centers are the Cities of Lodi, Stockton, Tracy, Modesto, Turlock, Merced, and Madera. The northwest part of the area, including Tracy and surrounding communities, is experiencing rapid growth as workers in the San Francisco Bay area accept the longer commute from the valley in exchange for the affordable housing. Table 8-7 shows the 1995 and 2020 population and crop acreage for the region.

TABLE 8-8

San Joaquin River Region Water Budget (taf)[a]

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	574	583	954	970
Agricultural	7,027	7,244	6,450	6,719
Environmental	3,396	1,904	3,411	1,919
Total	**10,996**	**9,731**	**10,815**	**9,609**
Supplies				
Surface Water	8,562	6,043	8,458	5,986
Groundwater	2,195	2,900	2,295	2,912
Recycled and Desalted	0	0	0	0
Total	**10,757**	**8,943**	**10,753**	**8,898**
Shortage	**239**	**788**	**63**	**711**

[a] Water use/supply totals and shortages may not sum due to rounding.

Flood protection in the Cosumnes River floodplain has historically been provided only by privately-owned levees. As shown here, rural residential development in the floodplain has relied on this limited protection.

Irrigated crop acreage in the area is forecasted to decrease, primarily due to urban development on agricultural lands. The primary crops are alfalfa, corn, cotton, deciduous fruit and nuts, grain, grapes, and pasture. Major employers include agriculture, food processing, and service sector businesses.

The area has many wildlife refuge and wetland areas. The Grasslands area, in western Merced County, is the largest contiguous block of wetlands in the Central Valley and is an important wintering ground for migratory waterfowl and shorebirds on the Pacific Flyway. Wetlands and wildlife areas include managed wetlands on Delta islands, Grassland Resource Conservation District, Los Banos Wildlife Area, Merced National Wildlife Refuge, North Grasslands Wildlife Area, San Luis National Wildlife Refuge, and Volta Wildlife Area. (In 1996, Kesterson National Wildlife Refuge and San Luis National Wildlife Refuge merged, with the combined refuge keeping the San Luis name.) Of the total wetlands in the region, about 40,700 acres are privately owned.

San Francisco's Hetch Hetchy Reservoir in Yosemite National Park. The reservoir is impounded by O'Shaughnessy Dam.

Water Demands and Supplies

Table 8-8 summarizes the region's water demands and supplies. Significant 1995-level and 2020-level water shortages occur in both average and drought years.

Surface Water

Much of the valley floor area receives its water supply from Sierra Nevada reservoirs. Some Sierra Nevada facilities—such as San Francisco's system and EBMUD's system—export water from the region to serve communities in the San Francisco Bay Region. Agricultural lands west of the San Joaquin Valley trough are mostly served by the CVP. Agricultural lands in the northwest corner of the region receive their water supply by direct diversion from Delta waterways. In the foothill and mountain areas, water is either diverted directly from streams and lakes or from local storage reservoirs and conveyance facilities.

In north to south order, the major Sierra Nevada rivers draining to the valley floor in this region are the Cosumnes, Mokelumne, Calaveras, Stanislaus, Tuolumne, Merced, Chowchilla, Fresno, and San Joaquin Rivers. The San Joaquin River, which forms the southerly boundary of the region, flows westward out of the mountains then turns north and flows in the valley trough to the Delta.

The Cosumnes River, one of the smaller Sierra Nevada rivers, is unique in that it has no significant reservoirs on its entire length, although it has local irrigation diversions. (USBR's Jenkinson Lake is located on Sly Park Creek, a tributary to the Cosumnes River.) Riparian lands along the lower river are managed as a nature preserve. Flood protection needs on the Cosumnes River were highlighted by the January 1997 floods, when numerous breaks in private levees on the valley floor caused widespread local flooding. As discussed in the following section, proposals for a managed floodway are under consideration.

The Mokelumne River system includes some hydroelectric power development in the upper watershed, but the major reservoirs are EBMUD's Camanche and Pardee Reservoirs, which develop water supply for urban communities in the San Francisco Bay Region. Woodbridge Diversion Dam on the Mokelumne River near Lodi diverts irrigation water from the river to Woodbridge Irrigation District.

The 317 taf New Hogan Reservoir, the only large reservoir on the Calaveras River, was constructed by the USACE to provide flood protection and water supply for the Stockton area. New Hogan maintains a flood control reservation of up to 165 taf. To the south of New Hogan on Littlejohns Creek, USACE constructed Farmington Reservoir to provide additional flood protection for the Stockton area. Stockton East Water District provides the City of Stockton with supply from New Hogan. As part of its New Melones water conveyance project, SEWD constructed facilities linking Farmington Reservoir on Littlejohns Creek to Goodwin Dam on the Stanislaus River.

The CVP's 2.4 maf New Melones Reservoir is the largest reservoir on the Stanislaus River. Up to 450 taf of New Melones' capacity is reserved for flood control storage. Upstream from New Melones are Beardsley Reservoir (98 taf) and Donnells Reservoir (64 taf), owned jointly by Oakdale Irrigation District and South San Joaquin Irrigation District. Downstream from New Melones are Tulloch Reservoir (67 taf) and Goodwin Reservoir (0.5 taf), also owned by OID and SSJID.

The 479 foot-high New Exchequer Dam is a rockfill dam.

SSJID also owns the nearby 35 taf Woodward Reservoir on Simmons Creek. By virtue of an agreement with USBR, OID and SSJID have the ability to store 200 taf in New Melones Reservoir. USBR has entered into contracts with SEWD and Central San Joaquin Water Conservation District for New Melones water supply. SEWD holds a contract for 75 taf/yr of interim supply from New Melones. CSJWCD has CVP contracts for 80 taf/yr, 31 taf of which is interim supply. (Interim supply in this context means supplies that are available until future in-basin demands require use of the water.) USBR must also use New Melones to meet SWRCB San Joaquin River salinity standards at Vernalis. As discussed in the following section, enactment of CVPIA and management of project water dedicated for environmental purposes have created conflicts in meeting the multiple needs that New Melones was intended to serve.

The Tuolumne River (largest of the San Joaquin River tributaries) was developed by three local agencies and the City and County of San Francisco, which constructed Hetch Hetchy Reservoir (360 taf), Lake Lloyd (268 taf) on Cherry Creek, and Lake Eleanor (26 taf) on Eleanor Creek. San Francisco also participated with Modesto and Turlock Irrigation Districts in the construction of New Don Pedro Reservoir. (The reservoir is owned by the irrigation districts, but San Francisco has a water storage agreement with them.) This 2 maf reservoir impounds supplies which are diverted into MID's and TID's canal systems at La Grange Dam. Each district has a small regulatory and offstream storage reservoir on its mainline canal downstream from La Grange—the 29 taf Modesto Reservoir and the 46 taf Turlock Lake. MID serves lands north of the Tuolumne River, and TID serves lands to the south of the river.

New Exchequer Dam impounds Merced ID's 1 maf Lake McClure, the only large water supply reservoir on the Merced River. Merced ID has two small dams downstream regulating flow into its canal system. In 1997, Mariposa Public Utility District completed a small water diversion project on the Merced River. The project included constructing 8 miles of 12-inch pipeline to convey Merced River water to the town of Mariposa and surrounding areas.

The Chowchilla and Fresno Rivers are small relative to their northern neighbors. Each river has only one significant water supply reservoir. Buchanan Dam on the Chowchilla River impounds the 150 taf Eastman Lake, and Hidden Dam on the Fresno River impounds the 90 taf Hensley Lake. Both dams were constructed by the USACE, but their operations were integrated with the CVP. Chowchilla Water District holds a water supply contract for Eastman Lake supply, while Hensley Lake supply is contracted to Madera Irrigation District.

USBR's Friant Dam on the San Joaquin River impounds the 521 taf Millerton Lake. Several hydropower reservoirs are located in the river's upper watershed above Friant; however, the only consumptive use of water associated with them is reservoir evaporation. Total system storage including Millerton Lake is 1.1 maf. CVP water released from Friant Dam is diverted into the Madera Canal to the north and the Friant-Kern Canal (to the Tulare Lake Hydrologic Region) to the south. Chowchilla and Madera Irrigation Districts are the largest CVP water contractors on the Madera Canal. Central California Irrigation District's Mendota Dam, located on the San Joaquin River at its confluence with Fresno Slough/North Fork Kings River, forms Mendota Pool, from which more than 20 agricultural water agencies divert their supplies. As mentioned in Chapter 3, CVP exchange contractors divert Delta-Mendota water from the pool to compensate for the impacts of Friant Dam construction on their prior rights to San Joaquin River water. CVP water delivered to the Mendota Pool from Tracy Pumping Plant is the source of supply for nearby USFWS national wildlife refuges.

CCID, USBR, and others have evaluated the possibility of replacing Mendota Dam with a new facility to improve the structure's operational capabilities. The original dam at this site was constructed in the 1880s by the Miller et Lux Corporation.

Surface water supplies for the part of this region west of the San Joaquin Valley trough are provided largely by the CVP, through the Delta-Mendota Canal and the San Luis Canal reach of the California Aqueduct. CVP contractors receiving DMC supplies in the northern part of the region are small agricultural water agencies. The City of Tracy, with a contract for 10 taf/yr, is the only urban CVP water user in the northern end. Oak Flat Water District is the only SWP contractor served from the California Aqueduct within this region, with a maximum contract entitlement of 5.7 taf. The California Aqueduct and DMC carry water from the Delta into San Luis Reservoir for storage and later delivery. San Luis Reservoir marks the beginning of the State-federal joint use San Luis Canal. Lands adjacent to the San Luis Canal downstream from the reservoir are part of the CVP's service area, and receive their water supply through contracts with USBR. San Luis Water District is one of the larger CVP contractors in this area, receiving its supplies through both the DMC and the SLC.

The northwest corner of this region, including the communities of Byron, Brentwood, and Thornton, receives much of its water supply via direct diversion of surface water from Delta waterways. Local water supply agencies include East Contra Costa Irrigation District and Byron-Bethany Irrigation District.

Groundwater

Groundwater is an important source of supply for the region. Many urban areas rely solely on groundwater for their supply. Groundwater overdraft occurs in much of the valley floor.

Looking upstream at the California Aqueduct (left side of photo) and the Delta-Mendota Canal (right side). Bethany Reservoir is in the upper left corner.

Local Water Resources Management Issues

Cosumnes River Flood Management

The Cosumnes River is unique among Sierra Nevada rivers for its lack of dams and related water development features. Efforts are ongoing to preserve and restore a riparian corridor along the river's path on the valley floor; the relationship of those efforts to recently emphasized floodplain management needs is being evaluated.

The Cosumnes River Preserve was established in 1987 to protect existing stands of valley oak riparian forest and to restore native habitat in flood-prone agricultural fields. The preserve, located between Sacramento and Stockton, is a cooperative effort of organizations including the Nature Conservancy, Ducks Unlimited, BLM, the Department, DFG, Wildlife Conservation Board, and Sacramento County.

The lack of upstream flood control on the Cosumnes River and the resulting periodic flooding have limited urban development in the lower watershed. Much of the agricultural land in the river's lower watershed is protected by private levees which experienced numerous breaks during the January 1997 floods. Nonstructural alternatives for flood control are being investigated, such as breaching levees and establishing levee setbacks to provide more area for flood waters to spread. Private lands have been identified for possible acquisition, subject to the willingness of sellers and the availability of funds.

Integrity of Delta Levees

Delta islands are protected by more than 1,000 miles of levees, and commonly lie 10 to 15 feet below sea level. Failure of these levees could occur as the result of earthquakes or floods, gradual deterioration, and/or improper maintenance. Composed largely of peat soils, many islands are vulnerable to seepage and subsidence. Subsidence of peat soils and settling of levee foundations increase the risk of levee failure.

Oak trees at the Cosumnes River Preserve.

EBMUD's Mokelumne River Aqueduct traverses the southern Delta.

The CALFED Bay-Delta Program identified the Delta levee system as an important resource. The program's strategy for improving its levee system integrity is to implement a Delta levee protection plan that would address levee maintenance, stabilization, subsidence reduction, emergency levee management, beneficial reuse of dredged material, and establishment of habitat corridors.

Interim South Delta Program and Temporary Barriers Project

In 1990, the Department, USBR and the South Delta Water Agency agreed to a draft settlement of a 1982 lawsuit by SDWA against the Department and USBR. The draft agreement focused on short-term and long-term actions to resolve agricultural water supply problems in the south Delta and included provisions to test and construct barrier facilities in certain south Delta channels. The testing program, referred to as the South Delta temporary barriers project, was initiated in 1991. Its objectives were short-term improvement of water conditions for the south Delta and the development of data for the design of permanent barriers. Long-term actions would be implemented through the Interim South Delta Program described in Chapter 6. ISDP's purpose is to improve water levels and circulation in south Delta channels for local agricultural diversions and to enhance the existing water delivery capability of the SWP through improved south Delta hydraulics. ISDP's preferred alternative would cost an estimated $54 million to construct and includes five components: constructing a new intake structure at Clifton Court Forebay; dredging a 4.9-mile reach of Old River; constructing flow control structures at Old River, Middle River, and Grant Line Canal; constructing an operable fish barrier at the head of Old River to benefit San Joaquin River salmon; and increasing diversions into Clifton Court Forebay to maximize pumping at Banks Pumping Plant.

Under the Department's temporary barriers program, small berms have been seasonally installed in the South Delta to improve channel water levels and water quality for Delta irrigators. A seasonal fishery barrier at the head of Old River is also installed as part of this program.

A draft EIR/EIS for ISDP was released in August 1996. The final EIR/EIS is scheduled for completion in late 1998. Meanwhile, installation and removal of temporary barriers in the south Delta continues. The number of temporary barriers installed and the installation schedule varies with hydrologic conditions and endangered species concerns.

San Joaquin County Groundwater Overdraft

Eastern San Joaquin County has a long history of declining groundwater levels. Groundwater extraction to meet agricultural and urban demands has created two pronounced pumping depressions since the late 1940s and early 1950s. The larger depression is between the Mokelumne River and the Stanislaus River. The center of this depression is east of Stockton, where groundwater levels can be more than 70 feet below sea level following the irrigation season. This pumping depression caused poorer water quality from the Delta to migrate toward the City of Stockton. Several municipal wells in west Stockton have been abandoned because of the decline in groundwater quality. The other groundwater depression is between the Cosumnes River and the Mokelumne River, extending north into Sacramento County. Groundwater levels here are more than 30 feet below sea level.

The Department recently completed a study of eastern San Joaquin County as part of a Stanislaus-Calaveras conjunctive use project. Data developed for this study suggested that the annual overdraft in the eastern San Joaquin County was about 70 taf, at a 1990 level of development. A later study completed by USBR as part of its American River water resources investigation estimated overdraft to be about 130 taf at a 2030 level of development. This study concluded that 77 taf/yr of additional supply would be needed to prevent migration of poor quality water into the Stockton area. Several overdraft management options are being considered, all of which require substituting surface water supplies for groundwater use. USBR proposed two major alternatives for providing future water supply—a conjunctive use alternative and a multipurpose Auburn Dam. In its 1998 record of decision for the study, USBR decided that it would not take further action to meet study area future water needs.

San Joaquin County filed a water rights application for an American River diversion of 322 taf in wet years via the Folsom South Canal. The existing canal would be extended, and would be used to provide supplemental supplies to reduce groundwater overdraft. San Joaquin County is also interested in participating in a conjunctive use project with EBMUD, in which EBMUD's American River CVP water would be stored in local groundwater basins prior to being diverted into the Mokelumne River Aqueduct. This approach was considered in EBMUD's 1995 water supply action plan described in the San Francisco Bay Region (Chapter 7), but was not included in EBMUD's draft EIR for conveyance of its CVP supply.

Penn Mine Remediation

Penn Mine is an abandoned copper/zinc mine first worked in the 1860s. Major activity at the site occurred in the early 1900s and during World War II. Mine stormwater runoff and acidic drainage historically entered the Mokelumne River near Campo Seco, above EBMUD's Camanche Reservoir, and caused fish kills in the river from the 1930s through the 1970s. EBMUD, in conjunction with DFG and the Central Valley RWQCB, made surface drainage improvements on the mine property and constructed Mine Run Dam in 1978 to provide storage and to control part of the mine runoff. EBMUD and the RWQCB began onsite neutralization and treatment of acid mine drainage in 1993. Litigation against EBMUD and the RWQCB by environmental organizations led to a negotiated agreement for long-term site remediation. An EIR/EIS completed in 1997 calls for excavation and removal of mine waste materials at the site, removal of Mine Run Dam, further site regrading, and revegetation.

Conservation Storage in Farmington Reservoir

USACE completed a reconnaissance study of Stockton metropolitan area flood control needs in 1997, in cooperation with the City of Stockton, San Joaquin County, and Stockton East Water District. The study evaluated modifying Farmington Reservoir to provide carryover storage. USACE also completed a conjunctive use study in 1997, evaluating Farmington Reservoir's potential to reduce groundwater overdraft in eastern San Joaquin County. Three alternatives were evaluated, including reservoir reoperation to allow year-round diversions at Rock Creek, dam modification for seasonal water storage, and dam modification for long-term water storage. (SEWD operates a Rock Creek diversion structure downstream of Farmington Dam to convey CVP water from the Stanislaus River to its service area during the irrigation season.) USACE's study showed that reoperating Farmington for year-round diversions at Rock Creek and groundwater

Burrowing owls are ground-dwelling owls found in open grassland areas and around cultivated fields. Increasing urbanization in the San Joaquin Valley will reduce the habitat available for these owls.

recharge would be the best alternatives for improving management of available water supplies from Littlejohns Creek and the Stanislaus River. If additional Stanislaus River water supplies became available to SEWD through CVP water deliveries, flood control releases from New Melones, or water marketing, storage in Farmington Reservoir might enhance other water management actions. A USACE study prepared in the 1980s suggested that Farmington Reservoir could be enlarged by as much as 160 taf for conservation storage.

SEWD identified two other actions to augment surface supplies—more groundwater recharge and a short-term transfer of 30 taf from Oakdale Irrigation District and South San Joaquin Irrigation District. The districts are preparing an EIR to market up to 30 taf/yr of their surface supply for 10 years, using existing conveyance facilities.

New Melones Reservoir Water Supply and Operations

SEWD and CSJWCD began constructing facilities in 1991 to convey 155 taf of interim CVP contract supply from New Melones Reservoir to their service areas. Much of the imported water was to be used to reduce local groundwater overdraft. Because of changes in the operation of New Melones Reservoir, little interim CVP water has been delivered to the two districts.

Enactment of CVPIA and the issuance of SWRCB Order WR 95-6, increased project water requirements for environmental purposes. Table 8-9 shows the quantities of environmental supplies provided from New Melones releases.

As discussed in Chapter 2, allocation of responsibility for meeting SWRCB Order WR 95-6 flow requirements is now pending in a water rights hearing before the Board. One alternative for meeting San Joaquin River flow requirements is the Vernalis adaptive management plan, negotiated among the river's water users for sharing their responsibilities for actions such as providing spring pulse flows. USBR is presently analyzing how VAMP implementation would affect New Melones operations.

Additionally, USBR and USFWS plan to conduct an appraisal-level temperature control study for New Melones Reservoir, as called for in CVPIA. The study will identify structural or nonstructural alternatives to control water temperatures in the river downstream from the dam.

Urban Growth Pressures from San Francisco Bay Area

San Joaquin Valley communities within commuting distance of the San Francisco Bay area are experiencing rapid growth, as persons who work in the Bay Area are attracted by lower housing costs in the Valley. During the real estate boom of the late 1980s and early 1990s, there was considerable local concern over water supply availability for proposed new towns on the western edge of the valley. At least nine new communities had been proposed in southwestern San Joaquin County, an area where additional groundwater development is constrained by both quality and quantity of supply. Few of these communities were ultimately approved by local land use planning authorities. One proposed community, New Jerusalem, was initially approved, but an amendment to the county's general plan is being processed to remove the community from the plan. Mountain House is one of the few new towns actually being developed.

TABLE 8-9

New Melones Releases for CVPIA Environmental Purposes (taf)

Water Year[a]	*Dedicated Water*	*Supplemental Water*	*Total*
1993	140.9	0.0	140.9
1994	22.7	45.1	67.8
1995	146.3	4.2	150.5
1996	113.4	0.0	113.4
1997	79.9	50.0	129.9

[a] USBR's water year is from March through February.

East County Water Supply Study

The East County Water Management Association is an organization of eleven cities and local agencies in eastern Contra Costa County—Antioch, Brentwood, Pittsburg, Byron-Bethany ID, East Contra Costa ID, Contra Costa County WA, Contra Costa WD, Diablo WD, Delta Diablo Sanitation District, Contra Costa County Sanitation District No.19, and Ironhouse Sanitary District. In response to urban growth pressures, the association conducted a study to identify and evaluate potential water management strategies for meeting the east county's future water needs. The study identified a variety of potential supplies to meet future water demands through 2040 including in-county surface water, in-county groundwater, recycled water, water transfers from outside the county, conjunctive use, and water conservation.

Because the area has access to surface water supplies through CVP contracts and local diversions, study results indicated that in-county surface water supplies could meet future water demands in average years. Shortages would occur after 2010 in drought years. Current study area groundwater use is about 14.5 taf/yr. Some areas (such as Brentwood, Discovery Bay, Bethel Island, and Hotchkiss Tract) depend entirely on groundwater. Others (such as Pittsburg, Antioch, and DWD) use groundwater to supplement surface water supplies. Groundwater quality problems in the eastern county may limit future groundwater development.

The study evaluated three water supply scenarios:

- Maximized local pooling of surface water supplies. This concept would require negotiation of new agreements for long-term transfer of surplus water supplies from two agricultural districts (ECCID and BBID) to agencies serving urban areas, and changes to the place of use/purpose of use in existing water rights.
- Continued groundwater pumping with maximized local pooling of surface water supplies.
- Continued groundwater pumping with existing levels of local pooling of surface water supplies.

The second scenario ranked the highest among the three scenarios. Spot water transfers and short-term demand reduction would provide drought year supply for this scenario. Recommendations made in the study included:

- ECWMA should commission a comprehensive groundwater study of the east county area. The study should focus on groundwater quantity and quality, and interactions between surface water and groundwater supplies. An in-county conjunctive use program to manage drought year shortages should be evaluated.
- An aquifer storage and recovery program should be investigated in the Randall-Bold water treatment plant area, in the event that ECWMA member agencies are required to limit their Delta diversions at some times of the year.
- ECWMA members should construct dual water distribution systems to facilitate future use of recycled water in all water service areas within the east county.
- Interties between water treatment plant service areas increase reliability and flexibility during emergencies. The Cities of Pittsburg and Antioch, CCWD, and DWD should discuss potential intertie benefits associated with CCWD's reliability improvement project.

Los Banos Grandes Reservoir Studies

The Department has studied potential SWP offstream storage sites south of the Delta, as described in Chapter 6. These studies led to a December 1990 *Los Banos Grandes Facilities Feasibility Report*, which recommended construction of a 1.7 maf reservoir and associated facilities on Los Banos Creek in western Merced County. The Department has placed this project on hold pending a CALFED decision on Delta

Grasslands Bypass Project Drainage Fee System

The fee system has tiered charges based on percent exceedance of monthly and annual selenium loads. These load targets are in accordance with RWQCB waste discharge requirements for agricultural drain water. If load targets are exceeded by more than 20 percent in any given year, the project may be terminated at the discretion of the USBR. An interim review of project performance will be conducted after two years of operation.

Monthly Fees for Percent Exceedance
(Dollars)

Year	*0.1 - 10%*	*10.1 - 15%*	*15.1 - 20%*	*20.1 - 25%*	*25+ %*
1	700	1,400	2,100	2,800	2,800
2	1,200	2,200	3,200	4,200	4,200
3	5,200	7,600	10,100	12,500	12,500
4	6,800	10,100	13,400	16,700	16,700
5	8,300	12,500	16,700	20,800	20,800

Annual Fees for Percent Exceedance
(Dollars)

Year	*0.1 - 5%*	*5.1 - 10%*	*10.1 - 15%*	*15.1 - 20%*	*20+%*
1	25,000	50,000	75,000	100,000	100,000
2	44,000	79,000	115,000	150,000	150,000
3	63,000	92,000	121,000	150,000	150,000
4	81,000	121,000	160,000	200,000	200,000
5	100,000	150,000	200,000	250,000	250,000

improvements. The project could then be reevaluated in consideration of those improvements and of the needs and financial capabilities of SWP contractors.

Merced Area Conjunctive Use Study

In 1993, the City of Merced and Merced Irrigation District began a two-year water supply planning process for eastern Merced County through 2030. The goals of the study were to manage groundwater, provide a reliable water supply for cities, protect and enhance the economic base of the region, protect MID's water rights, and maintain consensus for the plan. The advisory committee selected a groundwater recharge option as the preferred alternative. The groundwater basin would be operated in combination with a surface water storage and conveyance system. Studies to determine groundwater recharge quantities and locations are currently underway.

Agricultural Drainage

Significant efforts have been made to manage saline drainage water in the region. Closure of San Luis Drain has made it essential for agricultural districts to manage irrigation applications as efficiently as possible onsite until a regional solution for drainage management and disposal is developed. Some agricultural water districts in the region discharge drainage water to the San Joaquin River. Much of the salt and selenium loading in the river originate from Grassland WD's canals and from two sloughs tributary to the river—Mud and Salt Sloughs.

***Grasslands Bypass Channel Project*.** Agricultural drainage from the Grasslands Basin historically discharged to natural channels that meandered through Grasslands Water District. Flows in these channels eventually reach the San Joaquin River via Mud and Salt Sloughs. In an attempt to manage selenium loads entering the San Joaquin River, USBR is operating a 5-year Grasslands bypass demonstration project. A two-mile long channel was constructed to intercept drainage water that would otherwise flow towards Grasslands Water District. The new channel carries drainage water to the existing San Luis Drain, allowing the drainage water to discharge to the San Joaquin River. An agreement for reopening part of the San Luis Drain was signed by USBR and the San Luis and Delta-Mendota Water Authority. The agreement established a drainage incentive fee system to provide monetary incentives for reducing selenium loads discharged to the drain (see sidebar). The project became operational in 1996 and has significantly reduced salt and selenium loads entering Grasslands Water District and Salt Slough.

San Joaquin River Real Time Drainage Monitoring Program. Participants in the San Joaquin River Management Program set up a network of telemetered flow and salinity monitoring stations on the San Joaquin River. Data from the stations were linked to a flow model of the San Joaquin River and its tributaries. Information from the model was distributed to water managers by e-mail. A demonstration of the real-time monitoring effort was carried out in 1996. Grasslands Water District managers were informed that the model predicted a major increase in river flow. The district discharged a significant amount of high salinity water from its waterfowl ponds by partially draining them during the high flow event. This timed discharge resulted in better quality water in the San Joaquin River later that spring. A significant portion of the salt load from Grasslands had already passed through the system by the time agricultural diversions began. In 1997, CALFED approved Category III funding to implement a 2-year program to expand the monitoring network. The program is scheduled to begin in fall 1998.

Enlargement of Friant Dam

At 520 taf, Millerton Lake has a small storage capacity relative to the San Joaquin River's average annual flow. Enlargement of Friant Dam has been considered in the past to augment regional water supplies. Recently, needs for fishery flows and improved management of winter/spring floodwaters have been emphasized. USBR evaluated the potential yield of raising Friant Dam about 140 feet in the 1980s. The Resources Agency's 1995 SJRMP Plan recommended that enlarging Friant be studied for multipurpose use. Assembly Joint Resolution 7 in 1997 urged the federal government to promptly evaluate raising Friant Dam. Raising Friant Dam would provide water supplies for CVP water users and downstream riparian diverters, for SWRCB salinity and fishery flow requirements at Vernalis, and for dilution of agricultural drainage flows discharged to the river. These supplies would be obtained by storing surplus winter floodwaters, increasing flood protection levels for lands downstream. An issue that would need to be addressed is instream flows in the river immediately downstream from the dam, as described below.

Instream Flow Requirements Below Friant Dam

In 1988, the Natural Resources Defense Council filed a suit in U.S. District Court, seeking an injunction and declaratory judgment to prevent USBR from renewing long-term CVP water supply contracts without preparing environmental documentation and to require releases for instream uses from Friant Dam, based on Fish and Game Code Section 5937 and the public trust doctrine. The legal issues were:

- Does federal law require USBR to renew the water contracts subject to NEPA and ESA review?
- Does Fish and Game Code Section 5937 apply to federal projects?
- Has CVPIA preempted Fish and Game Code Section 5937?

The court found that CVPIA's passage had not caused the NEPA and ESA claims to be moot, nor had CVPIA preempted the plaintiff's claim under the Fish and Game Code. The court also ruled that USBR failed to comply with Section 7 of the ESA when it renewed contracts without consulting with federal wildlife regulatory agencies. The court declared all contracts renewed before CVPIA enactment invalid. The case was appealed to the Ninth Circuit Court of Appeals which upheld the District Court's ruling.

In a setting apart from the litigation, the Friant Water Users Authority, Natural Resources Defense Council, and Pacific Coast Federation of Fishermen's Associations have agreed to pursue mutually acceptable restoration activities on the San Joaquin River. Initially, the group has agreed to work on riparian habitat restoration along a 150-mile reach of the river from Friant Dam to the Merced River confluence. The objectives of the effort are to implement a plan for restoring a continuous riparian corridor in the study reach and to construct riparian habitat restoration projects.

Environmental Restoration Activities in the San Joaquin River Basin

Many restoration actions are being evaluated for the San Joaquin River system. Examples of completed actions include:

- A spawning gravel restoration project on the lower Stanislaus River was completed in 1996. This project consisted of constructing riffles and placing gravel for salmon spawning habitat at three sites, river miles 47.4, 50.4, and 50.9.
- A spawning gravel restoration project below Crocker-Huffman Dam on the Merced River was completed in 1990 and repaired in 1996.
- The Magneson Pond isolation project on the Merced River, completed in 1996, consisted of iso-

lating a gravel pit from the river and replacing spawning gravel.
- The M. J. Ruddy spawning gravel project was completed in 1993 on the Tuolumne River. Another project was completed in 1996 to construct channels above the M. J. Ruddy project, to equalize river flows to protect the spawning habitat from washout.
- The La Grange spawning riffle project, completed in 1994, consisted of constructing riffles and placing spawning gravel at three sites along the Tuolumne River.
- Funds from the SWP Four-Pumps Agreement have been used since 1994 to support one DFG warden assigned to enforce fishing regulations (reduce poaching of anadromous fish) on the San Joaquin River system.
- Temporary fish barriers have been constructed and removed on a seasonal basis every year at Hills Ferry on the San Joaquin River (downstream of the mouth of Merced River) and at the head of Old River in the Delta.
- Implementation of the CVPIA dedicated water provision and the Bay-Delta Accord have increased San Joaquin River instream flows. Spring pulse flows have also been provided.
- The 1996 Tuolumne River FERC settlement agreement among Turlock ID, Modesto ID, City and County of San Francisco, DFG, and others increased instream flows from New Don Pedro Reservoir, extended and supplemented fish monitoring requirements, and provided for non-flow fish habitat improvement measures.

Several programs are under way to provide additional fishery benefits in the region. Examples of ongoing fishery restoration projects include:
- The Category III program has contributed funding for a feasibility study of screening at Banta-Carbona Irrigation District's Main Lift Canal intake channel on the San Joaquin River.
- Plans for construction of Tuolumne Fish Hatchery are under way, although several environmental hurdles need to be addressed before a final decision is made to build the fish hatchery. Land for the hatchery was acquired by the Four-Pumps program in 1996.
- USBR is preparing plans to replace CCID's Mendota Dam. Replacement of the dam would improve fish passage and provide increased water supply to Mendota NWR.
- DFG and USFWS plan to restore the channel of a six-mile stretch of the Tuolumne River by isolating or filling gravel pits along the river and restoring spawning gravel habitat.

San Joaquin River Parkway Development

The San Joaquin River Conservancy is a State agency charged with acquiring and managing public lands within the San Joaquin River Parkway. The goal of the conservancy is to preserve and enhance the San Joaquin River's biological diversity, protect its cultural and natural resources, and provide educational and recreational opportunities to local communities.

The San Joaquin River Parkway includes the San Joaquin River and about 5,900 acres of land on both sides of the river, and extends about 22 miles from Friant Dam downstream to the Highway 99 crossing of the river. The parkway is planned as a riparian corridor with trails for hiking, horseback riding, and biking; boating access points; wildlife areas; and education areas. Approximately 1,900 acres are located in Madera County and 4,000 acres in Fresno County, of which approximately 1,600 acres are in public ownership. The conservancy, working with the Wildlife Conservation Board and the San Joaquin River Parkway and Conservation Trust, has been making land acquisitions for the parkway. Other completed projects include habitat restoration efforts and construction of 5 miles of a multiple-use recreation trail.

January 1997 San Joaquin River Region Flood Event

The January 1997 flood event was notable for its sustained rainfall intensity, the volume of floodwater, and the extent of the storm pattern—from the Oregon border down to the southern end of the Sierra. Over a three day period, warm moist winds from the southwest blew over the Sierra Nevada, pouring over 30 inches of rain on watersheds already saturated by one of the wettest Decembers on record. The volume of runoff exceeded the flood control capacity of New Don Pedro Reservoir and Millerton Lake. Although the peak flood release from New Don Pedro Dam was less than half the peak Tuolumne River inflow of 120,000 cfs, it was more than six times the downstream channel's flood control limit of 9,000 cfs. In all, thirty-six levee failures occurred along the San Joaquin River system, along with extensive damage related to high flows and inundation. Most of the damage occurred downstream of the Tuolumne River confluence.

