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2000 - Preparing for California's Next Drought -- Changes since 1987-92

STATE OF CALIFORNIA • THE RESOURCES AGENCY • DEPARTMENT OF WATER RESOURCES

Preparing For CALIFORNIA'S NEXT DROUGHT

Changes Since 1987-92

— JULY 2000 —

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The Resources Agency

Gray Davis, Governor
State of California

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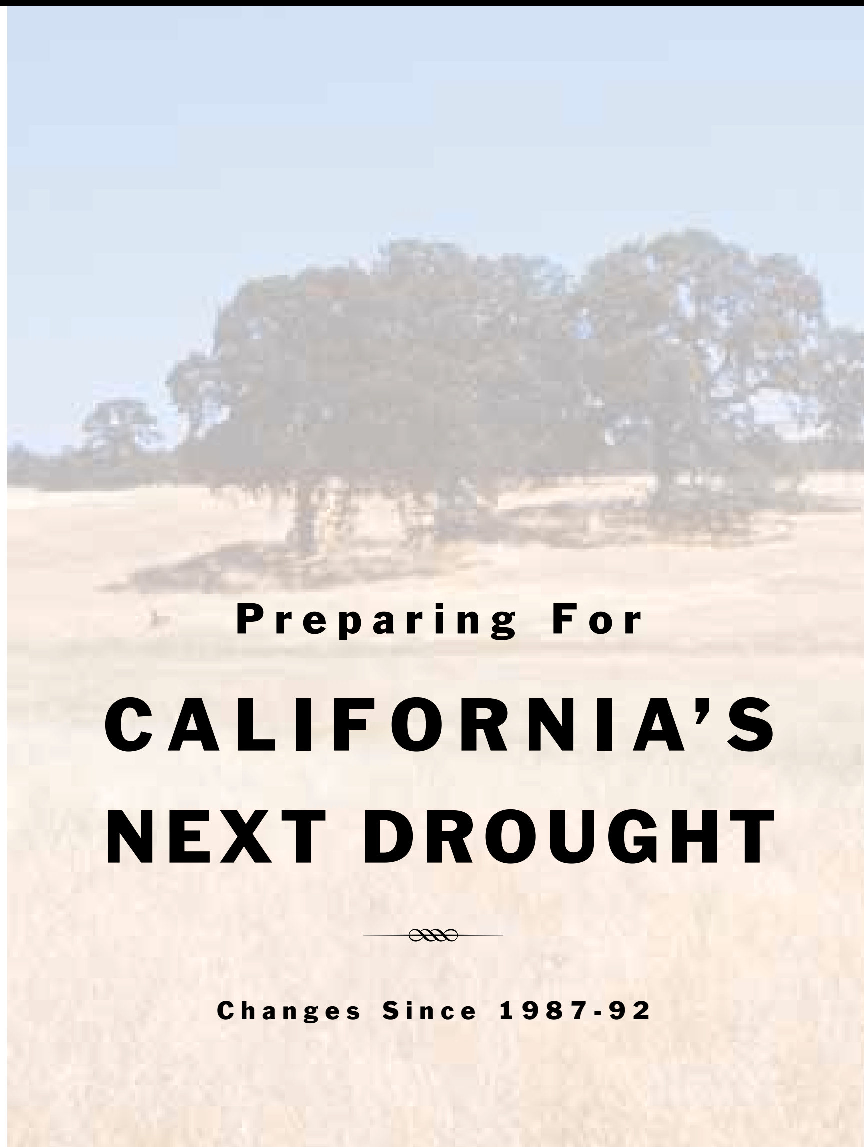
Department of Water Resources



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Preparation of this report was initiated in response to the unusually dry conditions experienced through January 2000. California was in the second year of a La Niña event, typically characterized by dryer than normal conditions in the southern part of the State. December 1999 was one of the driest Decembers on record. Snowpack levels in early January in the northern Sierra, the source of much of California's developed water supply, were only some 20 percent of seasonal average. Given that California had previously experienced a record five consecutive wet years, it seemed probable that 2000 would not be another wet year. Subsequently, climatic conditions demonstrated the great variability typical of California. Substantial precipitation and snowpack accumulation brought Northern California to near average water conditions before the end of February.

A dry 2000 would not have constituted a drought for most Californians, especially not with storage in the State's major reservoirs at above average levels as a consequence of the past five wet years. It was recognized, however, that planning should begin for actions to be taken in the event that the following year was also dry. In response to the substantial public interest created by the dry weather conditions, the Department evaluated water supply conditions, changed circumstances since the last drought, and other factors that would affect drought readiness in 2001.

The purpose of this report is to review items that the Department should consider in near-term drought planning, putting California's conditions today into perspective with experiences gained in the 1987-92 drought. The report begins with an overview of California hydrology and water supply, then describes conditions encountered in the 1987-92 drought. Changed conditions since that drought are summarized, and their implications discussed. The report concludes with a list of actions that the Department could take to respond to future drought conditions.

It is essential that California prepare for the return of very dry conditions. On June 9, 2000 Governor Davis and Interior Secretary Babbitt announced a "Framework for Action" as the completion of a five-year planning program to implement specific actions of the CALFED Bay-Delta Program. The Framework included a recommendation that Governor Davis appoint a panel to develop a Drought Contingency Plan by the end of 2000. This report will be used to brief the panel on drought actions considered to date, with the expectation that further and more focused actions/programs may be included in the Governor's Drought Contingency Plan.

THOMAS M. HANNIGAN
Director, Department of Water Resources

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Executive Summary And Key Findings

California rainfall and runoff vary widely throughout the State, and also vary greatly from year to year. The State's historical record of measured runoff amounts to little more than 100 years of data, but other information indicates that California has experienced climatic conditions both wetter and drier than those of the present within the past 1,000 years. Three twentieth century droughts were of particular importance from a water supply standpoint—the droughts of 1929-34, 1976-77, and 1987-92. The purpose of this report is to review conditions experienced by water agencies during the 1987-92 drought, in light of changed water management circumstances, to identify actions the Department could take to prepare for a drought occurring within the next few years.

The 1987-92 drought was notable for its six-year duration and the statewide nature of its impacts. Statewide reservoir storage was about 40 percent of average by the third year of the drought, and did not return to average conditions until 1994. The Central Valley Project and State Water Project met their contractors' delivery requests during the first four years of the drought, but then were forced by declining reservoir storage to reduce deliveries substantially. The SWP terminated deliveries to agricultural contractors and provided only 30 percent of requested urban deliveries in 1991, the single driest year of the drought. A 1991 Governor's executive order created a Drought Action Team to coordinate a response to deteriorating water supply conditions, and directed the Department to implement a drought water bank. Twenty-three counties had declared local drought emergencies by the end of 1991.

California's population has increased by more than 6 million people since the beginning of the last drought. There have been significant changes in California's water management framework. For example, California water users are now preparing a plan and negotiating associated agreements to reduce use of Colorado River water to California's basic apportionment in years when surplus water is not available. Other changes affect the ability of the CVP and SWP to export water from the Sacramento-San Joaquin River Delta. These changes included the new State Water Resources Control Board Bay-Delta water rights decision, Central Valley Project Improvement Act requirements reallocating project water for environmental purposes, Endangered Species Act listing of five new fish species, and management of water operations through the CALFED Operations Group.

New regional water management facilities constructed since the drought include the Department's Coastal Aqueduct, Mojave Water Agency's Mojave River and Morongo Basin Pipelines, Metropolitan Water District's Diamond Valley Lake, and Contra Costa Water District's Los Vaqueros Reservoir. Five new large-scale groundwater recharge/storage projects have gone into operation; several others are in advance planning stages.

Key findings discussed in the report include:

- Defining when a drought occurs is a function of dry conditions' impacts on water users. The Department used two primary criteria to evaluate statewide conditions during the 1987-92 drought—runoff and reservoir storage. A drought threshold was considered to be runoff for a single year or multiple years in the lowest ten percent of the historical range and reservoir storage for the same time period at less than 70 percent of average.
- Drought is a gradual phenomenon. Most natural disasters, such as floods or forest fires, occur relatively rapidly and afford little time for preparing for disaster response. With the exception of impacts to dryland farming and grazing, drought impacts occur slowly over multi-year periods, and increase with the length of dry conditions. Adverse impacts can be reduced by planning appropriate response actions prior to drought onset. The Urban Water Management and Planning Act, for example, requires California's larger urban water suppliers to develop contingency plans for shortages of up to 50 percent.
- Most Californians would experience minimal water supply impacts from a single dry year, thanks to the State's extensive system of water infrastructure. Most of California's major urban and agricultural production areas—with the exception of the Salinas Valley—are within reach of a regional conveyance facility or natural

waterway that would provide access for water transfers or exchanges. The Santa Barbara metropolitan area, the largest urban area to experience major water supply impacts during the 1987-92 drought, is now connected to the State's system of water infrastructure via the State Water Project's Coastal Aqueduct.

- Past droughts demonstrated that water users affected the earliest and to the greatest extent by drought conditions were those not connected to the State's system of water supply infrastructure, but reliant solely on annual rainfall. Typical examples were rural residents supplied by marginal wells, isolated communities relying on springs or small creeks, and ranchers dependent on dryland grazing. Residential water users and small water systems experiencing the most problems were those located in isolated North Coast communities and in the Sierra Nevada foothills. Water haulage and drilling new wells were typical drought response actions in these areas.
- The area at most economic risk from a single dry year would be the west side of the San Joaquin Valley, where dry hydrologic conditions would exacerbate federal water contractors' shortages associated with CVPIA implementation and Delta export restrictions. Significant socioeconomic impacts to low-income Westside farming communities were attributed to the last drought.
- Groundwater extractions increase substantially during droughts. The total number of well construction/modification reports filed with the Department was in the range of 25,000 reports per year during the last drought, up from fewer than 15,000 reports per year prior to the drought. Most new wells were for individual domestic supply. Rural homeowners with private wells are largely an unserved population with respect to drought-related assistance programs, although they constituted many of the public information requests directed to the Department during the last drought. The Department should implement drought outreach programs for these water users.
- Virtually all the State's larger water agencies implemented short-term demand management actions to respond to the last drought. The effects of demand hardening on water agencies' ability to implement shortage contingency measures should be monitored. Statewide, the acreage of permanent agricultural plantings that require water during drought years—such as orchards and vineyards—has increased. Most of the increased acreage is located in the San Joaquin Valley, much of it within the water-short CVP Delta export service area. As urban water agencies implement plumbing fixture retrofit programs or have greater percentages of new housing stock with low water use fixtures, it becomes increasingly difficult for the agencies to implement rationing programs without affecting customers' lifestyles.
- Changed Delta regulatory conditions have rendered the Department's 1993 drought water bank programmatic environmental impact report outdated. A future bank's scope would likely differ from that of the Department's previous banks. Almost 30 percent of California's counties now have local groundwater management ordinances; most ordinances restrict or control groundwater export from a county. Groundwater substitution transfers were a major source of the water purchased by the drought water bank. The proliferation of new county ordinances makes it less likely that the water bank, or local agencies seeking drought water supplies through transfers, would be able to implement transfers involving groundwater.
- Making specific plans for longer-term drought preparedness is complicated by Bay-Delta water management uncertainties. SWRCB's Bay-Delta water rights hearing process remains to be completed. The CALFED program is in a transitional state from planning to implementation, with a decision on its environmental documentation scheduled for later this year. The Bay-Delta Accord will expire in September 2000; discussions are ongoing as to the governance structure that could replace it, including how the function now performed by the CALFED Operations Group might be institutionalized.
- Despite uncertainties associated with Bay-Delta water project operations, having conceptual plans for multi-year operations is an important aspect of drought preparedness. The CALFED Operations Group has been focused on short-term operations under wet hydrologic conditions, responding to day-to-day Delta fishery requirements in the Delta. The last drought demonstrated the need for conservative management of carry-over storage during dry periods. The Department should work

with the CALFED Operations Group or its successor entity, and with the drought panel to be appointed by the Governor as part of CALFED's Bay-Delta Program, to begin conceptual development of multi-year SWP and CVP operations strategies.

- Implementation of many larger agencies' drought response plans is dependent on access to conveyance capacity—in either their own or in other agencies' facilities. The California Aqueduct often figures prominently in such plans, because it is the only facility linking Northern California water supplies with Southern California water users. Availability of aqueduct capacity for wheeling non-project water is becoming increasingly constrained by Delta export restrictions, as well as by contractual commitments and increasing SWP contractors' water demands. The growing number of south-of-Delta groundwater recharge/storage programs further contributes to wheeling requests. Considering the increasing level of interest in aqueduct wheeling, it may now be time for the Department to adopt a formal priority system for access to aqueduct capacity.

Hydrology And Water Supply

This chapter briefly summarizes California hydrology and water supplies and describes hydrologic conditions associated with past droughts. It is important to remember that California hydrologic data cover a limited period of historical record—only a few stream gages have a period of record in excess of 100 years, and likewise only a few precipitation records extend as much as 150 years. Efforts to go beyond the historical period of record to evaluate the occurrence of earlier droughts, or to forecast future droughts, are described at the end of this chapter.