The primary flood control issue facing the San Joaquin River Region is the lack of flood channel capacity. Channels and levees are generally designed for 50-year flood protection. Insufficient channel capacity is especially problematic in the lower San Joaquin River below the Merced River. At the lower end of the system, sediment deposition continues to raise the river bed and reduce channel capacity. Sediment deposition also promotes vegetation growth, thereby increasing channel roughness and further impeding flows. As urban development occurs on lands formerly used for agriculture, the need for higher levels of flood protection becomes more important.

The 1997 *Final Report of the Flood Emergency Action Team* to the Governor detailed several recommendations and possible actions for the San Joaquin River watershed, such as:

- A USACE reconnaissance study for the Tuolumne River to evaluate constructing a flood control impoundment on Dry Creek, restricting development in the floodplain, and developing offstream flood storage to be integrated with water supply storage.
- Acquisition of flood-prone lands (largely agricultural lands) in Stanislaus County which could be added to USFWS's San Joaquin National Wildlife Refuge. The lands would be managed to allow periodic flooding, and would provide temporary storage of flood peaks. A similar approach could be taken at the West Bear Creek Unit of the San Luis National Wildlife Refuge, where floodflows could be temporarily stored on existing refuge lands.
- Increasing the capacity of the lower San Joaquin River by measures such as channel dredging, setback levees, and improving bridge crossings.

Water Management Options for the San Joaquin River Region

Table 8-10 shows a list of options for the region, and the results of an initial screening of the options. The retained options were evaluated (Table 8A-2 in Appendix 8A) based on a set of fixed criteria discussed in Chapter 6.

Water Conservation

Urban. Urban water demand forecasts for 2020 assume that BMPs are in place; consequently, only those urban conservation efforts which exceed BMPs are considered as options. Urban water conservation options were deferred from detailed evaluation because they provide little cost-effective potential to create new water through depletion reductions.

Agricultural. The 2020 agricultural water demand forecasts assume that EWMPs are in place. As with the urban water management options, only those agricultural conservation efforts which exceed EWMPs are considered as options. Changes in irrigation management practices to attain SAEs of 76 to 80 percent would yield less than 1 taf/yr depletion reduction. Flexible water delivery, canal lining and piping, and tailwater recovery could each yield 2 taf/yr depletion reduction.

Modify Existing Reservoirs

Various agencies have looked at raising or modifying existing water supply and/or multipurpose reservoirs. USACE and SEWD are evaluating modifications or reoperation of Farmington Reservoir. Local runoff, plus New Melones or American River supplies, could be used to fill an enlarged reservoir.

New Reservoirs

Onstream Storage. Amador County Water Agency developed preliminary proposals for the Irish Hill and Volcano Reservoir projects. Irish Hill Reservoir, on Dry Creek, would serve areas near Ione with up to 23.7 taf of drought year supply. Volcano Reservoir, on Sutter Creek, would serve the communities of Sutter Creek and Amador City, in addition to providing flood control benefits for Sutter Creek. The estimated drought year supply would be 14.7 taf. Studies on both projects are inactive.

Amador County has participated in studies of the larger Middle Bar and Devils Nose reservoir projects. Alternatives for Middle Bar included a low and high dam, with drought year supplies of 12 taf and 159 taf, respectively. The larger Middle Bar Dam has been considered by EBMUD as a water supply option for its service area in the San Francisco Bay Region. The reservoir, however, could provide some local supply to Amador, Calaveras, and possibly San Joaquin Counties. A number of obstacles such as water rights, a FERC license, and financing would need to be addressed before proceeding with the project. The proposed Devils Nose project would be a hydroelectric power project with incidental water supply benefits, along the north fork and mainstem of the Mokelumne River. As con-

TABLE 8-10

San Joaquin River Region List of Water Management Options

Option	*Retain or Defer*	*Reason for Deferral*
Conservation		
Urban		
Outdoor Water Use to 0.8 ET_o	Defer	No significant depletion reductions attainable.
Indoor Water Use	Defer	No significant depletion reductions attainable.
Interior CII Water Use	Defer	No significant depletion reductions attainable.
Distribution System Losses	Defer	No significant depletion reductions attainable.
Agricultural		
Seasonal Application Efficiency Improvements	Defer	No significant depletion reductions attainable.
Flexible Water Delivery	Retain	
Canal Lining and Piping	Retain	
Tailwater Recovery	Retain	
Modify Existing Reservoirs/Operations		
Reoperate/Enlarge Farmington Reservoir	Retain	
New Reservoirs/Conveyance Facilities		
Montgomery Reservoir Offstream Storage (Merced County)	Retain	
Fine Gold Creek Offstream Storage (Madera County)	Retain	
Irish Hill Reservoir (Amador County)	Retain	
Volcano Reservoir (Amador County)	Defer	Geologic constraints.
Middle Bar Reservoir (Amador County)	Retain	
Devils Nose Reservoir (Amador County)	Retain	
Cape Cod Reservoir (Cosumnes River)	Defer	Major storage unlikely on Cosumnes River.
Bakers Ford Reservoir (Cosumnes River)	Defer	Major storage unlikely on Cosumnes River.
Mid-Valley Canal	Defer	Questionable water supply availability.
Groundwater/Conjunctive Use		
EBMUD/San Joaquin County Conjunctive Use	Defer	Under discussion; not yet defined.
Stockton East WD	Retain	
Madera Ranch	Retain	
Water Recycling		
Water recycling options	Defer	Water recycling options would not generate new water supply in this region.
Desalination		
Brackish Groundwater		
Agricultural Drainage	Defer	No present local agency plans.
Seawater		
—	—	—
Other Local Options		
—	—	—
Statewide Options		
—	—	See Chapter 6.

ceived, the project would include a 470-foot high dam at the Devils Nose site upstream from PG&E's Tiger Creek Forebay and below Salt Springs Reservoir. The reservoir would have a capacity of 145 taf. Water from the reservoir would be released via a 3-mile tunnel to a powerhouse with 41 mW of installed capacity. The proposed Devils Nose project was later merged with a proposed Cross County project, which included a conveyance system from Tiger Creek Afterbay to a 79 mW Cross County Powerhouse. Preliminary operation studies indicate a system yield of 23 to 30 taf/yr. EBMUD had also considered participation in the project. The project is currently dormant.

The Cosumnes River project was examined jointly by El Dorado, Sacramento, Amador, and San Joaquin Counties as a multipurpose project. The proposal included up to six reservoirs with hydroelectric power generation, flood control, and recreation to provide supplemental water supply benefits. Average year yield of the project was estimated at 170 taf. The project would include a 300 taf Cape Cod Reservoir and a 185 taf Bakers Ford Reservoir. The Cosumnes River is one of the few remaining undeveloped Sierra Nevada rivers. Interest in preserving the river's free-flowing characteristics and the difficulties associated with obtaining a FERC license would make large-scale water development on the river unlikely. Project planning is inactive.

Offstream Storage. USBR studied a 240 taf reservoir to store spills from Lake McClure. The proposed Montgomery Reservoir would be constructed on Dry Creek, north of the confluence of Merced River and Dry Creek, near the community of Snelling. Water would be conveyed by a two-way facility from Merced Falls Diversion Dam to Montgomery Reservoir. Releases would be used to improve instream flows and to maintain lower water temperatures for fall-run chinook salmon in the Merced River. Montgomery Reservoir would also provide additional flood protection in the San Joaquin River. About $3 million and three years would be required to complete the feasibility study and environmental review. The project, including the reservoir, conveyance, pumping, and appurtenant facilities has been estimated to cost about $135 million. The yield is estimated to be 35 taf during drought years. The drought year cost of this option is estimated to be $300/af. The project was recommended for further study in SJRMP's Plan.

In 1989, Madera Irrigation District asked USBR to investigate a 350 taf offstream storage project on Fine Gold Creek, a San Joaquin River tributary. Surplus flood flows would be pumped from Millerton Lake to the reservoir for water supply and power generation. Potential benefits also include fishery enhancements and flood protection. The average year yield is estimated to be 42 taf. According to MID's 1991 preliminary cost estimate, the project would cost in excess of $500 million. Project evaluation and investigation was estimated at $3 million, and at least 3 years would be required to complete feasibility and environmental investigations. The Fine Gold Creek project, although not originally formulated as such, is essentially an alternative to enlarging Friant Dam.

New Conveyance Facilities

Since the 1970s, several feasibility studies have been conducted on importing additional Delta supplies to reduce groundwater overdraft in the San Joaquin Valley. USBR's 1981 *A Report on the Mid-Valley Canal Feasibility Investigation* examined the possibility of constructing a canal that would supply portions of Madera, Merced, Fresno, Kings, Tulare, and Kern Counties with additional imported water.

The report suggested that water from the Delta could be conveyed to O'Neill Forebay using available capacity in the California Aqueduct. From O'Neill, a portion of the water would be delivered to Mendota Pool by an enlarged Delta-Mendota Canal, while the remainder would be conveyed to Kern County using available capacity in the California Aqueduct. To provide water to the rest of the service area, the proposal called for the construction of two branches of a new facility called the Mid-Valley Canal. The main branch would lift water from the Mendota Pool and carry it southeast to Fresno, Kings, and Tulare Counties. Madera and Merced Counties would receive their supply via a north branch, also diverting from Mendota Pool. Introduction of this additional water supply to the San Joaquin River Region could reduce groundwater overdraft and enhance wetlands, wildlife habitat, and recreation.

USBR initially identified a firm annual water supply in the Delta of approximately 500 taf available for export to the proposed service area. It was later determined that this supply was unavailable due to increased Delta outflow requirements and curtailment of proposed expansion of CVP facilities. Subsequent enactment of CVPIA and issuance of SWRCB Order WR 95-6 further limited available CVP water supply.

Groundwater Development or Conjunctive Use

Urban and agricultural water users have relied on both surface and groundwater supplies. Many local water purveyors use surface water allocations, purchased water, and excess flood water for groundwater recharge. Natural waterways, local agency canals, and State and federal conveyance facilities create opportunities for groundwater recharge, storage and conjunctive use programs.

EBMUD is continuing discussions with San Joaquin County interests for a joint groundwater storage/conjunctive use project. This option is part of EBMUD's water supply action plan described in Chapter 7; its yield is undefined at this time.

SEWD has proposed to construct a groundwater recharge facility at the northern terminus of the lower Farmington Canal. The canal would be extended about one-half mile, and a series of recharge basins constructed. The proposed facility could include up to 45 five-acre recharge basins, which could provide a combined recharge rate of 100 cfs. Estimated capital costs for the facility are about $14.25 million.

USBR and SLDMWA are investigating a proposed water banking project at Madera Ranch, southwest of the City of Madera. This storage facility would receive surplus water from the Delta for recharge. Water stored during wet years could be pumped in drought years for environmental, urban, and agricultural uses. The recharge pond area would be 3,500 acres and the potential storage capability is estimated to be about 390 taf. When available, flows in the Delta would be conveyed to Mendota Pool for diversion to the project at a rate of up to 400 cfs. Withdrawal capacity from the aquifer would be about 200 cfs, with average annual yield of about 70 taf at a cost of $226/af.

Phase I of the investigation, including geologic testing, and review of legal, financial, and environmental issues, was completed in April 1998. USBR recommends proceeding to Phase 2, pending discussions with the landowner. Two options would be examined in Phase 2. One would be a multi-year commitment to lease the facilities and services developed by the landowner. A second would be for USBR to purchase Madera Ranch property and develop a water banking facility.

Water Recycling

Most municipal and industrial water use in the San Joaquin River Region occurs on the east side of the San Joaquin Valley. Wastewater is generally spread for groundwater recharge. Wastewater that is directly or indirectly discharged to the San Joaquin River becomes available for downstream uses, including Delta outflow requirements. Because of extensive reapplication, no water recycling options within the basin qualify as new sources of supply from a regional viewpoint.

Several small water recycling projects serve local water management or wastewater disposal needs. Recycled water is currently used for golf course or pasture irrigation. The City of Stockton proposes to use recycled water for irrigation, groundwater storage, or transfer to possible future storage reservoirs such as a modified Farmington Reservoir.

Desalting

Many studies have explored saline groundwater desalting on the west side of the San Joaquin Valley. The Department has been involved in three such studies: a wastewater treatment evaluation facility in Firebaugh, a Los Banos demonstration desalting facility, and an Adams Avenue agricultural drainage research center. These studies indicated that production costs for treating agricultural drainage water were about $1,000/af. As discussed in Chapter 5, desalting costs are directly related to feedwater salinity. Today's costs for brackish groundwater treatment are in the range of $500 to $1,000/af, depending on feedwater salinity and the level of infrastructure already in place. Table 8-11 compares the salinity of various water sources.

The approximately 30 taf/yr of agricultural drainage water now collected for the Grasslands Bypass Project represents a source of brackish water available for treatment. Technology is available to treat the water, which would present a new supply to the region (as well as a means to improve San Joaquin River quality). For such a project to be feasible, a brine disposal solution would have to be found, as well as project participants. No such arrangements are currently under negotiation.

Statewide Options

Statewide water supply augmentation options are discussed and quantified in Chapter 6.

Options Likely to be Implemented in the San Joaquin River Region

Water supplies are not available to meet all of the region's 2020 water demands in average or drought years. Applied water shortages are forecasted to be

TABLE 8-11

Comparison of Salinity of Water Sources

Water Source	*Representative Weight of Solids in 1 Acre-foot of Water*
Mono Lake	110 tons
Salton Sea	60 tons
Seawater	48 tons
Brackish Groundwater (3,000 mg/L TDS)	4 tons
Colorado River at Parker Dam	1 ton
California Aqueduct at Banks Pumping Plant	500 pounds

63 taf and 711 taf in average and drought years, respectively. Ranking of retained water management options for the San Joaquin River Region is summarized in Table 8-12. Table 8-13 summarizes options that can likely be implemented by 2020 to relieve the shortages.

Reoperating Farmington Reservoir in conjunction with SEWD's plans for conjunctive use could augment supplies by 22 taf in average years and 8 taf in drought years.

Constructing Montgomery Reservoir could augment local drought year supplies by about 35 taf. As a statewide option, enlarging Friant Dam could provide 39 taf of additional average year supply for the region.

TABLE 8-12

Options Ranking for San Joaquin River Region

Option[a]	*Rank*	*Cost ($/af)*	*Potential Gain (taf)*	
			Average	*Drought*
Conservation				
Agricultural				
Flexible Water Delivery	L	1,000	2	2
Canal Lining and Piping	L	1,200	2	2
Tailwater Recovery	H	150	2	2
Modify Existing Reservoirs/Operations				
Reoperate Farmington Reservoir (surface supply only)	H	[b]	7	5
Enlarge Farmington Reservoir	M	350	17	8
New Reservoirs/Conveyance Facilities				
Montgomery Reservoir Offstream Storage	H	300	[b]	35
Fine Gold Creek Offstream Storage	M	[b]	42	[b]
Irish Hill Reservoir	L	430	33	24
Middle Bar Reservoir	L	[b]	—	159
Devils Nose Reservoir	L	[b]	[b]	25
Groundwater/Conjunctive Use				
Stockton East WD (includes reoperating Farmington)	H	100	22	8
Madera Ranch	M	230	—	70
Statewide Options				
See Chapter 6.				

[a] All or parts of the amounts shown for highlighted options have been included in Table 8-13.
[b] Data not available to quantify.

TABLE 8-13

Options Likely to be Implemented by 2020 (taf)
San Joaquin River Region

	Average	*Drought*
Applied Water Shortage	**63**	**711**
Options Likely to be Implemented by 2020		
Conservation	2	2
Modify Existing Reservoirs/Operations	—	—
New Reservoirs/Conveyance Facilities	—	35
Groundwater/Conjunctive Use	22	8
Water Marketing	—	—
Recycling	—	—
Desalting	—	—
Other Local Options	—	—
Statewide Options	39	—
Expected Reapplication	—	8
Total Potential Gain	**63**	**53**
Remaining Applied Water Shortage	**0**	**658**

FIGURE 8-4

Tulare Lake Hydrologic Region

Tulare Lake Hydrologic Region

. . .

Description of the Area

The Tulare Lake Region includes the southern half of the San Joaquin Valley and the uplands that surround it (Figure 8-4). The San Joaquin River watershed forms the northern boundary of the region, and the Tehachapi Mountains form the southern boundary. The region is bounded to the east by the Sierra Nevada crest and by the Temblor Range to the west. The climate in the valley varies from fog shrouded winters to long, hot summers. The valley typically receives about 6 to 11 inches of rainfall annually, while average precipitation in the mountains range from 12 to 36 inches, mostly in the form of snow. Most of the region's population is located on the east side of the valley. The area includes several rapidly growing cities, the largest of which are Fresno, Bakersfield, and Visalia. Other population centers include Hanford, Clovis, Tulare, Porterville, and Delano. Table 8-14 shows 1995 and 2020 populations and crop acreages.

The major employment sectors in Tulare Lake Region are based on agriculture, although the petroleum industry is important in parts of the valley's west side and in Kern County. In the sparsely populated areas on the west side of the valley, industrial water demands for petroleum recovery and production exceed municipal water demands. Most of the land area in the valley not devoted to urban and industrial purposes is used for agriculture. The predominant crop is cotton, followed by permanent orchards and vineyards. Major orchard crops are almonds and pistachios. Other major crops are alfalfa and pasture, grain, corn, and field and truck crops.

TABLE 8-14

Population and Crop Acreage

	Population (thousands)	*Irrigated Crop Acreage (thousands of acres)*
1995	1,738	3,127
2020	3,296	2,985

The Friant-Kern Canal extends southwards from Friant Dam, serving lands on the eastern side of the San Joaquin Valley. The canal is almost 152 miles long, and has a maximum capacity of 5,000 cfs.

This region receives runoff from four main river basins—the Kings, Kaweah, Tule, and Kern. The principal flood control and regulatory reservoirs for these rivers are Pine Flat Lake, Lake Kaweah, Success Lake,

The Buena Vista Aquatic Recreation Area, operated by Kern County, is located at the north end of the former Buena Vista Lakebed. The California Aqueduct (seen crossing the top of the photo, at the base of Elk Hills) skirts the lakebed's western edge.

and Isabella Lake. Major water conveyance facilities for the area include the California Aqueduct, the Friant-Kern Canal, and the Cross Valley Canal. Water districts within the region have developed an extensive network of canals, channels, and pipelines to deliver these water sources to users. Under normal conditions, the region has no natural outlet to the ocean. During high runoff years, excess water flows down the Kings River north fork channel toward Mendota Pool and on to the San Joaquin River. In the wettest years Kings River floodwaters reach the Tulare Lake via the south fork of the river. Excess runoff from the Kaweah and Tule Rivers also flows into Tulare Lakebed, flooding leveed agricultural fields.

The Tulare, Buena Vista, and Kern Lakebeds, once the region's drainage sinks, have been converted to agricultural use. Small areas in Buena Vista Lakebed are used for regulation of irrigation waters. Since 1977, excess snowmelt runoff from the Kern River has been transported to the California Aqueduct via the Kern River Intertie to alleviate flooding.

The region has several managed wetlands areas, including Pixley National Wildlife Refuge, Kern National Wildlife Refuge, and Mendota Wildlife Management Area.

Water Demands and Supplies

Table 8-15 shows regional water demands and supplies. Shortages at a 1995 level of development in average water year conditions represent the region's 820 taf of groundwater overdraft and 50 taf of shortages in Westlands Water District's service area.

Under 1995-level average hydrologic conditions, local surface supplies from the Kings, Kaweah, Tule, and Kern River systems are the most significant sources of surface water to the region. The next largest surface water source is the CVP, which delivers water through the joint State-federal San Luis Canal, Coalinga Canal, Friant-Kern Canal, and Cross Valley Canal. The other major source of surface water is the SWP.

The majority of the region's SWP supply is contracted to Kern County Water Agency. KCWA's SWP supply is distributed to fourteen of its member agencies; the largest entitlements go to Wheeler Ridge-Maricopa Water Storage District, Berrenda Mesa Water District, Belridge Water Storage District, and Lost Hills Water District. Since these four districts have limited (or no) groundwater supply, each relies almost entirely on SWP supplies to meet its water demands. Most other KCWA member agencies have Kern River, Friant-Kern Canal, Cross Valley Canal, or groundwater supplies available. Part of the City of Bakersfield's water supplies come from the SWP, via KCWA.

The Friant-Kern Canal conveys CVP supply to 24 long-term contractors in the region. Among the largest contractors for Friant-Kern supply are Arvin-Edison Water Storage District, Lower Tule River Irrigation District, and Delano-Earlimart Irrigation District. The San Luis Canal also distributes CVP supply, most of which goes to Westlands Water District. With an allocation of 1,150 taf/yr, Westlands Water District is CVP's largest contractor. Westlands supplies primarily agricultural users; however, about 5.5 taf/yr is supplied to urban users such as Lemoore Naval Air Station. (Even with a full CVP contract supply,

TABLE 8-15

Tulare Lake Region Water Budget (taf)[a]

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	690	690	1,099	1,099
Agricultural	10,736	10,026	10,123	9,532
Environmental	1,672	809	1,676	813
Total	13,098	11,525	12,897	11,443
Supplies				
Surface Water	7,888	3,693	7,791	3,593
Groundwater	4,340	5,970	4,386	5,999
Recycled and Desalted	0	0	0	0
Total	12,228	9,663	12,177	9,592
Shortage	**870**	**1,862**	**720**	**1,851**

[a] Water use/supply totals and shortages may not sum due to rounding.

Westlands purchases about 200 taf/yr from other sources to meet its growers' normal crop needs.)

Arvin-Edison Water Storage District and KCWA entered into agreements in 1974 for participation in the Cross Valley Canal. AEWSD also entered into water exchange agreements with ten agencies in the Friant-Kern Canal service area. The exchange water is delivered through the California Aqueduct and the Cross Valley Canal to AEWSD facilities. AEWSD receives 128 taf annually of exchange water and makes available to exchange entities the first 174 taf of its Class I and Class II CVP entitlements from the Friant-Kern Canal.

Including overdraft, 2020 average year groundwater extraction is forecasted to be about 5.1 maf for the region. Since groundwater provides a buffer for fluctuating year-to-year surface supplies, its availability is of great importance to the region. Although urban use is expected to increase about 410 taf by 2020, groundwater overdraft is expected to decrease 150 taf (from 820 taf to 670 taf) within the planning horizon due to declining agricultural use. Most of the urban water use in the region is served from groundwater, although the Cities of Fresno and Clovis are taking actions to begin treating surface water supplies.

Local Water Resources Management Issues

Groundwater Overdraft

Annual fluctuations in groundwater levels vary with availability of surface water. About 70 percent of

The Kern River near Oildale, at the edge of the Sierra Nevada foothills.

The former Tulare Lakebed has been reclaimed for farming. Floodwaters from the Sierra now reach the lakebed only in the wettest years.

the region's overdraft occurs in the Kings-Kaweah-Tule Rivers planning subarea. Urban water demands in the subarea are met almost exclusively by groundwater. Agricultural development in the subarea includes 645,000 acres of permanent crops. Overdraft in the region is mitigated to a certain extent by planned recharge programs, over-irrigating crops in wet years, and allowing seepage from unlined canal systems.

Groundwater Banking Programs

The Department, in cooperation with KCWA and local water districts, began developing the Kern Water Bank conjunctive use program in 1985 as a component of the SWP. The proposed KWB program consisted of eight separate projects or elements. The Kern Fan Element was to be constructed on lands owned by the Department. Pursuant to the SWP's Monterey Amendment, the KFE was subsequently transferred to the Kern Water Bank Authority.

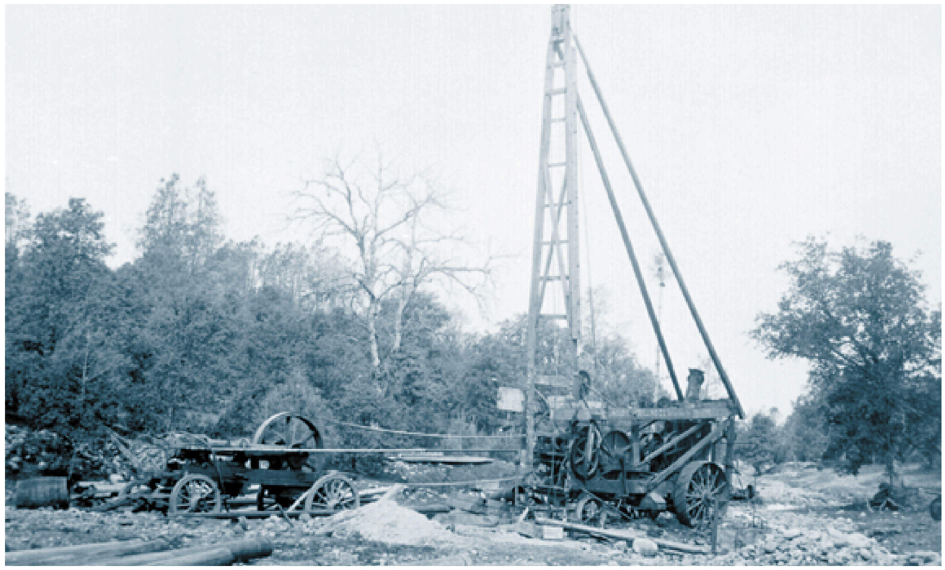
Semitropic Water Storage District is participating in an in lieu groundwater banking project with MWDSC, SCVWD, ACWD, and Z7WA. This project involves expanding SWSD's conveyance system, so that areas normally relying on groundwater will have surface water available in wet years. SWSD water users will receive excess surface water from its banking partners' SWP supply in wet years. In drier years, SWSD would release its SWP allocation to its partners and, if necessary, pump groundwater back into the California Aqueduct to meet its obligations. The maximum storage capacity of SWSD's groundwater basin is 1 maf. Commitments have been made for about 80 percent of the project. The remaining 200 taf of storage is available to other potential banking partners or for expansion of commitments by existing partners.

MWDSC and Arvin-Edison Water Storage District completed negotiations on a 350 taf water banking/exchange program. Water banked in this program would be provided by both AEWSD and MWDSC. AEWSD would provide up to 150 taf of its supplies to MWDSC, depending on the quantity of new water yield developed by the program. MWDSC would provide the remaining portion of the water supplies from its own sources. AEWSD will construct 500-600 acres of new infiltration basins, 15 new extraction wells, and a 4.5 mile pipeline intertie with the California Aqueduct.

Agricultural Drainage

Much of the Tulare Lake Region's agriculturally

California Aqueduct in foreground with the gates at the Kern River Intertie, which was constructed to allow Kern River floodwaters to enter the aqueduct. (In 1995, the intertie was operated in reverse under emergency conditions, to protect the aqueduct from overtopping due to upstream flood inflows.) The design flow for the intertie is 3,500 cfs.



Advances in well drilling technology were key to large-scale development of groundwater in the Central Valley. This photo show the state of technology circa 1914.

Courtesy of Water Resources Center Archives, University of California, Berkeley

rich westside must contend with high groundwater tables and drainage problems. Typically, applied irrigation water builds up above semi-impervious clay layers, creating a shallow, unconfined aquifer of generally poor to unusable quality. Efforts of the San Joaquin Valley Interagency Drainage Program to address westside drainage problems are described in Chapter 4.

Arroyo Pasajero and Other Westside Cross-Drainages

The Department, USBR, and USACE are completing a 5-year feasibility study to identify long-term solutions to flooding and sedimentation problems threatening the California Aqueduct at its crossing of Arroyo Pasajero. The SWP's problems at this uncontrolled ephemeral stream are similar to those being experienced by others in the area. Arroyo flows during the 1995 flood washed out a bridge on Interstate 5, resulting in the deaths of 7 motorists. Long-term solutions currently under consideration for the SWP include a substantial increase in floodwater and sediment storage. The Department is also investigating a similar problem 20 miles north of Arroyo Pasajero at the Cantua Creek stream group. These streams present similar flooding and sedimentation problems for the Aqueduct.

Kings River Fishery Restoration Actions

Kings River Conservation District and the Kings River Water Association are cooperating with USACE in a feasibility study of Kings River fishery habitat improvements associated with USACE's Pine Flat Dam. The study is evaluating impacts of original project construction, riparian habitat restoration downstream of the dam, potential operating strategies to minimize lake level fluctuations during spawning periods, and temperature control methods for trout populations. One component of the study includes a new multi-level intake structure for the reservoir, to better manage downstream river temperatures. USACE is also implementing a related project to install a bypass at the dam's powerplant so that releases can be made through the existing penstocks when the turbines are not in operation. This project will provide temperature control for the downstream trout fishery.

Water Management Options for the Tulare Lake Region

Table 8-16 shows a list of options for the region, and the results of an initial screening of the options. The retained options were evaluated (Table 8A-3 in Appendix 8A) based on a set of fixed criteria discussed in Chapter 6.

Water Conservation

Urban. Urban water demand forecasts for 2020 assume that BMPs are in place; consequently, only those urban conservation efforts which exceed BMPs are considered as options. Urban conservation options were deferred from evaluation because they provide little cost-effective potential to create new water through depletion reductions in the Tulare Lake Region.

TABLE 8-16

Tulare Lake Region List of Water Management Options

Option	*Retain or Defer*	*Reason for Deferral*
Conservation		
Urban		
Outdoor Water Use to 0.8 ET_o	Defer	No significant depletion reductions attainable.
Indoor Water Use	Defer	No significant depletion reductions attainable.
Interior CII Water Use	Defer	No significant depletion reductions attainable.
Distribution System Losses	Defer	No significant depletion reductions attainable.
Agricultural		
Seasonal Application Efficiency Improvements	Retain	
Flexible Water Delivery	Defer	Already highly developed; no significant depletion reductions attainable.
Canal Lining and Piping	Defer	No additional depletion reductions attainable.
Tailwater Recovery	Defer	No additional depletion reductions attainable.
Modify Existing Reservoirs/Operations		
Enlarge Pine Flat Dam	Retain	
Enlarge Lake Kaweah (Terminus Dam)	Retain	
Enlarge Success Lake	Defer	Being enlarged for flood control, not water supply.
New Reservoirs/Conveyance Facilities		
Rodgers Crossing Project	Defer	Segment of Kings River designated as a special management area, under the Wild and Scenic Rivers Act.
Mill Creek Reservoir	Defer	Cost too high.
Mid-Valley Canal	Defer	Questionable water supply availability.
Groundwater/Conjunctive Use		
City of Clovis Expansion of Recharge Facilities	Retain	
Kaweah River Delta Corridor Enhancement Recharge	Defer	Minimal yield.
Kern Water Bank Authority Recharge Facilities	Retain	
Buena Vista WSD Recharge	Retain	
Cawelo Water District Recharge	Retain	
Water Marketing		
SLDMWA Internal Reallocation of CVP Supply	Retain	
Water Recycling		
Water recycling options	Defer	Water recycling options would not generate new water supply.
Desalting		
Brackish Groundwater		
Agricultural Drainage	Defer	No present local agency plans.
Seawater		
—	—	—

TABLE 8-16

Tulare Lake Region List of Water Management Options (continued)

Option	*Retain or Defer*	*Reason for Deferral*
Other Local Options		
—	—	—
Statewide Options		
—	—	See Chapter 6.

Agricultural. The 2020 agricultural water demand forecasts assume that EWMPs are in place. As with the urban water management options, only those agricultural conservation efforts which exceed EWMPs are considered as options.

Improving irrigation scheduling would increase SAE to 76 percent, reducing depletions by 7 taf/yr. System improvements including pressure regulation and filtration and better irrigation scheduling would increase SAE to 78 percent and reduce depletions by 12 taf/yr. To reach 80 percent SAE, conversion to more efficient irrigation systems would be needed, reducing depletions by 17 taf/yr. Flexible water delivery is deferred because existing delivery systems in the region are highly developed, and further improvements would result in little depletion reduction at a high cost. Canal lining is deferred because areas in the region where lining and piping could reduce water depletions (the west side of the valley) already have such improvements. Tailwater recovery is not a significant future option because extensive tailwater recovery already occurs in the region.

Modifying Existing Reservoirs and New Reservoirs

Additional Storage in Kings River Basin. Pine Flat Dam, completed in 1954, is a USACE flood control project that also provides supplemental water supply to Kings River Basin water users. In 1974, the Kings River Conservation District commissioned a master plan to evaluate local solutions to flood control and water supply problems. This study identified three projects to improve storage and regulate Kings River flows. In order of cost-effectiveness, they were enlargement of Pine Flat Dam, Rodgers Crossing project, and Mill Creek project.

A 1989 USACE reconnaissance study investigated Kings River Basin flood control and water supply opportunities. After screening several alternatives, enlargement of Pine Flat Dam was retained for further study. A 15-foot increase of gross pool height appeared to have the best benefit/cost ratio. This alternative would increase the reservoir's storage capacity about 92.8 taf and provide an average of 12.7 taf/yr of

Flooding from Arroyo Pasajero spreads out as sheetflow over the lower portion of the Arroyo's alluvial fan. The Arroyo's periodic flooding closes State Highway 269 and threatens the integrity of the California Aqueduct.

Westlands Water District Distribution System

Westlands Water District is the CVP's largest water contractor. Among Central Valley agricultural water districts, WWD is unique both for its size (almost 1,000 square miles) and for its irrigation distribution system—which is based entirely on pipelines, rather than open canals. Altogether the distribution system has over 1,000 miles of buried pipe, varying in diameter from 10 to 96 inches. The basic design flow rate for each farm delivery system is 1 cfs per 80 acres.

additional average year yield. The major benefit would be flood control. The alternative was not economically feasible at the time. The Rodgers Crossing project, a proposed reservoir located upstream of Pine Flat Reservoir, was rendered infeasible when the damsite was included in a river segment subsequently designated as wild and scenic.