The water supplies used by Californians come from several sources—surface water released from reservoirs, surface water directly diverted from unstored streamflows, and groundwater. Supplies derived from desalting and water recycling are also important to individual agencies relying on these sources, but they collectively represent less than one percent on California's water supply.

Roughly three-quarters of California's runoff occurs north of Sacramento, while about the same proportion of water needs occurs south of Sacramento. Figure 1 shows the extensive system of conveyance infrastructure constructed in response to the imbalance in the locations of supplies and demands. Access to this conveyance capacity has important implications for water transfers, as discussed in Chapter 3.

SURFACE WATER HYDROLOGY AND SUPPLY

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 orographic precipitation is important for the State's water supply.

Average annual statewide precipitation is about 23 inches, corresponding to a volume of nearly 200 million acre-feet over California's land surface. About 65 percent of this precipitation is consumed through evaporation and transpiration by plants. The remaining 35 percent comprises the State's 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 interstate supplies from the Colorado and Klamath Rivers are added. Figure 2 shows the distribution of California's average annual precipitation and runoff.

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. Figure 3 compares average monthly precipitation in the Sacramento River region with precipitation during extremely wet (1982-83) and dry (1923-24) years.

THE WATER YEAR

Water agencies such as the Department or the U.S. Geological Survey report hydrologic data on a water year basis. The water year extends from October 1st through September 30th. This report, for example, was published in water year 2000 (October 1, 1999—September 30, 2000). Hydrologic data presented throughout this report are presented in terms of water years. The (water year) 1987-92 drought corresponds to the calendar period of fall 1986 through summer 1992. Water project delivery data (*e.g.,* State Water Project deliveries) are presented on a calendar year basis.

—Figure 1—

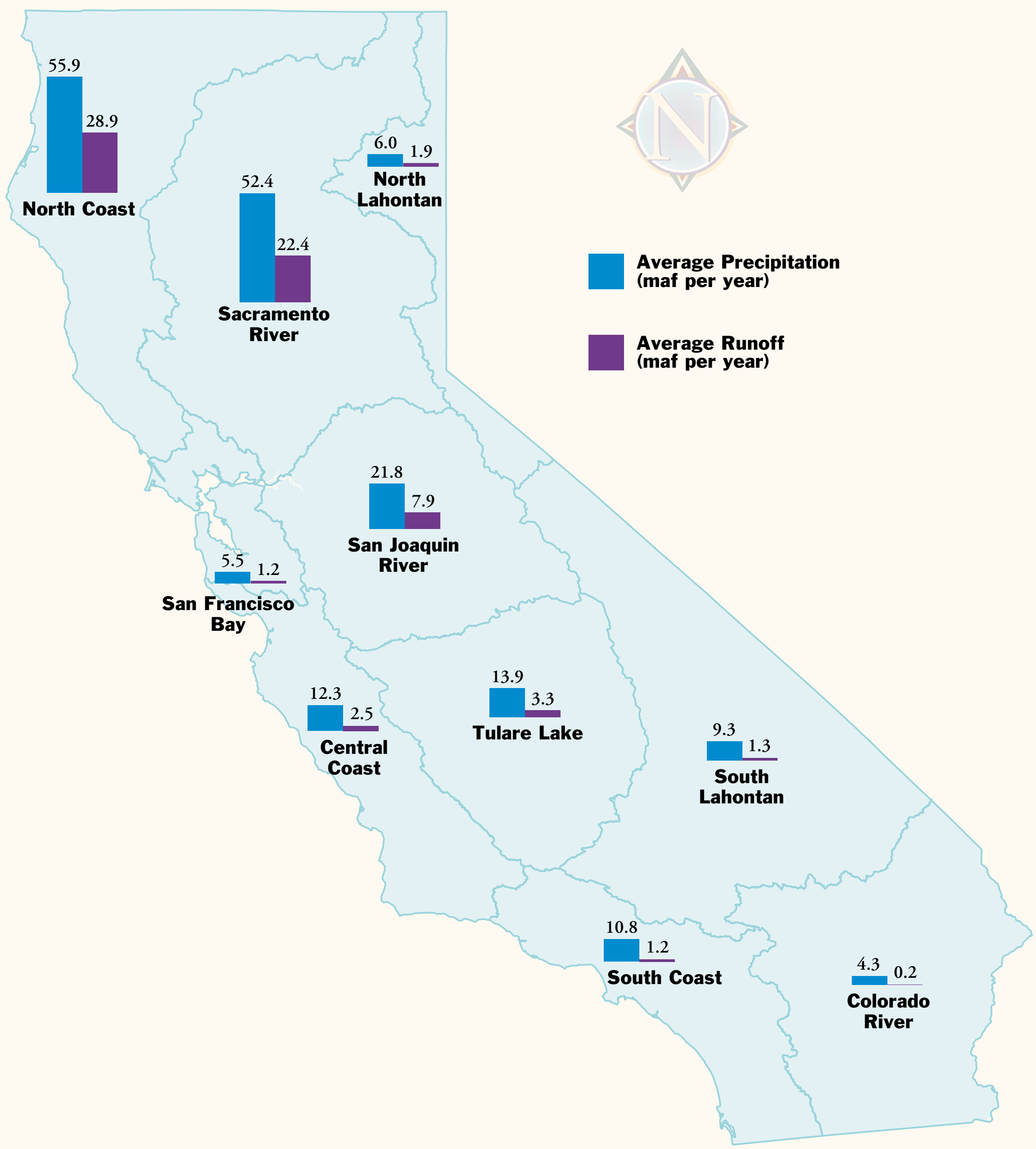
California's Major Water Projects

The influence of climatic variability on California's water supplies is much less predictable than are 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; the flooding of 1986 was followed by six years of drought (1987-92).

Figures 4 and 5 show estimated annual unimpaired runoff from the Sacramento and San Joaquin River

—FIGURE 2—

Distibution of Average Annual Precipitation and Runoff

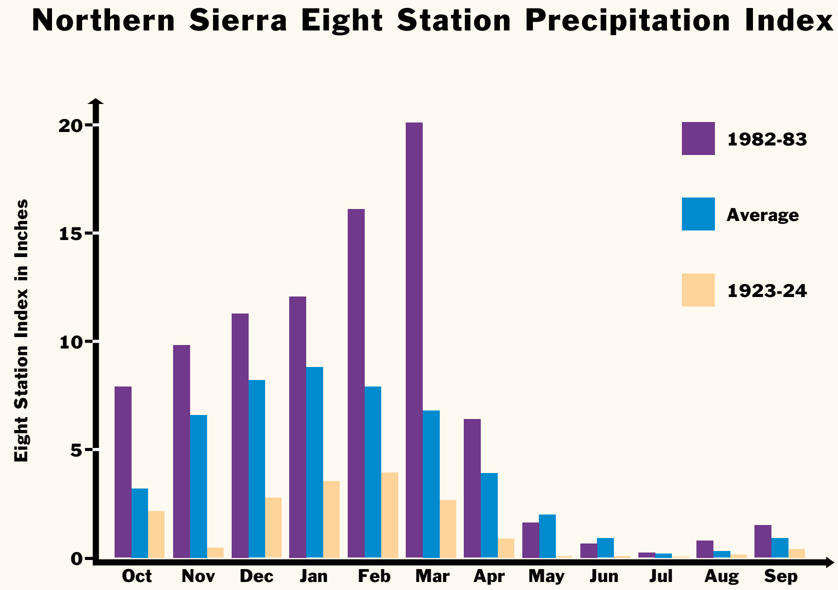


Basins to illustrate climatic variability. Because these basins provide much of the State's water supply, their hydrologies are often used as indices for water year classification systems.

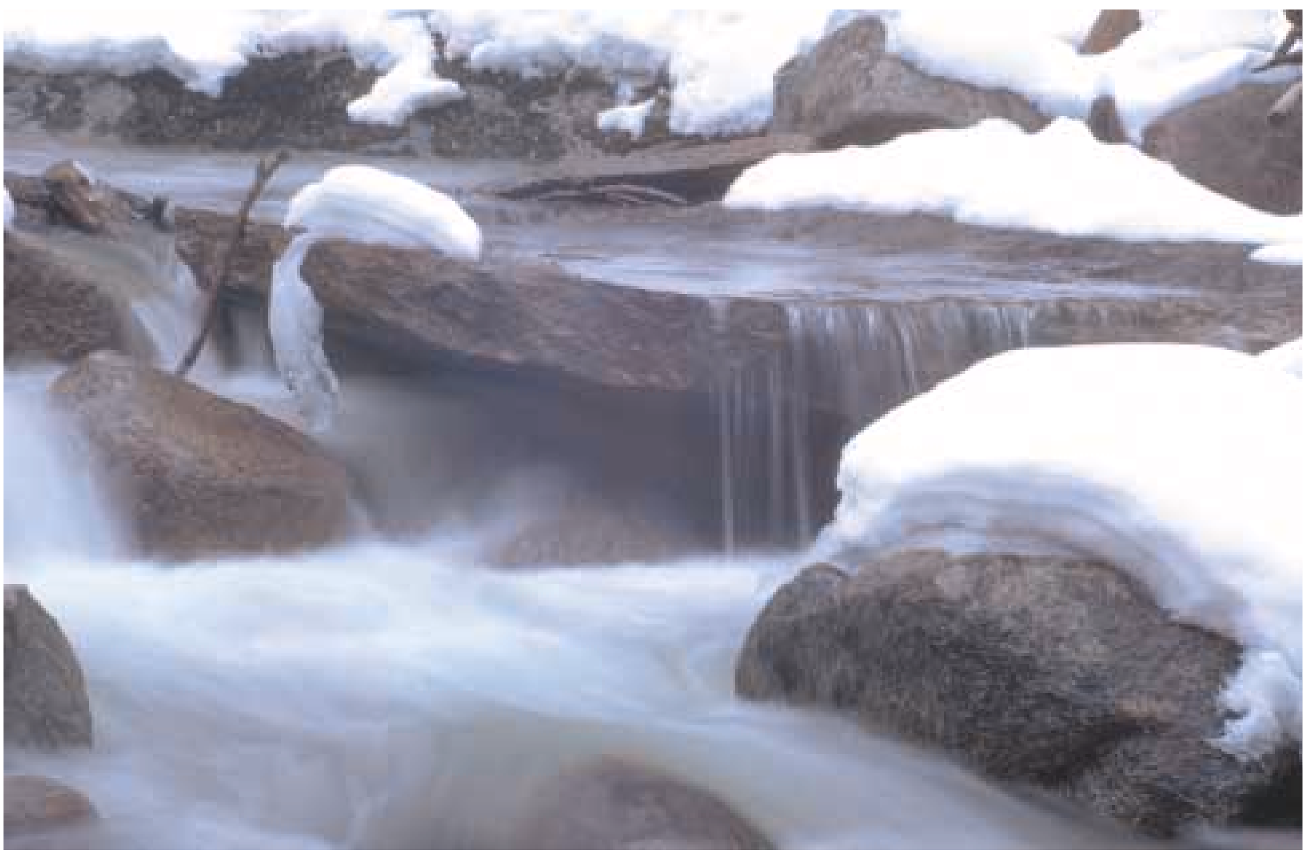
Water year classification systems provide a means to assess the amount of water originating in a basin. The Sacramento Valley 40-30-30 Index and the San Joaquin Valley 60-20-20 Index were developed by the State Water Resources Control Board for the Sacramento and San Joaquin River Basins as part of SWRCB's 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 (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 unimpaired flow above Bend Bridge, Feather River unimpaired inflow to Oroville Reservoir, Yuba River unimpaired flow at Smartville, and

—FIGURE 3—



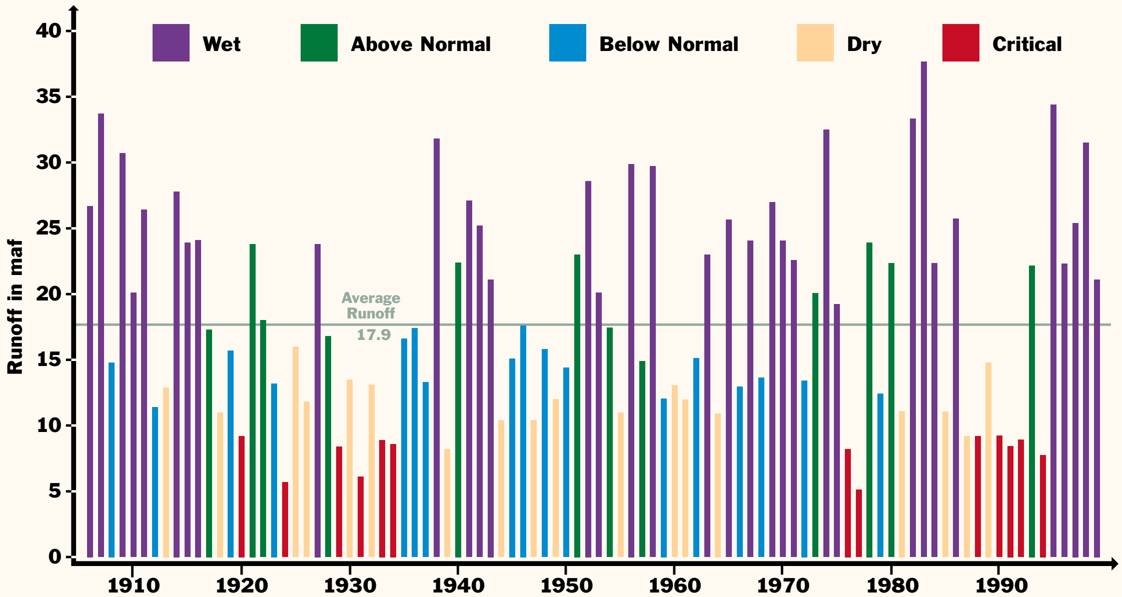
The eight stations are:
Mt. Shasta City; Shasta Dam; Brush Creek; Mineral; Quincy; Sierraville; Blue Canyon; Pacific House



Snowmelt runoff in the Sierra Nevada provides much of California's developed water supply. 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.

—Figure 4—

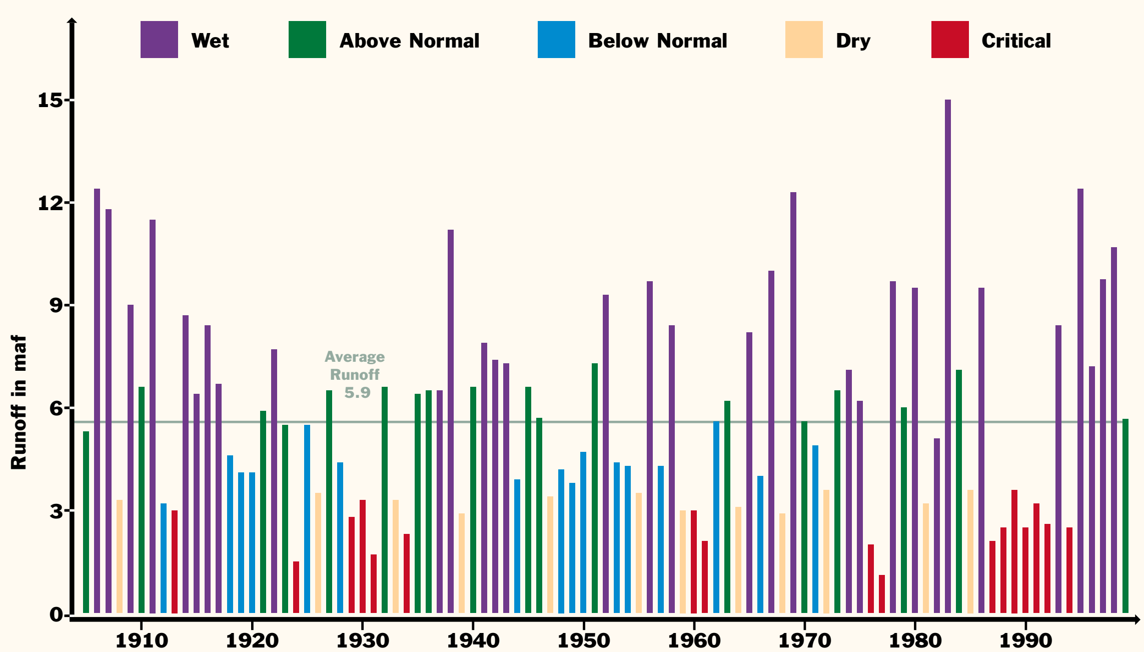
Sacramento Four Rivers Unimpaired Runoff



The Sacramento Four Rivers are: *Sacramento River above Bend Bridge, near Red Bluff; Feather River inflow to Oroville; Yuba River at Smartville; American River inflow to Folsom*

—Figure 5—

San Joaquin Four Rivers Unimpaired Runoff



The San Joaquin Four Rivers are: *Stanislaus River inflow to New Melones, Tuolumne River inflow to New Don Pedro, Merced River inflow to New Exchequer, San Joaquin River inflow to Millerton*

American River unimpaired inflow to Folsom Reservoir) is 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 Decision 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 as well as from seasonal runoff, the 40-30-30 Index provides a more representative characterization of water year types than does the SRI. However, no indexing scheme can be a perfect representation of water year type. For example, the inability to store large volumes of wet year runoff (due to reservoir flood control requirements and the relatively low ratio of storage capacity to wet year runoff volumes for most California rivers) distorts the 40-30-30 Index value for the year following a very wet year.

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 (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 unimpaired inflow 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 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.

GROUNDWATER SUPPLY

Under average hydrologic conditions, about 30 percent of California's urban and agricultural water needs are supplied by groundwater. This percentage increases in dry years when water users whose surface supplies are reduced turn to groundwater, if available.

—Figure 6—

Total Well Driller Reports Filed Annually with DWR

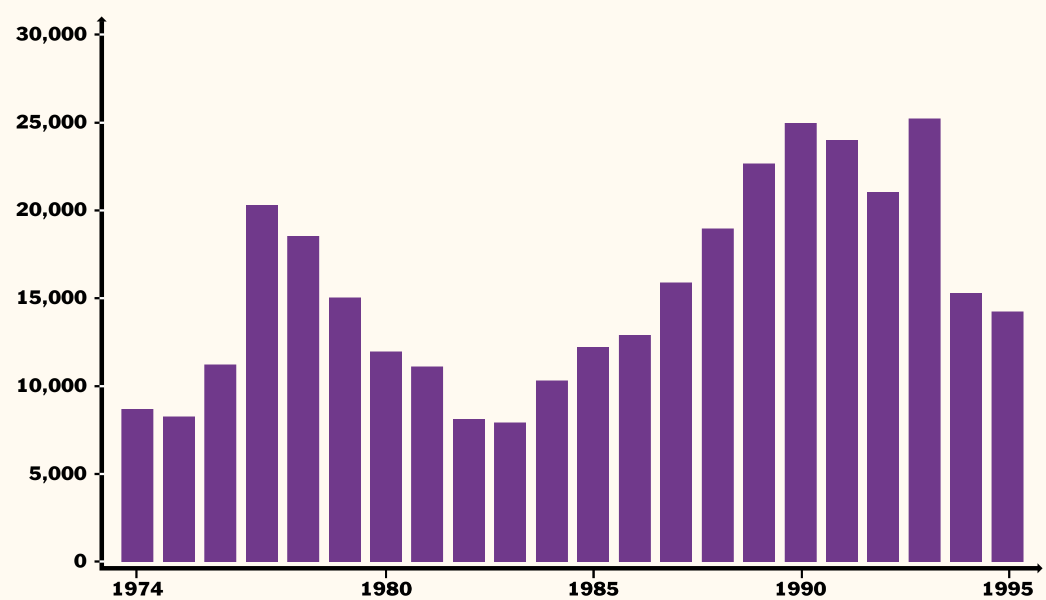
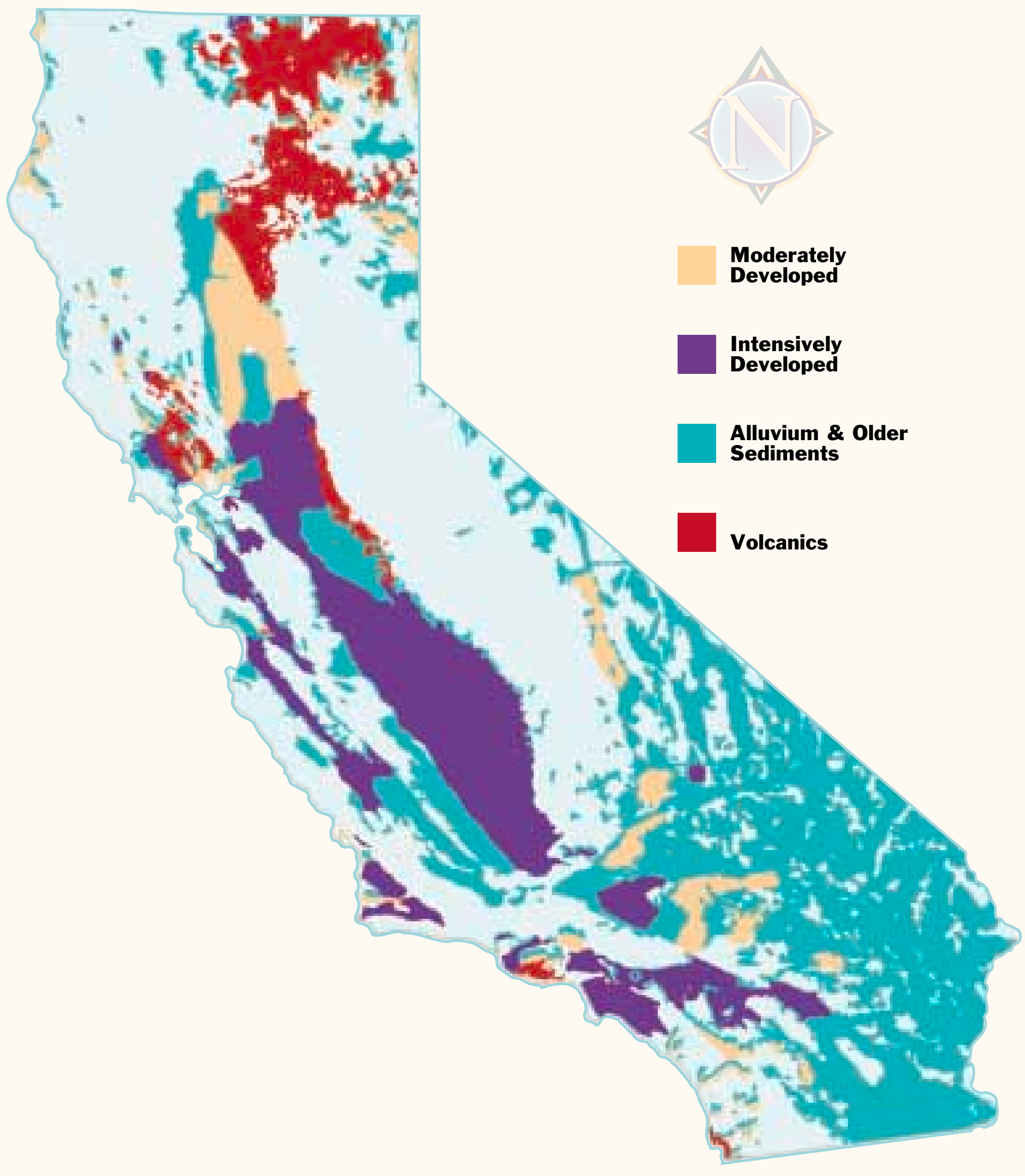


Figure 6 shows the total number of well construction/modification reports received annually by the Department, illustrating the relationship between groundwater use and hydrologic conditions. Well drilling activity increased during the 1987-92 drought and was at a minimum in wet years such as 1982 or 1983.

The amount of water stored in California's groundwater basins is far greater than that stored in the State's surface water reservoirs, although only a fraction of these groundwater resources can be economically and practically extracted for use. Figure 7 shows major areas of current and potential groundwater development in California. The greatest amounts of groundwater extraction occur in the Central and Salinas Valleys and in the Southern California coastal plain. At a 1995 level of development, California's estimated developed groundwater supplies were about 12.5 maf under average hydrologic conditions. This amount is exclusive of groundwater overdraft, estimated at about 1.5 maf annually. More than 1 maf of this estimated annual overdraft occurs in the San Joaquin Valley.