Mill Creek is a small, uncontrolled, intermittent stream tributary to the Kings River below Pine Flat Dam. The creek's 77,000 acre watershed produces an average annual runoff of approximately 30 taf. Heavy local rainstorm events occasionally result in flows in excess of 10,000 cfs, high enough to cause damage along the Kings River channel downstream. In the 1970s, USACE studied the feasibility of constructing a dam on Mill Creek, just upstream of its confluence with the Kings River. The benefits of such a project would include additional flood protection, water conservation, power generation, and recreation. The proposed reservoir would have a capacity in excess of 600 taf and would be directly linked with Pine Flat Reservoir by a tunnel, allowing the reservoirs to be operated conjunctively. In wet years, Kings River water that would flood agricultural lands in Tulare Lakebed could be diverted and stored in Mill Creek Reservoir. USACE's studies indicated that the project was not economically viable.

Additional Storage in Kaweah River Basin. Lake Kaweah is located on the Kaweah River about 20 miles east of Visalia. Terminus Dam, completed in 1962 by the USACE, provides flood protection and irrigation water supply to downstream users. A draft USACE feasibility report investigated continuing flood control problems and water resource needs on the Kaweah River and identified three alternative solutions—enlarge Terminus Dam, construct a flood detention dam on Dry Creek above Lake Kaweah, or construct a reservoir on Dry Creek with a connecting tunnel to Lake Kaweah. Upon further study, only Terminus enlargement was considered feasible due to environmental and cultural impacts of facilities on Dry Creek. Enlarging Terminus Dam would involve raising the spillway, increasing flood control storage by about 42 taf. On an average annual basis, the study estimates that in-basin irrigation water supply would increase by 8.4 taf through better regulation of flood flows. Congress authorized enlargement of Terminus Dam in the Water Resources Development Act of 1996. Construction is tentatively scheduled to begin in 2000 and to be completed in 2002. The Terminus Dam enlargement is projected to have a capital cost of about $37 million.

Additional Storage in Tule River Basin. In response to flood protection problems experienced during large storms, Tulare County and the Tule River Association requested USACE to consider providing additional storage in the basin by enlarging Success Lake. Success Lake is estimated to provide about a 55-year level of protection for the City of Porterville. A 1992 reconnaissance study found that a 10-foot increase in gross pool height with a corresponding increased storage capacity of 28 taf was the preferred alternative. The enlargement would provide a 100-year level of flood protection and increase irrigation water supply by 2.8 taf annually. USACE entered into a feasibility cost-sharing agreement with Lower Tule River ID for updating the 1992 study and for preparing an EIR/EIS. The draft feasibility study and EIR/EIS are scheduled to be released in 1998. Since the reservoir enlargement's primary purpose is flood control, the project is not considered further in this chapter as a water supply option.

New Conveyance Facilities

The Mid-Valley Canal and the constraints on its implementation were discussed in the San Joaquin River Hydrologic Region. The conveyance project is presently not feasible because it has no water supply.

Groundwater Development or Conjunctive Use

Many water districts and cities in the region use excess surface water allocations, purchased water, and floodwater for groundwater recharge. Local distribution systems and CVP and SWP conveyance facilities create opportunities for agencies to exchange and purchase surface supplies for groundwater recharge. Opportunities for groundwater recharge or conjunctive use projects are limited in some parts of the region, such as the west side of the valley, because of near-surface poor quality groundwater.

The City of Clovis has an agreement with Fresno Irrigation District entitling the city to an average of 14.9 taf of Kings River water and 1.1 taf of Class II water from Millerton Lake. Currently, the city's surface water supply is used exclusively for groundwater recharge. Existing facilities can recharge approximately 7.8 taf/yr. As the city expands into surrounding agricultural lands and acquires additional water supplies, average annual surface supplies are expected to increase to 30.1 taf by 2015. With this increase in supply, the city is developing new recharge sites to recharge an additional 3.5 taf/yr.

Visalia plans to develop new wells as its water needs grow, estimating that 15 additional wells will be necessary to meet average year water demands in 2020. Visalia is also working with the Kaweah Delta Water Conservation District and Tulare County on a Kaweah River Delta corridor study to investigate multiple use sites for groundwater recharge, floodwater management, and habitat restoration. The study is currently in the feasibility stage. The project would include recharge basins with a storage capacity of about 750 af. A demonstration project has been proposed to model integration of the multiple uses.

Pursuant to Monterey Agreement contract amendments and the transfer of the KFE, KWBA has been operating about 3,000 acres of recharge basins under an emergency CEQA exemption and an interim ESA Section 7 consultation, allowing the authority to recharge winter floodwaters. Since May 1995, KWBA has recharged about 700 taf on behalf of its member agencies. KWBA prepared a 75-year habitat conservation plan/natural community conservation plan covering the use of the 20,000-acre property. The HCP sets aside about 10,000 acres for habitat purposes. ESA listed species found in the project area include the kit fox, kangaroo rat, and blunt-nosed leopard lizard. KWBA plans to expand the recharge facility to 6,800 acres. The cost for this expansion, including additional conveyance structures, is about $30 million.

Buena Vista Water Storage District is planning to construct up to 200 acres of additional facilities to store excess Kern River water. The new facilities are estimated to cost about $250,000.

Cawelo Water District recently entered into an agreement with Texaco Inc. for water generated during oil recovery. A significant amount of water is trapped in oil bearing zones. The quality of much of this water is good, once it has been separated from the oil. The agreement negotiated by Texaco and CWD made possible the construction of an 8 mile pipeline to carry as much as 25 taf/yr of this water to the district. Additionally, Cawelo purchased almost 90 acres of land straddling Poso Creek in 1996. The district will allow the land to be flooded during high flows to enhance groundwater recharge. Work will begin shortly on a feasibility study to address the district's long-term plans for more recharge facilities.

Looking at the upstream face of Terminus Dam, with the outlet works structure in the background.

Water Marketing

As described in Chapter 6, the San Luis and Delta-Mendota Water Authority has negotiated an internal reallocation of its members' CVP supplies with USBR. Under this agreement, participating member agencies of SLDMWA may exchange wet year supplies for drought year supplies with SCVWD. Westlands Water District has initiated a short-term buy-back program for its water users who wish to sell their unused allocation or other supply to the district. The buy-back program would be implemented only if WWD had not finalized transfers from other sources to meet its total supplemental water needs. Marketing under this program would be intra-regional. WWD is also currently preparing a draft programmatic EIR on purchasing and transferring up to 200 taf/yr to its service area. Because details on proposed transfers are not yet available, this program is not included in the water management options evaluation.

Urban and agricultural development have reduced the habitat available to the San Joaquin Valley kit fox, a listed species.

Water Recycling and Desalting

In the Tulare Lake Region, most urban water use occurs on the east side of the San Joaquin Valley. Wastewater produced from urban use is generally recharged to groundwater basins where it reduces groundwater overdraft, or is extracted for other uses. No water recycling projects in the region qualify as new sources of supply from a regional perspective. As discussed in the San Joaquin River Region section, options for desalting agricultural drainage water were deferred for the Tulare Lake Region.

Statewide Options

Statewide water supply augmentation options are discussed and quantified in Chapter 6.

Options Likely to be Implemented in the Tulare Lake Region

Water supplies are not available to meet all of the region's 2020 water demands in average or drought years. Applied water shortages are forecasted to be 720 taf and 1,851 taf in average and drought years, respectively. Ranking of retained water management options for the Tulare Lake Region is summarized in Table 8-17. Table 8-18 summarizes options that can likely be implemented by 2020 to relieve the shortages.

Improvements in agricultural irrigation demand management will likely occur over the entire region, although much of the region is already efficient in its agricultural water management. Areas where further efficiency improvements will have the most effect will be where agricultural lands overlie shallow groundwater of poor quality. The west side of the valley will receive the most benefits from irrigation water conservation practices. These practices could reduce depletion annually by 17 taf if system upgrades are employed to increase SAEs to 80 percent.

The portion of the region's 2020 water shortage attributable to groundwater overdraft is estimated to be 670 taf. Several plans exist to expand recharge facilities or to construct new ones.

The region's local surface supplies have already been extensively developed and further development opportunities are limited. Modification of existing facilities through the enlargement of Lake Kaweah and Pine Flat Lake could produce about 21 taf/yr of additional yield for irrigation supply.

Water Marketing—WaterLink Program

In 1996, an electronic water marketing system went on-line in Westlands Water District. The WaterLink system was designed by the University of California Berkeley and Davis campuses, the Natural Heritage Institute, and farmers and water district staff. The project was funded by a grant from USBR. WaterLink allows district growers to use their home computers to post and read bids, access information on average prices and trading volumes, and negotiate transactions. WaterLink can also be used to schedule water deliveries and eventually to obtain water account balances, a feature that will enable water users to manage their water supplies more effectively. WaterLink is an intra-net system, available only to district growers, to allow them to make internal trades of in-district supplies.

TABLE 8-17

Options Ranking for Tulare Lake Region

Option[a]	*Rank*	*Cost ($/af)*	*Potential Gain (taf)*	
			Average	*Drought*
Conservation				
Agricultural				
Seasonal Application Efficiency Improvements (76%)	H	100	7	7
Seasonal Application Efficiency Improvements (78%)	M	250	12	12
Seasonal Application Efficiency Improvements (80%)	M	450	17	17
Modify Existing Reservoirs/Operations				
Enlarge Pine Flat Dam	H	470	13	[b]
Enlarge Lake Kaweah (Terminus Dam)	H	370	8	[b]
Groundwater/Conjunctive Use				
City of Clovis Expansion of Recharge Facilities	H	280	—	11
Kern Water Bank Authority Recharge Facilities	H	60	—	339
Buena Vista Water Storage District Recharge	H	75	—	29
Cawelo Water District Water Banking Project	H	50	—	13
Water Marketing				
SLDMWA internal reallocation of CVP supply	H	[b]	10	—
Statewide Options				
See Chapter 6.				

[a] All or parts of the amounts shown for highlighted options have been included in Table 8-18.
[b] Data not available to quantify.

TABLE 8-18

Options Likely to be Implemented by 2020 (taf)
Tulare Lake Region

	Average	*Drought*
Applied Water Shortage	**720**	**1,851**
Options Likely to be Implemented by 2020		
Conservation	17	17
Modify Existing Reservoirs/Operations	21	—
New Reservoirs/Conveyance Facilities	—	—
Groundwater/Conjunctive Use	—	392
Water Marketing	10	—
Recycling	—	—
Desalting	—	—
Other Local Options	—	—
Statewide Options	466	387
Expected Reapplication	4	187
Total Potential Gain	518	983
Remaining Applied Water Shortage	**202**	**868**

8A

Options Evaluations for Interior Regions

TABLE 8A-1

Options Evaluation Sacramento River Region

Option	Evaluation Scores							
	Engineering	*Economics*	*Environ-mental*	*Institutional/ Legal*	*Social/ Third Party*	*Other Benefits*	*Overall Score*	*Rank*
Modify Existing Reservoirs/Operations								
Reoperate PG&E Reservoirs	3	3	2	0	1	0	**9**	**L**
New Reservoirs/Conveyance Facilities								
Dry Creek Reservoir (Lake County)	3	3	2	1	3	0	**12**	**L**
Thurston Lake Pump-Storage Project	2	3	2	2	2	2	**13**	**M**
Parks Bar Reservoir (Yuba County)	3	2	2	3	3	4	**17**	**H**
Waldo Reservoir (Yuba County)	3	2	2	3	3	4	**17**	**H**
Texas Hill Reservoir	3	2	2	2	2	1	**12**	**L**
Small Alder Reservoir	3	2	2	2	2	1	**12**	**L**
GDPUD Diversion from American River	3	3	3	3	3	0	**15**	**M**
Groundwater/Conjunctive Use								
New Wells (Redding, Butte, and Colusa Basins)	4	4	3	4	3	0	**18**	**H**
Big Valley Conjunctive Use	3	4	3	2	3	2	**17**	**H**
Other Local Options								
New Surface Water Diversion from Sacramento River and Cache Creek by YCFC&WCD	3	3	2	2	3	0	**13**	**M**
New Surface Water Diversion from Sacramento River by Cities of Benicia, Fairfield, and Vacaville	3	3	2	2	3	0	**13**	**M**
Statewide Options								
See Chapter 6.								

TABLE 8A-2

Options Evaluation San Joaquin River Region

Option	*Evaluation Scores*							*Rank*
	Engineering	*Economics*	*Environ-mental*	*Institutional/ Legal*	*Social/ Third Party*	*Other Benefits*	*Overall Score*	
Conservation								
Agricultural								
Flexible Water Delivery	3	0	3	3	2	1	**12**	**L**
Canal Lining and Piping	3	0	3	3	2	1	**12**	**L**
Tailwater Recovery	3	4	3	3	3	1	**17**	**H**
Modify Existing Reservoirs/Operations								
Reoperate Farmington Reservoir	3	3	3	2	3	3	**17**	**H**
Enlarge Farmington Reservoir	2	3	3	2	3	3	**16**	**M**
New Reservoirs/Conveyance Facilities								
Montgomery Reservoir Offstream Storage	3	3	3	2	3	3	**17**	**H**
Fine Gold Creek Offstream Storage	3	2	2	2	3	3	**15**	**M**
Irish Hill Reservoir	3	2	2	1	3	1	**12**	**L**
Middle Bar Reservoir	3	1	1	2	2	2	**11**	**L**
Devils Nose Reservoir	3	1	1	2	2	1	**10**	**L**
Groundwater/Conjunctive Use								
Stockton East WD	3	3	4	2	3	3	**18**	**H**
Madera Ranch	3	3	4	2	2	2	**16**	**M**
Statewide Options								
See Chapter 6.								

TABLE 8A-3

Options Evaluation Tulare Lake Region

Option	*Evaluation Scores*							*Rank*
	Engineering	*Economics*	*Environ-mental*	*Institutional/ Legal*	*Social/ Third Party*	*Other Benefits*	*Overall Score*	
Conservation								
Agricultural								
SAE Improvements (76%)	3	4	3	4	3	1	**18**	**H**
SAE Improvements (78%)	3	3	3	3	2	1	**15**	**M**
SAE Improvements (80%)	2	3	3	2	2	1	**13**	**M**
Modify Existing Reservoirs/Operations								
Enlarge Pine Flat Dam	3	3	3	4	3	2	**18**	**H**
Enlarge Lake Kaweah (Terminus Dam)	3	3	3	4	3	3	**19**	**H**
Groundwater/Conjunctive Use								
City of Clovis Expansion of Recharge Facilities	4	3	4	3	4	0	**18**	**H**
Kern Water Bank Authority Recharge Facilities	4	4	3	3	4	0	**18**	**H**
Buena Vista Water Storage District Recharge	4	4	3	4	3	0	**18**	**H**
Cawelo Water District Recharge	4	4	4	4	4	0	**20**	**H**
Water Marketing								
SCVWD/SLDMWA Reallocation	4	4	4	4	3	0	**19**	**H**
Statewide Options								
See Chapter 6.								

9

Options for Meeting Future Water Needs in Eastern Sierra and Colorado River Regions of California

This chapter covers the North and South Lahontan Hydrologic Regions in the eastern Sierra, and the Colorado River Hydrologic Region (Figure 9-1). These sparsely populated regions constitute 33 percent of the State's land area.

FIGURE 9-1
Eastern Sierra and Colorado River Hydrologic Regions

USBR's Parker Dam on the Colorado River.

FIGURE 9-2

North Lahontan Hydrologic Region

North Lahontan Hydrologic Region

. . .

Description of the Area

The North Lahontan Region has two planning subareas (Figure 9-2), the Lassen Group and the Alpine Group. The Lassen Group PSA consists of Lassen and Modoc Counties. This high desert area is arid, with relatively flat valley areas adjacent to mountains. Valley elevations are about 4,000 and 4,500 feet for Honey Lake and Surprise Valleys. The Warner Mountains, which form the western boundary of Surprise Valley, range in elevation from about 7,000 to more than 9,000 feet. Annual precipitation ranges from as little as 4 inches in Surprise Valley in Modoc County to over 50 inches in the mountains of the Susan River watershed in Lassen County. The Alpine Group PSA includes parts of Sierra, Nevada, Placer, El Dorado, Alpine, and Mono Counties. The subarea includes the Truckee, Carson, and Walker River drainages. These rivers originate at high elevations on the eastern slopes of the Sierras and flow to terminal lakes or desert sinks in Nevada. Annual precipitation ranges from 8 inches in the valleys to more than 70 inches in the Sierra (much of this amount is snow).

The Lassen Group PSA is rural and sparsely populated. The City of Susanville is the largest population center in the subarea. In the Alpine PSA, more than 90 percent of the population lives in the Lake Tahoe and Truckee areas. The City of South Lake Tahoe and Town of Truckee are the largest communities in the subarea. The Tahoe-Truckee region has many part-time residents and visitors during the summer and winter recreational seasons, reflecting the importance of tourism to the area. Tourism and related recreational opportunities are vital to the region's economy and to much of the region's service-sector employment.

Cattle ranching is the main agricultural land use in the Lassen Group PSA. Irrigated land acreage is small (less than 4 percent of the region's land area). Commercial crop production is limited because of the short growing season. Pasture and alfalfa are the dominant irrigated crops. About 75 percent of the region's irrigated land is in Modoc and Lassen Counties, and most of the remainder is in the Carson and Walker River Basins in Alpine and Mono Counties. Irrigated lands in the Carson and Walker River Basins are almost exclusively pasture at elevations above 5,000 feet. Most of the uplands areas are federally owned and managed as national forest lands. Table 9-1 shows population and crop acreage for the region.

TABLE 9-1

Population and Crop Acreage

	Population (thousands)	*Irrigated Crop Acreage (thousands of acres)*
1995	84	161
2020	125	165

Water Demands and Supplies

The water budget for the North Lahontan Region is shown in Table 9-2. Agricultural water demands are generally met with local surface water supplies, when available. Throughout the northern portions of the region, runoff is typically scant and stream flow decreases rapidly after the snowpack melts in the higher elevations.

No major changes in North Lahontan Region water use are anticipated within the Bulletin's planning horizon. Irrigated agriculture is constrained by climate

A majority of the land in the North Lahontan Region is owned by the federal government, managed primarily by USFS and BLM. National forest lands provide habitat for many species of wildlife, including some of California's larger mammals.

and by economically available water supplies. A small amount of agricultural expansion is expected, but only in areas that can support minor additional groundwater development. Likewise, the modest need for additional municipal supplies can be met by expanding present surface systems or increasing groundwater use. Drought year shortages are caused by a reduction in surface water supplies for agriculture and an increase in unit crop irrigation requirements for pasture and alfalfa. No urban water shortages are forecast.

Most of Susanville's water supply comes from groundwater and from Cady and Bagwell Springs. The city has not experienced any water supply shortages nor does it expect any shortages within the next 20 years.

The Honey Lake Valley Groundwater Basin is an interstate groundwater basin. The California portion of the basin is about 45 miles long and 10 to 15 miles wide. Groundwater extracted from the basin is used mainly for irrigation. Groundwater use in the basin appears to be near the basin's perennial yield. A 1987 agreement among the Department, the State of Nevada, and USGS resulted in a study of the groundwater flow system in eastern Honey Lake Valley. Upon conclusion of the study in 1990, the Nevada State Engineer ruled that only about 13 taf could be safely transferred from Nevada's portion of the basin for proposed new water development for Washoe County in Nevada. The Nevada out-of-basin transfer project has not been implemented.

The 7,840-acre Honey Lake Wildlife Area is on the north edge of Honey Lake about 20 miles southeast of Susanville. The HLWA consists of intensively managed wetlands, cropped fields, and uplands adjacent to the 60,000-acre Honey Lake. It provides important habitat for migratory waterfowl, sandhill

TABLE 9-2

North Lahontan Region Water Budget (taf)[a]

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	39	40	50	51
Agricultural	530	584	536	594
Environmental	374	256	374	256
Total	**942**	**880**	**960**	**901**
Supplies				
Surface Water	777	557	759	557
Groundwater	157	187	183	208
Recycled and Desalted	8	8	8	8
Total	**942**	**752**	**950**	**773**
Shortage	**0**	**128**	**10**	**128**

[a] Water use/supply totals and shortages may not sum due to rounding.

TABLE 9-3
Major Reservoirs in the Truckee River Basin in California

Reservoir	*Owner*	*Operator*	*Usable Storage (taf)*	*Construction Date[a]*	*Height (Feet)*	*Drainage Area (Square Miles)*
Tahoe	Sierra Pacific Power Company[b]	Truckee-Carson Irrigation District	744.6	1913	18	506
Donner	Sierra Pacific Power Company/ Truckee-Carson Irrigation Dist.	Sierra Pacific Power Company	9.5	1927	14	14
Martis Creek[c]	USACE	USACE	20.4	1971	113	40
Prosser Creek	USBR	USBR	29.8	1962	163	50
Independence	Sierra Pacific Power Company	Sierra Pacific Power Company	17.5	1939	31	8
Stampede	USBR	USBR	226.5	1970	239	136
Boca	USBR	Washoe County Water Conservation District	41.1	1937	116	172

[a] Date existing dam was completed.
[b] USBR manages the facilities under easement from Sierra Pacific Power Company.
[c] Flood control storage only.

cranes, and other birds migrating on the Pacific Flyway. During the irrigation season, most of HLWA's water supply comes from Willow Creek and its tributaries. HLWA has adjudicated water rights, administered by the Department, as established in the 1940 Susan River Decree. Groundwater at the refuge is used for crop irrigation, for maintaining wetlands water levels, and for domestic purposes.

The Truckee River originates above Lake Tahoe. The river's flow downstream from Tahoe City is controlled by a small dam on the lake's outlet. The river flows through northeastern California and northwestern Nevada and terminates in Pyramid Lake, located within the Pyramid Lake Indian Reservation in Nevada. Additional Truckee River Basin storage facilities are listed in Table 9-3.

Most of the water supply developed by Truckee River Basin reservoirs is used in Nevada to meet urban demands in the Reno/Sparks area, irrigation demands, and fish and wildlife requirements in the lower Truckee River in Nevada and in Pyramid Lake. On average, about one-third of the Truckee River's annual flow is diverted through the Truckee Canal in Nevada to irrigate land in the Carson Division of USBR's Newlands Project near Fallon, Nevada.

Truckee River operations have evolved in response to litigation, negotiation, court decrees, agreements, and legislation. The 1915 Truckee River General Electric Decree and the 1935 Truckee River Agreement form the basis of current river operations. The 1944 Orr Ditch Decree established individual water rights in Nevada and, by incorporating the Truckee River Agreement, provided criteria for operating the federal reservoirs to serve those rights.

Modification of Truckee River operations occurred when two Pyramid Lake fish species were listed under the ESA. Cui-ui, the Indian name for a species of sucker found only in Pyramid Lake, were listed as an endangered species in 1967. Lahontan cutthroat trout were initially listed as endangered in 1970 and were subsequently reclassified as threatened in 1975. USBR's Stampede Reservoir, constructed in 1970 to serve irrigation and municipal uses, is operated to provide water for these fish, as required by a 1982 federal court decision. Proposed changes in Truckee River operations are described in the following water management issues section.

In the Truckee Basin within California, the urban water use occurs in and around the Town of Truckee, and is supplied by Truckee Donner PUD. TDPUD is the largest purveyor in the basin, accounting for about half of the water delivered to commercial and residential customers; its supplies are derived from groundwater. The Martis Valley groundwater basin is the principal source of water supply. The areas of Northstar, Squaw Valley, and Glenshire use groundwater from smaller basins or from fractured rock sources. The developed area around Donner Lake is

USBR's Stampede Reservoir is the second largest reservoir in the Truckee River Basin. Lake Tahoe is the largest reservoir in the basin.

Courtesy of USBR

served by surface water. Future water demands in the Truckee Basin are not expected to exceed the interstate allocations contained in the Truckee-Carson-Pyramid Lake Water Rights Settlement Act (PL 101-618), which limits the basin's annual use to 32 taf.

On the California side of the Lake Tahoe Basin, South Tahoe PUD, Tahoe City PUD, and North Tahoe PUD account for most of the water delivered to urban users. Water is supplied from the lake and from groundwater sources. The interstate allocation for California's Lake Tahoe Basin in PL 101-618 would limit future water use in the basin to 23 taf of gross diversions, which represents the basin's estimated future water needs at its full development. Future development in the Lake Tahoe Basin is strictly limited by the bistate Tahoe Regional Planning Agency to protect the basin's environmental quality. In both the Truckee and Tahoe Basins, water use for snowmaking at the area's ski resorts has been addressed in the interstate allocations.

Urban development in the Carson and Walker River Basins is minimal and is clustered around the towns of Markleeville in Alpine County and Bridgeport in Mono County. More than 90 percent of the watershed on the California side is federally owned, primarily under the management of the Toiyabe National Forest. Groundwater is the source of supply for individual users and small community systems located in valley areas. In the upper watershed, communities may lack suitable sites to locate wells and therefore must depend on surface water sources. The Town of Markleeville depends on surface water and experienced a water shortage in 1989 when the stream that supplies the community went dry. Water had to be piped 4 miles from another creek to the town's treatment plant.

In the upper Carson River watershed, water is stored in several very small alpine reservoirs originally constructed to supply irrigation needs. Much of this water is still used for irrigation downstream in Nevada. The largest of the alpine reservoirs is Heenan Lake on Monitor Creek, tributary to the East Fork Carson River, with a capacity of nearly 3 taf. The Carson River supports a popular recreational trout fishery in the upper watershed. DFG has used Heenan Lake for raising Lahontan cutthroat trout to stock at other locations throughout the Sierra. DFG currently manages State-owned lands adjacent to Heenan Lake and has arranged to purchase water on an annual basis to maintain a minimum reservoir pool for fish rearing.

Two special-purpose reservoirs were constructed in the upper Carson watershed to receive treated wastewater effluent exported from South Tahoe PUD in the Lake Tahoe Basin. (Disposal of treated wastewater within the Lake Tahoe Basin was banned to help protect the lake's clarity.) Beginning in the 1960s, wastewater effluent was delivered to Indian Creek Reservoir for subsequent release to agricultural users as a supplemental irrigation supply. In 1989, exports (about 5 taf/yr) were redirected to Harvey Place Reservoir. Indian Creek Reservoir is now used for freshwater recreation.

In addition to several small reservoirs in the upper watershed, the Walker River watershed has two large reservoirs—Topaz Reservoir (an offstream storage facility on the West Walker) and Bridgeport Reservoir on the East Walker. Both of the large reservoirs were built by Walker River Irrigation District to sustain summer irrigation flows in its service area downstream in Nevada. WRID holds California water rights to store 57.6 taf of West Walker water, plus 200 af of local inflow, in Topaz Reservoir. WRID can store up to 39.7 taf in Bridgeport Reservoir. SWRCB has established instream flow and minimum reservoir pool requirements at Bridgeport, in response to fish kills that occurred during the last drought. Both reservoirs are popular local recreational destinations.

Part of the East Fork Carson River—approximately 10 miles from the town of Markleeville to the California/Nevada state line—has been added to the California wild and scenic river system. On the West Walker River, approximately 37 river miles have also been given State designation. The designated reach is from Tower Lake at the headwaters downstream to the confluence with Rock Creek, and about 1 mile of Leavitt Creek.

As occurred in the Truckee River Basin, water right disputes in the Carson and Walker River Basins were settled with federal court decrees. The 1980 Alpine Decree on the Carson River and the 1936 Decree C-125 on the Walker River control most river operations. The decrees established surface water rights, including reservoir storage rights, of water users in both California and Nevada. However, the decrees only quantify individual water rights of parties to the litigation and did not address rights perfected under state law by others—not all existing water uses are necessarily covered in the decrees. PL 101-618 established an interstate allocation in the Carson River Basin; the California allocation corresponds to existing water uses.

Local Water Resources Management Issues

Truckee River Operating Agreement

Negotiation of a proposed Truckee River Operating Agreement and preparation of its draft EIR/EIS have been the major water management activities in the region. A new operating agreement for the Truckee River is required by PL 101-618. Negotiation of a proposed TROA and preparation of an EIR/EIS for the TROA began in 1991. The draft EIR/EIS was released for public review in 1998 and is expected to be completed in 1999.

PL 101-618 settled years of disputes over Truckee and Carson River waters by making an interstate allocation between California and Nevada. It also settled certain tribal water right claims and provided for water supplies for specified environmental purposes in Nevada. The act allocated 23 taf annually to California in the Lake Tahoe Basin and 32 taf annually in the Truckee River Basin below Lake Tahoe. The act allocated water corresponding to existing Carson River Basin water uses to California. The remainder of the

USBR's Prosser Creek Reservoir is one of the Truckee River system reservoirs whose operation would be covered by the TROA.

Truckee and Carson River supply was allocated to Nevada.

When executed, the TROA would establish river operations procedures to meet water rights on the Truckee River and to enhance spawning flows in the lower Truckee River for cui-ui and Lahontan cutthroat trout. TROA would provide for management of water within the Truckee Basin in California, including instream flow requirements and reservoir storage for fishery and recreation uses, and would include procedures for coordinating releases and exchanges of water among the watershed's reservoirs. TROA would become the exclusive federal regulation governing releases of water stored in Lake Tahoe, Martis Creek, Prosser Creek, Stampede, and Boca Reservoirs. The agreement would provide an accounting procedure for surface and groundwater diversions in California's part of the Truckee Basin and would establish criteria to minimize short-term reductions in river flow potentially caused by future well construction near the river.

In 1993, an agreement was signed by Sierra Pacific Power Company, Washoe County Water Conservation District, and Sierra Valley Water Company settling a dispute about when the water company was required to stop diverting water from the Little Truckee River. This agreement, which resolves disputes that had often occurred during droughts, is being incorporated into the proposed TROA.

Walker River

Recent activities in the Walker River Basin have focused on the declining level of Walker Lake in Nevada and the resulting impact on the lake's fishery. Because Walker Lake is a terminal sink, salts accumulate as the lake water evaporates. Declining lake levels have resulted in most Great Basin terminal sinks being too saline to support fisheries. Walker Lake is one of three terminal lakes in Nevada that support fish life. The water level at Walker Lake has declined from an elevation of about 4,080 feet in 1882 to 3,944 feet in 1994; salinity has increased during the same period from about 2,500 mg/L TDS to 13,300 mg/L TDS.

In most years, Walker River is the primary source of inflow to Walker Lake. Flow in the river comes from runoff in the Sierra in California. Upstream agricultural diversions have contributed to reduced inflows, resulting in a declining lake level and increased lake salinity. If the trend continues, the Lahontan cutthroat and the tui chub (an important food source for the trout) may not be able to survive in the lake. To maintain lake salinity at the current level, about 33 taf/yr more inflow is needed. Even with a stable lake level, salinity will slowly increase because Walker Lake has no natural outlet. A solution to Walker Lake problems could affect water users in California and Nevada. Potential tribal water rights claims on the Nevada side of the basin could also affect existing water users.

Lake Tahoe

Lake Tahoe's clarity has been declining as increasing development around the shoreline increases the sediment load and nutrients reaching the lake. Nutrients, such as nitrogen and phosphorous used in lawn or golf course fertilizers, can enter the lake in the form of storm water runoff. Nutrients promote growth of algae, reducing clarity. Clarity of lakes is measured by the depth to which a Secchi disk, a small plastic disk of specific size, is visible. In the late 1960s, average Secchi disk visibility in Lake Tahoe was about 100 feet. Now the figure is closer to 70 feet.

Programs to manage Lake Tahoe water quality by regulating development and preventing pollutants from reaching the lake are being implemented at the federal, state, and local levels. The Tahoe Regional Planning Agency, a bistate agency created by Congress, sets regional environmental standards, issues land use permits (including conditions to protect water quality), and takes enforcement actions throughout the basin. TRPA's regional plan provides for achievement and maintenance of environmental targets by managing growth and development. In addition to its regulatory activities, TRPA carries out a capital improvement program to repair environmental damage done before its regional plan was adopted. TRPA has identified nearly $500 million in capital improvements needed to achieve environmental targets. Federal, state, and local governments have invested nearly $90 million in erosion control, storm water drainage, stream zone restoration, public transit, and other capital projects. Over 70 percent of the land in the Tahoe Basin is controlled by the USFS's Lake Tahoe Basin Management Unit. The LTBMU has implemented a watershed restoration program and a land acquisition program to prevent development of sensitive private lands.

In recent years, federal and state agencies have increased funding to protect the environment of Lake Tahoe. The State of Nevada approved a $20 million bond measure to perform erosion control and other measures on the east side of the lake. In California, Proposition 204 provides $10 million in bond funds for land acquisition and programs to control soil erosion, restore watersheds, and preserve environmentally sensitive lands.

Leviathan Mine

Leviathan Mine, an abandoned sulfur mine located in Alpine County, is one of the most significant abandoned mine sites in the region. From 1863 to 1952, operations at the site involved tunnel mining. Later, the site was converted to an open-pit operation. Under this operation, tailings and overburden material were placed in (or washed into) streams, creating water pollution problems with acid mine drainage and metals. The mine was ultimately abandoned, leaving an open pit, waste and spoil areas, and surface water drainage and erosion problems. Neither the owner nor the county had the resources to clean up the site.

In 1980, SWRCB approved a pollution abatement project for Leviathan Mine. The remediation project included channeling Leviathan Creek, filling and regrading the mine pit, excavating and regrading the waste dump, creating onsite evaporation ponds, regrading the spoil areas, and improving drainage. The State acquired the site in 1983 and the project was completed in 1985. Although the project reduced the amount of acid mine drainage reaching the creek, contamination problems still occur today from pond overflows, acidic springs, seepage, and erosion. The RWQCB is currently involved in activities to further reduce the pollution.

Sierra Nevada Ecosystem Project

The Sierra Nevada Ecosystem Project was an assessment of forests, key watersheds, and significant natural areas on federal lands. In 1996, the University of California released its *Sierra Nevada Ecosystem Study*, the result of a three year, congressionally-mandated study of the entire Sierra Nevada, with primary emphasis on gathering and analyzing data to assist Congress in future management of the mountain range. The study stated that "excluding the hard-to-quantify public good value of flood control and reservoir-based recreation, the hydroelectric generating, irrigation, and urban use values of water are far greater than the combined value of all other commodities produced in the Sierra Nevada." The report estimated the value of water at 60 percent of that of all commodities produced in the foothills and mountains of the Sierra Nevada.

January 1997 Flood Event

The January 1997 flood was among the most significant floods on record in the North Lahontan Region. Lake Tahoe recorded its highest level since 1917 at an elevation of 6,229.39 feet. This elevation was the lake's highest since the 1935 Truckee River Agreement, which limited the operating range of Lake Tahoe's surface elevation to between 6,223.0 feet (its natural rim) and 6,229.1 feet. Flood damage occurred along the Truckee's channel immediately downstream from the lake, although the greatest economic damages occurred in the Reno-Sparks area. In California, flooding in downtown Truckee caused the closure of major highways. Downstream from Truckee, the river washed away Floriston Dam, a diversion dam used by Sierra Pacific Power Company to divert water to its run-of-river hydroelectric plant at Farad.

Stream flows along the Carson and Walker River systems exceeded previous flood records. Flows along the East Fork Carson River at Markleeville and West Fork Carson River at Woodfords peaked at 21,000 cfs and 8,000 cfs, respectively, considerably above the record peak flows attained in 1963 and in excess of a 100-year flood event for these reaches of the river. The East Walker River near Bridgeport and West Walker River near Coleville peaked at 1,810 cfs and 6,220 cfs, respectively, also above previously record flows. In Mono County, about 8 miles of U.S. Highway 395 were washed out, isolating the communities of Coleville and Walker. At the lower mouth of the Walker Canyon, homes and properties in the community of Walker were damaged when the West Walker River spilled its banks.

Water Management Options for the North Lahontan Region

Table 9-4 shows a list of options for the region, and the results of an initial screening of the options. The retained options were evaluated (Table 9A-1 in Appendix 9A) based on a set of fixed criteria discussed in Chapter 6. Potential options to augment water supplies during drought conditions are water conservation, groundwater pumping, and reservoir construction. Land is idled during droughts if water is not available. In Mono County, cutbacks in surface water deliveries

TABLE 9-4

North Lahontan Region List of Water Management Options

Option	*Retain or Defer*	*Reason for Deferral*
Conservation		
Urban		
Outdoor Water Use to 0.8 ETo	Retain	
Indoor Water Use	Retain	
Interior CII Water Use	Defer	No significant depletion reductions attainable.
Distribution System Losses	Defer	No significant depletion reductions attainable.
Agricultural		
Seasonal Application Efficiency Improvements	Defer	No significant depletion reductions attainable.
Flexible Water Delivery	Defer	No significant depletion reductions attainable.
Canal Lining and Piping	Defer	No significant depletion reductions attainable.
Tailwater Recovery	Defer	No significant depletion reductions attainable.
Modifying Existing Reservoirs/Operations		
—	—	—
New Reservoirs/Conveyance Facilities		
Petes Valley Reservoir	Defer	High costs.
Willard Creek Reservoir	Defer	High costs.
Goat Mountain Reservoir	Defer	High costs.
Crazy Harry Gulch Reservoir	Defer	High costs.
Honey Lake Dike and Reservoir	Defer	Water quality inadequate for agriculture. Very low yields with large estimated capital costs.
Long Valley Creek Reservoir	Defer	Very little firm yield.
Hope Valley Reservoir	Defer	High costs.
Leavitt Meadows Reservoir	Defer	Site is located on the West Walker River, upstream of a reach designated as wild and scenic. Also subject to interstate water issues with Nevada.
Pickle Meadow Reservoir	Defer	Same concerns as Leavitt Meadows site.
Roolane Reservoir	Defer	Same concerns as Leavitt Meadows site.
Mountain Lakes Reservoir	Defer	Same concerns as Leavitt Meadows site.
Groundwater/Conjunctive Use		
Agricultural Groundwater Development	Retain	
Eastside Warner Mountain Recharge	Defer	DFG concerns about potential wildlife impacts have diminished local interest in a pilot program and/or reconnaissance level planning study.
Water Marketing		
—	—	—
Water Recycling		
Water recycling options	Defer	Water recycling options would not generate new water supply in this region.

TABLE 9-4

North Lahontan Region List of Water Management Options (continued)

Option	*Retain or Defer*	*Reason for Deferral*
Desalting		
Brackish Groundwater		
—	—	—
Seawater		
—	—	—
Other Local Options		
—	—	—
Statewide Options		
—	—	—

during the recent drought resulted in pasture not being irrigated.

Water Conservation

Urban. Urban water demand forecasts for 2020 assume that BMPs are in place; consequently, only those urban conservation efforts which exceed BMPs are considered as options. Urban conservation options in this region provide little potential for depletion reductions. Reducing outdoor water use to 0.8 ET_o in new and existing development would only conserve about 1 taf/yr. Likewise, reducing indoor water use to 55 gpcd would conserve about 1 taf/yr.

Agricultural. The 2020 agricultural water demand forecasts assume that EWMPs are in place. As with the urban water management options, only those agricultural conservation efforts which exceed EWMPs are considered as options. The efficiency of border irrigation systems used for alfalfa and pasture can be improved through leveling fields and better managing applications. No significant depletion reductions are expected in the region, however, since most alfalfa irrigation occurs in Honey Lake Valley where excess applied irrigation water recharges the groundwater basin.

New Reservoirs or Conveyance Facilities

In 1992, the Department investigated six potential reservoir sites in Lassen County that could provide up to 20 taf of storage. Sites were located on the Susan River, Willow Creek, and Long Valley Creek. An analysis of project costs indicates that the reservoirs were not economically feasible for agricultural water users in the region.

In the late 1950s and early 1960s, the Department examined potential reservoir sites in Mono County that could serve agricultural lands in California. USBR, USGS, NRCS, and WRID have studied these and other potential sites in California that could provide water for Nevada uses. Projects that serve Nevada only are not included as options. The four potential sites in Mono County located on the West Walker River have similar economic constraints as the sites in Lassen County. They are also subject to interstate water rights concerns.

Groundwater Development or Conjunctive Use

Although groundwater is available in the larger valleys used for irrigated agriculture, water needs are usually met from surface water. Groundwater cannot be economically used to replace surface water uses because of pumping costs.

Modoc County Resource Conservation District investigated groundwater recharge on six creeks which drain the east slopes of the Warner Mountains in Surprise Valley. This project would recharge the alluvial fans using existing stream channels or constructed recharge facilities. Experimental construction of recharge areas on one or two of the creeks was proposed, but potential environmental impacts and lack of funding prevented implementation. This option was deferred.

Options Likely to be Implemented in the North Lahontan Region

Water supplies are not available to meet all of the region's 2020 water demands in average or drought years. Applied water shortages are forecasted to be 10 taf and 128 taf in average and drought years, respectively. Ranking of retained water management options for the North Lahontan Region is summarized in Table 9-5. Table 9-6 summarizes options that can likely be implemented by 2020 to relieve the shortages.

Although groundwater could be developed to help meet drought year water needs, it is not ranked highly due to its cost. During droughts, pasture irrigation will probably continue to be curtailed.

TABLE 9-5

Options Ranking for North Lahontan Region

Option	*Rank*	*Cost ($/af)*	*Potential Gain (taf)*	
			Average	*Drought*
Conservation				
Urban				
Outdoor Water Use to 0.8 ET_o – New and Existing Development	M	[a]	1	1
Indoor Water Use (55 gpcd)	M	600	1	1
Groundwater/Conjunctive Use				
Agricultural Groundwater Development	M	[a]	[a]	[a]

[a] Data not available to quantify.

TABLE 9-6

Options Most Likely to be Implemented by 2020 (taf)
North Lahontan Region

	Average	*Drought*
Applied Water Shortage[a]	**10**	**128**
Options Likely to be Implemented by 2020		
Conservation	—	—
Modify Existing Reservoirs/Operations	—	—
New Reservoirs/Conveyance Facilities	—	—
Groundwater/Conjunctive Use	—	—
Water Marketing	—	—
Recycling	—	—
Desalting	—	—
Other Local Options	—	—
Statewide Options	—	—
Expected Reapplication	—	—
Remaining Applied Water Shortage	**10**	**128**

[a] Majority of shortages in this region are agricultural.

FIGURE 9-3

South Lahontan Hydrologic Region

South Lahontan Hydrologic Region

. . .

Description of the Area

The South Lahontan Region encompasses the area from the drainage divide between the Walker River and Mono Lake Basin to the divide south of the Mojave River (Figure 9-3). The region is bordered on the east by the Nevada stateline and on the west by the crest of the southern Sierra Nevada and San Gabriel Mountains. The region includes all of Inyo County and parts of Mono, San Bernardino, Kern, and Los Angeles Counties. Prominent geographic features of the region are Owens Valley and Death Valley. The region contains the highest and lowest points in the lower 48 states—Mount Whitney (elevation 14,495 feet) and Death Valley (elevation 282 feet below mean sea level).

The region includes several closed drainage basins and many desert valleys containing central playas, or dry lakes. Major waterbodies in the region are, from north to south, Mono Lake, Owens River, and Mojave River. The Amargosa River contains water only during rare flash floods. Floodwaters in the Amargosa River would eventually flow south to a sink area at the Silver Lake and Soda Lake Playas. This sink area is also the terminus of the Mojave River, which flows eastward from its headwaters in the San Bernardino Mountains across the Mojave Desert to the playa lakes. Average annual precipitation for the region's valleys ranges between 4 and 10 inches. Death Valley receives only 1.9 inches annually. The Sierra Nevada can receive up to 50 inches annually, much of it in the form of snow. In some years, the community of Mammoth Lakes can have snow accumulations of more than 10 feet.

The Joshua Tree, a member of the yucca family, is endemic to the Mojave Desert.

Although sparsely populated, the region contains some rapidly growing urban areas, including the Cities of Lancaster and Palmdale in Antelope Valley (Los Angeles County) and the Cities of Victorville, Hesperia, and Apple Valley in San Bernardino County. Many residents in these areas have chosen a long commute to the greater Los Angeles area in exchange for affordable housing. Future population growth in the region is expected to be concentrated in communities within commuting distance of the Los Angeles area. Bishop, Ridgecrest, and Barstow are other population centers in the region. The economies of these and other small towns in the eastern part of the region are tied to the region's military facilities and other governmental employers, and to providing services for travelers and tourists.

Public lands constitute about 75 percent of the region's area, providing a major recreational resource. Popular destinations in the region include the Mono Lake area, June Lakes and Mammoth Lakes, Inyo National Forest, Death Valley National Monument, and the recently created Mojave National Preserve. Only about 1 percent of the region's land is used for urban and agricultural purposes. Most of the irrigated acreage, primarily alfalfa and pasture, is in the Mono-Owens PSA. (This PSA includes Owens Valley, the Lake Crowley area northwest of Bishop, and Hammil and Fish Lake Valleys.) Some deciduous orchard acreage is found in the western part of the region. Table 9-7 shows population and crop acreage for the region.

The Owens River, with the Sierra Nevada in the background.

TABLE 9-7

Population and Crop Acreage

	Population (thousands)	*Irrigated Crop Acreage (thousands of acres)*
1995	713	61
2020	2,019	45

Major perennial waterbodies in the region are Mono Lake and Owens River. Since relatively little surface water is available in the rest of the region, the region's environmental water use is concentrated in the Mono Lake-Owens Valley corridor. The major environmental water use requirements are associated with maintenance of Mono Lake levels and fishery instream flow requirements for the Owens River system. DFG operates four fish hatcheries in the Mono-Owens area: Mt. Whitney, Big Springs, Hot Creek, and Black Rock Hatcheries.

The largest surface water development in the region is the Los Angeles Aqueduct and its associated facilities, described in the following section. There are also a few relatively small, high-elevation dams operated by Southern California Edison for nonconsumptive hydropower purposes. These dams do not provide water supply for the region. SWP's 75 taf Lake Silverwood on the East Branch of the California Aqueduct regulates and stores imported water.

Water Demands and Supplies

The water budget for the South Lahontan Region is shown in Table 9-8. Increased environmental water demands from recently settled court actions involving LADWP's water diversions from the Owens Valley and Mono Lake are reflected in the base water budget. A pending order issued by an air pollution control district in 1997 could increase environmental water demands in the region. This increase is not included in the water budget because final action has not yet been taken (see the local water resources management issues section).

Los Angeles Aqueduct

The Los Angeles Aqueduct is the region's major water development feature, although it does not serve water to the region. In 1913, the first pipeline of LAA was completed and began conveying water from Owens Valley to the City of Los Angeles. The aqueduct was extended north of the Mono Basin and diversions be-

TABLE 9-8

South Lahontan Region Water Budget (taf)[a]

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	238	238	619	619
Agricultural	332	332	257	257
Environmental	107	81	107	81
Total	**676**	**651**	**983**	**957**
Supplies				
Surface Water	322	259	437	326
Groundwater	239	273	248	296
Recycled and Desalted	27	27	27	27
Total	**587**	**559**	**712**	**649**
Shortage	**89**	**92**	**270**	**308**

[a] Water use/supply totals and shortages may not sum due to rounding.

gan in 1940. A second pipeline was completed in 1970, increasing the aqueduct's annual delivery capacity to about 550 taf/yr. Both aqueducts terminate at the 10 taf Los Angeles Reservoir in the South Coast Region. The first aqueduct begins at the intake on Lee Vining Creek and the second begins at Haiwee Reservoir.

There are eight reservoirs in the LAA system with a combined storage capacity of about 323 taf (Table 9-9). These reservoirs were constructed to store and regulate flows in the aqueduct. The northernmost reservoir is Grant Lake in Mono County. Six of the eight reservoirs are located in the South Lahontan Region. Bouquet and Los Angeles Reservoirs are in the South Coast Region.

TABLE 9-9

Los Angeles Aqueduct System Reservoirs

Reservoir	*Capacity (taf)*	*County*
Grant	47	Mono
Crowley	183	Mono
Pleasant Valley	3	Inyo
Tinemaha	6	Inyo
Haiwee	39	Inyo
Fairmont	0.5	Los Angeles
Bouquet	34	Los Angeles
Los Angeles	10	Los Angeles

Water from both aqueducts passes through 12 powerplants on its way to Los Angeles. The annual energy generated is over 1 billion kWh, enough to supply the needs of 220,000 homes.

State Water Project

The East Branch of the California Aqueduct follows the northern edge of the San Gabriel Mountains, bringing imported water to Silverwood Lake. Table 9-10 shows SWP contractors in the region and their contractual entitlements.

Antelope Valley-East Kern Water Agency, the largest SWP contractor in the region, serves 5 major and 16 small municipal agencies, as well as Edwards AFB, Palmdale Air Force Plant 42, and U.S. Borax and Chemical Facilities. AVEK was formed to bring imported water into the area.

Mojave Water Agency was created in 1960 in response to declining groundwater levels in the area. Communities within MWA's boundaries have no source of supply other than groundwater. Communi-

TABLE 9-10

SWP Contractors in the South Lahontan Region

Contractor	*Annual Entitlement (taf)*	*1995 Deliveries (taf)*
Antelope Valley-East Kern WA	138.4	47.3
Crestline-Lake Arrowhead WA	5.8	0.4
Littlerock Creek ID	2.3	0.5
Mojave WA	75.8	8.7
Palmdale WD	17.3	7.0

ties served by MWA include Barstow, Apple Valley, Hesperia, and Victorville. While most of MWA's service area is within the South Lahontan Region, the service area extends into the Colorado River Hydrologic Region (the Lucerne and Johnson Valleys and the Morongo Basin). Part of MWA's SWP entitlement (7.3 taf) is allocated to that area.

MWA has taken little of its SWP entitlement to date, due to lack of conveyance facilities. In 1994, MWA completed its Morongo Basin pipeline, a 71-mile pipeline with a capacity of 100 cfs from the SWP's East Branch to the Mojave River (7 miles) and then 20 cfs to Morongo Basin and Johnson Valley. This pipeline allows MWA to bring SWP water into part of its large (almost 5,000 square miles) service area. In 1997, MWA began construction of its 71-mile Mojave River Pipeline (94 cfs capacity) to bring imported water to Barstow and neighboring cities. The El Mirage Aqueduct is the next proposed addition to its distribution system. The aqueduct would deliver approximately 4 taf of imported water annually from the East Branch to the westernmost subarea of the Mojave River Basin near El Mirage. Imported water would be used to recharge the area's overdrafted groundwater basin.

In 1997, MWA and Berrenda Mesa Water District (a member agency of KCWA) concluded the permanent transfer of 25 taf of SWP annual entitlement, thereby increasing MWA's total annual entitlement to 75.8 taf.

Littlerock Reservoir is one of the few surface water storage facilities in the Mojave Desert area. The original dam at this site was a multi-arch concrete structure. This photo shows the dam after its seismic rehabilitation.

Local Surface Water Supplies

The Mammoth Community Water District supplies the town of Mammoth Lakes, located at the northern end of the region. About 70 percent of MCWD's supply comes from Lake Mary, the largest of a number of small alpine lakes in the Mono Lakes Basin. At present, the remainder of MCWD's supply comes from groundwater. Although MCWD serves a permanent population of only about 5,000 people, its average daily population is about 13,000, with peak weekends and holiday periods reaching 30,000 people per day. These wide fluctuations in service levels above the base population are typical of the recreational and resort communities in the area.

Although the Mojave River appears on maps as a major waterway in the region, it is an ephemeral stream for much of its length. Local communities extract groundwater, which is recharged by river flows, but do not directly divert significant amounts of surface water from the river. There is one dam on the Mojave River at the base of the San Bernardino Mountains—Mojave River Forks Dam, a 90 taf USACE flood control facility.

The 3.5 taf capacity Littlerock Reservoir provides water supply to Littlerock Creek Irrigation District and to Palmdale Water District. PWD funded most of a recent seismic rehabilitation of the 1924-vintage dam in exchange for control of the water supply for 50 years. Water from Littlerock Reservoir may be released into a ditch that conveys flows to PWD's Lake Palmdale, a 4.2 taf storage reservoir.

In the San Bernardino Mountains, Lake Arrowhead, owned by the Arrowhead Lake Association, is a 48 taf reservoir providing recreational opportunities and water supply for lakeshore residents.

Groundwater Supplies

Historically the South Lahontan Region has relied mostly on groundwater, which is the only water supply available in most parts of the region. Groundwater basin capacities in the Mojave River and Antelope Valley PSAs, for example, total about 70 maf each. (Economically usable storage is significantly less than this amount.) Water quality influences groundwater use. Some areas in the Mono-Owens area have highly mineralized groundwater due to geothermal activity, while saline groundwater is not uncommon in areas near playa lakes.

The Mojave River groundwater basin is a large alluvial formation in the Mojave Desert, the only local

Surface water is found in most desert waterways only after infrequent storms. If local groundwater resources are not sufficient to supply an area's needs, water must be imported to augment local supplies. This photo shows the Mojave River bed at Red Rock Canyon.

water source for residents in the western third of San Bernardino County (part of the basin is in the Colorado River Region). The Mojave River and groundwater basin act as one water source, with the river recharging the basin and groundwater discharging in several places to provide surface flows in the river. The basin is divided into subareas at hydrogeologic boundaries including the Helendale and Waterman Faults. The operational storage capacity of the basin is about 4.9 maf; currently there is about 3.0 maf of water in storage. The basin has experienced declining groundwater levels due to overextractions (see Mojave River adjudication section).

The Antelope Valley groundwater basin underlies the closed drainage in the westernmost part of the Mojave Desert in northern Los Angeles and southeastern Kern Counties. It provides most of the local water supplies to users in the high desert from the San Gabriel Mountains to the Sierras, including Edwards Air Force Base. Agricultural pumping from the basin has declined for several decades while urban extraction has increased due to rapid population growth.

Local Water Resources Management Issues

Owens Valley Area

In 1972, Inyo County filed suit against the City of Los Angeles, claiming that increased groundwater pumping for the second aqueduct was harming the Owens Valley environment. Inyo County asked that LADWP's groundwater pumping be analyzed in an

Searles Lake

The Mojave Desert has numerous playa lakes, dry or semi-dry lakebeds that occupy topographic low points in closed drainage basins. Playa lakes contain surface water only briefly after the region's infrequent rains. There may, however, be high groundwater levels immediately beneath an apparently dry lakebed. Groundwater found near these lakebeds is usually too mineralized for most beneficial uses, because salts have been concentrated in lakebed deposits during evaporation of the surface waters. Searles Lake in northwestern San Bernardino County is an example of an extremely mineralized playa lake.

Within geologic time, California's climate was much wetter than it is today. During the late Quaternary Period, the Owens River flowed into several (now dry) lakes in the Mojave Desert, filling Searles Lake to a depth of over 600 feet. Long-term deposition of evaporates in the lakebed created thick layers of salts and borate minerals. These deposits have been the basis of extensive mining operations at the lake, estimated to have produced more than $1 billion worth of mineral commodities.

Borax mining at the lakebed began as early as 1874. Current mining techniques entail pumping brines from lakebed sediments and processing them at onsite chemical plants to produce commodities such as sodium carbonate, sodium borate, and sodium sulfate. These chemicals are used in the manufacture of drugs, dyes, glass, glazes, paper, soap, detergent, enamel, chemical products, abrasives, gasoline additives, fire retardants, and metal alloys.

EIR. LADWP prepared an EIR in 1976 and another in 1979, both of which the Third District Court of Appeals found inadequate. In 1983, Inyo County and LADWP decided to work together to develop an EIR and water management plan to settle the litigation.

A third EIR was prepared jointly by LADWP and Inyo County and released in 1990. In 1991, both parties executed a long-term water management agreement delineating how groundwater pumping and surface water diversions would be managed to avoid significant decreases in vegetation, water-dependent recreational uses and wildlife habitat. Several entities challenged the adequacy of the EIR and in 1993 were granted *amici curiae* status by the Court of Appeals, allowing them to enter in the EIR review process. An agreement was subsequently executed in 1997, ending 25 years of litigation between Los Angeles and Inyo County.

LADWP and Inyo County have begun discussions on how to implement provisions of the agreements and EIR. Timelines for many provisions have already been developed and plans for major activities such as rewatering the Lower Owens River are under review.

Surface water diversions for Owens Valley agriculture from the Owens River began in the 1800s. The Los Angeles Aqueduct was completed in 1913. Owens Lake became a dry lakebed by 1929. On windy days, airborne particulates from the dry lakebed violate air quality standards in the southern Owens Valley. In 1997, the Great Basin Unified Air Pollution Control District ordered the City of Los Angeles to implement control measures at Owens Lake to mitigate the dust problems. Under the order, 8,400 acres of lakebed would be permanently flooded with a few inches of water, another 8,700 acres would be planted with grass and irrigated, and 5,300 acres would be covered with a four-inch layer of gravel. This order could reduce the city's diversions by 51 taf/yr or about 15 percent of its supply. In July 1998, a compromise was reached when LADWP agreed to begin work at Owens Lake by 2001 and to ensure that federal clean air standards would be met by 2006. In turn, the APCD agreed to scale back the improvements sought in its 1997 order. Under this agreement, LADWP's dust-control strategy may include shallow flooding, vegetation planting, and gravel placement. The implementation schedule requires that 6,400 acres of lakebed be treated by the end of 2001. By the end of 2006, an additional 8,000 acres would be treated, plus any additional lakebed necessary to bring particulate counts into compliance with federal air quality standards. The plan hinges on final approval from the Los Angeles City Council, the APCD's board, and the State Air Resources Board. The agreement also requires EPA to grant a 5-year extension of Clean Air Act requirements that direct states to abate particulate pollution by 2001 or seek an extension until 2006.

Mono Basin

Mono Lake, located east of Yosemite National Park at the base of the eastern Sierra Nevada, is the second largest lake completely within California. It is recognized as a valuable environmental resource. The lake is famous for its tufa towers and spires, structures formed by years of mineral deposition by its saline waters. The lake has no outlet. There are two islands in the lake that provide a protected breeding area for large colonies of California gulls and a haven for migrating waterfowl.

Much of the water flowing into Mono Lake comes from snowmelt runoff. Since 1941, LADWP has diverted water from Lee Vining, Walker, Parker, and Rush Creeks into tunnels and pipelines that carry the water to the Owens Valley drainage. There it is conveyed, together with Owens River flows, to Los Angeles via the LAA.

Diversions from its tributaries lowered Mono Lake's water level from elevation 6,417 feet in 1941 to a historic low of 6,372 feet in 1981. With decreased inflow of fresh water, the lake's salinity increased dramatically. When water levels drop to 6,375 feet or lower, a land bridge to Negit Island is created, allowing predators to reach gull rookeries; this first happened in 1978 and again during the 1987-92 drought.

As a result of these impacts, the lake and its tributaries have been the subject of extensive litigation between the City of Los Angeles and environmental groups since the late 1970s. In 1983, the California Supreme Court ruled that SWRCB has authority to reexamine past water allocation decisions and the responsibility to protect public trust resources where feasible. SWRCB issued a final decision on Mono Lake (Decision 1631) in 1994. The amendments to LADWP's water right licenses are set forth in the order accompanying the decision.

The order sets instream flow requirements for fish in each of the four streams from which LADWP diverts water. The order also establishes water diversion criteria to protect wildlife and other environmental resources in the Mono Basin. These water diversion criteria prohibit export of water from Mono Basin until the lake level reaches 6,377 feet, and restrict Mono Basin water exports to allow the lake level to rise to an elevation of 6,391 feet in about 20 years. Once the water level of 6,391 feet is reached, it is expected that LADWP will be able to export about 31 taf/yr of water from the basin. The order requires LADWP to prepare restoration plans for the four streams from which it diverts and to restore part of the waterfowl habitat which was lost due to lake level decline. In May 1997, parties to the restoration planning process presented a signed settlement on Mono Basin restoration to the SWRCB. If approved, the settlement would guide restoration activities and annual monitoring through 2014. Parties to the settlement include LADWP, the Mono Lake Committee, DFG, State Lands Commission, DPR, California Trout, National Audubon Society, USFS, BLM, and The Trust for Public Land.

Key features of stream restoration plan include restoring peak flows to Rush, Lee Vining, Walker, and Parker Creeks; reopening abandoned channels in Rush Creek; and developing a monitoring plan. One of the restoration actions required by SWRCB—bypassing sediment around LADWP diversion dams—was deferred for further analysis. The waterfowl habitat restoration plan proposes that a Mono Basin waterfowl habitat restoration foundation administer a $3.6 million trust established by LADWP. Five of the parties to the agreement would serve as initial members of the foundation. Activities would include annual monitoring, restoring open water habitat adjacent to the lake, and rewatering Mill Creek. LADWP would continue its brine shrimp productivity studies, open several channels on Rush Creek, and make its Mill Creek water rights available for rewatering Mill Creek, based on the recommendations of the foundation.

The plans are being considered by SWRCB and a decision is expected at the end of 1998.

Mojave River Adjudication

The Mojave River groundwater basin has experienced overdraft since the early 1950s, with the largest increase in overdraft occurring in the 1980s. About 80 percent of basin recharge comes from the Mojave River. In 1990, the City of Barstow filed a complaint in Superior Court against the City of Adelanto seeking an average annual guaranteed flow of 30 taf to mitigate reduced runoff and declining groundwater levels in the Barstow area. The complaint also requested a writ of mandate against MWA to compel it to import water from the SWP. MWA filed a cross-complaint requesting a determination of water rights in the basin.

In 1991, the court ordered that the litigation be placed on hold to give parties time to negotiate a settlement and to develop a solution to the overdraft. A Mojave Basin adjudication committee was formed to facilitate data gathering and to draft a stipulated judgment and physical solution. The court's final ruling on basin adjudication was issued in January 1996. In its ruling, the court emphasized that the area has been in overdraft for decades and that MWA must alleviate overdraft through conservation and purchase of supplemental water. MWA was appointed as the basin watermaster.

The adjudication stipulated that any party pumping more than 10 af/yr became a party to the judgment and is bound by it. The judgment stated that each party has a right to its base annual production, which was its highest usage between 1986 and 1990. The judgment also required MWA to reduce this amount by at least 5 percent each year for four years as one way to achieve a physical solution to the longstanding overdraft. Any party exceeding its annual allotment must purchase replenishment water from MWA or from other parties to the judgment. If there is still overdraft after the end of the first five years of the stipulated judgment, water use in overdrafted subareas will be further reduced. The judgment recognized five basin subareas and required that if an upstream subarea does not meet its obligation to a downstream subarea, the upstream area must pay for supplemental water.

Supplemental water for the Mojave River Basin will come from MWA's SWP entitlement, or from water marketing arrangements, and will be delivered through the California Aqueduct. In March 1997, MWA began constructing its Mojave River pipeline, extending about 71 miles from the California Aqueduct to Newberry Springs, a rural community east of Barstow. MWA also recently purchased the permanent right to 25 taf of additional SWP annual entitlement, nearly a 50 percent increase from the agency's previous entitlement. The combination of reduced pumping, increased SWP deliveries and other imports, and new delivery facilities are expected to reduce overdraft in the basin.

Antelope Valley Water Management

The Antelope Valley Water Group was formed in 1991 to provide coordination among valley water agencies and other interested entities. AVWG members include the Cities of Palmdale and Lancaster, Edwards AFB, AVEK, Antelope Valley United Water Purveyors Association, Los Angeles County Waterworks Districts, PWD, Rosamond Community Services District, and Los Angeles County. AVWG completed an Antelope Valley water resources study in 1995 to address regional water management issues.

The study evaluated the valley's existing and future water supplies from groundwater, the SWP, Littlerock Reservoir, and recycling, and compared these supplies with projected water demands. The study concluded that water supply reliability is low in the study area—full 1998 demands would be met only half the time without overdrafting groundwater resources. The study recommended water conservation, recycling, and conjunctive use measures to reduce expected shortages. The study identified three sites (two on Amargosa Creek and one on Littlerock Creek) with high potential for groundwater recharge through spreading and identified SWP water, recycled water, and local runoff as potential recharge sources. The study also identified several potential groundwater injection sites within existing Los Angeles County Waterworks and PWD municipal wellfields. Treated SWP water was identified as a potential recharge source.

In 1996, PWD adopted a water facilities master plan for its service area, updating a 1988 plan. PWD relies on three water sources: Littlerock Reservoir, local groundwater, and SWP water. The plan indicates that about 40 percent of PWD supply is from groundwater. Declining groundwater levels have been a local concern in the Palmdale area, although extractions presently appear to be within the basin's perennial yield. The plan also indicates that existing supplies are insufficient to meet drought demands. Average year shortages are projected to occur by 2005.

To meet drought year demands, the plan calls for the construction of up to 12 new production wells. The plan's draft EIR identified declining groundwater levels as an unavoidable impact of constructing new wells. Mitigation measures recommended included conservation and drought year demand reduction, conjunctive use programs (as identified in the Antelope Valley water resources study), acquisition of an additional 3.1 taf/yr of SWP entitlement, participation in water transfers, and development of recycled water.

Interstate Groundwater Basins

California and Nevada share three interstate groundwater basins in the South Lahontan Region: Fish Lake Valley, crossed by Highway 168 east of Westgard Pass; Pahrump Valley, located to the east of Death Valley; and Mesquite Valley, just south of Pahrump Valley. Groundwater extraction on the California side of the border supports small-scale agricultural development, largely for alfalfa. Pahrump Valley is the most populated of the three valleys; most of its development is located in Nevada around the community of Pahrump. Pahrump and Mesquite Valleys are within about 35 miles of the rapidly growing Las Vegas metropolitan area. In the early 1990s, the Southern Nevada Water Authority proposed exporting groundwater from several rural counties in central Nevada to help meet Las Vegas' rapidly increasing need for water. Opposition by rural Nevada counties to SNWA's proposal caused SNWA to defer this project. Inyo County residents have historically been concerned about the proximity of Las Vegas to the interstate basins, although no new interstate issues have come up since SNWA's proposed project.

Water Management Options for the South Lahontan Region

Table 9-11 shows a list of options for the region, and the results of an initial screening of the options. The retained options were evaluated (Table 9A-2 in Appendix 9A) based on a set of fixed criteria discussed in Chapter 6.

Water Conservation

Urban. Urban water demand forecasts for 2020 assume that BMPs are in place; consequently, only those urban conservation efforts which exceed BMPs are considered as options. Reducing outdoor water use to 0.8 ET_o in new development would attain 20 taf/yr of depletion reductions, while extending this measure to include existing development would reduce depletions by 31 taf/yr. Reducing residential indoor water use to 60 and 55 gpcd would attain depletion reductions of 7 and 15 taf/yr, respectively. Reducing CII water use by an additional 3 and 5 percent would attain 2 and 4 taf/yr of depletion reductions, respectively. Reducing distribution system losses to 7 and 5 percent would save 4 and 12 taf/yr, respectively.