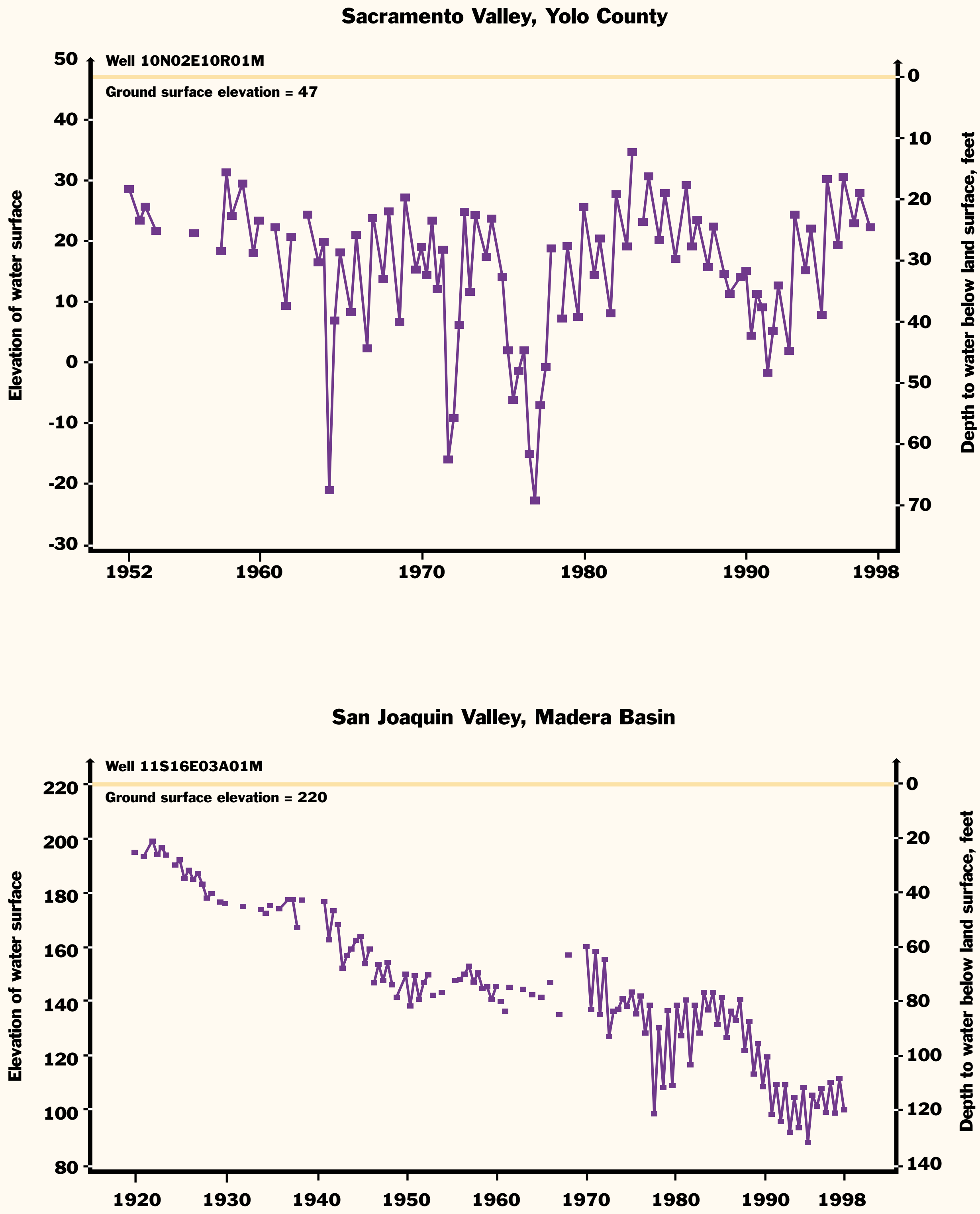
—Figure 7—

Areas of Current and Potential Groundwater Development



—FIGURE 8—

Sample Hydrographs of Agricultural Wells in the Sacramento and San Joaquin Valleys



The majority of California's groundwater production occurs from alluvial materials in the large basins indicated in Figure 7. Groundwater levels in such basins typically decline during droughts due to increased extractions. For example, groundwater extractions were estimated to exceed recharge by 11 maf in the San Joaquin Valley during the first five years of the 1987-92 drought. Drawing down groundwater reserves in drought years is analogous to surface reservoir carryover storage operations. The extent to which groundwater levels recover depends on the amount of subsequent extractions and recharge. Figure 8 shows hyrographs for two wells—one located in a basin experiencing long-term overdraft and the other in a basin not experiencing long-term overdraft. Both hydrographs show the effects of increased extractions during the 1976-77 and 1987-92 droughts, followed by post-drought rebound.

PAST CALIFORNIA DROUGHTS

Droughts exceeding three years are relatively rare in Northern California, the source of much of the State's water supply. Historical multi-year droughts include: 1912-13, 1918-20, 1923-24, 1929-34, 1947-50, 1959-61, 1976-77, and 1987-92. The 1929-34 drought established the criteria commonly used in designing storage capacity and yield of large Northern California reservoirs. Table 1 compares the 1976-77 and 1987-92 droughts to the 1929-34 drought in the Sacramento and San Joaquin Valleys.

One approach to supplementing California's limited period of measured data is to statistically reconstruct data through the study of tree rings. Information 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 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 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. The Department is currently funding the University to expand tree ring data for the Sacramento River watershed to cover approximately the past 1,000 years. Similar tree ring studies covering the period between 1550 and 1977 were conducted for the Colorado and Santa Ynez Rivers. According to these studies, the most severe drought on the Colorado River occurred during 1580-1600, and the most severe drought on the Santa Ynez River occurred during 1621-37.

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. A conclusion that can be drawn from these investigations is that California is subject to droughts more severe and more prolonged than anything witnessed in the historical record.

—Table 1—

Severity of Extreme Droughts in the Sacramento and San Joaquin Valleys

Drought	Sacramento Valley Runoff		San Joaquin Valley Runoff	
Period	(maf/yr)	(% Average 1901-96)	(maf/yr)	(% Average 1906-96)
1929-34	9.8	55	3.3	57
1976-77	6.6	37	1.5	26
1987-92	10.0	56	2.8	47

PAST CALIFORNIA DROUGHTS

The historical record of California hydrology is brief in comparison to the time period of geologically modern climatic conditions. The following sampling of changes in climatic and hydrologic conditions help put California's twentieth century droughts into perspective, by illustrating the variability of possible conditions. Most of the dates shown below are necessarily approximations, since the dates must be inferred from indirect sources.

11,000 years before present	Beginning of Holocene Epoch—Recent time, the time since the end of the last major glacial epoch
6,000 years before present	Approximate time when trees were growing in areas now submerged by Lake Tahoe. Lake levels were lower then, suggesting a drier climate.
900—1300 A.D. *(approximate)*	The Medieval Warm Period, a time of warmer global average temperatures. The Arctic ice pack receded, allowing Norse settlement of Greenland and Iceland. The Anasazi civilization in the Southwest flourished, its irrigation systems supported by monsoonal rains.
1300—1800 A.D. *(approximate)*	The Little Ice Age, a time of colder average temperatures. Norse colonies in Greenland failed near the start of the time period, as conditions became too cold to support agriculture and livestock grazing. The Anasazi culture began to decline about 1300 and had vanished by 1600, attributed in part to drought conditions that made agriculture infeasible.
Mid-1500s A.D.	Severe, sustained drought throughout much of the continental U.S., according to dendrochronolgy. Drought suggested as a contributing factor in the failure of European colonies at Parris Island, South Carolina and Roanoke Island, North Carolina.
1850s A.D.	Sporadic measurements of California precipitation began.
1890s A.D.	Long-term streamflow measurements began at a few California locations.

PREDICTING FUTURE DROUGHTS

Accurate long-term weather forecasting would be extremely valuable for water project operations. Currently, predictions sufficiently detailed to be useful for project operations are limited to about two weeks at best, and these predictions have perhaps a 50 percent accuracy rate. Had water project operators known in advance that 1987-92 would be dry, project operations could have been modified to increase carry-over storage and to equalize deliveries over the six years of drought.

Long-term forecasting remains in its scientific infancy. The National Weather Service issues 30 and 90-day forecasts. Academic institutions, such as the Scripps Institution of Oceanography in San Diego, have attempted experimental seasonal forecasts. The accuracy and level of detail of these efforts remains insufficient for water project operations. It is only recently, for example, that researchers have had sufficient understanding of global weather patterns and atmospheric/oceanic interactions to be able to identify conditions associated with the El Niño Southern Oscillation in the Pacific Ocean. That understanding has yet to be translated to forecasts of runoff, partly because ENSO events affect different parts of California differently.

Using global weather models to predict future climatological conditions requires collection of massive amounts of data and access to substantial computational power (*i.e.,* supercomputers). Although electronic data processing capabilities have increased exponentially since the early days of mainframe computers, data collection will remain a limiting factor into the foreseeable future, due to the sheer volume of information needed to represent global atmospheric/oceanic conditions. Atmospheric conditions themselves may furthermore be inherently too variable to support long-range forecasts of sufficient reliability for short-term water project operations. A more realistic expectation might be the ability to forecast shifts in global conditions, such as potential global warming or decadal oscillations in ocean temperatures in the equatorial Pacific. It can be safely said that the ability to accurately predict dry conditions will remain elusive within this report's short planning horizon.

Excavations for construction of Metropolitan Water District's Diamond Valley Lake in Riverside County yielded numerous paleontologic resources, including partial remains of mastodons. The mastodons, together with other extinct species such as long-horned bison and ground sloths, occupied Diamond and Domenigoni Valleys during the Pleistocene Epoch, the time of the last Ice Age. The area's climate was then cooler and wetter than the present. Photograph courtesy of MWD.

DROUGHTS—WHEN WATER USERS LACK WATER

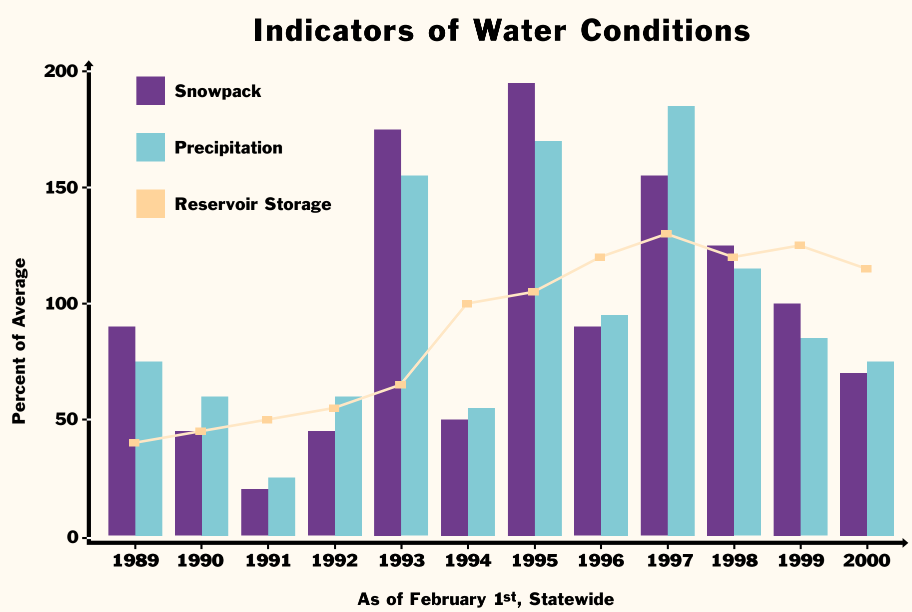
One dry year does not constitute a drought in California, but does serve as a reminder of the need to plan for droughts. California's extensive system of water supply infrastructure—its reservoirs, groundwater basins, and inter-regional conveyance facilities—mitigates the effect of short-term dry periods. Defining when a drought begins is a function of drought impacts to water users. Hydrologic conditions constituting a drought for water users in one location may not constitute a drought for water users in a different part of the state or with a different water supply. Individual water suppliers may use criteria such as rainfall/runoff, amount of water in storage, or expected supply from a water wholesaler to define their water supply conditions

Figure 9 illustrates several indicators commonly used to evaluate California water conditions. The percent of average values are determined for measurement sites and reservoirs in each of the State's ten major hydrologic regions. Snowpack is an important indicator of runoff from Sierra Nevada watersheds, the source of much of California's developed water supply.

The Department used two primary criteria to evaluate statewide drought conditions during the 1987-92 drought—runoff and reservoir storage, either actual or predicted. A drought threshold was considered to be runoff for a single year or multiple years in the lowest ten percent of the historical range, and reservoir storage during the same time period at less than 70 percent of average. These were not hard and fast values, but guidelines for identifying drought conditions.

Drought is a gradual phenomenon. Although droughts are sometimes characterized as emergencies, they differ from typical emergency events. Most natural disasters, such as floods or forest fires, occur relatively rapidly and afford little time for preparing for disaster response. Droughts occur slowly, over a multiyear period. There is no universal definition of when a drought begins or ends. Impacts of drought are typically felt first by those most reliant on annual rainfall—ranchers engaged in dryland grazing, rural residents relying on wells in low-yield rock formations, or small water systems lacking a reliable water source. Criteria used to identify statewide drought conditions do not address these localized impacts. Drought impacts increase with the length of a drought, as carry-over supplies in reservoirs are depleted and water levels in groundwater basins decline.

—FIGURE 9—

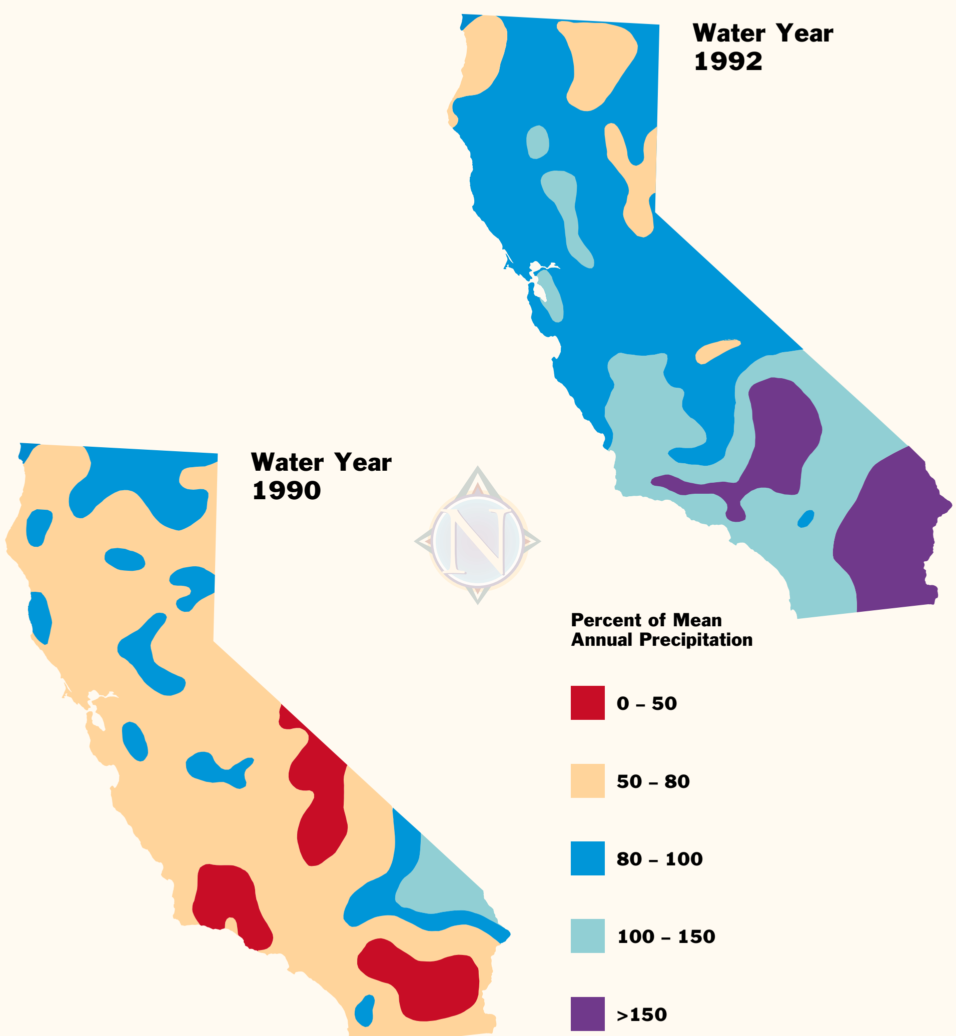


THE 1987-92 DROUGHT

This chapter focuses on conditions experienced during the most recent drought, the six-year event from 1987 to 1992. A few examples from the 1976-77 drought are also mentioned, but detailed discussion of this earlier event is minimized because conditions have changed greatly since then. Impacts experienced during the 1976-77 drought—when 47 of the State's 58 counties declared local emergencies—served as a wake-up call to water managers statewide, spurring implementation of many improvements to water supply reliability.

—FIGURE 10—

Statewide Distribution of Precipitation for Water Years 1990 and 1992

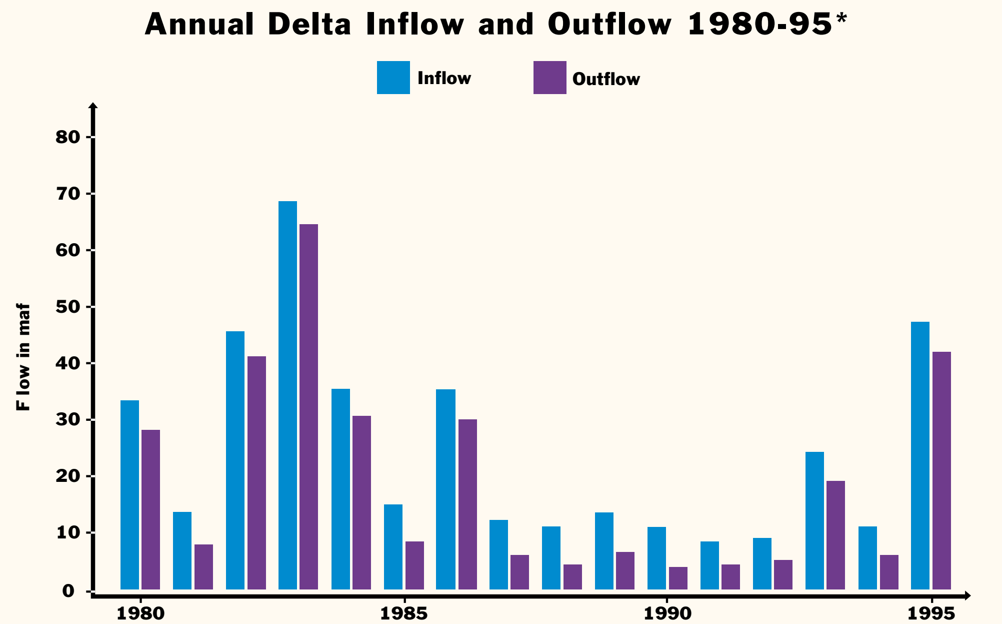


WATER SUPPLIES AND WATER PROJECT OPERATIONS

The 1987-92 drought was notable for its six-year duration and the statewide nature of its impacts. Because of California's size, droughts may or may not occur simultaneously throughout the entire state. The jet stream's position during the winter storm season is an important determinant of regional precipitation amounts. California, spanning more than nine degrees of latitude (a north-to-south extent equaled or exceeded only by Alaska and Texas), seldom experiences uniform levels of wetness or dryness, as illustrated in Figure 10. Historical values for the Sacramento River and San Joaquin River indices shown in the previous chapter also demonstrate this point. As defined by these indices, the Sacramento River system experienced two dry years and four critically dry years during the drought; the San Joaquin River system experienced six critically dry years. Figure 11 shows historical Delta inflows and outflows, as another way of illustrating Central Valley runoff during the drought.

Defining drought conditions in urbanized coastal Southern California is complicated. Historically, imports (from Northern California, from the eastern Sierra, and from the Colorado River) have provided about 65 percent of the region's water supply. Hydrologic conditions in the Colorado River Basin may vary greatly from those being experienced in California; the extensive storage in the river basin further acts as a buffer to short-term hydrologic changes. Colorado River unimpaired flow at the gaging station used for interstate compact administration was below the long-term historical average during the 1987-92 drought, but the immediately prior multi-year wet period had filled system reservoirs. When the SWP sharply curtailed deliveries in 1991, MWD (the most junior of California's major Colorado River water users) was able to maintain a full Colorado River Aqueduct due to availability of surplus river water.

—FIGURE 11—

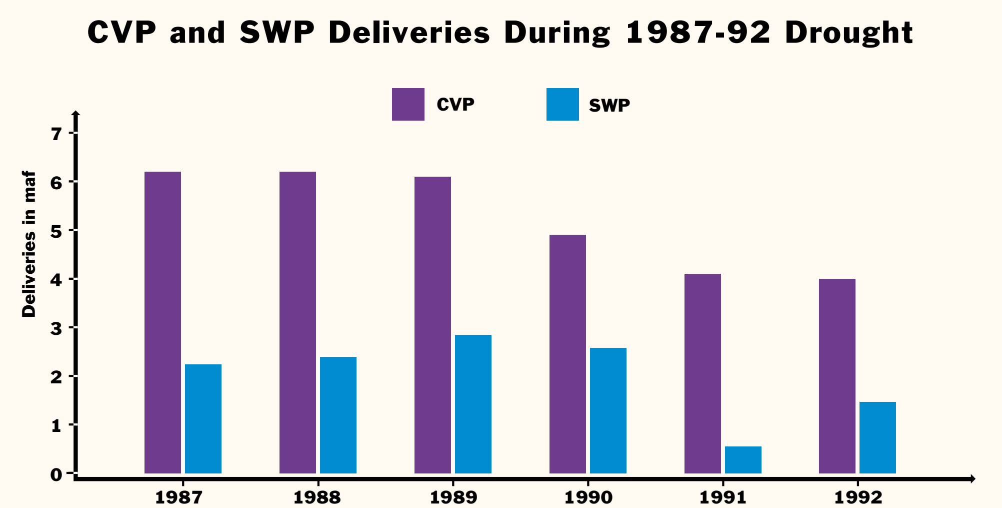


*1983 was the wettest year in Northern California in the 20th century.

Water users served by most of the State's larger suppliers did not begin to experience shortages until the third or fourth years of the drought. Reservoir storage provided a buffer against drought impacts during the initial years of the drought. The CVP and SWP met delivery requests during the first four years of the drought, but were then forced by declining reservoir storage to cut back deliveries substantially, as illustrated in Figures 12 and 13. (Cachuma Reservoir storage is also shown to provide an example of drought impacts to a Southern California reservoir not connected to imported water supplies.) In 1991, the SWP terminated deliveries to agricultural contractors and provided only 30 percent of requested urban deliveries. The CVP, with its larger storage capacity, reduced agricultural deliveries by 75 percent and urban deliveries by 25 percent in 1991.

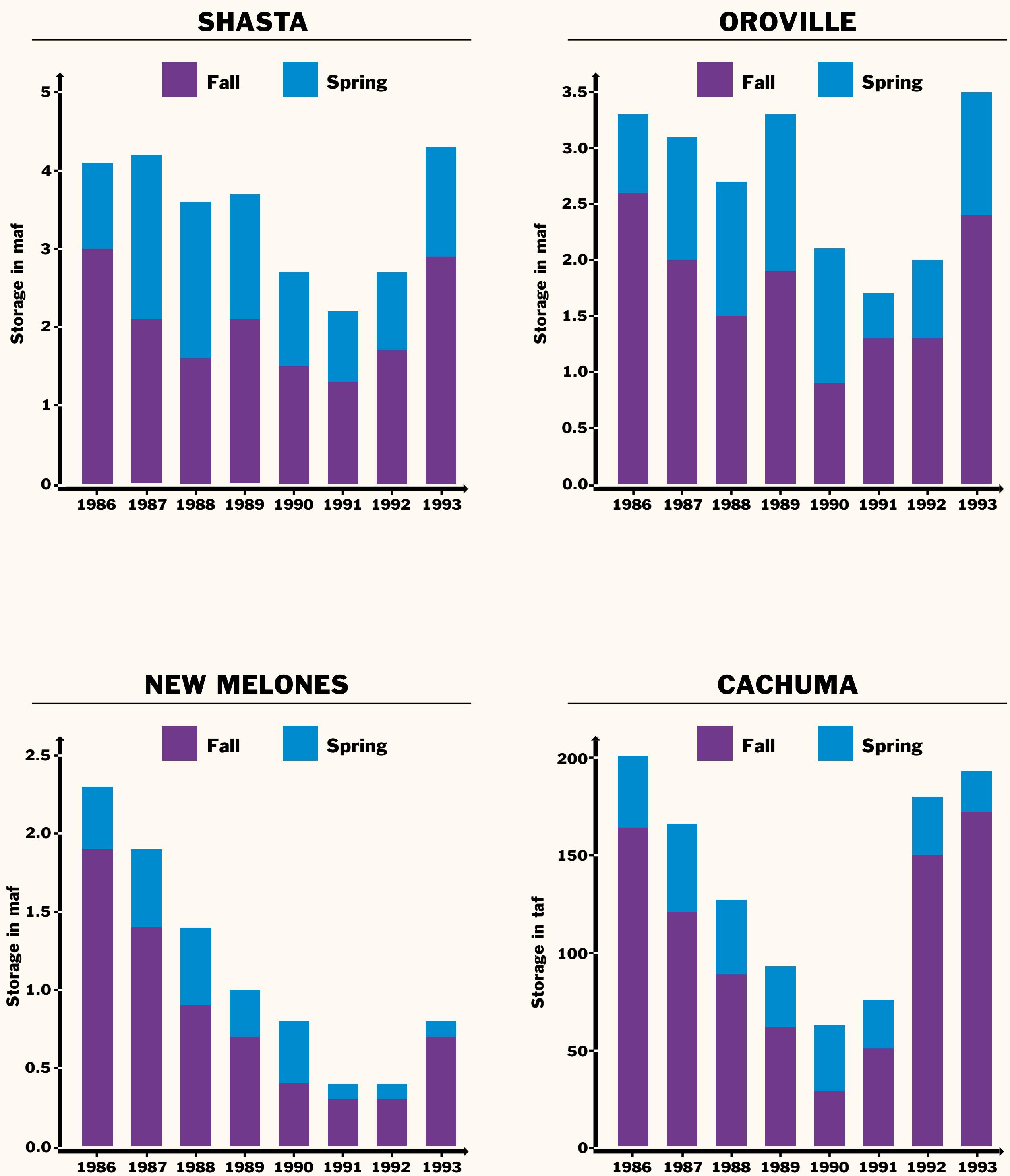
By the third year of the drought, overall statewide reservoir storage was about 40 percent of average. Statewide reservoir storage did not return to average conditions until 1994, thanks to an unusually wet

—FIGURE 12—



—Figure 13—

Examples of Reservoir Storage During 1987-92 Drought



1993. Some examples of surface water supply impacts included:

- Among large urban agencies' water development projects, the City and County of San Francisco's system experienced the greatest supply impacts, having only about 25 percent of total storage capacity in 1991. The City and County constructed two turnouts—one 75 cubic feet per second and the other 25 cfs—on the California Aqueduct to obtain access to supplies from water transfers.
- Lake Tahoe, the principal storage facility for the U.S. Bureau of Reclamation's Newlands Project in Nevada, not only fell below its natural rim but also reached a record low of more than a foot below the rim. Storage on the Truckee River system, all dedicated to Nevada uses, reached a low of ten percent of total capacity in 1991.
- The creek providing water for Markleeville, the county seat of Alpine County, dried up. A pipeline was constructed to a new water source. This example is typical of impacts faced by small rural water systems with marginal water supplies.