Agricultural. The 2020 agricultural water demand forecasts assume that EWMPs are in place. As with the urban water management options, only those agricultural conservation efforts which exceed EWMPs

TABLE 9-11

South Lahontan Region List of Water Management Options

Option	*Retain or Defer*	*Reason for Deferral*
Conservation		
Urban		
Outdoor Water Use to $0.8ET_o$	Retain	
Indoor Water Use	Retain	
Interior CII Water Use	Retain	
Distribution System Losses	Retain	
Agricultural		
Seasonal Application Efficiency Improvements	Retain	
Flexible Water Delivery	Defer	No significant depletion reductions attainable.
Canal Lining and Piping	Defer	No significant depletion reductions attainable.
Tailwater Recovery	Defer	No significant depletion reductions attainable.
Modify Existing Reservoirs/Operations		
Remove Sediment from Littlerock Reservoir	Defer	Excessive costs for additional yield.
New Reservoirs/Conveyance Facilities		
—	—	—
Groundwater/Conjunctive Use		
—	—	—
Water Marketing		
Mojave Water Agency	Retain	
Palmdale Water District	Retain	
Water Recycling		
Water recycling options	Defer	Water recycling options in this region do not generate new water supply.
Desalting		
Brackish Groundwater		
—	—	—
Seawater		
—	—	—
Other Local Options		
Line Palmdale Ditch	Defer	No net increase in supply.
Reduce Outflow to Playa Lakes	Defer	Restrictions on use of flows that provide recharge to overdraft basins. Costs are high and water quality is poor.
Statewide Options		
—	—	See Chapter 6.

are considered as options. It is estimated that water savings of 2, 3, and 5 taf/yr could be achieved in this region, by improving SAE to 76, 78, and 80 percent, respectively. Options for flexible water delivery and canal lining and piping are not feasible in this region because most water supply comes from individual wells with minimal conveyance facilities.

Modify Existing Reservoirs or Operations

Sediment has accumulated in Littlerock Reservoir and minor additional yield could be realized by removing the sediment. Studies are now under way to evaluate the costs and benefits of this option. Preliminary estimates indicate that the cost of this option is in the order of $2,000/af. Because of the high costs, this option was deferred.

New Reservoirs or Conveyance Facilities

There are no proposed new reservoir developments in this region. The region's aridity and consequent lack of surface water resources make new reservoirs infeasible. Future local water resources development will be based on groundwater sources.

Water Marketing

The California Aqueduct could convey purchased water to MWA's distribution system to supply some of the region's rapidly urbanizing areas. MWA has entered into a multi-year banking and exchange agreement with Solano County Water Agency. During wet years, SCWA can bank up to 10 taf of its annual SWP entitlement in MWA's groundwater basin. During drought years, SCWA can take part of MWA's SWP entitlement in exchange (up to half the banked amount with a maximum of 10 taf/yr). MWA is also pursuing two demonstration water marketing projects of 2 taf each. PWD is seeking to purchase 3.1 taf/yr of SWP entitlement from Central Valley agricultural water purveyors. Other voluntary marketing arrangements could be developed through option agreements, storage programs, and purchases of water through the DWB or other spot markets.

Capacity has been developed to store additional imported supplies in the Mojave River Basin at MWA's Rock Springs groundwater recharge facility near Hesperia. Additional recharge facilities in the Barstow area are in the final planning stages, which would further increase MWA's ability to take delivery of imported supplies when its Mojave River Aqueduct is completed. Sufficient basin storage is available to store water in wet years when more SWP supplies or purchased supplies might be available.

Water Recycling

Water recycling options are deferred for this region because planned projects would not generate new supply.

Other Local Options

The ditch that conveys water from Littlerock Reservoir to Palmdale Lake has an estimated 20 percent conveyance loss, which could be reduced by canal lining. Canal lining would reduce groundwater recharge by approximately 1 taf/yr, resulting in no net increase in water supply. This option was deferred.

Some flow of the Mojave River reaches Soda Lake where the flow is lost to evaporation. Annual outflow past Afton Canyon averages 8.4 taf. However, the basin adjudication restricts use of flows that provide recharge to downstream subareas of the basin that are in overdraft. Reducing outflow to Soda Lake was deferred as an option.

Likewise, local storm runoff collects in many small playas throughout the basin. These playas generally do not contribute to groundwater recharge, due to the low permeability of playa soils. Water collected in the playas evaporates, rather than recharging groundwater. Diversion or collection of runoff to playas and recharging it to groundwater basins could increase groundwater supplies by eliminating the evaporation. Six dry lakebeds could potentially store an additional 1.8 taf once every five years. Costs for this option are $1,000 to $3,300/af. Water quality at the playas is generally poor, with high levels of salts and minerals. This option was deferred.

Statewide Options

Statewide water supply augmentation options are discussed and quantified in Chapter 6.

Options Likely to be Implemented in the South Lahontan Region

Water supplies are not available to meet all of the region's 2020 water demands in average or drought years. Applied water shortages are forecasted to be 270 taf in average years and 308 taf in drought years. Most of the region's shortage will be in the Mojave River planning subarea. Water shortages in the Antelope Valley subarea are forecast only in drought years. Ranking of retained water management options for the South Lahontan Region is summarized in Table 9-12. Table 9-13 summarizes options that can likely be implemented by 2020 to relieve the shortages. The options likely to be implemented in this region include SWP supplies and water transfers conveyed by the California Aqueduct.

TABLE 9-12

Options Ranking for South Lahontan Region

Option[a]	*Rank*	*Cost ($/af)*	*Potential Gain (taf)*	
			Average	*Drought*
Conservation				
Urban				
Outdoor Water Use to 0.8 ET_o-New Development	M	750	20	20
Outdoor Water Use to 0.8 ET_o-New and Existing Development	M	[b]	31	31
Indoor Water Use (60 gpcd)	M	400	7	7
Indoor Water Use (55 gpcd)	M	600	15	15
Interior CII Water Use (3%)	M	500	2	2
Interior CII Water Use (5%)	M	750	4	4
Distribution System Losses (7%)	M	200	4	4
Distribution System Losses (5%)	M	300	12	12
Agricultural				
Seasonal Application Efficiency Improvements (76%)	H	100	2	2
Seasonal Application Efficiency Improvements (78%)	M	250	3	3
Seasonal Application Efficiency Improvements (80%)	M	450	5	5
Water Marketing				
Mojave Water Agency	H	[b]	4	4
Palmdale Water District (3.1 taf SWP entitlement)	H	[b]	3	2
Statewide Options				
See Chapter 6.				

[a] All or parts of the amounts shown for highlighted options have been included in Table 9-13.
[b] Data not available to quantify.

TABLE 9-13

Options Most Likely to be Implemented by 2020 (taf)
South Lahontan Region

	Average	*Drought*
Applied Water Shortage	**270**	**308**
Options Likely to be Implemented by 2020		
Conservation	56	56
Modify Existing Reservoirs/Operations	-	-
New Reservoirs/Conveyance Facilities	-	-
Groundwater/Conjunctive Use	-	-
Water Marketing	7	6
Recycling	-	-
Desalting	-	-
Other Local Options	-	-
Statewide Options	174	204
Expected Reapplication	33	42
Total Potential Gain	**270**	**308**
Remaining Applied Water Shortage	**0**	**0**

FIGURE 9-4
Colorado River Hydrologic Region

Colorado River Hydrologic Region

. . .

Description of the Area

The Colorado River Region encompasses the southeastern corner of California. The region's northern boundary, a drainage divide, begins along the southern edge of the Mojave River watershed in the Victor Valley area of San Bernardino County and extends northeast across the Mojave Desert to the Nevada stateline. The southern boundary is the Mexican border. A drainage divide forms the jagged western boundary through the San Bernardino, San Jacinto, and Santa Rosa Mountains, and the Peninsular Ranges (including the Laguna Mountains). The Nevada stateline and the Colorado River (the boundary with Arizona) delineate the region's eastern boundary (Figure 9-4).

Covering over 12 percent of the total land area in the State, the region is California's most arid. It includes volcanic mountain ranges and hills; distinctive sand dunes; broad areas of Joshua tree, alkali scrub, and cholla communities; and elevated river terraces. Much of the region's topography consists of flat plains punctuated by hills and mountain ranges. The San Andreas fault traverses portions of the Coachella and Imperial Valleys. A prominent topographic feature is the Salton Trough in the south-central part of the region.

The climate for most of the region is subtropical desert. Average annual precipitation is much higher in the western mountains than in the desert areas. Winter snows generally fall above 5,000 feet; snow depths can reach several feet at the highest levels during winter. Most of the precipitation in the region falls during the winter; however, summer thunderstorms can produce rain and local flooding. Despite its dry climate and rugged terrain, the region contains large and productive agricultural areas and popular vacation resorts. Table 9-14 shows the region's population and crop acreage for 1995 and 2020.

TABLE 9-14

Population and Crop Acreage

	Population (thousands)	*Irrigated Crop Acreage (thousands of acres)*
1995	533	749
2020	1,096	750

Coachella Valley date palms. The Colorado River Region is the main location in California where dates are grown for commercial production.

Most of the population is concentrated in the Coachella and Imperial Valleys. Major cities in the Coachella Valley include Palm Springs, Indio, and Palm Desert. Other urban centers in the region are the Cities of El Centro, Brawley, and Calexico in Imperial Valley; the Cities of Beaumont and Banning in the San Gorgonio Pass area; and the Cities of Needles and Blythe along the Colorado River.

Agriculture is an important source of income for the region. Almost 90 percent of the developed private land is used for agriculture, most of which is in the Imperial, Coachella, and Palo Verde Valleys. The primary crops are alfalfa, winter vegetables, spring melons, table grapes, dates, Sudan grass, and wheat. Recreation and tourism are another important source of income for the region. In Coachella Valley, the Palm Springs area and adjoining communities are an important resort and winter golf destination. Recreational opportunities provided by the more than 100 golf courses in the Coachella Valley, water-based recreation on the Colorado River and Salton Sea, and desert camping all contribute to the area's economy.

Water Demands and Supplies

Table 9-15 shows the water budget for the Colorado River Region. Agricultural water demand makes up the majority of the water use in the region. There are two major areas where water is used for wildlife habitat in the region, the Salton Sea National Wildlife Refuge and the Imperial Wildlife Area. There are also several private wetlands.

About 90 percent of the region's water supply is from surface deliveries from the Colorado River (through the All American and Coachella Canals, local diversions, and the Colorado River Aqueduct by means of an exchange for SWP water). Other supplies are from groundwater, SWP water, local surface water, and recycled water. Bulletin 160-98 base year groundwater overdraft in the region was estimated to be about 70 taf and occurs in the Coachella Valley.

Major water agencies in the region are the Palo Verde Irrigation District, Imperial Irrigation District, Coachella Valley Water District, Bard Water District, Mojave Water Agency, Desert Water Agency, and San Gorgonio Pass Water Agency.

The region's primary shortages with existing supplies are expected to occur in the Coachella planning subarea because of groundwater overdraft. (In the future, reduction in California's Colorado River water use to the State's basic apportionment creates an average year shortage of as much as 0.9 maf in the South Coast Region. This 2020 shortage is shown in the South Coast water budget.)

Supplies from the Colorado River

Most of the water supply in the region comes from the Colorado River, an interstate (and international) river whose use is apportioned among the seven Colorado River Basin states by a complex body of statutes, decrees, and court decisions known collectively as the law of the river. Table 9-16 summarizes key elements of the law of the river. USBR acts as the watermaster for the Colorado River, and all users of Colorado River water must contract with USBR for their supplies. Figure 9-4 shows the locations of key Colorado River storage and conveyance facilities.

TABLE 9-15

Colorado River Region Water Budget (taf)[a]

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	418	418	740	740
Agricultural	4,118	4,118	3,583	3,583
Environmental	39	38	44	43
Total	**4,575**	**4,574**	**4,367**	**4,366**
Supplies				
Surface Water	4,154	4,128	3,920	3,909
Groundwater	337	337	285	284
Recycled and Desalted	15	15	15	15
Total	**4,506**	**4,479**	**4,221**	**4,208**
Shortage	**69**	**95**	**147**	**158**

[a] Water use/supply totals and shortages may not sum due to rounding.

Hoover Dam and Lake Mead. Lake Mead and Lake Powell are the largest of the Colorado River system reservoirs.

Courtesy of USBR

TABLE 9-16

Key Elements of the Law of the River

Document	*Date*	*Main Purpose*
Colorado River Compact	1922	Equitable apportionment of the water from the Colorado River system between the two basins. The Upper Basin and the Lower Basin are each provided a basic apportionment of 7.5 maf annually of consumptive use. The Lower Basin is given the right to increase its consumptive use an additional 1 maf annually.
Boulder Canyon Project Act	1928	Authorized USBR to construct Boulder (Hoover) Dam and the All American Canal (including the Coachella Canal), and gave congressional consent to the Colorado River Compact. Also provided that all users of Colorado River water must enter into a contract with USBR for use of the water.
California Limitation Act	1929	Limited California's share of the 7.5 maf annually apportioned to the Lower Basin to 4.4 maf annually, plus no more than half of any surplus waters.
Seven Party Agreement	1931	An agreement among PVID, IID, CVWD, MWDSC, City of Los Angeles, City of San Diego, and County of San Diego to recommend to the Secretary of Interior how to divide use of California's apportionment among the California water users. Details are shown in Table 9-17.
U.S. - Mexican Treaty	1944	Guarantees Mexico a supply of 1.5 maf annually of Colorado River water.
U.S. Supreme Court Decree in A***rizona v. California, et al.***	1964	Apportions water from the mainstream of the Colorado River among the Lower Division states. When the Secretary determines that 7.5 maf of mainstream water is available, it is apportioned 2.8 maf to Arizona, 4.4 maf to California, and 0.3 maf to Nevada. Also quantifies tribal water rights for specified tribes, including 131,400 af for diversion in California.
Colorado River Basin Project Act	1968	Requires Secretary of the Interior to prepare long-range operating criteria for major Colorado River reservoirs.
U.S. Supreme Court Decree in *Arizona v. California, et al.*	1979	Quantifies Colorado River mainstream present perfected rights in the Lower Basin states.

TABLE 9-17

Annual Apportionment of Use of Colorado River Water
(all amounts represent consumptive use)

Interstate/International		
Upper Basin States (Wyoming, Utah, Colorado, New Mexico, small portion of Arizona)		7.5 maf
Lower Basin States (Arizona, Nevada, California)		7.5 maf
	Arizona	2.8 maf
	Nevada	0.3 maf
	California	4.4 maf
Republic of Mexico[a]		1.5 maf

[a] Plus 200 taf of surplus water, when available. Water delivered to Mexico must meet specified salinity requirements.

Intrastate (Seven Party Agreement)[b]	
Priority 1	Palo Verde Irrigation District (based on area of 104,500 acres).
Priority 2	Lands in California within USBR's Yuma Project (not to exceed 25,000 acres).
Priority 3	Imperial Irrigation District and lands served from the All American Canal in Imperial and Coachella Valleys, and Palo Verde Irrigation District for use on 16,000 acres in the Lower Palo Verde Mesa.
Priorities 1 through 3 collectively are not to exceed 3.85 maf/yr. There is no specified division of that amount among the three priorities.	
Priority 4	MWDSC for coastal plain of Southern California-550,000 af/yr.
Priority 5	An additional 550,000 af/yr to MWDSC, and 112,000 af/yr for the City and County of San Diego[c].
Priority 6	Imperial Irrigation District and lands served from the All American Canal in Imperial and Coachella Valleys, and Palo Verde Irrigation District for use on 16,000 acres in the Lower Palo Verde Mesa, for a total not to exceed 300,000 af/yr.
Total of Priorities 1 through 6 is 5.362 maf/yr.	
Priority 7	All remaining water available for use in California, for agricultural use in California's Colorado River Basin.

[b] Indian tribes and miscellaneous present perfected right holders that are not identified in California's Seven Party Agreement have the right to divert up to approximately 85 taf /yr (equating to about 50 taf/yr of consumptive use) within California's 4.4 maf basic apportionment. These users are presently consumptively using approximately 32 taf/yr (assuming about 25 taf/yr of unmeasured return flow).

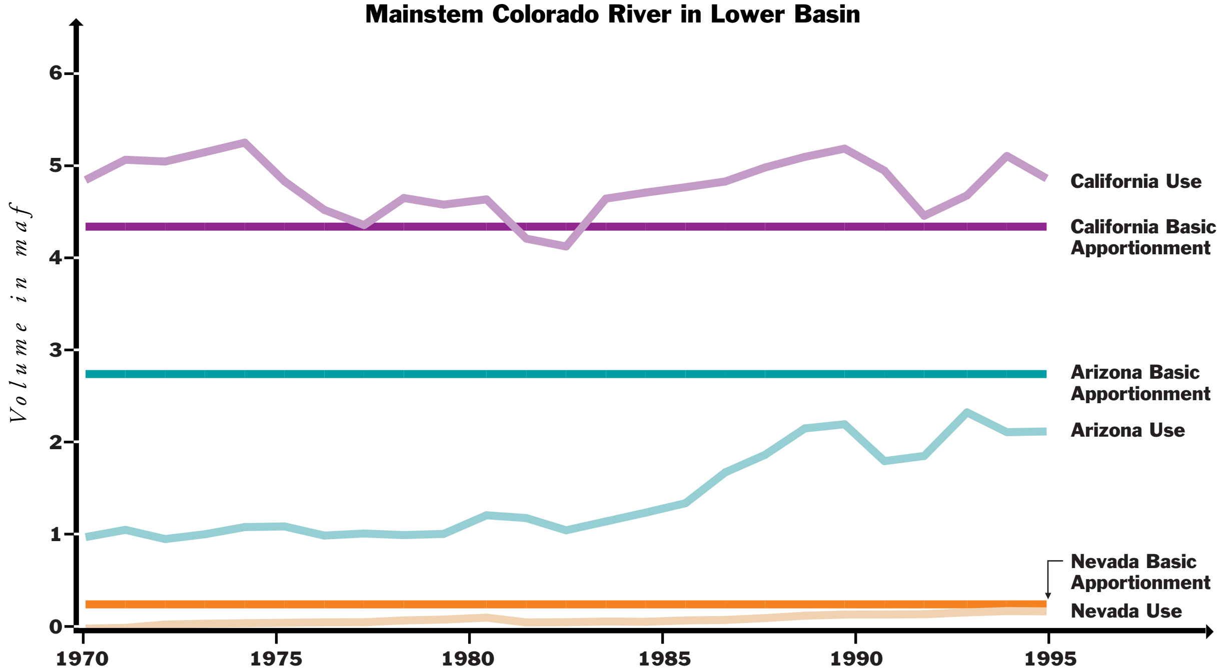
[c] Subsequent to execution of the Seven Party Agreement, San Diego executed a separate agreement transferring its apportionment to MWDSC.

Within California, local agencies' apportionments of Colorado River water were established under the Seven Party Agreement (Table 9-17), which has been incorporated into water delivery contracts which the Secretary of the Interior has executed with California water users. Uses occurring within a state are charged to that state's allocation. Thus, federal water uses or uses associated with federal reserved rights (e.g., tribal water rights) must also be accommodated within California's basic apportionment of 4.4 maf/yr plus one-half of any available surplus water.

The major local agencies in California using Colorado River water in the Colorado River Region are PVID, BWD, IID, and CVWD. The Reservation Division of USBR's Yuma Project provides water to Colorado River Indian tribes in California. The remainder of California's Colorado River water use occurs in the South Coast Region (Chapter 7). Figure 9-5 is a plot of Lower Basin states' apportionments compared with historical Colorado River water use. As shown in the figure, California's use has historically exceeded its basic apportionment, because California has been allowed to divert Arizona's and Nevada's unused apportionments, and to divert surplus water. With completion of the Central Arizona Project and the 1996 enactment of a state groundwater banking act,

FIGURE 9-5

Basic Apportionment and Consumptive Use of Mainstem Colorado River in Lower Basin



Arizona used more than its basic apportionment in 1997. Reduction of California's Colorado River use from current levels to 4.4 maf annually (when surplus water is not available) has significant water management implications for the South Coast Region. In calendar year 1996, actual consumptive use of the Lower Basin states (without considering USBR's unmeasured return flow credit of 239 taf) was:

Nevada	241 taf
Arizona	2,813 taf
California	5,256 taf
Total Lower Basin	8,310 taf

Within the Colorado River Region, IID, BWD, and PVID receive virtually all of their supplies from the Colorado River. IID and CVWD's Colorado River supplies are diverted into USBR's All American Canal at Imperial Dam; CVWD is served from the Coachella Branch of the AAC. PVID diverts via the Palo Verde Canal from the Colorado River near Blythe. BWD receives its supplies from facilities of USBR's Yuma Project, which serves lands in both California and Arizona.

The interstate allocations provided in the 1922 Compact were made after a period of relatively wet hydrology on the Colorado River. Some have suggested that the allocations overstate the river's normally available water supply, even without consideration of subsequent calls on that water supply for tribal water rights and endangered species fishery water needs. Table 9-18 provides an overview of average river hydrology. While consumptive use from the mainstem in the Lower Basin is assumed to be its basic apportionment of 7.5 maf, Upper Basin use is still well below its Colorado River Compact apportionment. Current

TABLE 9-18

Estimated Colorado River Flow and Uses[a]

	maf
Average Flow (1906-95)	
Upper Basin	15.1
Lower Basin	1.4
Total	**16.5**
Current Uses	
Upper Basin	3.8
Lower Basin (mainstem)[b]	7.5
Mexico	1.5
Mainstem Evaporation and Losses	1.9
Total	**14.7**
Average Flow into Reservoir Storage (16.5 - 14.7)	**1.8**

[a] Prepared by the CRB.

[b] Reflects restriction on MWDSC's diversion as Central Arizona Project and Southern Nevada Water System increase diversions to Arizona's and Nevada's basic apportionments.

USBR's Imperial Dam on the Colorado River. The structures in the foreground are a series of desilting basins used to reduce the sediment load of river water before it enters the All American Canal.

Courtesy of USBR

projections are that the Upper Basin will not reach its full Compact apportionment until after 2060.

Supplies from Other Sources

Local agencies contracting with the SWP for part of their supplies are shown in Table 9-19.

Neither CVWD nor DWA have facilities to take direct delivery of SWP water. Instead, both agencies have entered into exchange agreements with MWDSC, whereby MWDSC releases water from its Colorado River Aqueduct into the Whitewater River for storage in the upper Coachella Valley groundwater basin. In turn, MWDSC takes delivery of an equal amount of the agencies' SWP water. San Gorgonio Pass Water Agency, which serves the Banning/Beaumont area, also lacks the facilities to take delivery of SWP water, and to date has received no actual supply from the SWP. SGPWA will receive SWP supply when the Department completes its extension of the East Branch of the California Aqueduct in 2000.

Groundwater, local surface water, and water recycling provide the remaining supplies for this region. CVWD, working with DWA, has an active groundwater recharge program for the upper end of the Coachella Valley (generally, the urbanized part of the valley). CVWD recharges groundwater with imported Colorado River supplies and with Whitewater River flows using percolation ponds constructed in the Windy Point area. CVWD and DWA levy extraction fees on larger groundwater users in the upper Coachella

TABLE 9-19

SWP Contractors in the Colorado River Region

Agency	*Maximum Annual Contract Entitlement (taf)*	*SWP Deliveries in 1995 (taf)*
Coachella Valley WD	23.1	23.1
Desert Water Agency	38.1	38.1
Mojave Water Agency[a]	75.8	8.7
San Gorgonio Pass Water Agency	17.3	0

[a] Contract entitlement covers both South Lahontan and Colorado River Regions; 7.3 taf of this amount is allocated to Colorado River Region.

Valley. Imperial Valley, the largest water-using area in the region, does not have significant supplies of usable groundwater.

Local Water Resources Management Issues

Management of California's Colorado River Water

The major water management issue in this region is California's use of Colorado River water in excess of its basic annual apportionment of 4.4 maf. In the past, Arizona and Nevada were not using the full amount of their basic apportionments, and in accordance with the law of the river, California was able to use the amount apportioned to, but not used by, Nevada and Arizona. Discussions among the seven basin states and ten Colorado River Indian Tribes over changes to Colorado River operating criteria and ways for California to reduce its Colorado River water use began as early as 1991. The drought in Northern California prompted California to request that USBR make surplus water available, so that maximum use could be made of Colorado River water in Southern California. These discussions over changes to reservoir operations and how surplus or shortage conditions could be established continued for a time in a forum known as the "7/10 process."

More recently, the California local agencies, working through the Colorado River Board of California, have been developing a proposal for discussion with the other basin states to illustrate how, over time, California would reduce its use to the basic apportionment of 4.4 maf/yr. Drafts of the proposal, known as the Colorado River Board draft 4.4 Plan, have been shared with the other states. Efforts are being made to reach intrastate consensus on the plan in 1998. As Bulletin 160-98 goes to press, the most current version of the draft plan is the December 1997 version. The following text is based on that version.

As currently formulated, the draft plan would be implemented in two phases. The first phase (between the present and 2010 or 2015) would entail implementing already identified measures (such as water conservation and transfers) to reduce California's Colorado River water use to about 4.6 to 4.7 maf/yr. The second phase would implement additional measures to reduce California's use to its basic annual 4.4 maf apportionment in those years when neither surplus water nor other states' unused apportionments was available. One of the fundamental assumptions made in the plan is that MWDSC's Colorado River Aqueduct will be kept full, by making water transfers from agricultural users in the Colorado River Region to urban water users in the South Coast Region. (The Colorado River Aqueduct's capacity is a maximum of

Imperial Irrigation District, formed in 1911, acquired conveyance facilities constructed by a bankrupt privately owned irrigation company. In 1918, IID constructed Rockwood Heading (shown here) on the original canal system. Keeping the canal system from being choked by the Colorado River's high sediment loading was difficult; note the dredge shown in the background. These early facilities were subsequently replaced by the All American Canal.

Courtesy of Imperial Irrigation District.

1.3 maf/yr. However, as shown in Table 9-17, MWDSC has a fourth priority right to only 550 taf annually—the remaining capacity of the aqueduct has historically been filled with unused apportionment water of other entities or with water from hydrologic surpluses.)

In the December 1997 draft plan, specific actions were included in the first phase: core water transfers (every year water transfers) such as the existing IID/MWDSC agreement and the proposed IID/SDCWA transfer; seepage recovery from unlined sections of the All American and Coachella Canals; drought year water transfers similar to the PVID/MWDSC pilot project; groundwater banking in Arizona; and conjunctive use of groundwater in areas such as the Coachella Valley. The actions are described in more detail below. The draft plan recognizes that transfers of conserved water must be evaluated in the context of preserving the Salton Sea's environmental resources, and also that plan elements must address environmental impacts on the lower Colorado River and its listed species.

Other actions to occur as part of the first phase would include implementation of the San Luis Rey Indian water rights settlement authorized in PL 100-675 and implementation of measures to administer agricultural water entitlements within the first three priorities of the Seven Party Agreement. Examples of such measures include quantifying amounts of water conserved or transferred, and annually reconciling water use with water allocations (e.g., overrun accounting).

An important element of the CRB draft 4.4 plan is the concept that existing reservoir operating criteria be changed by USBR to make optimum use of the river's runoff and available basin storage capacity. California agencies developed new proposed operating criteria that are included in the draft plan. The draft plan contemplates that changes in operating criteria would be part of both the first and second phases. The other basin states have been cautious in their reaction to California's proposals for reservoir reoperation, and have suggested, for example, that new criteria should not be implemented until California has prepared the environmental documents and executed the agreements that would be needed to begin implementation of the plan. (In its 1995 five-year review of Colorado River operating criteria, USBR had announced that it planned no changes to existing criteria.)

The second phase of the CRB draft 4.4 plan would include additional average year and drought year water transfers. Specifics on these transfers would be developed during the first phase of plan implementation. One suggested component is construction of desalting facilities on rivers tributary to the sea, to divert and treat agricultural drainage water that would otherwise enter the sea. The treated water could be conveyed to urban water users in the South Coast Region via the Colorado River Aqueduct. As with any alternative that would reduce the amount of relatively fresh water reaching the sea, the environmental impacts of this approach would require careful evaluation. Other components of the second phase would include further transfers of conserved agricultural water to the

New Parker Dam photo

USBR's Parker Dam on the Colorado River impounds Lake Havasu. At this location, the Colorado River forms the stateline between California and Arizona. MWDSC's Colorado River Aqueduct and the Central Arizona Project divert from Lake Havasu.

South Coast and further work on reservoir operating criteria. Implementation of some elements of phase two of the plan may extend beyond the Bulletin 160-98 planning horizon.

Tribal Water Rights

Colorado River Indian Tribes. As a result of the 1964 U.S. Supreme Court decree in Arizona v. California, California's basic apportionment of Colorado River water was quantified and five lower Colorado River Indian Tribes were awarded 905 taf of annual diversions, 131 taf of which were allocated for diversion in and chargeable to California pursuant to a later supplemental decree.

In 1978, the tribes asked the court to grant them additional water rights, alleging that the U.S. failed to claim a sufficient amount of irrigable acreage, called omitted lands, in the earlier litigation. The tribes also raised claims called boundary land claims for more water based on allegedly larger reservation boundaries than had been assumed by the court in its initial award. In 1982, the special master appointed by the Supreme Court to hear these claims recommended that additional water rights be granted to the Indian tribes. In 1983, however, the Supreme Court rejected the claims for omitted lands from further consideration and ruled that the claims for boundary lands could not be resolved until disputed boundaries were finally determined. Three of the five tribes—Fort Mojave Indian Tribe, Quechan Indian Tribe, and Colorado River Indian Tribe—are pursuing additional water rights related to the boundary lands claims. A settlement has been reached on the Fort Mojave claim and may soon be reached on the CRIT claim. Both settlements would then be presented to the special master. The Quechan claim has been rejected by the special master on the grounds that any such claim was necessarily disposed of as part of a Court of Claims settlement entered into by the tribe in a related matter in the mid-1980s. As with all claims to water from the mainstem of the Colorado River and any determination by the special master, only the U.S. Supreme Court itself can make the final ruling.

If both the Fort Mojave and CRIT settlements were approved, the tribes would receive water rights in addition to the amounts granted them in the 1964 decree.

San Luis Rey Indian Water Rights Settlement Act. The San Luis Rey Indian Water Rights Settlement Act (Public Law No. 100-675; 102 Stat. 4000 [1988]) is to provide for the settlement of the reserved water rights claims of the La Jolla, Rincon, San Pasqual, Pauma, and Pala Bands of Mission Indians. Litigation (affecting the interests of the United States, the City of Escondido, the Escondido Mutual Water Company, the Vista Irrigation District, and the Bands) and proceedings before the Federal Energy Regulatory Commission involved tribal water rights claims to the waters of the San Luis Rey River and questions about the validity of rights-of-way granted by the U.S. across tribal and allotted lands. The act authorizes and directs the Secretary of the Interior to arrange for a 16 taf/yr supplemental supply of water to benefit the Bands and the local communities. This supply can be obtained either from water development from public lands in California outside the service area of the CVP, from water salvaged as the result of lining part of the AAC or Coachella Canal, or through a contract with MWDSC. Title II of PL 100-675 authorized the Secretary of the Interior to line parts of the canals, and permitted the Secretary to enter into an agreement or agreements with PVID, IID, CVWD, and/or MWDSC for the construction or funding. The act did not authorize appropriation of federal funds for canal lining.

Water Conservation Programs

There have been several large-scale water conservation actions involving Colorado River water users, as shown in Table 9-20.

Salton Sea

The present day Salton Sea was formed in 1905, when Colorado River water flowed through a break in a canal that had been constructed along the U.S./Mexican border to divert the river's flow to agricultural lands

Colorado River Board of California

The Colorado River Board of California is the State agency responsible for administering California's Colorado River water allocation, and for dealing with the other basin states on river management issues. The Board is composed of six members representing the California agencies who were signatories to the 1931 Seven-Party Agreement, two public members, and two ex-officio members (the directors of the Department and DFG). The six local agencies represented on the CRB are CVWD, IID, LADWP, MWDSC, PVID, and SDCWA. CRB's office and staff are located in Glendale.

TABLE 9-20

Existing Colorado River Region Water Conservation Actions

Year	*Action*	*Participants*	*Comments/Status*	*Estimated Savings*
1980	Line 49 miles of Coachella Branch of All American Canal	USBR, CVWD, MWDSC	Project completed.	132 taf/yr
1988	IID distribution system improvements and on-farm water management actions	IID, MWDSC	Multi-year agreement, extends into 2033. Projects MWDSC has funded include canal lining, regulatory reservoir and spill interceptor canal construction, tailwater return systems, non-leak gates, 12-hour delivery of water, drip irrigation systems, linear-move irrigation systems, and system automation. MWDSC has funded over $150 million for conservation program costs through 1997.	107 taf/yr in 1998
1992	Groundwater banking in Arizona	MWDSC, CAWCD, SNWA	Test program to bank up to 300 taf.	MWDSC and SNWA have stored 139 taf in Arizona groundwater basins.
1992	PVID land fallowing	PVID, MWDSC	Project completed. Two-year land fallowing test program. Covered 20,215 acres in PVID. MWDSC paid $25 million to farmers over a two-year period.	Total of 186 taf was made available from the program, although the water was subsequently released from Lake Mead when flood control releases were made from the reservoir.
1995	Partnership agreement	USBR, CVWD	Provides, among other things, for studies to optimize reasonable beneficial use of water in the district.	N/A

in the Imperial Valley. Until that break was repaired in 1907, the full flow of the river was diverted into the Salton Sink, a structural trough whose lowest point is about 278 feet below sea level. Within geologic time, the Colorado River's course has altered several times. At times, the river discharged to the Gulf of California as it does today. At other times it flowed into the Salton Sink. Lake Cahuilla, the most recent of several prehistoric lakes to have occupied the Salton Sink, dried up some 300 years ago.

Over the long term, the sea's elevation has gradually increased, going from a low on the order of -250 feet in the 1920s to its present level of about -226 feet. The sea's maximum elevation in recent years was -225.6 in 1995. Since some shoreline areas are relatively flat, a small change in elevation can result in a large difference in the extent of shoreline submerged. Levees have been constructed to protect adjacent farmland and structures at some sites along the shoreline; the remaining managed acreage of the Salton Sea National Wildlife Refuge is also protected from the sea by levees.

The Salton Sea is the largest lake located entirely within California, with a volume of about 7.5 maf at its present elevation of -226 feet. The sea occupies a closed drainage basin—if there were no inflows to maintain lake levels, its waters would evaporate as did those of prehistoric Lake Cahuilla. The area's average annual precipitation is 3 inches or less, while average annual evaporation is in excess of 5 feet. The sea receives over 1 maf of inflow annually, primarily from

A false-color infrared satellite photo of the Salton Sea (January 1998 Landsat 5). The irrigated areas in Imperial Valley are clearly visible to the south of the sea, as are the Algodones Dunes to the southeast. The City of Mexicali and irrigated acreage in the Mexicali Valley can also be seen.

agricultural drainage. The largest sources of inflow (about 80 percent of the total) are the New and Alamo Rivers which drain agricultural lands in the Mexicali and Imperial Valleys and flow into the sea's southern end. The New River also receives untreated and minimally treated wastewater flows from the Mexicali area; monitoring results generally indicate that pollution associated with wastewater discharges does not reach the sea because of its distance from the Mexican border.

In 1924, President Coolidge issued an executive order withdrawing seabed lands lying below elevation -244 feet for the purpose of receiving agricultural drainage water. That order was expanded in 1928 to lands below elevation -220 feet. The sea supports water-based recreational activities, and has had a popular corvina fishery. During the 1950s, the highest per capita sport fishing catches in California were from the Salton Sea. Over the years, concerns about the sea's salinity have been voiced in the context of maintaining the recreational fishery that was established with introduced species able to tolerate high salinities.

The sea also provides important wintering habitat for many species of migratory waterfowl and shorebirds, including some species whose diets are based exclusively on the fish in the sea. Wetlands near the sea and adjoining cultivated agricultural lands offer the avian population a mix of habitat types and food sources. An area at the sea's south end was established as a national wildlife refuge in 1930, although most of that area is now under water as a result of the sea's rising elevation. Some of the 380 bird species wintering in the area include pelicans, herons, egrets, cranes, cormorants, ibises, ducks, grebes, falcons, plovers, avocets, sandpipers, and gulls. The Salton Sea is considered to be a major stopover point for birds migrating on the Pacific Flyway, and has one of the highest levels of bird diversity of refuges in the federal system.

Historically, salinity has been the water quality constituent of most concern at the sea. Present levels are about 44,000 mg/L TDS (seawater is about 35,000 mg/L TDS). This high level of salinity reflects long- term evaporation and concentration of salts found in its inflow. Selenium has been a more recent constituent of interest, due to its implications for

Roadrunners are one of the bird species found year-round in the Salton Sea area.

aquatic species. Although selenium levels in the water column in the sea are less than the federal criterion of 5*u*g/L, this concentration can be exceeded in seabed sediment and in influent agricultural drainage water. Agricultural drain flows also contribute significant nutrient loading to the sea, which supports large algal blooms at some times of the year. These algal blooms have contributed to odor problems and low dissolved oxygen levels in some areas of the sea.

Over the years, USBR and others have considered potential solutions to stabilize the sea's salinity and elevation. Most recently, the Salton Sea Authority (a joint powers authority consisting of Riverside and Imperial Counties, IID, and CVWD) and others have been performing appraisal level evaluations of some of the frequently suggested alternatives. Categories of alternatives considered include:

- Diking off part(s) of the sea to create evaporation pond(s) adjoining the primary water body. This approach would divert part of the sea's water into managed impoundments, where the water would be concentrated into a brine and the salts would eventually be removed. The facilities would be sized to maintain a primary waterbody at some desired salinity concentration and elevation. The desired salinity concentration would probably be near that of ocean water (or slightly greater) to maintain the recreational fishery.
- Pumping Salton Sea water and exporting it to some other location. Possible discharge locations include nearby dry desert lakebeds (to create evaporation ponds), evaporation ponds to be constructed near the sea, the Gulf of California, or the Laguna Salada in Mexico.
- Building treatment facilities (such as a desalting plant) to remove salts from inflows to the sea.
- Importing fresh water to the sea. The most apparent source would be the Colorado River, but only in years when flood control releases were being made in excess of U.S. needs.

Maintaining a viable Salton Sea has several water management implications. First will be the actions needed to stabilize the sea's salinity in the near-term, such as the Authority's diking proposal. Eventually, a long-term solution will need to be developed. A wide range of costs has been mentioned for a long-term solution, including amounts in the billion-dollar range. Some of the possible long-term solutions suggested would entail constructing facilities in Mexico, bringing a greater level of complexity to their implementation. Other water management programs in the region, such as proposals to transfer conserved agricultural water supplies, will have to be evaluated in terms of their impacts on the sea. Recent proposals to desalt water in the Alamo or New Rivers and to transport that water in the Colorado River Aqueduct to the South Coast for urban water supply have raised concerns about maintaining the sea's environmental productivity. Such proposals might be implemented as part of the second phase of CRB's draft 4.4 Plan. (In 1997, CVWD filed an application with the SWRCB for water rights to storm water flows and drainage flows in the Whitewater River at the sea's northern end. MWDSC made a similar filing for agricultural drainage flowing into the sea's southern end.)

Congressional legislation introduced in 1998 would authorize expenditure of federal funds for a multi-year study of the sea's resources and potential solutions for managing its salinity.

Coachella Valley Groundwater Overdraft

Most PSAs within the Colorado River Region have sufficient water to meet future water needs, with the exception of Coachella Valley. Groundwater overdraft is occurring in the upper (urbanized) part of the valley; DWA and CVWD have been managing extractions in that basin to minimize future overdraft. Imported surface water at the upper end of the valley has provided a source of recharge water.

Groundwater overdraft is also occurring in the

Groundwater recharge ponds at Windy Point, to the east of San Gorgonio Pass in Riverside County. Water from the Whitewater River, along with Colorado River Aqueduct supplies exchanged for SWP deliveries of CVWD and DWA, provides recharge in the upper Coachella Valley area.

lower (agricultural) portion of the valley, an area that roughly coincides with CVWD's Improvement District No.1. CVWD estimates that actual 1995 water use within the district was about 520 taf, part of which was supplied by overdrafting the groundwater basin. (Irrigators in the lower valley are supplied by surface water from the Coachella Canal and by groundwater.) The district is in the process of preparing a groundwater management plan for the lower valley, and has considered alternatives including basin adjudication, water conservation, water recycling, and direct or in lieu recharge with water imported from the Colorado River or from the SWP. CVWD estimates that overdraft in the lower valley is about 170 taf/yr. Overdraft calculated from Bulletin 160-98 water budgets is 70 taf/yr for the upper and lower valley combined.

Lower Colorado River Environmental Water Issues

Listed fish species on the mainstem of the Colorado River include the Colorado squawfish, razorback sucker, humpback chub, and bonytail chub. Restoration actions to protect these fish may affect reservoir operation and streamflow in the mainstem and tributaries. Other species of concern in the basin include the bald eagle, Yuma clapper rail, belted kingfisher, southwestern willow flycatcher, and Kanab ambersnail.

In 1993, USFWS published a draft recovery implementation plan for endangered fish in the upper Colorado River Basin. The draft plan included protecting instream flows, restoring habitat, reducing impacts of introduced fish and sportsfish management, conserving genetic integrity, monitoring habitat and populations, and increasing public awareness of the role and importance of native fish.

Problems facing native fish in the mainstem Colorado River and its tributaries will not be easily resolved. For example, two fish species in most danger of extinction, the bonytail chub and razorback sucker, are not expected to survive in the wild. Although there was a commercial razorback fishery until 1950, in recent years most stream and reservoir fisheries in the basin have been managed for non-native fish. These management practices have harmed residual populations of natives. Many native fish are readily propagated in hatcheries, and thus recovery programs include captive broodstock programs to maintain the species. Reestablishing wild populations from hatchery stocks will have to be managed in concert with programs to manage river habitat. For example, although 15 million juvenile razorback suckers were planted in Arizona streams from 1981-90, the majority of these planted fish were likely eaten by introduced predators. In 1994, the states of Colorado, Wyoming, and Utah reached an agreement with USFWS on protocols for stocking non-native fish in the Upper Basin—stocking protocols consistent with native fish recovery efforts. In a program which began in 1989, USBR and other state and federal agencies have cooperated to capture, rear, and successfully reintroduce about 15,000 razorback sucker larvae in Lake Mojave.

Instream flows in the mainstem and key tributaries are being evaluated as components of native fish recovery efforts. State and federal agencies are conducting studies to estimate base flow and flushing flow needs for listed and sensitive species in various river reaches. An example of flushing flow evaluation occurred in the spring of 1996 when releases from Glen Canyon Dam were increased for several days to attempt to redistribute sediment and create shallow water habitat in the mainstem below the dam.

In a 1997 court action involving the southwestern willow flycatcher, an environmental group filed a lawsuit against USBR and USFWS under the ESA's citizen suit provisions. The group alleged that USBR's operation of Lake Mead was endangering the flycatcher's habitat at the upper end of Lake Mead. The federal district court for Arizona ruled in favor of USBR, but the environmental group appealed the district court's decision to the Ninth Circuit Court of Appeals. The appellate court subsequently declined to hear the case, letting the district court's decision stand.

Lower Colorado River Multi-Species Conservation Program

In 1995, DOI executed partnership agreements with California, Nevada, and Arizona to develop a multi-species conservation program for ESA-listed species and many non-listed, but sensitive, species within the 100-year floodplain of the lower Colorado River, from Glen Canyon Dam downstream to the Mexican border. In 1996, a joint participation agreement was executed to provide funding for the program. USFWS has designated the LCRMSCP steering committee as an ecosystem conservation and recovery implementation team pursuant to ESA. The steering committee is composed of representatives from the three states, DOI, Indian tribes, water agencies, power agencies, environmental organizations, and others.

The conservation program will work toward recovery of listed and sensitive species while providing for current and future use of Colorado River water and power resources, and includes USBR's Colorado River operations and maintenance actions for the lower river. Over 100 species will be considered in the program, including the southwestern willow flycatcher, Yuma clapper rail, and the four listed fish species mentioned above. Developing the program is estimated to take three years. Costs of program development and implementation of selected interim conservation measures, estimated at $4.5 million, are to be equally split between DOI and the nonfederal partners.

USBR initiated a formal Section 7 consultation process with USFWS, who issued a five-year biological opinion on USBR operation and maintenance activities from Lake Mead to the southerly international boundary with Mexico in 1997. USBR has estimated that the cost of implementing the biological opinion's reasonable and prudent alternatives and measures could be as high as $26 million.

The steering committee is currently participating in funding several interim conservation measures. These include a razorback sucker recovery program at Lake Mojave, restoration of Deer Island near Parker, Arizona, and a "Bring Back the Natives" program sponsored by the National Fish and Wildlife Foundation.

Water Management Options for the Colorado River Region

The only forecasted shortages within the Colorado River region are those resulting from groundwater overdraft in Coachella Valley. Implementing the draft CRB 4.4 Plan entails developing options in the Colorado River Region to keep MWDSC's Colorado River Aqueduct flowing at its full capacity, as described earlier. The reduction in California's use of Colorado River water to the basic 4.4 maf apportionment reduces the supply available to California by as much as 0.9 maf/yr.

Table 9-21 shows a list of options for the region, and the results of an initial screening of the options. The retained options were evaluated (Table 9A-3 in Appendix 9A) based on a set of fixed criteria discussed in Chapter 6. These options could be used for implementing the draft CRB 4.4 Plan and for reducing the Colorado River Region's groundwater overdraft.

Water Conservation

Urban. Urban water demand forecasts for 2020 assume that BMPs are in place; consequently, only those urban conservation efforts which exceed BMPs are considered as options. All urban conservation options were retained. Reducing outdoor water use to 0.8 ET_o in new development would attain 9 taf/yr of depletion reductions, while extending this measure to include existing development would reduce depletions by 18 taf/yr. Reducing indoor water use to 60 gpcd and 55 gpcd would reduce depletions by 2 and 3 taf/yr, respectively. Reducing commercial, institutional, and industrial water use by 3 percent and 5 percent would save 1 and 2 taf/yr, respectively. Reducing distribution system losses to 7 and 5 percent would result in 9 and 13 taf/yr of depletion reductions, respectively.

Agricultural. The 2020 agricultural water demand forecasts assume that EWMPs are in place. As with

TABLE 9-21

Colorado River Region List of Water Management Options

Option	*Retain or Defer*	*Reason for Deferral*
Conservation		
Urban		
Outdoor Water Use to $0.8ET_o$	Retain	
Indoor Water Use	Retain	
Interior CII Water Use	Retain	
Distribution System Losses	Retain	
Agricultural		
Seasonal Application Efficiency Improvements	Retain	
Flexible Water Delivery	Retain	
Canal Lining and Piping	Retain	
Tailwater Recovery	Retain	
Modify Existing Reservoirs/Operations		
Reoperating Colorado River System Reservoirs	Defer	Concurrence of USBR and other basin states not yet obtained.
New Reservoirs/Conveyance Facilities		
Additional Conveyance Capacity for Colorado River Water	Defer	California's current excess use of Colorado River water.
Groundwater/Conjunctive Use		
Groundwater Recharge Project at East Mesa	Defer	Scoped as one-time program.
Water Marketing		
Interstate banking	Retain	
Intrastate banking and transfers	Retain	
Land fallowing program	Retain	
Water Recycling		
Water recycling options	Defer	Water recycling options would not generate new water supply.
Desalting		
Brackish Groundwater		
—	—	—
Seawater		
—	—	—
Other Local Options		
Desalting local drainage water	Defer	To be evaluated in phase 2 of draft CRB 4.4 Plan.
Lining All American Canal	Retain	
Additional Lining of Coachella Canal	Retain	
Weather Modification	Defer	Complicated by interstate management issues.
Statewide Options		
—	—	See Chapter 6.

TABLE 9-22

Potential Colorado River Water Conservation Programs

Program	*Participants*	*Comments/Status*	*Estimated Savings*
Lining of All American Canal	USBR, IID CVWD, MWDSC	Authorized by PL 100-675. Final EIS/EIR published. Preferred alternative is constructing a new, lined parallel canal.	Not implemented yet. Potential of 67.7 taf/yr savings.
Agreement for a long-term transfer of up to 200 taf/yr	IID, SDCWA	SCDWA and IID executed an agreement in 1998. Initial agreement negotiated for wheeling water in MWDSC's Colorado Aqueduct. EIR/EIS not yet prepared.	Not implemented yet - up to 200 taf/yr savings.
Additional lining of Coachella Canal	USBR, others	Authorized by PL 100-675. Draft EIR/EIS issued.	Not implemented yet. Potential of 25.68 taf/yr savings.

the urban water management options, only those agricultural conservation efforts which exceed EWMPs are considered as options. Improving seasonal application efficiency to 80 percent from the base of 73 percent could reduce depletions by 50 taf/yr. Improving flexible water delivery, canal lining (on-farm and distribution system), and tailwater recovery systems could together realize 140 taf/yr in depletion reductions. However, the ability to implement conservation options that would reduce the amount of fresh water inflow to the Salton Sea must be evaluated on a project-specific basis. Goals for preservation of the sea's environmental resources may limit the extent of feasible conservation measures.

Land Fallowing. Programs such as the Palo Verde test land fallowing program could be implemented to provide water for transfer to urban areas in the South Coast Region during drought periods. In 1992, MWDSC conducted a two-year land fallowing test program with PVID. Under this program, growers in PVID fallowed about 20,000 acres of land. The saved water, about 93 taf/yr, was stored in Lower Colorado River reservoirs for future use by MWDSC (the water was later released when Colorado River flood control releases were made from Lake Mead). MWDSC paid each grower $1,240 per fallowed acre, making the cost of the water to MWDSC about $135/af. Similar programs could be implemented in the future to provide about 100 taf/yr during drought years. Future land fallowing agreements would need to consider the availability of storage for the transferred water.

Potential Sources of Water for Intrastate Marketing

The ability to market conserved water has already been demonstrated in the region. Table 9-22 summarizes some potential sources of water for intrastate transfers. Such transfers could make up some of the shortages in the South Coast Region resulting from California reducing its use to California's basic apportionment of 4.4 maf.

Construction of additional conveyance capacity from the Colorado River Region to the South Coast Region has been a recent subject of discussion. Proposition 204 provides funding for a feasibility study of a new conveyance facility from the Colorado River to the South Coast Region. Conveyance facilities mentioned include a new aqueduct from the Imperial Valley area to San Diego (on the United States side of the border), as well as San Diego's participation in enlarging the existing aqueduct serving Tijuana, Mexico. Tijuana's situation is similar to San Diego's, in that Tijuana is seeking to expand its urban supplies by negotiating transfer of agricultural water from the Mexicali Valley. Figure 9-6 is a map of the U.S. - Mexican border area, showing the area's larger water facilities. A preliminary engineering study of constructing a new canal from Imperial Valley to SDCWA's service area has been prepared for SDCWA. Additional work, including geotechnical exploration and environmental studies, would be needed to evaluate the project's feasibility. The preliminary study highlighted the need to evaluate desalting the water that the aqueduct would supply, to enable San Diego's continued reliance on a high level of water recycling. New conveyance facilities from the Colorado River Region to the South Coast Region have been deferred from evaluation in Bulletin 160-98 because it does not appear that they would be constructed within the Bulletin's planning horizon, given the other basin states' concerns about California's

FIGURE 9-6

U.S.-Mexican Border Region

use of Colorado River water and the international complexities associated with a joint project with Mexican agencies.

SDCWA and IID have been negotiating a potential transfer of water saved due to extraordinary conservation measures within IID. The agencies initially executed a 1995 MOU concerning negotiation of a transfer agreement, followed by 1998 execution of an agreement specifying the transfer's terms and conditions. The agreement has a minimum 45-year term, and can be extended for an additional 30 years. An initial transfer of 20 taf would begin in 1999, with the annual quantity of transferred water increasing to a maximum of 200 taf. In order to transfer the acquired water, SDCWA (a member agency of MWDSC) has negotiated an initial wheeling agreement with MWDSC for use of capacity in MWDSC's Colorado River Aqueduct. Environmental documentation for the transfer is pending.

Past conservation projects in the region have included land fallowing, canal lining, distribution system reservoir and spill interceptor canal construction, and irrigation distribution system improvements. Some proposed projects to recover canal seepage include:

- ***Lining part of the All American Canal.*** Public Law 100-675 authorized the Secretary of the Interior to line the canal or to otherwise recover canal seepage, using construction funds from PVID, IID, CVWD, or MWDSC. USBR's environmental documentation evaluated a parallel canal alternative, several in-place lining alternatives, and a well field alternative, and concluded that the preferred alternative was the construction of a concrete-lined canal parallel to 23 miles of the existing canal. The parallel canal alternative has the potential to conserve an estimated 67.7 taf annually of Colorado River water. Recently, the well field alternative has been reevaluated and found to be infeasible. The well field alternative, although less expensive than canal lining, has been set aside because of international concerns about groundwater extraction near the border.
- ***Lining the Remaining Section of the Coachella Canal.*** This project would involve lining the remaining 33.4 miles of the Coachella Canal, which loses about 32.4 taf/yr through seepage. Four alternatives that have been identified are conventional lining, underwater lining, parallel canal, and no action. It is estimated that the preferred alternative, conventional lining, would conserve 25.7 taf/yr.

Intrastate Groundwater Recharge or Banking

IID has proposed a groundwater recharge project at East Mesa in the Imperial Valley. The proposed recharge project would divert a portion of flood control releases from Lake Mead to a recharge site or sites located along the alignment of the old, unlined Coachella Canal. (The old canal was abandoned when an adjacent lined canal was constructed.) IID estimates that up to 20 taf could be recharged in 1998. IID prepared a mitigated negative declaration for a one-time program in 1998, when flood control releases are occurring. Since Colorado River flood control releases have historically been infrequent, future water supply for such a recharge program would be available only occasionally. This option was scoped as a one-time project and is not considered as a 2020-level option in Bulletin 160-98.

MWDSC has executed agreements with three entities to study the potential of groundwater banking arrangements that would involve storing surplus Colorado River water, when available, in groundwater basins near its Colorado River Aqueduct. The water would be withdrawn for use in the South Coast in drought years. An agreement with Cadiz Land Company covered a potential project that would entail constructing a 35-mile pipeline from the Cadiz Valley/Fenner Valley area, and diverting up to 100 taf/yr of surplus Colorado River water to storage. Estimated available groundwater storage capacity is 500 taf, with drought year withdrawal capability of 100 taf. This arrangement could additionally have a marketing component; perhaps 20 to 30 taf/yr of recharge in Cadiz and Fenner Valleys could be blended with Colorado River water and delivered to the South Coast Region. An agreement with Catellus Development Company covered a potential groundwater storage site in the Mojave Desert with an estimated capacity of 600 taf. The withdrawal capability of this site is estimated at about 150 taf/yr. A third agreement was with CVWD. CVWD is presently performing pilot studies to estimate recharge and withdrawal capabilities in the lower valley. (MWDSC and CVWD have already been evaluating increased recharge at the upper end of the valley, in the Whitewater River drainage basin.)

Technical studies of the feasibility of these projects remain to be completed, and environmental documentation has not yet been prepared. It appears likely that at least 100 taf/yr of drought year supplies could be provided through this group of potential storage sites.

Interstate Banking/Conservation

Under an existing agreement between MWDSC and the Central Arizona Water Conservation District, MWDSC can store a limited amount of Colorado River water in Arizona for future use. The Southern Nevada Water Authority is also participating in the program. The agreement stipulates that MWDSC and SNWA can store up to 300 taf in central Arizona through the year 2000. As of 1997, MWDSC has placed 89 taf in storage and SNWA has placed 50 taf in storage, for a total of 139 taf. About 90 percent of the stored water can be recovered, contingent upon the declaration of a surplus. When MWDSC is able to draw on this source, it can divert up to a maximum of 15 taf in any one month. The stored water would be made available by Arizona foregoing the use of part of its normal supply from Central Arizona Project. MWDSC plans to recover the stored water at times in the future when its Colorado River Aqueduct diversions may be limited. Like the East Mesa project described in the preceding section, this interstate project was a one-time action, and is not considered as a 2020-level option in Bulletin 160-98.

In its 1996 session, the Arizona Legislature enacted legislation establishing the Arizona Water Banking Authority. The Authority is authorized to purchase unused Colorado River water and to store it in groundwater basins to meet future needs. Conveyance to storage areas is provided by the Central Arizona Project. The legislation further provided that the Authority may enter into agreements with California and Nevada agencies to bank water in Arizona basins, with the following limitations:

- Regulations governing interstate banking would need to be promulgated by the Secretary of the Interior.
- The Arizona Department of Water Resources finds that DOI's regulations adequately protect Arizona's rights to Colorado River water.
- The ability to bank interstate water would be subordinate to banking of water to supply Arizona needs.
- Interstate banking would be precluded in years when Arizona is using its full apportionment of 2.8 maf (including water being delivered to Arizona for banking by Arizona agencies), unless surplus conditions were declared for the river system.
- Interstate withdrawals from the bank are limited to 100 taf/yr, although there is no statutory limitation on annual deposits.

Under this legislation, future interstate banking in Arizona would have a maximum annual yield of 100 taf. However, Arizona may effectively limit withdrawals in drought years by declining to decrease its diversions of surface water to allow recovery of the banked water. USBR released draft rules and regulations for the interstate banking program for public comment in December 1997, and is presently reviewing the public comments.

Reoperating Colorado River System Reservoirs

Member agencies represented by the CRB have discussed proposing reservoir operating criteria to the Secretary of the Interior that would benefit California while protecting the apportionments of the other basin states and satisfying Mexican treaty obligations. Such criteria would also constitute part of the package of actions for California to transition its use of river water from current levels to 4.4 maf/yr. Operations studies have evaluated specific shortage and surplus criteria for the river system, including selection of desired probabilities for water supply reliability and reservoir operating elevations.

Results of the operations studies performed by CRB and by USBR suggest that there could be minimal hydrologic risk to using reservoir reoperation—particularly as a limited-term measure to help California reduce its Colorado River use—as a water management option for this region. As described in Chapter 3, the Colorado River has a high ratio of storage capacity to average annual runoff. Projections of consumptive use for the upper basin states suggest that those states will not attain full use of their compact apportionments until after year 2060. USBR's surplus declarations to date have not adversely impacted the other states' use of their apportionments—for example, flood control releases were made both in 1997 and 1998, and are expected in 1999. The more significant impediment to implementing reoperation would be concerns of the other basin states about impacts of an extended period of reoperation on future shortages, considering the river's variable year to year runoff.

For Bulletin 160-98, reservoir reoperation is not evaluated as a water management option and no numerical evaluation is made, since consensus of USBR and the basin states has not yet been obtained.

Weather Modification

A fundamental management issue associated with

Colorado River water supplies is the apparent overstatement of the Compact apportionment relative to the river's historical hydrology. There have been proposals over the years to augment the river's base flow to provide additional supplies. For example, USBR had developed a proposed pilot program in 1993 to evaluate cloud seeding potential in the Upper Basin. The State of Colorado did not favor moving ahead with this program.

Weather modification has recently been raised again as part of a possible menu of options to resolve California's use in excess of the 4.4 maf basic apportionment, although no specific proposals have been made. In concept, this option would entail cloud seeding in the Upper Basin to increase runoff, and might yield a 5 percent increase in base flow from the area seeded. Large-scale weather modification projects are typically difficult to implement due to institutional and third-party concerns, and can require several years of study and testing prior to being placed in operational status. Weather modification on the Colorado River is also complicated by interstate management issues. This option has been deferred for these reasons.

Options for Coachella Valley

As discussed earlier, MWDSC has executed an agreement with CVWD to study banking of surplus Colorado River water, when available, in the lower Coachella Valley. Banking programs typically entail putting more water into the groundwater basin than is extracted, to address losses and to avoid potential localized impacts to existing basin pumpers. Over the long term this extra recharge would help stabilize groundwater basin levels. CVWD is presently in the planning stages of expanding its existing pilot recharge/extraction site in the lower valley. CVWD also plans to form a groundwater replenishment district to help manage overdraft.

MWDSC and CVWD are evaluating additional recharge possibilities in the Whitewater River drainage at the north end of the valley. Water recharged in this area could come from surplus Colorado River flows, from year-to-year purchases of SWP water or purchase of SWP entitlement, or from other water marketing arrangements that could take advantage of SWP/CRA conveyance. For example, CVWD purchased about 39 taf of water from other SWP contractors in 1996, on a one-time basis. Additional recharge possibilities in the Whitewater drainage have not yet been quantified, and are not evaluated further in Bulletin 160-98.

CVWD could, as other SWP urban water contractors are doing, participate in the permanent transfer of agricultural entitlement water provided for in the Monterey Agreement contract amendments. CVWD could also purchase water from other sources, by way of exchange with MWDSC, subject to negotiation of conveyance in the SWP and CRA. Since no specific proposals are currently pending, this option is not quantified in the Bulletin.

Statewide Options

Statewide water supply augmentation options are discussed and quantified in Chapter 6.

Options Likely to be Implemented in the Colorado River Region

Applied water shortages are forecasted to be 147 taf in average years and 158 taf in drought years. Ranking of retained water management options for the Colorado River Region is summarized in Table 9-23. Table 9-24 summarizes options that can likely be implemented by 2020 to relieve the shortages.

Options identified for this region will likely be used for reducing Coachella Valley overdraft and for managing water to benefit the South Coast Region, as called for in CRB's draft 4.4 Plan. An evaluation of these options is shown in Table 9A-3 in Appendix 9A. Bulletin 160-98 assumes that water made available by option implementation is first allocated to reduce overdraft within the region, and that remaining water is then available for use in the South Coast Region.

For readers interested in comparing Bulletin 160-98 options with the draft CRB 4.4 Plan, Table 9-25 summarizes the Bulletin's findings in a format similar to that used in the draft CRB 4.4 Plan. There is an important differences between the two documents—Bulletin 160-98 assumes that water conservation due to EWMP implementation occurs as part of base demand forecasts and not as an optional measure. Actions that may be implemented as part of phase two of the draft CRB 4.4 Plan are not shown in the table, because they have not yet been formulated and quantified.

TABLE 9-23

Options Ranking for Colorado River Region

Option[a]	*Rank*	*Cost ($/af)*	*Potential Gain (taf)*	
			Average	*Drought*
Conservation				
Urban				
Outdoor Water Use to 0.8 ET_o - New Development	M	750	9	9
Outdoor Water Use to 0.8 ET_o-New and Existing Development	M	[b]	18	18
Indoor Water Use (60 gpcd)	M	400	2	2
Indoor Water Use (55 gpcd)	M	600	3	3
Interior CII Water Use (3%)	M	500	1	1
Interior CII Water Use (5%)	M	750	2	2
Distribution System Losses (7%)	M	200	9	9
Distribution System Losses (5%)	M	300	13	13
Agricultural				
Seasonal Application Efficiency Improvements (76%)	H	100	22	22
Seasonal Application Efficiency Improvements (78%)	M	250	36	36
Seasonal Application Efficiency Improvements (80%)	M	450	50	50
Flexible Water Delivery	L	1,000	30	30
Canal Lining and Piping	L	1,200	45	45
Tailwater Recovery	H	150	65	65
Water Marketing				
Intrastate Banking	H	[b]	—	100
Interstate Banking	M	[b]	—	50
Land Fallowing Program	M	140	—	100
Other Local Options				
Lining All American Canal	H	120	68	68
Additional Lining of Coachella Canal	H	[b]	26	26
Statewide Options				
See Chapter 6.				

[a] All parts of the amounts shown for the highlighted options have been included in Table 9-24.
[b] Data not available to quantify.

TABLE 9-24

Options Likely to be Implemented by 2020 (taf)

Colorado River Region[a]

	Potential Gain (taf)	
	Average	*Drought*
Applied Water Shortage	**147**	**158**
Options Likely to be Implemented by 2020		
Conservation[b]	215	215
Modify Existing Reservoirs/Operation	—	—
New Reservoirs/Conveyance Facilities	—	—
Groundwater/Conjunctive	—	—
Water Marketing	—	250
Recycling	—	—
Desalting	—	—
Other Local Options	94	94
Statewide Options	8	7
Expected Reapplication	2	2
Total Potential Gain	**319**	**568**
Remaining Applied Water Shortage	**0**	**0**

[a] Options in excess of regional needs to reduce groundwater overdraft are available for implementing the draft CRB 4.4 Plan in South Coast Region.
[b] Water supply for San Diego CWA/IID transfer provided by agricultural conservation which could be any mix of base demand forecast EWMP implementation (210 taf) and future agricultural conservation options (190 taf).

TABLE 9-25

Future Actions Described in Bulletin 160-98

That Could be Part of Draft CRB 4.4 Plan Implementation[a]

Action	Potential Gain (taf)	
	Average	*Drought*
Agricultural conservation[b] to meet SDCWA/IID Agreement	200	200
Other agricultural conservation[b] from EWMP implementation and optional conservation measures	200	200
Intrastate groundwater banking from MWDSC agreements with Cadiz, Catellus, or Coachella	—	100
Interstate groundwater banking from Arizona groundwater bank	—	50
Possible future land fallowing agreement between MWDSC and PVID	—	100
Lining All American Canal	68	68
Additional lining of Coachella Canal	26	26
Statewide Options	8	7
Total	**502**	**751**

[a] Since this table shows future actions, it does not include the 1980 Coachella Canal lining, 1988 MWDSC/IID agreement, or 1992 MWDSC/CACWD/SNWA agreement described earlier in this chapter.
[b] These actions are subject to environmental review to ensure that reduced depletions will not have significant impacts to the Salton Sea.

9A

Options Evaluations for Eastern Sierra and Colorado River Regions

TABLE 9A-1

Options Evaluation North Lahontan Region

Option	*Evaluation Scores*							*Rank*
	Engineering	*Economics*	*Environ-mental*	*Institutional/ Legal*	*Social/ Third Party*	*Other Benefits*	*Overall Score*	
Conservation								
Urban								
Outdoor Water Use - New and Existing Development	3	1	4	2	2	1	**13**	**M**
Indoor Water Use (55 gpcd)	2	2	4	2	2	1	**13**	**M**
Groundwater/Conjunctive Use								
Agricultural Groundwater Development	3	1	3	3	3	0	**13**	**M**

TABLE 9A-2

Options Evaluation South Lahontan Region

Option	*Evaluation Scores*							
	Engineering	*Economics*	*Environ-mental*	*Institutional/ Legal*	*Social/ Third Party*	*Other Benefits*	*Overall Score*	*Rank*
Conservation								
Urban								
Outdoor Water Use - New Development	3	2	4	2	2	1	**14**	**M**
Outdoor Water Use - New and Existing Development	3	1	4	2	2	1	**13**	**M**
Indoor Water Use (60 gpcd)	3	3	4	2	2	1	**15**	**M**
Indoor Water Use (55 gpcd)	2	2	4	2	2	1	**13**	**M**
Interior CII Water Use (3%)	3	3	4	2	2	1	**15**	**M**
Interior CII Water Use (5%)	3	2	4	1	2	1	**13**	**M**
Distribution System Losses (7%)	3	4	4	2	2	1	**16**	**M**
Distribution System Losses (5%)	2	3	4	2	2	1	**14**	**M**
Agricultural								
SAE Improvements (76%)	3	4	3	4	3	1	**18**	**H**
SAE Improvements (78%)	3	3	3	3	2	1	**15**	**M**
SAE Improvements (80%)	2	3	3	2	2	1	**13**	**M**
Water Marketing								
Mojave Water Agency	4	4	4	4	3	0	**19**	**H**
Palmdale Water District	4	4	4	4	3	0	**19**	**H**
Statewide Options								
See Chapter 6.								