As described later in this chapter, the drought spurred many water agencies to begin planning for new facilities to improve water supply reliability. Only two new water management facilities of regional scope were put into service during the drought. In Northern California, the Department's North Bay Aqueduct pipeline was completed in 1988, replacing previously constructed interim facilities. The NBA was used to convey SWP water and water transfers to Napa Valley communities experiencing significant shortages of local surface supplies. In the San Joaquin Valley, initial operational testing was being conducted for the Kern Water Bank, a project originally developed by the Department for SWP supply augmentation and subsequently turned over to local agencies to implement. In a 1990 test program, the Department banked about 100 thousand acre-feet of SWP water in

The Lake Tahoe shoreline in 1992, with a then-unusable recreational pier in the foreground. In addition to causing Lake Tahoe to reach a record low elevation, the drought also affected water-based recreation—both winter skiing and summer boating.

Although business sectors such as the landscaping industry and water-based recreation concessionaires were negatively affected by the drought, the water well drilling industry prospered. Many private well owners deepened existing wells or drilled new ones during the 1987-92 drought; well owners commonly experienced delays in obtaining service due to the large backlog of drilling jobs. The drought also served to remind homeowners of the maintenance needs associated with private wells.

what was then known as the Semitropic local element of the KWB. Semitropic Water Storage District returned, through exchange, about half the stored water in 1992.

Delta regulatory constraints affecting CVP and SWP operations during the drought were based on SWRCB Decision 1485. (D -1485 requirements took effect in 1978, immediately following the 1976-77 drought.) Other operational constraints included temperature standards established by SWRCB through Orders WR 90-5 and 91-01 for portions of the Sacramento and Trinity Rivers. On the Sacramento River below Keswick Dam, these orders included a daily average water temperature objective of 56° F during critical periods when high temperatures could be detrimental to survival of salmon eggs and pre-emergent fry.

Groundwater extraction increased substantially during the drought. The total number of well driller reports filed with the Department was in the range of 25,000 reports per year for several years, up from fewer than 15,000 reports per year prior to the drought. The majority of the new wells drilled were for individual domestic supply. Water levels and the amounts of groundwater in storage declined substantially in some areas. As indicated earlier, groundwater extractions were estimated to exceed groundwater recharge by 11 maf in the San Joaquin Valley during the first five years of the drought. Precise surveys of the California Aqueduct identified an increase in subsidence along the aqueduct alignment in the San Joaquin Valley, in response to increased groundwater extractions.

Examples of impacts to groundwater supply included:

- Numerous private domestic wells went dry, as did wells supplying small systems in rural areas.

Homeowners with private wells were forced to drill new wells or deepen existing ones. Groundwater users most at risk were typically those relying on extractions from small coastal basins with limited recharge, or on low-yield fractured rock formations such as those in the Sierra Nevada foothills. Dry wells at a number of small water systems in rural areas of the Sierra Nevada foothills resulted in the need to haul water. Counties affected included Butte, Amador, Mariposa, and Tuolumne.

- Water levels in Salinas Valley aquifers declined, and increased seawater intrusion was noted. San Antonio and Nacimiento Reservoirs, used by Monterey County Water Resources Agency for groundwater recharge, were only at six percent of capacity in 1991. The valley's extensive agricultural production relies almost entirely on groundwater. (A new water recycling project providing supplemental irrigation supplies in the Castroville area did not become operational until after the drought ended.)
- Some communities in the Central Coast area rely on small groundwater basins formed by coastal terrace deposits, with recharge to these basins being limited largely to direct precipitation over the basin. These communities typically experienced shortages throughout the drought, and instituted rationing in response. Santa Barbara experienced the largest water supply reductions of any of California's larger municipalities; its limited groundwater and local surface water supplies were unable to support area residents' needs. As described later in this chapter, the city was forced to adopt several emergency measures including a 14-month ban on lawn watering.
- Groundwater supplies ranged from none to minimal for the small North Coast communities that frequently experience water supply problems. In Mendocino, for example, supplies are provided by individual private wells. It has been estimated that ten percent of the town's wells go dry every year, an amount that increases to 40 percent during droughts. Other communities with problems included Weaverville and Fort Bragg (building moratoria/connection bans), Klamath (connected to a private well), and Willits (hauled water, installed temporary pipeline). Wells or springs serving several small water systems in the Russian River corridor went dry; water haulage was necessary.

ACTIONS TAKEN BY WATER AGENCIES TO RESPOND TO DROUGHT

Department of Water Resources

The Department devoted substantial resources to drought-related information collection and dissemination, including staffing a Drought Center to serve as a central point of contact for information and emergency assistance requests. The Department also chaired the interagency Drought Action Team established by Governor's Executive Order No. W-3-91. The Division of Flood Management compiled and disseminated climatology, hydrology, and water storage data. Staff in District offices were tasked with performing anecdotal surveys of local water agency conditions, and with providing increased local assistance support in water conservation and other programs. Information collected by the Department was provided to the media, to the general public, and to the Legislature. Numerous status reports and other drought-related information were published; examples are listed in the references at the end of this report.

In addition to routine SWP operations, the Department conducted several trial programs to improve SWP water supply reliability. The demonstration groundwater storage program with SWSD was one example. In 1989, a weather modification project using aerial cloud seeding was operated in the Feather River watershed. The Department additionally began a demonstration weather modification program using ground-based propane generators in the Middle Fork Feather River watershed in 1991. The program was terminated after three years when initial results indicated that a redesign was necessary, by which time the drought had ended.

The Department used the California Aqueduct to wheel water for other agencies' drought-related water transfers, and also for the drought water bank. The bank, the most ambitious of the Department's drought response activities, is described in detail below. The Department developed the bank in response to the Governor's 1991 Executive Order. The bank operated three times—during 1991 and 1992, then again in 1994, a critically dry year. Figure 14 shows locations of bank transactions in 1991 and 1992. Details of bank operation are provided in Table 2.

The Department purchased water under 351 short-term agreements in 1991. About 50 percent of the water came from land fallowing, and about 30 percent from groundwater substitution. The remainder of the water came from reservoir storage. In 1992, about 80 percent of bank purchases came from groundwater

Lake Oroville in 1990. Oroville Dam is at left edge of photo. The 3.54 maf reservoir was at about one-third capacity at the time of this photo. During the 1976-77 drought, its storage declined to about one-quarter of full capacity.

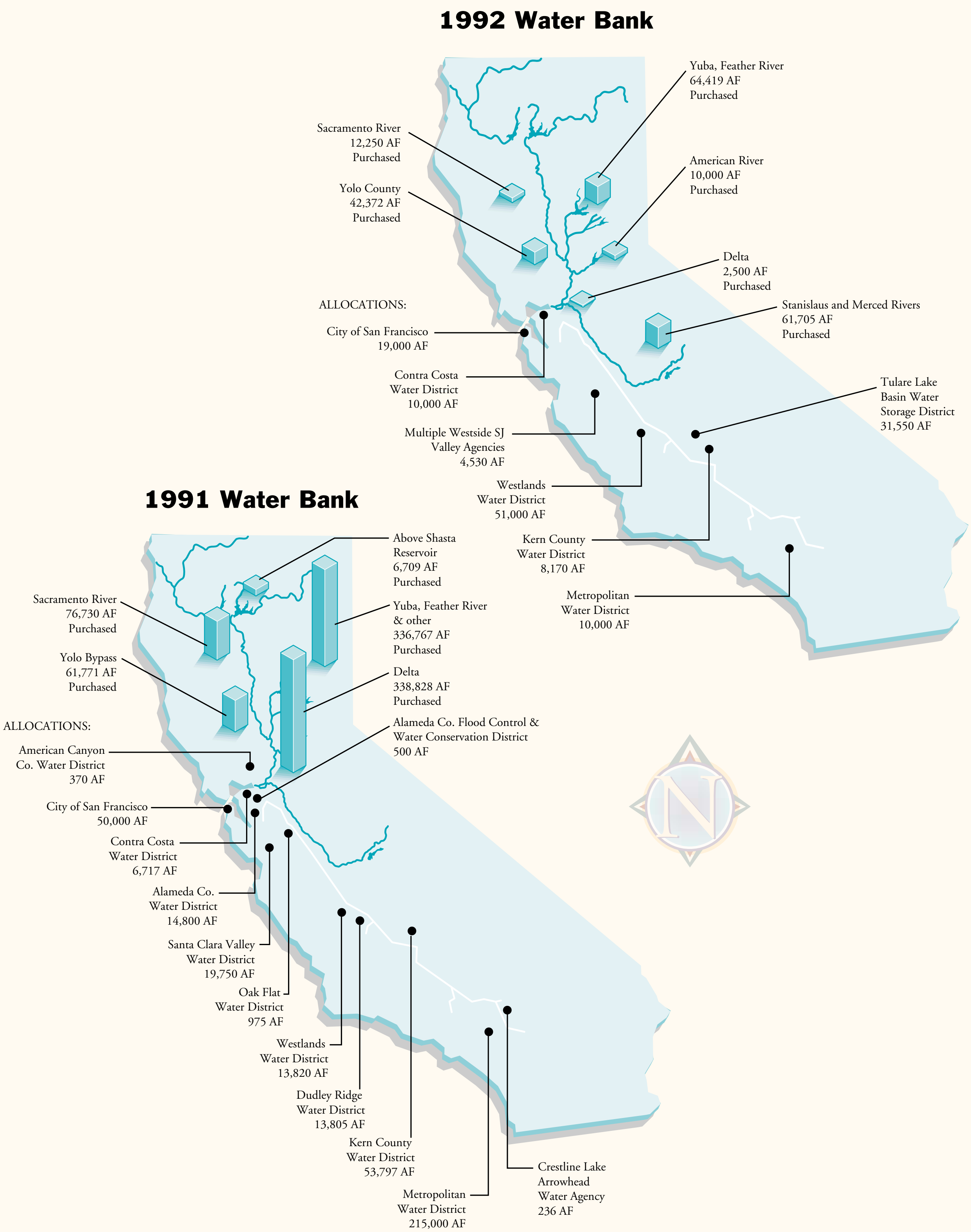
substitution and 20 percent from reservoir storage. No land fallowing contracts were executed in 1992. While land fallowing was a major feature of the 1992 bank, it is also the water source that has the greatest potential for generating third party impacts. The costs to the seller of participating in land fallowing are higher, and it was determined that water purchased from other sources could be less expensive. Finally, demands in the 1992 and 1994 banks were much less than those in 1991, and a judgement was made that land fallowing was not needed to meet critical water needs.

The 1991 and 1992 banks were able to acquire sufficient water to meet critical needs of all participants. The highest priority critical needs were basic domestic use, health and safety, and fire protection. Agricultural critical needs allocations were based on supplies for permanent plantings such as orchards and vineyards. DFG, in a program operated in parallel to the drought water bank, used emergency drought relief funding appropriated during the Legislature's 1991-92 extraordinary session to purchase almost 75 taf for fish and wildlife purposes. Most of the water was used for wetlands at wildlife refuges.

Water users and residents in regions of bank sales expressed concerns about third-party impacts of the fallowing and groundwater substitution associated with the 1991 and 1992 banks. Some private groundwater users in Butte County not participating in the bank filed claims against the Department alleging impacts to their wells. The Department conducted extensive groundwater monitoring programs in areas of the groundwater substitution purchases, including installing extensometers to measure subsidence. The Department paid Yolo and Butte Counties amounts equivalent to two percent of the value of the groundwater substitution contracts in their counties, to fund preparation of county water plans or to update existing plans. The Department also funded external reviews of 1991 and 1992 Bank operation, which included economic evaluation of third-party impacts (see references in Appendix).

—FIGURE 14—

The 1991 and 1992 Drought Water Banks



—TABLE 2—

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[b]	-	25	-
SWP Carryover	266	-	-
Total Allocation	**656**	**159**	**174**
Selling Price ($/af)[c]	**175**	**72**	**68**

[a] *Includes about 58 taf for SWP short-term water purchase program.*

[b] *20 taf of this amount was part of the 75 taf purchased by DFG with emergency drought relief funding.*

[c] *Price to buyers at Banks Pumping Plant. Includes the cost of the water, adjustments for carriage losses and administrative charges. Does not include transportation charges which ranged from $15 to $200/af, depending on the point of delivery and other factors.*

In 1993, the Department completed a programmatic environmental impact report covering operation of potential drought water banks over the next 5 to 10 years. A bank would be implemented as needed on an annual basis upon an executive order of the Governor, a decision by the Secretary for Resources, or a finding by the Department's Director that drought or other unanticipated conditions would significantly curtail water supplies. The bank would continue to operate until water supplies returned to noncritical levels.

The Department opened another drought water bank in 1994, together with a short-term water purchase program for SWP contractors. The Department began organizing a 1995 bank in September 1994, anticipating another dry year. By mid-November, water agencies had signed contracts with the Department to purchase water from the bank for critical needs. The bank acquired options to purchase 29 taf of water from five willing sellers. The options were subsequently not exercised due to wet conditions in 1995.

Other Water Agencies

The majority of the State's urban water retailers and water wholesalers implemented demand reduction techniques—either voluntary or mandatory—at some point during the drought. Demand reduction programs were typically accomplished through extensive customer education and outreach programs. Mandatory rationing levels reached as high as 50 percent in some hard-hit communities. Small communities in isolated areas lacking back-up water sources and the ability to interconnect with other water agencies typically had no recourse other than demand reduction or water haulage. Customers of agricultural water agencies reduced planted acreage to match water supplies expected to be available. Table 3 shows contingency measures implemented by some of California's larger urban agencies in 1991, the driest year of the drought. That year's relatively cool summer helped urban water users meet rationing goals by lessening landscape water use needs.

Examples of other actions taken by water agencies are briefly summarized below.

- Increased groundwater extraction was a common response action. Agencies drilled new wells, deepened existing ones, or expanded distribution systems to serve groundwater to lands previously supplied only from surface water. Some agricultural water agencies worked with their customers to develop delivery schedules that stretched agencies' stored surface water by making growers responsible for meeting part of crop water needs

—TABLE 3—

1991 Urban Water Shortage Management

Water Agency[a] Contingency Measures

	Reduction Goal[b]	A	B	C	D	E	F	G	H	I	J	K
Alameda County WD	18%		X		X		X	X	X			X
Contra Costa WD	26%	X		X	X		X	X	X	X	X	X
East Bay MUD	15%	X	X	X	X	X	X	X	X	X	X	
LA Dept. of Water and Power	15%	X	X		X	X	X	X	X	X	X	X
MWD	31%	X	X	X	X	X		X			X	X
Metropolitan WD of Orange County	20%		X	X	X	X	X	X	X	X		X
Orange County WD	20%			X		X		X	X			X
San Diego Co. Water Authority	20%	X	X	X	X	X	X	X	X	X	X	X
City of San Diego	20%			X			X	X	X	X		X
San Francisco PUC	25%	X	X		X		X	X	X		X	X
Santa Clara Valley WD	25%	X	X		X			X	X	X	X	X

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] *Shortage contingency measures differ for wholesale and retail water agencies. This table includes both wholesalers and retailers.*

[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.*

through private groundwater extraction. Groundwater, either directly or through substitution, was the source of supply in many transfers.

- Water systems of all sizes constructed interconnections with neighboring agencies, to facilitate water transfers and exchanges. The City and County of San Francisco turnouts on the California Aqueduct are an example of interconnections made solely for the purpose of water transfers.
- Some agencies constructed temporary or emergency pipelines to a back-up supply when their primary source of supply became inadequate. Multi-agency water transfers and exchanges used to make a temporary SWP water supply available to southern Santa Barbara County, for example, entailed construction of a 16-inch pipeline between Ventura and Oxnard. The City of Willits used pipe supplied by the Office of Emergency Services to make a temporary connection to an alternate water supply.
- The drought increased interest in water recycling projects, especially in Southern California. Planning began for a number of new projects. After the drought ended, however, studies of many smaller projects (and of projects not eligible for federal cost-sharing) were deferred. Projects most likely to remain active were typically those driven by wastewater disposal requirements, and those eligible for federal cost-sharing.
- Coastal communities' interest in seawater desalting likewise increased. The drought served as a catalyst for initiating research studies, bench scale tests, and demonstration projects, primarily in Southern California. Most of these efforts terminated with the end of the drought, because seawater desalting remains noncompetitive with other water supply augmentation options. The City of Santa Barbara did contract for installation of a modular, portable seawater desalting plant, in response to its severe reductions in local water

The major limitation to seawater desalting has been its high cost, much of which is directly related to high energy needs. With the decommissioning of Santa Barbara's desalting plant, California's installed capacity of seawater desalting for municipal use is less than 5 taf per year.

supplies. The plant, rated at a production capacity of 7.5 taf/year, operated only during 1991. The plant was subsequently mothballed; later, part of its equipment was sold. During the time of its brief operation, it was the State's largest seawater desalting plant designed for providing municipal water supply.

- In a general sense, the drought encouraged water agencies to review the reliability of their water supplies and to initiate planning programs addressing identified needs for improvement. Examples of agencies performing extensive reviews of supply reliability in response to the drought included MWD, SDCWA, East Bay Municipal Utility District, and Alameda County Water District.
- The water transfers listed as contingency measures in Table 3 were short-term transfers. Short-term transfers, including those for the Department's drought water bank, were widely implemented during the drought. It is difficult to accurately quantify the amount of short-term transfers implemented during the drought, because many transfers involved pre-1914 water rights not subject to SWRCB jurisdiction. Some short-term "transfers" were not actually transfers from the standpoint of water rights administration, as in the case of transfers of contractual allocations among CVP contractors.
- Long-term water transfers are usually considered to be part of improving water agencies' overall supply reliability, not as drought response actions. A water agency could execute a long-term agreement for transfers only in dry/drought years, or one which would entail exchanging wet year supplies for dry year supplies over the agreement's duration. Some agreements of this nature were executed subsequent to the drought's end.
- The drought encouraged water and power agencies to implement weather modification (cloud seeding) programs, most located in Coast Range and Sierra Nevada watersheds. The number of operating programs increased from perhaps a dozen prior to the drought to 20 during the drought. However, the absence of cloud masses suitable for seeding is a limiting factor on the potential for water supply augmentation during droughts.

—Table 4—

Sample Drought Impacts

Lost jobs & revenues in landscaping/nursery industries
Homeowner costs for replacing lawns & landscaping
Unemployment and other socioeconomic impacts in farming-dependent communities in the San Joaquin Valley
Increased wildfire damages
Widespread loss of trees in Sierra Nevada forests
Dramatic declines in Central Valley striped bass populations
Continuing decline in winter-run chinook salmon escapement
Lost revenues to water-based recreation businesses
Reduced hydroelectric power generation

DROUGHT IMPACTS TO WATER AGENCIES

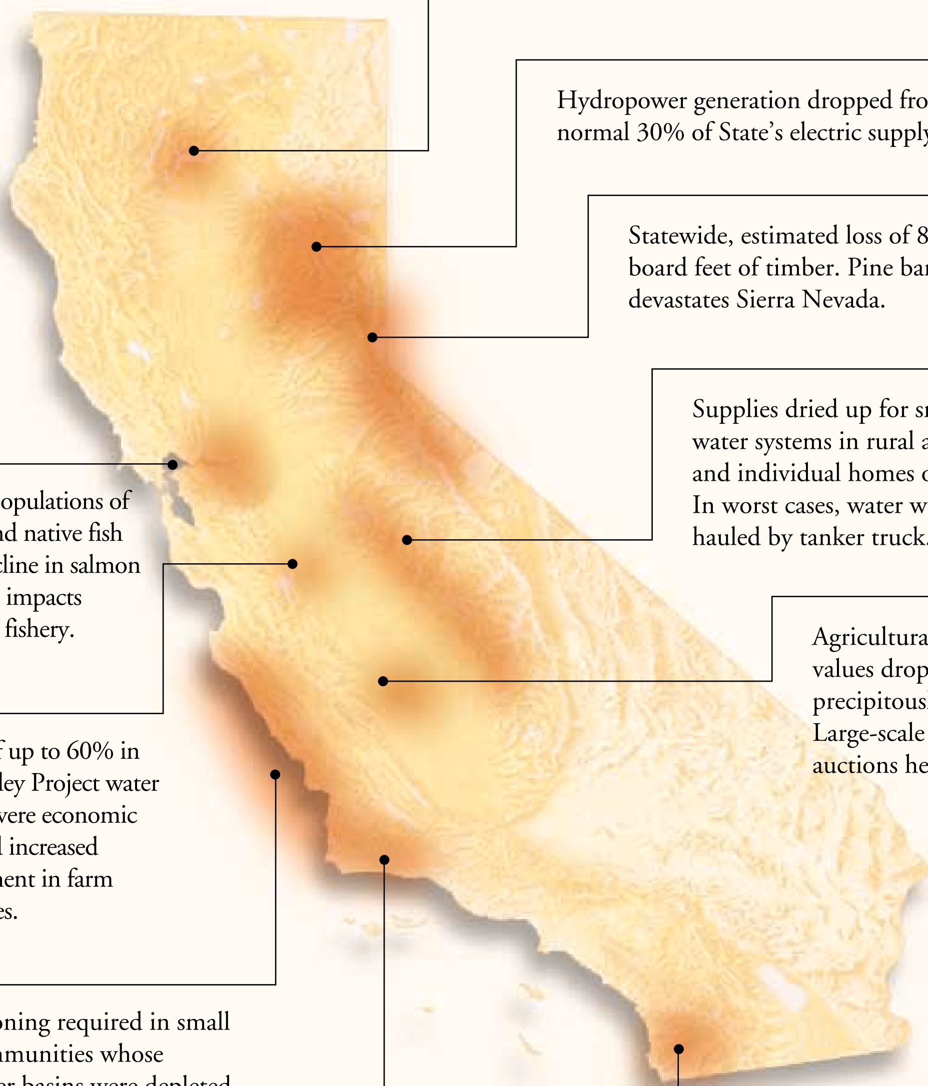
Discussion of drought impacts to the environment and at the water user or economic sector level is beyond the scope of this report; information on this subject can be found in the references provided in the Appendix. Examples of impacts described in the references are shown in Table 4 and in Figure 15.

The fundamental drought impact to water agencies was a reduction in available water supplies. Examples of further drought impacts to water agencies are briefly summarized below.

- Declining revenues and increasing operational costs were problems faced by most water agencies. Revenues declined as customers responded to calls for voluntary or mandatory reductions in water use. Costs increased, as agencies reacted to shortages by purchasing water, deepening wells, or implementing water education and conservation campaigns. Water agencies thus increased their rates to recover costs, sending a mixed message to the public—use less water, pay more.
- Agricultural water agencies were especially affected by drought-related financial problems. Estimated statewide drought-idled acreage was on the order of 500,000 acres, about five percent of 1988-level harvested acreage. With reduced revenues, water agencies were hard-pressed to cover fixed costs. Financial problems experienced by Kern County Water Agency's member districts, together with

—Figure 15—

Impacts Experienced During 1987-92 Drought



A marina at USBR's 1 maf Folsom Lake in 1992. The drought caused significant economic impacts to operators of water-based recreational businesses throughout much of California.

concerns about SWP water allocation rules, were an impetus for subsequent negotiation of the Monterey Amendments between the Department and the SWP contractors

- Some agencies not experiencing drought-induced water quantity problems nevertheless experienced water quality problems—most typically, agencies relying on groundwater. Increased extractions resulted in lowered water tables and resultant contaminant migration toward production wells. The City of Fresno, for example, took at least 34 of its municipal wells out of service as a result of increased concentrations of pesticides, solvents, and salts. Most municipalities relying on small coastal groundwater basins observed increased amounts of seawater intrusion.
- Saltier water was also a concern for in-Delta diverters. The Department installed temporary barriers at two South Delta locations—Middle River and Old River near the Delta-Mendota Canal intake—to improve water levels/water quality/circulation for agricultural diverters. Contra Costa Water District relied largely on CVP supplies during the drought, because water quality at its Rock Slough intake was poor. (As part of Los Vaqueros project construction, CCWD subsequently constructed a new intake farther upstream on Old River, to lessen salinity intrusion impacts.)
- Some Southern California water agencies experienced increased salt concentrations as a result of receiving a higher percentage of Colorado River water in their MWD supplies. The total dissolved solids content of MWD's Colorado River supplies is typically on the order of 700 milligrams per liter. MWD attempts to provide a 50/50 blend of SWP and Colorado River water to its member agencies, to the extent practical. Reduced SWP supplies during the latter part of the drought limited MWD's blending capability, and MWD lacked facilities to deliver a 50/50 blend throughout all of its service area. SDCWA was probably the most affected member agency. Imported MWD water provides 70 to 95 percent of

Residential outdoor water use varies widely throughout California, and is influenced by factors such as climate and housing density. During the last drought, homeowners in areas experiencing the highest cutbacks in supply typically experienced loss of landscaping. Some water agencies provided financial assistance to customers replacing lawn areas with low water use landscaping, or to customers implementing landscape water audit recommendations.