TABLE 9A-3

Options Evaluation Colorado River Region

Option	Evaluation Scores							
	Engineering	*Economics*	*Environ-mental*	*Institutional/ Legal*	*Social/ Third Party*	*Other Benefits*	*Overall Score*	*Rank*
Conservation								
Urban								
Outdoor Water Use - New Development	3	2	4	2	2	1	**14**	**M**
Outdoor Water Use - New and Existing Development	3	1	4	2	2	1	**13**	**M**
Residential Indoor Water Use (60 gpcd)	3	3	4	2	2	1	**15**	**M**
Residential Indoor Water Use (55 gpcd)	2	2	4	2	2	1	**13**	**M**
Interior CII Water Use (3%)	3	3	4	2	2	1	**15**	**M**
Interior CII Water Use(5%)	3	2	4	1	2	1	**13**	**M**
Distribution System Losses (7%)	3	4	4	2	2	1	**16**	**M**
Distribution System Losses (5%)	2	3	4	2	2	1	**14**	**M**
Agricultural[a]								
SAE Improvements (76%)	3	4	3	4	3	1	**18**	**H**
SAE Improvements (78%)	3	3	3	3	2	1	**15**	**M**
SAE Improvements (80%)	2	3	3	2	2	1	**13**	**M**
Flexible Water Delivery	3	0	3	3	2	1	**12**	**L**
Canal Lining and Piping	3	0	3	3	2	1	**12**	**L**
Tailwater Recovery	3	4	3	3	3	1	**17**	**H**
Water Marketing								
Interstate Banking	3	3	3	2	3	0	**14**	**M**
Intrastate Banking	3	3	3	3	3	2	**17**	**H**
Land Fallowing Program	3	3	4	3	2	1	**16**	**M**
Other Local Options								
Lining the All American Canal	3	4	3	2	4	3	**19**	**H**
Additional Lining of Coachella Canal	3	4	3	2	4	3	**19**	**H**
Statewide Options								
See Chapter 6.								

[a] Implementability subject to environmental impact review on Salton Sea.

10

Conclusions

This chapter assesses California's water future, based on today's conditions and on options being considered by California's water purveyors. The Department's Bulletin 160 series does not forecast a particular vision or preferred future (such as statewide use of xeriscape landscaping or favoring production of certain agricultural crops over others), but instead attempts to forecast the most probable future based on today's data, economic conditions, and public policies.

Although no forecast can be perfect, several key trends appear inevitable. California's population will increase dramatically by 2020. How growth is accommodated and the land use planning decisions made by cities and counties have important implications for future urban and agricultural water use. California's agricultural acreage is forecasted to decline slightly by 2020 (reflecting the State's increasing urbanization), as is its agricultural water use. California agriculture is still anticipated to lead the nation's agricultural production because of advantages such as climate and proximity to domestic and export markets. As the State's population expands, greater attention will be directed to preserving and restoring California ecosystems and to maintaining the natural resources which have attracted so many people to California.

The 1848 discovery of gold at Sutter's Mill on the American River led to California's statehood in 1850. California celebrates its sesquicentennial in 2000.

Miners in the Sierra, *painting by Charles Nahl and Frederick Wenderoth, 1851. Courtesy of Smithsonian Institution*

This chapter begins by reviewing water supply and demand information and the statewide applied water budget with existing facilities and programs presented in Chapter 6. Water management options identified as likely to be implemented in Chapters 6-9 are then tabulated and included in a state-

TABLE 10-1

California Water Budget with Existing Facilities and Programs (maf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	8.8	9.0	12.0	12.4
Agricultural	33.8	34.5	31.5	32.3
Environmental	36.9	21.2	37.0	21.3
Total	**79.5**	**64.7**	**80.5**	**66.0**
Supplies				
Surface Water	65.1	43.5	65.0	43.4
Groundwater	12.5	15.8	12.7	16.0
Recycled and Desalted	0.3	0.3	0.4	0.4
Total	**77.9**	**59.6**	**78.1**	**59.8**
Shortage	**1.6**	**5.1**	**2.4**	**6.2**

wide applied water budget with options. The chapter ends with an evaluation of how actions planned by water purveyors statewide would affect forecasted water shortages, and a summary of key findings.

Future with Existing Facilities and Programs

Table 10-1 repeats the California water budget with existing facilities and programs shown in Chapter 6. (Regional water budgets with existing facilities and programs are shown in Appendix 6A and in the regional chapters.)

Water Supply

As described in Chapter 3, Bulletin 160-98 water budgets do not account for the State's entire water supply and use. Less than one-third of the State's precipitation is quantified in the water budgets. Precipitation provides California with nearly 200 maf of total water supply in average years. Of this renewable supply, about 65 percent is depleted through evaporation and transpiration by vegetation. This large volume of water (approximately 130 maf) is excluded from Bulletin 160 water supply and water use calculations. The remaining 35 percent stays in the State's hydrologic system as runoff.

Over 30 percent of the State's runoff is not explicitly designated for urban, agricultural, or environmental uses. Similar to precipitation depletions by vegetation, non-designated runoff is excluded from the Bulletin 160 water supply and water use calculations.

The State's remaining runoff is available as renewable water supply for urban, agricultural, and environmental uses in the Bulletin 160 water budgets.

About 65 percent of the precipitation that falls on California's land surface is consumed through evaporation and transpiration by vegetation. The remaining 35 percent comprises the water supply that may be managed or dedicated for urban, agricultural, and environmental purposes.

In addition to this supply, Bulletin 160 water budgets include a few supplies that are not generated by intrastate precipitation. These supplies include imports from the Colorado and Klamath Rivers and new supplies generated by water recycling and desalting.

The State's 1995-level average year applied water supply—from intrastate sources, interstate sources, and return flows—is about 78 maf. Even assuming a reduction in Colorado River supplies to California's 4.4 maf basic apportionment, average year statewide supply is projected to increase 0.2 maf by 2020 without additional water supply options. This projected increase in water supply is due mainly to higher CVP and SWP deliveries in response to higher 2020 level

USBR's Corning Pumping Plant diverts water from the Tehama-Colusa Canal into the Corning Canal, which supplies agricultural users in southern Tehama County. California's Central Valley provides about 80 percent of the State's agricultural production.

demands (for example, from CVP urban water users in the Central Valley and from SWP urban water users in the South Coast and South Lahontan Regions). Additional groundwater extraction and facilities now under construction will also provide new supplies. The State's 1995-level drought year supply is about 60 maf. Drought year supply is projected to increase slightly by 2020 without future water supply options, for the same reasons that average year supplies are expected to increase.

Bulletin 160-98 estimates statewide groundwater overdraft of about 1.5 maf/yr at a 1995 level of development. Increasing overdraft in the 1990s reverses the trend of basin recovery seen in the 1980s. Most increases are occurring in the San Joaquin and Tulare Lake Regions, due primarily to Delta export restrictions associated with SWRCB's Order WR 95-6, ESA requirements, and reductions in CVP supplies.

Water recycling is a small, yet growing, element of California's water supply. At a 1995 level of development, water recycling and desalting produce about 0.3 maf/yr of new water (reclaiming water that would otherwise flow to the ocean or to a salt sink), up significantly from the 1990 annual supply of new water. The California Water Code urges wastewater treatment agencies located in coastal areas to recycle as much of their treated effluent as possible, recognizing that this water supply would otherwise be lost to the State's hydrologic system. Greater recycled water production at existing treatment plants and additional production at plants now under construction are expected to increase new recycled and desalted supplies by nearly 30 percent to 0.4 maf/yr by 2020.

Water Demand

California's estimated demand for water at a 1995 level of development is about 80 maf in average years and 65 maf in drought years. California's water demand in 2020 is forecasted to reach 81 maf in average years and 66 maf in drought years. California's increasing population is a driving force behind increasing water demands.

California's population is forecasted to increase to 47.5 million people by 2020 (about 15 million people more than the 1995 base). Forty-six percent of the State's population increase is expected to occur in the South Coast Region. Even with extensive water conservation, urban water demand will increase by about 3.2 maf in average years. (Bulletin 160-98 assumes that all urban and agricultural water agencies will implement BMPs and EWMPs by 2020, regardless of whether they are cost-effective for water supply purposes.)

Irrigated crop acreage is expected to decline by 325,000 acres—from the 1995 level of 9.5 million acres to a 2020 level of 9.2 million acres. Reductions in forecasted irrigated acreage are due primarily to urban encroachment and to impaired drainage on lands in the western San Joaquin Valley. Increases in water use efficiency combined with reductions in irrigated agricultural acreage are expected to reduce average year water demand by about 2.3 maf by 2020. Shifts from lower to higher value crops are expected to continue, with an increase in permanent plantings such as orchards and vineyards. This trend would tend to harden agricultural demands associated with permanent plantings, making it less likely that this acreage would be temporarily fallowed during droughts.

Average and drought year water needs for environmental use are forecasted to increase only slightly by 2020. Drought year environmental water needs are considerably lower than average year environmental water needs, reflecting the variability of unimpaired flows in wild and scenic rivers. North Coast wild and scenic rivers constitute the greatest component of environmental water demands. CVPIA implementation, Bay-Delta requirements, new ESA restrictions, and FERC relicensing could significantly modify environmental demands within the Bulletin 160-98 planning period.

Water Shortages

The shortage shown in Table 10-1 for 1995 average water year conditions reflects the Bulletin's assumption that groundwater overdraft is not available as a supply. Groundwater overdraft represents a significant portion of the 2020 average water year shortage. Forecasted water shortages vary widely from region to region, as shown in Table 10-2 and presented graphically in Figure 10-1. For example, the North Coast and San Francisco Bay regions are not expected to experience future shortages during average water years but are expected to see shortages in drought years. Most of the State's remaining regions experience average year and drought year shortages now, and are forecasted to experience increased shortages in 2020. The largest future shortages are forecasted for the Tulare Lake and South Coast regions, areas that rely heavily on imported water supplies. These regions are also where some of the greatest increases in population are expected to occur.

As discussed in Chapter 6, there are uncertainties associated with the magnitude of forecasted shortages. Chapter 6 presented a range of potential shortage amounts for programs whose uncertainties could be quantified—CALFED and SWRCB Bay-Delta water right actions. Other uncertainties cannot be quantified now—impacts of future ESA listings and FERC relicensing. Furthermore, the evaluation of water management options performed for the Bulletin was based on the options' present affordability to local agencies. Circumstances that increase or decrease options' affordability will correspondingly affect forecasted shortages.

What is apparent is that Californians face water shortages now, and will face increasing shortages in the future. The shortages shown in Table 10-2 highlight the need for future water management actions to reduce the gap between forecasted supplies and demands. As Californians experienced during the most recent drought (especially in 1991 and 1992), drought year shortages are large. Urban residents faced cutbacks in supply and mandatory rationing, some small rural communities saw their wells go dry, agricultural lands were fallowed, and environmental water supplies were reduced. By 2020, without additional facilities and programs, these conditions will worsen.

Finding reliable water supplies for the more than 15 million new Californians will be a challenge for the State's water purveyors. Almost half of the State's forecasted 2020 population increase is expected to occur in the South Coast Region.

Water shortages have direct and indirect economic consequences. Direct consequences include costs to residential water users to replace landscaping lost during droughts, costs to businesses that experience water supply cutbacks, or costs to growers who fallow land because supplies are not available. Indirect conse-

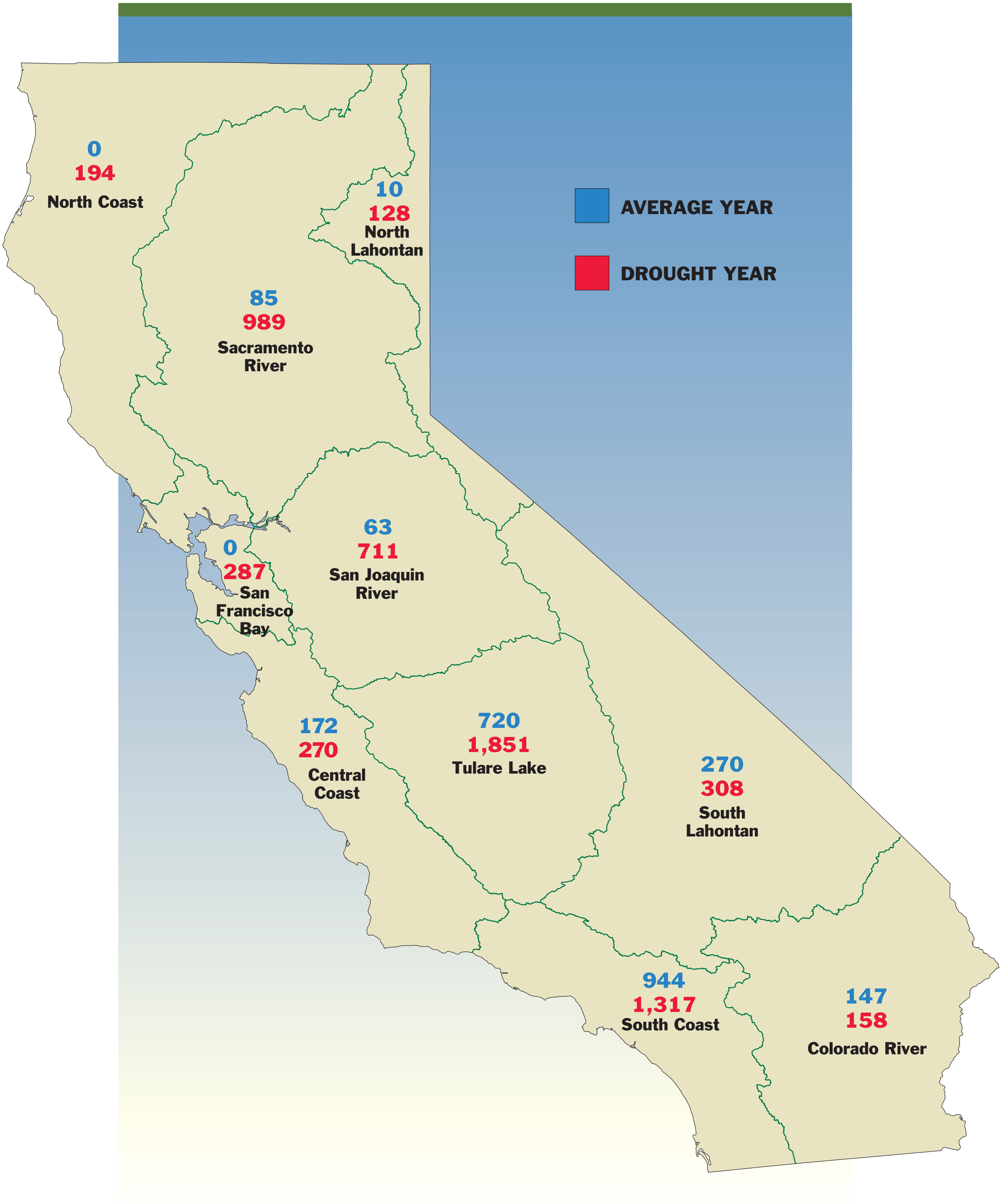
TABLE 10-2

Applied Water Shortages by Hydrologic Region (taf) with Existing Facilities and Programs

	1995		*2020*	
Region	*Average*	*Drought*	*Average*	*Drought*
North Coast	0	177	0	194
San Francisco Bay	0	349	0	287
Central Coast	214	282	172	270
South Coast	0	508	944	1,317
Sacramento River	111	867	85	989
San Joaquin River	239	788	63	711
Tulare Lake	870	1862	720	1,851
North Lahontan	0	128	10	128
South Lahontan	89	92	270	308
Colorado River	69	95	147	158
Total (rounded)	**1,590**	**5,150**	**2,410**	**6,210**

FIGURE 10-1

2020 Shortages by Hydrologic Region with Existing Facilities and Programs (taf)



The January 1997 flood disaster was the largest in the State's history. Flooding forced more than 120,000 people from their homes, and over 55,000 people were housed in temporary shelters. Nearly 300 square miles of agricultural land were flooded. Livestock and wildlife were trapped by the flooding.

quences include decisions by businesses and growers not to locate or to expand their operations in California, and reductions in the value of agricultural lands. Other consequences of shortages are less easily measured in economic terms—loss of recreational activities or impacts to environmental resources, for example.

Summary of Options Likely to be Implemented

The options summarized in this section represent water purveyors' strategies for meeting future needs. This information relies heavily on actions identified by local water agencies, which collectively provide about 70 percent of the State's developed water supply. As described earlier, water management options likely to be implemented were selected based on a ranking process that evaluated factors such as technical feasibility, cost, and environmental considerations. This process is most effective in hydrologic regions where local agencies have prepared plans for meeting future needs in their service areas. Affordability is a key factor for local agencies in deciding the extent to which they wish to invest in alternatives to improve their water service reliability. Water agencies must balance costs and quantity of supply (and sometimes quality of supply) based on their service area needs.

The Bulletin 160 series focuses on water supply. The statewide compilation of likely options has not been tailored to meet other water-related objectives such as flood control, hydropower generation, recreation, or nonpoint source pollution control. The evaluation process used to select likely options ranked the options based on their ability to provide multiple benefits, as described in Chapter 6. For example, one aspect of the relationship between water supply and flood control needs is illustrated in the sidebar on reservoir reoperation.

The results shown in Table 10-3 were obtained by adding statewide options identified as likely in Chapter 6 to regional options identified as likely in Chapters 7-9.

Options shown in Table 10-3 include demand re-

Reservoir Reoperation for Flood Control

The January 1997 floods demonstrated that Central Valley flood protection needs improvement. The 1997 *Final Report of the Governor's Flood Emergency Action Team* identified many actions that could be taken to increase valley flood protection, including better emergency preparedness, floodplain management actions, levee system improvements, construction of new floodways, temporary storage of floodwaters on wildlife refuges, reoperation or enlargement of existing reservoirs to increase flood storage, and construction of new reservoirs. The latter two actions have water supply implications. Reoperating existing reservoirs to provide greater flood control storage usually comes at the expense of water supply. Reoperation is particularly problematical in the San Joaquin River Basin, where water supplies are already limited. As more demands are placed on existing water supplies, reservoir reoperation will become increasingly difficult to implement. In contrast, enlarging reservoirs or constructing new reservoirs can provide both water supply and flood control benefits.

TABLE 10-3

Summary of Options Likely to be Implemented by 2020, by Option Type (taf)

Option Type	*Average*	*Drought*
Local Demand Reduction Options	**507**	**582**
Local Supply Augmentation Options		
Surface Water	110	297
Groundwater	24	539
Water Marketing	67	304
Recycled and Desalted	423	456
Statewide Supply Options		
CALFED Bay-Delta Program	100	175
SWP Improvements	117	155
Water Marketing (Drought Water Bank)	—	250
Multipurpose Reservoir Projects	710	370
Expected Reapplication	**141**	**433**
Total Options	**2,199**	**3,561**

duction beyond BMP and EWMP implementation included in Table 10-1. Future demand reduction options are options that would produce new water supply through reduction of depletions. For these optional water conservation measures to have been identified as likely, they must be competitive in cost with water supply augmentation options.

Local supply augmentation options comprise the largest potential new drought year source of water for California. (Local options include implementation of the draft CRB 4.4 Plan to reduce California's use of Colorado River water.) In Table 10-3 and in the water budgets, only water marketing options that result in a change of place of use of the water (from one hydrologic region to another), or a change in type of use (e.g., agricultural to urban) have been included. Considerably more marketing options have been described in earlier chapters than are shown in the water budgets, reflecting local agencies' plans to purchase future supplies from sources yet to be identified. Where the participants in a proposed transfer are known, the selling region's average year or drought year supply has been reduced in the water budgets. Presently, the only transfers with identified participants that are large enough to be visible in the water budgets are those associated with the draft CRB 4.4 Plan. Water agencies' plans to acquire water through marketing arrangements will depend on their ability to find sellers and on the level of competition for water purchases among water agencies and environmental restoration programs (such as CVPIA's AFRP or CALFED's ERP).

Possible statewide options include actions that could be taken by CALFED to develop new water supplies. The timing and extent of new water supplies that CALFED might provide are uncertain at the time of the Bulletin's printing. Bulletin 160-98 uses a placeholder analysis for new CALFED water supply development to illustrate the potential magnitude of new water supply the program might provide. The placeholder does not address specifics of which surface storage facilities might be selected, since this level of detail is not available. Water supply uncertainties associated with CALFED's selection of a draft preferred alternative were discussed in Chapter 6.

Other statewide options include specific projects to improve SWP water supply reliability, the State's drought water bank, and two multipurpose reservoirs. A third potential multipurpose reservoir option, an enlarged Shasta Lake, was recommended for further study because additional work is needed to quantify benefits and costs associated with different reservoir sizes.

The two multipurpose reservoir projects included as statewide options—Auburn Reservoir and enlarged Millerton Lake (Friant Dam)—were included to emphasize the interrelationship between water supply needs and the Central Valley's flood protection needs. Both reservoir sites offer significant flood protection benefits. Both projects have controversial aspects, and neither of them is inexpensive. However, they merit serious consideration. The lead time for planning and implementing any large reservoir project is long, and it would take almost to the Bulletin 160-98 2020 planning horizon for these projects to be constructed.

Implementing new water management options must be done in accordance with environmental protection requirements, including requirements for protection of species of special concern, such as this badger.

The potential future water management options summarized in this section are still being planned. Their implementation is subject to completion of environmental documents, permit acquisition, compliance with regulatory requirements such as those of ESA, and availability of funding. The permitting processes will address mitigating environmental impacts and resolving third-party impacts. If water management options are delayed or rendered infeasible as a result of these processes, or if their costs are increased to the point that the options are no longer affordable for the local sponsors, statewide shortages will be correspondingly affected.

Implementing Future Water Management Options

Table 10-4 was developed by combining the regional and statewide analyses of water management options with the water budget with existing facilities and programs (Table 10-1). Table 10-4 illustrates the effect these options would have on future shortages. (Appendix 10A shows regional water budgets with option implementation.) The table indicates that water management options now under consideration by water purveyors throughout the State will not reduce shortages to zero in 2020. The difference between av-

TABLE 10-4

California Water Budget with Options Likely to be Implemented (maf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	8.8	9.0	11.8	12.1
Agricultural	33.8	34.5	31.3	32.1
Environmental	36.9	21.2	37.0	21.3
Total	**79.5**	**64.7**	**80.1**	**65.5**
Supplies				
Surface Water	65.1	43.5	66.4	45.4
Groundwater	12.5	15.8	12.7	16.5
Recycled and Desalted	0.3	0.3	0.8	0.9
Total	**77.9**	**59.6**	**79.9**	**62.8**
Shortage	**1.6**	**5.1**	**0.2**	**2.7**

TABLE 10-5

Water Shortages by Hydrologic Region With Likely Options (taf)

	1995		*2020*	
Region	*Average*	*Drought*	*Average*	*Drought*
North Coast	0	177	0	176
San Francisco Bay	0	349	0	0
Central Coast	214	282	0	100
South Coast	0	508	0	0
Sacramento River	111	867	0	722
San Joaquin River	239	788	0	658
Tulare Lake	870	1,862	202	868
North Lahontan	0	128	10	128
South Lahontan	89	92	0	0
Colorado River	69	95	0	0
Total (rounded)	**1,590**	**5,150**	**210**	**2,650**

erage year and drought year water shortages is significant. Water purveyors generally consider shortages in average years as basic deficiencies that should be corrected through long-term demand reduction or supply augmentation measures. Shortages in drought years may be managed by such long-term measures in combination with short-term actions used only during droughts. Short-term measures could include purchases from the State's drought water bank, urban water rationing, or agricultural land fallowing. Agencies may evaluate the marginal costs of developing new supplies and conclude that the cost of their development exceeds that of shortages to their service areas, or exceeds the cost of implementing contingency measures such as transfers or rationing. As water agencies implement increasing amounts of water conservation in the future (especially plumbing fixture changes), there will be a correspondingly lessened ability to implement short-term drought response actions such as rationing. Demand hardening will influence agencies' decisions about their future mix of water management actions.

Ability to pay is another consideration. Large urban water agencies frequently set high water service reliability goals and are able to finance actions necessary to meet the goals. Agencies supplying small rural communities may not be able to afford expensive projects. Small communities have limited populations over which to spread capital costs and may have difficulty obtaining financing. If local groundwater resources are inadequate to support expected growth, these communities may not be able to afford projects such as pipelines to bring in new surface water supplies. Small rural communities that are geographically isolated from population centers cannot readily interconnect with other water systems.

Agricultural water agencies may be less able to pay for capital improvements than urban water agencies. Much of the State's earliest large-scale water development was for agriculture, and irrigation works were constructed at a time when water development was inexpensive by present standards. Agricultural users today may not be able to compete with urban users for development of new supplies. Some agricultural water users have historically been willing to accept lower water supply reliability in return for less expensive water supplies. It may be less expensive for some agricultural users to idle land in drought years rather than to incur capital costs of new water supply development. This can be particularly true for regions faced with production constraints such as short growing seasons or lower quality lands — areas where the dominant water use may be irrigated pasture. In areas such as the North Lahontan Region, for example, local agencies generally do not have plans for new programs or facilities to reduce agricultural water shortages in drought years. Table 10-5 shows forecasted shortages by hydrologic region to illustrate the effects of option implementation on a regional basis. The same information is presented graphically in Figure 10-2.

Local agencies that expect to have increased future demands generally do more water supply planning than do agencies whose demands remain relatively level. Most agricultural water agencies are not planning for greater future demands, although some agencies are examining ways to improve reliability of their existing supplies. Cost considerations limit the types of options available to many agricultural users. The agricultural sector has thus developed fewer options that could be evaluated in statewide water supply planning. Many

FIGURE 10-2

2020 Shortages by Hydrologic Region with Likely Options (taf)

options have been generated from planning performed by urban agencies, reflecting Urban Water Management Planning Act requirements that urban water suppliers with 3,000 or more connections, or that deliver over 3 taf of water per year, prepare plans showing how they will meet service area needs.

Geography plays a role in the feasibility of implementing different types of options, and not solely with respect to the availability of surface water and groundwater supplies. Water users in the Central Valley, Bay Area, and Southern California having access to major regional conveyance facilities have greater opportunities to rely on water marketing arrangements and conjunctive use options than do water users isolated from the State's main water infrastructure.

Bulletin 160-98 Findings

Bulletin 160-98 forecasts water shortages in California by 2020, as did the previous water plan update. The water management options identified in the Bulletin as likely to be implemented by 2020 would reduce, but not completely eliminate future shortages. Water agencies faced with meeting future needs must determine how those needs can be met within the statutory and regulatory framework affecting water use decisions, including how the needs can be met in a manner equitable to existing water users. Land use planning decisions made by cities and counties—locations where future growth will or will not be allowed, housing densities, preservation goals for open space or agricultural reserves—will have a significant influence on California's future water demands. Good coordination among local land use planning agencies and water agencies, as well as among water agencies themselves at a regional level, will facilitate finding solutions to meeting future needs.

Bulletin 160-98 makes no specific recommendations regarding how California water purveyors should meet the needs of their service areas. It is the water purveyors themselves who must make these decisions. The purpose of Bulletin 160-98 is to forecast the future based on today's conditions. Clearly, different agencies and individuals have different perspectives about how the future should be shaped. The CALFED discussions, for example, illustrate conflicting values among individuals and agencies.

There is not one magic bullet for meeting California's future water needs—not new reservoirs, not new conveyance facilities, not more groundwater extraction, not more water conservation, not more water recycling. Each of these options has its place. The most frequently used methods of providing new water supplies have changed with the times, reflecting changing circumstances. Much of California's early water development was achieved by constructing reservoirs and diverting surface water. Advances in technology, in the form of deep well turbine pumps, allowed substantial groundwater development. More recent improvements in water treatment technology have made water recycling and desalting feasible options. Today, water purveyors have an array of water management options available to meet future water supply reliability needs. The magnitude of potential shortages, especially drought year shortages, demonstrates the urgency of taking action. The do-nothing alternative is not an alternative that will meet the needs of 47.5 million Californians in 2020.

California water agencies have made great strides in water conservation since the 1976-77 drought. Bulletin 160-98 forecasts substantial demand reduction from implementing presently identified urban BMPs and agricultural EWMPs, and assumes a more rigorous level of implementation than water agencies are now obligated to perform. Presently, less than half of California's urban population is served by retailers that have signed the urban MOU for water conservation measures. Less than one-third of California's agricultural lands are served by agencies that have signed the corresponding agricultural MOU. Bulletin 160-98 assumes that all water purveyors statewide will implement BMPs and EWMPs by 2020, even if the actions are not cost-effective from a water supply perspective. Water conservation offers multipurpose benefits such as reduced urban water treatment costs and potential reduction of fish entrainment at diversion structures. The Bulletin also identifies as likely additional demand reduction measures that would create new water and would be cost-competitive with supply augmentation options. These optional demand reductions are almost as large as the average year water supply augmentation options planned by local agencies.

California water agencies have also made great strides in water recycling. By 2020, total recycling could potentially be almost 1.4 maf, which would exceed the goal expressed in Section 13577 of the Water Code that total recycling statewide be 1 maf by 2010. (The potential 2020 total recycling of 1.4 maf would be equivalent to about 2 percent of the State's 2020 water supply.) Water recycling offers multipurpose benefits, such as reduction of treatment plant discharges to waterbodies. Cost is a limiting factor in implementing recycling projects. When economic considerations are taken into account, the potential new water supply (water new to the State's hydrologic system) from recycling is forecasted to be about 0.8 maf.

Clearly, conservation and recycling alone are not sufficient to meet California's future needs. Bulletin 160-98 has included all of the conservation and recycling measures likely to be implemented by 2020. Adding supply augmentation options identified by California's water purveyors still leaves a shortfall in meeting forecasted demands. Review of local agencies' likely supply augmentation options shows that relatively few larger-scale or regional programs are in active planning, especially among small and mid-size water agencies. This outcome reflects local agencies' concerns about perceived implementability constraints associated with larger-scale options, and their affordability.

In the interests of maintaining California's vibrant economy, it is important that the State of California take an active role in assisting water agencies in meeting their future needs. New storage facilities are an important part of the mix of options needed to meet California's future needs. Just as water conservation and recycling provide multiple benefits, storage facilities offer flood control, power generation, and recreation in addition to water supply benefits. The devastating January 1997 floods in the Central Valley emphasized the need for increased attention to flood control. Apart from CALFED's investigation of storage alternatives, little planning is currently being done for storage projects that would meet regional or statewide needs. It is important for small and mid-size water agencies who could not develop such facilities on their own to have access to participation in regional projects. The more diversified water agencies' sources of supply are, the better their odds of improved water supply reliability.

An appropriate State role would be for the Department to take the lead in performing feasibility studies of potential storage projects—not on behalf of the SWP, but on behalf of all potentially interested water agencies. State funding support is needed to identify likely projects, so that local agencies may determine how those projects might benefit their service areas. In concept, the Department could use State funding to complete project feasibility studies, permitting, and environmental documentation for likely new storage facilities, removing uncertainties that would prevent smaller water agencies from funding planning studies themselves. This concept is not new. Historically, Department investigations into the State's water resources (for example, Bulletin 3, the original *California Water Plan*) formulated projects that were later built by local agencies.

Agencies wishing to participate in projects shown to be feasible in Department studies would repay their share of the State planning costs as a condition of participation in a project. Feasible projects would likely be constructed by a consortium of local agencies acting through a joint powers agreement or other contractual mechanism. The water users would be responsible for construction costs.

Meeting California's future needs will require cooperation among all levels of government—federal, State, and local. Likewise, all three of California's water-using sectors—agricultural, environmental, and urban—must work together to recognize each others' legitimate needs and to seek solutions to meeting the State's future water shortages. When the Bay-Delta Accord was signed in 1994, it was hailed as a truce in one of the State's longstanding water wars. The Accord, and the efforts by California agencies to negotiate a resolution to interstate and intrastate Colorado River water issues, represent a new spirit of fostering cooperation and consensus rather than competition and conflict. Such an approach will be increasingly necessary, given the magnitude of the water shortages facing California. Mutual accommodation of each others' needs is especially important in drought years, when water purveyors face the greatest water supply challenges. With continued efforts to prepare for the future, California can have safe and reliable water supplies for urban areas, adequate long-term water supplies to maintain the State's agricultural economy, and restoration and protection of fish and wildlife habitat.

10A

Regional Water Budgets with Likely Options

The following tables show the water budgets for each of the State's ten hydrologic regions with options identified as likely. Water use/supply totals and shortages may not sum due to rounding.

TABLE 10A-1

North Coast Region Water Budget with Options (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	169	177	201	194
Agricultural	894	973	927	1,011
Environmental	19,544	9,518	19,545	9,518
Total	**20,607**	**10,668**	**20,672**	**10,722**
Supplies				
Surface Water	20,331	10,183	20,371	10,212
Groundwater	263	294	288	321
Recycled and Desalted	13	14	13	14
Total	**20,607**	**10,491**	**20,672**	**10,546**
Shortage	**0**	**177**	**0**	**176**

TABLE 10A-2

San Francisco Bay Region Water Budget with Options (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	1,255	1,358	1,317	1,371
Agricultural	98	108	98	108
Environmental	5,762	4,294	5,762	4,294
Total	**7,115**	**5,760**	**7,176**	**5,773**
Supplies				
Surface Water	7,011	5,285	7,067	5,607
Groundwater	68	92	72	96
Recycled and Desalted	35	35	37	70
Total	**7,115**	**5,412**	**7,176**	**5,773**
Shortage	**0**	**349**	**0**	**0**

TABLE 10A-3

Central Coast Region Water Budget with Options (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	286	294	347	359
Agricultural	1,192	1,279	1,127	1,223
Environmental	118	37	118	37
Total	**1,595**	**1,610**	**1,592**	**1,620**
Supplies				
Surface Water	318	160	477	287
Groundwater	1,045	1,142	1,043	1,161
Recycled and Desalted	18	26	71	71
Total	**1,381**	**1,328**	**1,592**	**1,519**
Shortage	**214**	**282**	**0**	**100**

TABLE 10A-4

South Coast Region Water Budget with Options (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	4,340	4,382	5,435	5,528
Agricultural	784	820	455	477
Environmental	100	82	104	86
Total	**5,224**	**5,283**	**5,993**	**6,090**
Supplies				
Surface Water	3,839	3,196	4,084	3,832
Groundwater	1,177	1,371	1,243	1,592
Recycled and Desalted	207	207	667	667
Total	**5,224**	**4,775**	**5,994**	**6,090**
Shortage	**0**	**508**	**0**	**0**

TABLE 10A-5

Sacramento River Region Water Budget with Options (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	766	830	1,139	1,236
Agricultural	8,065	9,054	7,939	8,822
Environmental	5,833	4,223	5,839	4,225
Total	**14,664**	**14,106**	**14,917**	**14,282**
Supplies				
Surface Water	11,881	10,022	12,282	10,279
Groundwater	2,672	3,218	2,636	3,281
Recycled and Desalted	0	0	0	0
Total	**14,553**	**13,239**	**14,918**	**13,560**
Shortage	**111**	**867**	**0**	**722**

TABLE 10A-6

San Joaquin River Region Water Budget with Options (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	574	583	954	970
Agricultural	7,027	7,244	6,448	6,717
Environmental	3,396	1,904	3,411	1,919
Total	**10,996**	**9,731**	**10,813**	**9,607**
Supplies				
Surface Water	8,562	6,043	8,497	6,029
Groundwater	2,195	2,900	2,317	2,920
Recycled and Desalted	0	0	0	0
Total	**10,757**	**8,943**	**10,814**	**8,949**
Shortage	**239**	**788**	**0**	**658**

TABLE 10A-7

Tulare Lake Region Water Budget with Options (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	690	690	1,099	1,099
Agricultural	10,736	10,026	10,106	9,515
Environmental	1,672	809	1,676	813
Total	**13,098**	**11,525**	**12,880**	**11,426**
Supplies				
Surface Water	7,888	3,693	8,292	4,167
Groundwater	4,340	5,970	4,386	6,391
Recycled and Desalted	0	0	0	0
Total	**12,228**	**9,663**	**12,678**	**10,558**
Shortage	**870**	**1,862**	**202**	**868**

TABLE 10A-8

North Lahontan Region Water Budget with Options (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	39	40	50	51
Agricultural	530	584	536	594
Environmental	374	256	374	256
Total	**942**	**880**	**960**	**901**
Supplies				
Surface Water	777	557	759	557
Groundwater	157	187	183	208
Recycled and Desalted	8	8	8	8
Total	**942**	**752**	**950**	**773**
Shortage	**0**	**128**	**10**	**128**

TABLE 10A-9

South Lahontan Region Water Budget with Options (taf)

	1995		2020	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	238	238	568	568
Agricultural	332	332	252	252
Environmental	107	81	107	81
Total	**676**	**651**	**927**	**901**
Supplies				
Surface Water	322	259	651	578
Groundwater	239	273	248	296
Recycled and Desalted	27	27	27	27
Total	**587**	**559**	**926**	**901**
Shortage	**89**	**92**	**0**	**0**

TABLE 10A-10

Colorado River Region Water Budget with Options (taf)

	1995		*2020*	
	Average	*Drought*	*Average*	*Drought*
Water Use				
Urban	418	418	715	715
Agricultural	4,118	4,118	3,393	3,393
Environmental	39	38	44	43
Total	**4,575**	**4,574**	**4,152**	**4,151**
Supplies				
Surface Water	4,154	4,128	3,852	3,852
Groundwater	337	337	285	284
Recycled and Desalted	15	15	15	15
Total	**4,506**	**4,479**	**4,152**	**4,151**
Shortage	**69**	**95**	**0**	**0**

Abbreviations and Acronyms

A

AB	Assembly Bill
AAC	All American Canal
ACID	Anderson-Cottonwood Irrigation District
ACWD	Alameda County Water District
AD	allowable depletion
ADWR	Arizona Department of Water Resources
AEWSD	Arvin-Edison Water Storage District
af	acre-foot/acre-feet
AFB	Air Force Base
AFRP	Anadromous fish restoration program (or plan)
AMD	acid mine drainage
AOP	advanced oxidation process
APCD	air pollution control district
ARP	aquifer reclamation program
ARWI	American River Watershed Investigation
ARWRI	American River Water Resources Investigation
ASR	aquifer storage and recovery
AVEK	Antelope Valley-East Kern Water Agency
AVWG	Antelope Valley Water Group

B

BARWRP	Bay Area regional water recycling program
BAT	best available technology
BBID	Byron-Bethany Irrigation District
BDAC	Bay-Delta Advisory Council
B/C	benefit-to-cost (ratio)
BLM	Bureau of Land Management
BMP	Best management practice
BVWSD	Buena Vista Water Storage District
BWD	Bard Water District
BWRDF	Brackish water reclamation demonstration facility

C

CAL-AM	California-American Water Company
Cal/EPA	California Environmental Protection Agency
CALFED	State (CAL) and federal (FED) agencies participating in Bay-Delta Accord
CAP	Central Arizona Project
CAWCD	Central Arizona Water Conservation District
CCID	Central California Irrigation District
CCMP	Comprehensive conservation and management plan
CCWD	Colusa County Water District or Contra Costa Water District
CDI	capacitive deionization
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
cfs	cubic feet per second
CII	commercial, industrial, and institutional
CIMIS	California irrigation management information system
CLWA	Castaic Lake Water Agency
CMWD	Calleguas Municipal Water District
COA	Coordinated Operation Agreement
COG	Council of Governments
CMO	crop market outlook
COP	certificate of participation
CPUC	California Public Utilities Commission
CRA	Colorado River Aqueduct
CRB	Colorado River Board
CRIT	Colorado River Indian Tribes
CSD	community services district
CSIP/SVRP	Castroville Seawater Intrusion Project/ Salinas Valley Reclamation Project
CSJWCD	Central San Joaquin Water Conservation District
CUWCC	California Urban Water Conservation Council

CVHJV	Central Valley Habitat Joint Venture
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVPM	Central Valley production model
CVWD	Coachella Valley Water District
CWA	Clean Water Act
CWD	Coastal Water District, Cawelo Water District, or county water district

D

D-1485	State Water Resources Control Board Water Right Decision 1485
DAU	detailed analysis unit
DBCP	dibromochloropropane
DBP	disinfection by-products
DCID	Deer Creek Irrigation District
D/DBP	disinfectant/disinfection by-product
DDT	dichloro diphenyl trichloroethane
DEIR	draft environmental impact report
DEIS	draft environmental impact statement
DFA	California Department of Food and Agriculture
DFG	California Department of Fish and Game
DHS	California Department of Health Services
DMC	Delta-Mendota Canal
DOE	Department of Energy
DOF	California Department of Finance
DOI	Department of the Interior
DPR	Department of Parks and Recreation or Department of Pesticide Regulation
DU	distribution uniformity
DWA	Desert Water Agency
DWB	DWR's Drought Water Bank
DWD	Diablo Water District
DWR	California Department of Water Resources
DWRSIM	DWR's operations model for SWP/CVP system

E

EBMUD	East Bay Municipal Utility District
ec	electrical conductivity
ECCID	East Contra Costa Irrigation District
ECWMA	East County Water Management Association
ED	electrodialysis
EDB	ethylene dibromide
EDCWA	El Dorado County Water Agency
EDF	Environmental Defense Fund
EDR	electrodialysis reversal
EID	El Dorado Irrigation District
EIR	environmental impact report
EIS	environmental impact statement
ENSO	El Niño Southern Oscillation cycle
EPA	U.S. Environmental Protection Agency or Energy Policy Act of 1992
ERP	ecosystem restoration program or plan
ESA	Endangered Species Act
ESP	emergency storage project
ESU	evolutionarily significant unit
ESWTR	Enhanced Surface Water Treatment Rule
ET	evapotranspiration
ET_o	reference evapotranspiration
ETAW	evapotranspiration of applied water
EWMP	efficient water management practice

F

FAIRA	Federal Agriculture Improvement and Reform Act
FC&WCD	flood control and water conservation district
FCD	flood control district
FERC	Federal Energy Regulatory Commission
FY	fiscal year

G

GAC	granular activated carbon
GBUAPCD	Great Basin Unified Air Pollution Control District
GCID	Glenn-Colusa Irrigation District
GDPUD	Georgetown Divide Public Utility District
GO	general obligation
gpcd	gallons per capita per day
gpf	gallons per flush
gpm	gallons per minute

H

HCP	habitat conservation plan
HLWA	Honey Lake Wildlife Area
HR	House Resolution
HUD	Department of Housing and Urban Development

I

IBWC	International Boundary and Water Commission
ICR	information collection rule
ID	irrigation district or improvement district
IE	irrigation efficiency
IEP	Interagency Ecological Program
IID	Imperial Irrigation District
IOT	intake opportunity time
IRP	integrated resources planning
IRWD	Irvine Ranch Water District
ISDP	Interim South Delta Program

J

JPA	joint powers authority

K

KCWA	Kern County Water Agency
KPOP	Klamath Project Operations Plan
KRCC	Klamath River Compact Commission
KWB	Kern Water Bank
KWBA	Kern Water Bank Authority
kWh	kilowatt hour

L

LAA	Los Angeles Aqueduct
LADWP	Los Angeles Department of Water and Power
LAFCO	local agency formation commission
LBG	Los Banos Grandes
LCRMSCP	Lower Colorado River Multi-Species Conservation Program
LEPA	low-energy precision application
LMMWC	Los Molinos Mutual Water Company
LTBMU	Lake Tahoe Basin Management Unit

M

m	meter
maf	million acre-feet
MCL	maximum contaminant level
MCWD	Marina Coast Water District or Mammoth Community Water District
MCWRA	Monterey County Water Resources Agency
MF	microfiltration or Middle Fork
mgd	million gallons per day
mg/L	milligrams per liter
M&I	municipal & industrial
MID	Madera Irrigation District, Maxwell Irrigation District, Merced Irrigation District, or Modesto Irrigation District
MMWC	McFarland Mutual Water Company
MMWD	Marin Municipal Water District
MOU	memorandum of understanding
MPWMD	Monterey Peninsula Water Management District
MRWPCA	Monterey Regional Water Pollution Control Agency
MTBE	methyl tertiary butyl ether
MUD	municipal utility district
mW	megawatt
MWA	Mojave Water Agency
MWD	municipal water district
MWDOC	Municipal Water District of Orange County
MWDSC	Metropolitan Water District of Southern California

N

NAWMP	North American Waterfowl Management Plan
NCFC&WCD	Napa County Flood Control and Water Conservation District
NCMWC	Natomas-Central Mutual Water Company
NED	national economic development (plan)
NEPA	National Environmental Policy Act
NF	nanofiltration or North Fork
NGO	non-governmental organization
NID	Nevada Irrigation District
NISA	National Invasive Species Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOP	notice of preparation
NPDES	national pollutant discharge elimination system
NPDWR	national primary drinking water regulations
NRCS	Natural Resources Conservation Service
NTU	Nephelometric Turbidity Unit
NWD	Northridge Water District
NWR	National Wildlife Refuge

O

OCWD	Orange County Water District
OID	Oakdale Irrigation District
O&M	operations and maintenance

P

PAC	powdered activated carbon
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	perchloroethylene
PCGID/PID	Princeton-Codora-Glenn Irrigation District/Provident Irrigation District
PCWA	Placer County Water Agency
PEIR	programmatic environmental impact report
PEIS	programmatic environmental impact statement
PG&E	Pacific Gas and Electric Company
PGVMWC	Pleasant Grove-Verona Mutual Water Company
PL	Public Law
PMWC	Pelger Mutual Water Company
ppb	parts per billion
PROSIM	USBR's operations model for the CVP/SWP
PSA	planning subarea
psi	pounds per square inch
PTA	packed-tower aeration
PUC	public utility commission
PUD	public utility district
PVID	Palo Verde Irrigation District or Pleasant Valley Irrigation District
PVWMA	Pajaro Valley Water Management Agency
PWD	Palmdale Water District

R

RBDD	Red Bluff Diversion Dam
RCD	resource conservation district
RD	reclamation district
RDI	regulated deficit irrigation
RO	reverse osmosis
RWQCB	Regional Water Quality Control Board

S

SAE	seasonal application efficiency
SAFCA	Sacramento Area Flood Control Agency
SAWPA	Santa Ana Watershed Project Authority
SB	Senate Bill
SBCFC&WCD	Santa Barbara County Flood Control and Water Conservation District
SBVMWD	San Bernardino Valley Municipal Water District
SCCWRRS	Southern California comprehensive water reclamation and reuse study
SCE	Southern California Edison
SCVWD	Santa Clara Valley Water District
SCWA	Solano County Water Agency or Sonoma County Water Agency
SDCWA	San Diego County Water Authority
SDWA	Safe Drinking Water Act or South Delta Water Agency
SEIS	supplemental environmental impact statement
SEWD	Stockton East Water District
SF	South Fork
SFBJV	San Francisco Bay Joint Venture
SFEP	San Francisco Estuary Project
SFPUC	San Francisco Public Utility Commission
SFWD	San Francisco Water Department
SGPWA	San Gorgonio Pass Water Agency
SID	Solano Irrigation District
SJBAP	San Joaquin Basin Action Plan
SJRMP	San Joaquin River Management Plan (or Program)
SLC	San Luis Canal
SLD	San Luis Drain
SLDMWA	San Luis & Delta-Mendota Water Authority
SLOCFC&WCD	San Luis Obispo County Flood Control and Water Conservation District
SMBRP	Santa Monica Bay restoration project
SMUD	Sacramento Municipal Utility District
SNWA	Southern Nevada Water Authority
SOC	synthetic organic compound
SOFAR	South Fork American River (project)
SPPC	Sierra Pacific Power Company
SRCD	Suisun Resource Conservation District
SRF	state revolving fund
SRFCP	Sacramento River Flood Control Project
SRI	Sacramento River index
SSA	Salton Sea Authority
SSJID	South San Joaquin Irrigation District
SSWD	South Sutter Water District

STPUD	South Tahoe Public Utility District
SVGMD	Sierra Valley Groundwater Management District
SVOC	semi-volatile organic compound
SVRID	Stanford Vina Ranch Irrigation District
SVRP	Salinas Valley reclamation project
SWP	State Water Project
SWPP	source water protection program or supplemental water purchase program
SWRCB	State Water Resources Control Board
SWSD	Semitropic Water Storage District

T

taf	thousand acre-feet
TCC	Tehama-Colusa Canal
TCD	temperature control device
TCE	trichloroethylene
TDPUD	Tahoe Donner Public Utility District
TDS	total dissolved solids
THM	trihalomethane
TID	Turlock Irrigation District
TID-MID	Turlock Irrigation District and Modesto Irrigation District
TOC	total organic carbon
TROA	Truckee River Operating Agreement
TRPA	Tahoe Regional Planning Agency

U

UC	University of California
UCD	University of California at Davis
UF	ultrafiltration
ULFT	ultra low flush toilet
USBR	U.S. Bureau of Reclamation
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UV	ultraviolet
UWCD	United Water Conservation District

V

VAMP	Vernalis adaptive management plan
VOC	volatile organic compound

W

WA	water agency, water authority, or wildlife area
WCD	water conservation district
WCWD	Western Canal Water District
WD	water district
WMD	water management district
WMI	watershed management initiative
WQA	water quality authority
WQCP	water quality control plan
WR 95-6	SWRCB Order WR 95-6
WRCD	Westside Resource Conservation District
WRDA	Water Resources Development Act
WRF	water reclamation facility or water recycling facility
WRID	Walker River Irrigation District
WSD	water storage district
WTP	water treatment plant
WWD	Westlands Water District
WWTP	wastewater treatment plant

Y

YCFC&WCD	Yolo County Flood Control and Water Conservation District
YCWA	Yuba County Water Agency

Z

Z7WA	Zone 7 Water Agency

Glossary

A

active storage capacity the usable reservoir capacity available for seasonal or cyclic water storage. It is gross reservoir capacity minus inactive storage capacity.

afterbay a reservoir that regulates fluctuating discharges from a hydroelectric power plant or a pumping plant.

agricultural drainage (1) the process of directing excess water away from root zones by natural or artificial means, such as by using a system of drains placed below ground surface level; also called subsurface drainage; (2) the water drained away from irrigated farmland.

alluvium unconsolidated soil strata deposited by flowing water.

anadromous fish that spend a part of their life cycle in the sea and return to freshwater streams to spawn.

applied water demand the quantity of water delivered to the intake of a city's water system or factory, the farm headgate or other point of measurement, or a marsh or other wetland, either directly or by incidental drainage flows. For instream use, it is the portion of the stream flow dedicated to instream use or reserved under the federal or State legislation.

aquifer a geologic formation that stores water and yields significant quantities of water to wells or springs.

arid a term describing a climate or region in which precipitation is so deficient in quantity or occurs so infrequently that intensive agricultural production is not possible without irrigation.

artificial recharge addition of surface water to a groundwater reservoir by human activity, such as putting surface water into spreading basins.

average annual runoff for a specified area is the average value of annual runoff volume calculated for a selected period of record, at a specified location, such as a dam or stream gage.

average year water demand demand for water under average hydrologic conditions for a defined level of development.

B

best management practice (BMP) a generally accepted practice for some aspect of natural resources management, such as water conservation measures, drainage management measures, or erosion control measures. Most frequently used in this Bulletin to refer to water conservation measures adopted by the California Urban Water Conservation Coalition.

biota living organisms of a region, as in a stream or other body of water.

brackish water water containing dissolved minerals in amounts that exceed normally acceptable standards for municipal, domestic, and irrigation uses. Considerably less saline than sea water.

bromide a salt which naturally occurs in small quantities in sea water; a compound of bromine.

C

chaparral a major vegetation type in California characterized by dense evergreen shrubs with thick, hardened leaves.

closed basin a basin whose topography prevents surface outflow of water.

confined aquifer a water-bearing subsurface stratum that is bounded above and below by formations of impermeable, or relatively impermeable, soil or rock.

conjunctive use the operation of a groundwater basin in combination with a surface water storage and conveyance system. Water is stored in the groundwater basin for later use by intentionally recharging the basin during years of above-average water supply.

D

Decision 1485 operating criteria standards for operating the CVP and SWP under Water Right Decision 1485 for the Sacramento-San Joaquin Delta and Suisun Marsh, adopted by the State Water Resources Control Board in August 1978.

Decision 1631 a water right decision specifying required Mono Lake levels, adopted by the State Water Resources Control Board in 1994.

deep percolation percolation of (irrigation) water through the ground and beyond the lower limit of the root zone of plants into groundwater.

demand management alternatives water management programs—such as water conservation or drought rationing—that reduce demand for water.

dependable supply the average annual quantity of water that can be delivered during a drought period.

depletion the water consumed within a service area and no longer available as a source of supply. For agriculture and wetlands, it is ETAW (and ET of flooded wetlands) plus irrecoverable losses. For urban water use, it is ETAW (water applied to landscaping or home gardens), sewage effluent that flows to a salt sink, and incidental ET losses. For instream use, it is the amount of dedicated flow that reaches a salt sink.

desalting a process to reduce the salt concentration of sea water or brackish water.

detailed analysis unit (DAU) the smallest study area used by the Department for analyses of water demand and supply. Generally defined by hydrologic features or boundaries of organized water service agencies. In major agricultural areas, a DAU typically includes 100,000 to 300,000 acres.

discount rate the interest rate used to calculate the present value of future benefits and future costs or to convert benefits and costs to a common time basis.

dissolved organic compounds carbon-based substances dissolved in water.

dissolved oxygen (DO) the amount of oxygen dissolved in water or wastewater, usually expressed in milligrams per liter, parts per million, or percent of saturation.

distribution uniformity (DU) a measure of the variation in the amount of water applied to the soil surface throughout an irrigated area, expressed as a percent.

drainage area the area of land from which water drains into a river; for example, the Sacramento River Basin, in which all land area drains into the Sacramento River. Also called watershed or river basin.

drought condition hydrologic conditions during a defined period when rainfall and runoff are much less than average.

drought year supply the average annual supply of a water development system during a defined drought period.

E

efficient water management practice (EWMP) an agricultural water conservation measure, such as those adopted under the MOU regarding water conservation.

effluent wastewater or other liquid, treated or in its natural state, flowing from a treatment plant or process.

environmental water the water for wetlands, for the instream flow in a major river or in the Bay-Delta, or for a designated wild and scenic river

estuary the lower course of a river entering the sea where tidal action meets river flow.

evapotranspiration (ET) the quantity of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces.

evapotranspiration of applied water (ETAW) the portion of the total evapotranspiration which is provided by irrigation and landscape watering.

F

firm yield the maximum annual supply from of a water development project under drought conditions, for some specified level of demands.

forebay a reservoir at the intake of a pumping plant or power plant to stabilize water levels; also a storage basin for regulating water for percolation into groundwater basins.

fry a recently hatched fish.

G

gray water waste water from a household or small commercial establishment. Gray water does not include water from a toilet, kitchen sink, dishwasher, washing machine, or water used for washing diapers.

gross reservoir capacity the total storage capacity available in a reservoir for all purposes, from the streambed to the normal maximum operating level. Includes dead (or inactive) storage, but excludes surcharge (water temporarily stored above the elevation of the top of the spillway).

groundwater water that occurs beneath the land surface and fills the pore spaces of the alluvium, soil, or rock formation in which it is situated.

groundwater basin a groundwater reservoir, defined by an overlying land surface and the underlying aquifers that contain water stored in the reservoir. In some cases, the boundaries of successively deeper aquifers may differ and make it difficult to define the limits of the basin.

groundwater overdraft 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 water supply conditions approximate average conditions.

groundwater recharge the natural or intentional infiltration of surface water into the zone of saturation (i.e., into groundwater).

groundwater storage capacity volume of void space that can be occupied by water in a given volume of a formation, aquifer, or groundwater basin.

groundwater table the upper surface of the zone of saturation, in an unconfined aquifer.

H

hardpan a layer of nearly impermeable soil beneath a more permeable soil, formed by natural chemical cementation of the soil particles.

head ditch the water supply ditch at the head of an irrigated field.

hydraulic barrier a barrier developed in an estuary by release of fresh water from upstream reservoirs to prevent intrusion of seawater into the body of fresh water. Also, a barrier created by injecting fresh water to control seawater intrusion in an aquifer, or created by water injection to control migration of contaminants in an aquifer.

hydrologic balance an accounting of all water inflow to, water outflow from, and changes in water storage within a hydrologic unit over a specified period of time.

hydrologic basin the drainage area upstream from a given point on a stream.

hydrologic region a study area consisting of multiple planning subareas. California is divided into 10 hydrologic regions.

I

instream use use of water within its natural watercourse as specified in an agreement, water rights permit, etc. For example, the use of water for navigation, recreation, fish and wildlife, aesthetics, and scenic enjoyment.

irrecoverable losses the water lost to a salt sink or lost by evaporation or evapotranspiration from a conveyance facility or drainage canal, or in fringe areas of cultivated fields.

irrigated acreage land area that is irrigated, which is equivalent to total irrigated crop acreage minus the amount of acreage that was multiple-cropped.

irrigation return flow applied water that is not transpired, evaporated, or infiltrated into a groundwater basin but that returns to a surface water body.

L

land subsidence the lowering of the natural land surface due to groundwater (or oil and gas) extraction.

laser land leveling precision leveling of cultivated fields to improve irrigation efficiency.

laterals the part of an irrigation districts's delivery system that conveys water from the district's main canals to turnouts for farmers' fields

leaching the flushing of salts from the soil by the downward percolation of applied water.

leaching requirement the theoretical amount of irrigation water that must pass (leach) through the soil beyond the root zone to keep soil salinity within acceptable levels for sustained crop growth.

level of development in a planning study, the practice of holding water demands constant at some specified level so that hydrologic variability can be studied.

M

maximum contaminant level (MCL) the highest drinking water contaminant concentration allowed under federal and State Safe Drinking Water Act regulations.

moisture stress a condition of physiological stress in a plant caused by lack of water.

multipurpose project a project, usually a reservoir, designed to serve more than one purpose, and whose costs are normally allocated among the different functions it provides. For example, a project that provides water supply, flood control, and generates hydroelectricity.

N

National Pollutant Discharge Elimination System (NPDES) a provision of Section 402 of the federal Clean Water Act that established a permitting system for discharges of waste materials to water courses.

net water demand (net water use) the amount of water needed in a water service area to meet all requirements. It is the sum of evapotranspiration of applied water in an area, the irrecoverable losses from the distribution system, and the outflow leaving the service area; does not include reuse of water within a service area.

nonpoint source waste water discharge other than from point sources. See also point source.

nonreimbursable costs the part of project costs allocated to general statewide or national beneficial purposes and funded from general revenues, rather than by water users.

normalized demand the process of adjusting actual water use in a given year to account for unusual events such as dry weather conditions, government price support programs for agriculture, rationing programs, or other unusual conditions.

O

overdraft see *groundwater overdraft.*

P

pathogens viruses, bacteria, or other organisms that cause disease.

perched groundwater groundwater supported by a zone of material of low permeability located above an underlying main body of groundwater.

perennial yield the maximum quantity of water that can be annually withdrawn from a groundwater basin over a long period of time (during which water supply conditions approximate average conditions) without developing an overdraft condition.

permeability the capability of soil or other geologic formations to transmit water.

phytoplankton minute plants, such as algae, that live suspended in bodies of water.

planning subarea (PSA) an intermediately-sized study area used by the Department, consisting of multiple detailed analysis units.

point source a specific site from which wastewater or polluted water is discharged into a water body.

pollution (of water) the alteration of the physical, chemical, or biological properties of water by the introduction of any substance into water that adversely affects any beneficial use of water.

project yield the water supply attributed to all features of a project, including integrated operation of units that could be operated individually.

pump lift the distance between the groundwater table and the overlying land surface.

pumped storage project a hydroelectric powerplant and reservoir system using an arrangement whereby water released for generating energy during peak load periods is stored and pumped back into the upper reservoir, usually during periods of reduced power demand.

pump-generating plant a plant which can either pump water or generate electricity, depending on the direction of water flow.

R

recharge basin a surface facility constructed to infiltrate surface water into a groundwater basin.

recycled water urban wastewater that becomes suitable, as a result of treatment, for a specific beneficial use. Also called reclaimed water. See also *water recycling.*

return flow the portion of withdrawn water not consumed by evapotranspiration or system losses which returns to its source or to another body of water.

reuse the additional use of previously used water. As used in this report, it is not water that has been recycled for beneficial use at a wastewater treatment plant.

reverse osmosis a method to remove salts and other constituents from water by forcing water through membranes.

riparian located on the banks of a stream or other body of water. Riparian water rights are rights held by landowners adjacent to a natural waterbody.

runoff the volume of surface flow from an area.

S

salinity generally, the concentration of mineral salts dissolved in water. Salinity may be expressed in terms of a concentration or as an electrical conductivity. When describing salinity influenced by seawater, salinity often refers to the concentration of chlorides in the water. See also t*otal dissolved solids.*

salinity intrusion the movement of salt water into a body of fresh water. It can occur in either surface water or groundwater bodies.

salmonid fish species belonging to the salmon family, including salmon and trout.

salt sink a saline body of water, such as the ocean.

salt-water barrier a physical facility or method of operation designed to prevent the intrusion of salt water into a body of fresh water (see hydraulic barrier).

Seasonal Application Efficiency (SAE) the sum of ETAW and cultural water requirements divided by applied water.

seepage the gradual movement of a fluid into, through, or from a porous medium.

self-produced water a water supply (often from wells) developed and used by an individual or entity. Also called "self-supplied water."

service area the geographic area served by a water agency.

soluble minerals naturally occurring substances capable of being dissolved.

spreading basin see *recharge basin.*

spreading grounds see *recharge basin.*

supply augmentation alternatives water management programs—such as reservoir construction or groundwater extraction—that increase supply.

surface supply water supply from streams, lakes, and reservoirs.

T

tailwater applied irrigation water that runs off the end of a field. Tailwater is not necessarily lost; it can be collected and reused on the same or adjacent fields.

tertiary treatment in wastewater treatment, the additional treatment of effluent beyond that of secondary treatment to obtain higher quality of effluent.

total dissolved solids (TDS) a quantitative measure of the residual minerals dissolved in water that remain after evaporation of a solution. Usually expressed in milligrams per liter. Abbreviation: TDS. See also *salinity*.

transpiration an essential physiological process in which plant tissues give off water vapor to the atmosphere.

trihalomethane (THM) a chlorinated halogen compound such as chloroform, carbon tetrachloride or bromoform.

U

unimpaired flow the flow past a specified point on a natural stream that is unaffected by stream diversion, storage, import, export, return flow, or change in use caused by modifications in land use.

W

wastewater domestic or municipal sewage or effluent from an industrial process.

water quality description of the chemical, physical, and biological characteristics of water, usually in regard to its suitability for a particular purpose or use.

water recycling the treatment of urban wastewater to a level rendering it suitable for a specific beneficial use.

water service reliability the degree to which a water service system can successfully manage water shortages.

watershed see *drainage basin.*

water table see *groundwater table.*

water transfers marketing arrangements that can include the permanent sale of a water right by the water right holder; a lease of the right to use water from the water right holder; the sale or lease of a contractual right to water supply.

water year a continuous 12-month period for which hydrologic records are compiled and summarized. Different agencies may use different calendar periods for their water years.

CONVERSION FACTORS

Quantity	To convert from customary unit	To metric unit	Multiply customary unit by	To convert to customary unit, multiply metric unit by
Length	inches (in)	millimeters (mm)●	25.4	0.03937
	inches (in)	centimeters (cm)	2.54	0.3937
	feet (ft)	meters (m)	0.3048	3.2808
	miles (mi)	kilometers (km)	1.6093	0.62139
Area	square inches (in^2)	square millimeters (mm^2)	645.16	0.00155
	square feet (ft^2)	square meters (m^2)	0.092903	10.764
	acres (ac)	hectares (ha)	0.40469	2.4710
	square miles (mi^2)	square kilometers (km^2)	2.590	0.3861
Volume	gallons (gal)	liters (L)	3.7854	0.26417
	million gallons (10^6 gal)	megaliters (ML)	3.7854	0.26417
	cubic feet (ft^3)	cubic meters (m^3)	0.028317	35.315
	cubic yards (yd^3)	cubic meters (m^3)	0.76455	1.308
	acre-feet (ac-ft)	thousand cubic meters ($m^3 \times 10^3$)	1.2335	0.8107
	acre-feet (ac-ft)	hectare-meters (ha - m)■	0.1234	8.107
	thousand acre-feet (taf)	million cubic meters ($m^3 \times 10^6$)	1.2335	0.8107
	thousand acre-feet (taf)	hectare-meters (ha - m)■	123.35	0.008107
	million acre-feet (maf)	billion cubic meters ($m^3 \times 10^9$)◆	1.2335	0.8107
	million acre-feet (maf)	cubic kilometers (km^3)	1.2335	0.8107
Flow	cubic feet per second (ft^3/s)	cubic meters per second (m^3/s)	0.028317	35.315
	gallons per minute (gal/min)	liters per minute (L/min)	3.7854	0.26417
	gallons per day (gal/day)	liters per day (L/day)	3.7854	0.26417
	million gallons per day (mgd)	megaliters per day (ML/day)	3.7854	0.26417
	acre-feet per day (ac-ft/day)	thousand cubic meters per day ($m^3 \times 10^3$/day)	1.2335	0.8107
Mass	pounds (lb)	kilograms (kg)	0.45359	2.2046
	tons (short, 2,000 lb)	megagrams (Mg)	0.90718	1.1023
Velocity	feet per second (ft/s)	meters per second (m/s)	0.3048	3.2808
Power	horsepower (hp)	kilowatts (kW)	0.746	1.3405
Pressure	pounds per square inch (psi)	kilopascals (kPa)	6.8948	0.14505
	head of water in feet	kilopascals (kPa)	2.989	0.33456
Specific capacity	gallons per minute per foot of drawdown	liters per minute per meter of drawdown	12.419	0.08052
Concentration	parts per million (ppm)	milligrams per liter (mg/L)	1.0	1.0
Electrical conductivity	micromhos per centimeter	microsiemens per centimeter (mS/cm)	1.0	1.0
Temperature	degrees Fahrenheit (°F)	degrees Celsius (°C)	(°F - 32)/1.8	(1.8 x °C) + 32

● When using "dual units," inches are normally converted to millimeters (rather than centimeters).

■ Not used often in metric countries, but is offered as a conceptual equivalent of customary western U.S. practice (a standard depth of water over a given area of land).

◆ ASTM Manual E380 discourages the use of billion cubic meters since that magnitude is represented by giga (a thousand million) in other countries. It is shown here for potential use for quantifying large reservoir volumes (similar to million acre-feet).

OTHER COMMON CONVERSION FACTORS

1 cubic foot=7.48 gallons=62.4 pounds of water

1 cubic foot per second (cfs)=450 gallons per minute (gpm)

1 cfs=646,320 gallons a day=1.98 ac-ft a day

1 acre-foot=325,900 gallons=43,560 cubic feet

1 million gallons=3.07 acre-feet

1 million gallons a day (mgd)=1,120 ac-ft a year