SDCWA's service area supply; SDCWA received essentially 100 percent Colorado River water during 1991-92. Construction of Diamond Valley Reservoir and completion of the Inland Feeder will facilitate better regional distribution of SWP water for blending.

DROUGHT-RELATED LEGISLATION

Public and media interest in droughts fosters heightened awareness of water supply reliability issues in the Legislature. More than 50 drought-related legislative proposals were introduced during the severe, but brief 1976-77 drought. About one-third of these eventually became law. Similar activity on drought-related legislative proposals was observed during the 1987-92 drought.

Selected chaptered drought or water supply reliability bills from the 1987-92 drought are summarized below, followed by a summary of the proposed State Drought Emergency Relief and Assistance Act of 1991. The Legislature took action on the provisions contained in this proposal during an extraordinary session held in 1991-92.

Chaptered Drought or Water Supply Reliability Legislation

- Various technical and clarifying changes were made to Water Code provisions governing temporary and long-term water transfers.
- The use of potable water for specified non-potable purposes was declared to be a waste or unreasonable use of water if suitable, cost-effective reclaimed water supplies were available. Several measures expanding the types of applicable non-potable purposes were enacted.
- Leases of water for up to five years, with specified limitations, were exempted from SWRCB jurisdiction over water transfers. (Chapter 847-91)
- Groundwater substitution transfers were explicitly authorized; related findings were made. (Chapter 779-92)
- The Water Conservation in Landscaping Act directed the Department to draft and adopt a model water efficient landscape ordinance by July 1992. Local agencies not adopting their own ordinances by January 1993 were required to begin enforcement of the model ordinance as of that date. (Chapter 1145-90)
- The Agricultural Water Suppliers Efficient Management Practices Act required the Department to establish an advisory committee to review efficient agricultural water management practices, and to offer assistance to agricultural water suppliers seeking improved efficiencies. (Chapter 739-90)
- The Water Recycling Act of 1991 set a statewide goal of recycling 700 taf/year by 2000 and 1 maf/year by 2010. (Chapter 187-91)
- The Agricultural Water Conservation and Management Act of 1992 authorized agricultural water suppliers to institute water conservation or efficient water management programs. (Chapter 184-91)
- The Department was required to develop standards for installation of graywater systems in residential buildings. (Chapter 226-92)
- Effective January 1992, water purveyors were required to meter new connections. (Chapter 407-91)
- Caltrans was required to implement drought-resistant freeway landscaping, and to allow local agencies to place recycled water pipelines in highway rights-of-way. Another measure urged the Department of General Services to use drought resistant plants in new landscaping.
- The Urban Water Management and Planning Act, in effect since 1983, was amended in multiple sessions. Amendments in 1991 required water suppliers to estimate available water supplies at the end of one, two, and three years, and to develop contingency plans for shortages of up to 50 percent.
- The Department and the Department of Fish and Game were directed to submit various reports to the Legislature describing water supply availability and drought-related water needs for fish and wildlife.

Proposed State Drought Emergency Relief and Assistance Act of 1991

The Governor's Drought Action Team supported introduction of this legislative proposal to enhance the State's ability to respond to drought conditions and to provide funding for local assistance activities. As proposed, the measure's provisions would:

- Appropriate $34.8 million from the General Fund to the Department for financial assistance to local water suppliers for emergency drought-relief water supply, technical water conservation assistance, and operation of the Department's Drought Information Center. Would also secure legislative approval of projects potentially eligible for funding from 1988 water conservation bond monies. (legislative approval of projects eligible for 1988 bond funding enacted as Extraordinary Session Chapter 10-91)

- Authorize the Department to obtain short-term commercial financing, backed by State Water Project revenues, to fund drought-relief measures. (enacted as Extraordinary Session Chapter 5-91)
- Give the governing body of a water supplier explicit authority to enter into contracts with the drought water bank or with other water suppliers for transfer of water outside the service area of the water supplier. (enacted as Extraordinary Session Chapter 1-91)
- Declare that no temporary transfer of water under any provision of law for drought relief in 1991 or 1992 would affect any water rights. (enacted as Extraordinary Session Chapter 2-91)
- Authorize water suppliers to contract with and pay their customers for water when customers voluntarily reduce or eliminate use of water. (enacted as Extraordinary Session Chapter 3-91)
- Appropriate $1 million from the General Fund to SWRCB for expedited and expanded efforts to process petitions for temporary changes to water rights to accommodate drought-relief water transfers.
- Appropriate $10 million from the General Fund to SWRCB for financial assistance to local water suppliers for water recycling projects that could be completed by June 30, 1992. (failed passage)
- Appropriate $24.2 million from the General Fund to DFG to maintain and protect populations of fish and wildlife and offset revenue losses. Priority would be placed on threatened and endangered species. (as enacted, appropriated $16.38 million.)
- Appropriate $1.2 million from the General Fund to the Department of Health Services for augmentation of the Emergency Clean Water Grant Fund.
- Appropriate $2.6 million from the General Fund to the California Conservation Corps to increase corps membership by 300 to assist state agencies with drought-relief activities. (as enacted, appropriated $2.29 million)
- Appropriate $33.6 million from the General Fund to the Department of Forestry and Fire Protection for increased fire protection activities and for capital outlay purposes involving installation or rehabilitation of wells and pipelines to restore water supplies to fire stations and conservation camps. (failed passage)

THE DROUGHT AND EMERGENCY MANAGEMENT ACTIONS

As the 1987-92 drought entered its fifth year, carry-over storage in the State's major reservoirs had been depleted and water agencies throughout California were facing the prospect of major reductions in supplies. The Governor signed an executive order in February 1991, creating a Drought Action Team and directing the team to coordinate a response to water supply conditions. The team was headed by the Director of DWR; its membership included representatives from nine other State agencies, with invited participation from additional State and federal agencies. Among other things, the team was charged with advising the Governor on "determining whether

WATER CONSERVATION IN LANDSCAPING ACT

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 not adopting their own ordinances by January 1993 were required to begin enforcement of the model ordinance as of that date.

The model ordinance applied 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. The purpose of the ordinance was to promote water efficient landscape design, installation, and maintenance. The ordinance's general approach 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.)

To date, there has been no statewide-level review of how cities and counties are implementing this requirement; hence, its water savings potential remains to be quantified. Estimating urban landscaping water use is difficult due to lack of data. 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.

—FIGURE 16—

Counties with Local Drought Emergencies in 1991

and when to proclaim a state of emergency due to drought conditions".

Prior to formation of the Drought Action Team, the Governor had declared a state of emergency in the City and County of Santa Barbara in 1990, at the request of both jurisdictions. By early 1991, ten counties had declared local drought emergencies. By the end of 1991, 23 counties had declared local drought emergencies, as shown on Figure 16. Ultimately, no statewide declaration of emergency was made for the 1987-92 drought, although a declaration would almost certainly have been made but for the "March Miracle" rains in 1991. Had such a declaration been made, the Governor would have had broad powers to take emergency response actions, as summarized below. Prior to the "March Miracle," for example, plans were being made to require that all communities develop strategies to respond to a worst case scenario of a 50 percent reduction in their normal water supplies.

Emergency Services Act

The Emergency Services Act (Government Code Section 8550 *et seq*.) authorizes the Governor to proclaim a state of emergency where he or she finds that conditions of disaster or extreme peril exist, caused by conditions such as flood, fire, storm, epidemic, riot, drought, earthquake, or volcanic eruption. These conditions of emergency must be beyond the control, or likely control, of the services, personnel, equipment and facilities of any single city or county. The emergency must also require the combined forces of a mutual aid region to combat.

Generally, the act is triggered by a local emergency proclamation and a request to the Governor to proclaim an emergency. The Governor may also proclaim an emergency without such a local request, if he finds that a state of emergency exists, and local authority is inadequate to cope with the emergency. The Governor must proclaim the termination of the state of emergency at the earliest possible date that conditions warrant.

Where a state of emergency has been proclaimed, the Governor's authority to respond includes:

- The Governor may make written orders and regulations which have the force and effect of law.
- The Governor may suspend the provisions of regulatory statutes, statutes prescribing procedures for conduct of state business, and state regulations, where he or she finds that strict compliance would impede mitigating the effects of an emergency.
- The Governor may commandeer or use private property or personnel. Compensation must be paid.
- The Governor has authority to exercise any police power of the State within the area designated in the emergency proclamation.
- The Governor may direct State agencies to use their personnel, equipment and facilities to prevent or alleviate damage or threatened damage due to the emergency.
- The Governor may undertake preparatory steps such as planning, mobilization of equipment, and training.

Drought differs from other emergencies in that it occurs over a period of time, instead of being a sudden occurrence like fire, flood, or earthquake. Accordingly, its burdens on cities and counties are likely to be cumulative, rather than sudden and overwhelming. To invoke the extraordinary remedies of the Emergency Services Act, *conditions of disaster or extreme peril to the safety of persons and pro perty* should exist, and not be a matter of speculation. The act permits the Governor to assign a State agency any emergency response activity related to the powers and duties of that agency. This assignment may be accomplished by executive order without the need of the Governor having to proclaim a state of emergency.

Emergency Procedures in General

The governing body of a city or county declares a local emergency when conditions of disaster or extreme peril exist which are, or are likely to be, beyond the control of the services, personnel, equipment, and facilities of local government and require the combined forces of other jurisdictions. The declaration enables the city or county to use emergency funds, resources, and powers, and to divert funds from other programs to cover emergency costs. It is normally a prerequisite to requesting the Governor's declaration of a state of emergency. The Director of OES may issue a letter of concurrence to a city or county declaration of local emergency. The Director's concurrence makes financial assistance available for repair/restoration of damaged/destroyed public property under the State's Natural Disaster Assistance Act.

The Governor declares a state of emergency when the conditions described in the preceding section are met. The proclamation does the following:

- Makes mutual aid assistance mandatory from other cities, counties, and state agencies.
- Enables the State to use the emergency powers described previously.

- Allows for State reimbursement, on a matching basis, of city or county response and repair costs connected with the emergency, and property tax relief for damaged or destroyed private property.
- Is a prerequisite to requesting federal recovery assistance.

Declaration of a major disaster is made by the President when damage exceeds resources of state and local government and private relief organizations. Under a major disaster declaration two type of federal assistance are provided, as authorized under the Stafford Act (PL 93-288).

Assistance to individuals and businesses may include:

- Temporary housing assistance
- Low interest loans (individuals, businesses, and farmers/ranchers)
- Individual and family grants

Assistance to state and local governments, special districts, and certain private nonprofit agencies may include:

- Debris clearance
- Repair/replacement of public property (roads, buildings)
- Emergency protective measures (search and rescue, demolition of unsafe structures)
- Repair/replacement of water control facilities

Public agencies often have specific powers in their enabling acts to adopt water rationing and other demand reduction measures. Municipal water districts, for example, have specific authority to adopt a drought ordinance restricting use of water, including the authority to restrict use of water for any purpose other than household use. During a local emergency, cities and counties may promulgate orders and regulations necessary for the protection of life and property, and they have the authority to provide mutual aid to any affected area. Where a county has declared an emergency, it is not necessary for cities affected by emergency conditions within the county to make an independent declaration of local emergency.

Water Code Sections 350-358 authorize public and private water purveyors to declare a water shortage emergency and to adopt regulations and restrictions to conserve water. The governing body of a purveyor may declare a water shortage emergency whenever it determines that consumers' requirements cannot be satisfied without depleting the water supply to the extent that there would be insufficient water for human consumption, sanitation, and fire protection. The governing body may adopt regulations and restrictions on water delivery and use to conserve water for the greatest public benefit, with particular regard to domestic use, sanitation, and fire protection. The regulations may provide for connection moratoria. DHS has the authority to impose terms and conditions on permits for public drinking water systems to assure that sufficient water is available. This includes the authority to require an agency to continue its moratorium on new connections adopted pursuant to Water Code Section 350 et seq.

Article X, Section 2 of the California Constitution prohibits waste or unreasonable use or unreasonable method of use or diversion of water. Court decisions interpreting the Constitution have stressed that a use reasonable in times of plenty may be unreasonable in time of shortage, and reasonable use must be determined in the light of statewide conservation considerations. Water Code Section 275 directs the Department and the SWRCB to take appropriate actions before courts, administrative agencies, and legislative bodies to prevent waste or misuse of water.

CHAPTER 3

Changed Conditions Since The Last Drought

In the relatively short time since the 1987-92 drought, significant changes in California's water management framework have occurred. This chapter describes the changes and discusses their water management implications.

LEGAL, REGULATORY, AND INSTITUTIONAL CHANGES

Heightened interest in supply reliability created by the drought, together with drought-induced ecosystem impacts, were factors leading to the development of some of the changes summarized below. The changes have mixed impacts on water agencies' abilities to respond to the next drought—some lessen water supply reliability and some improve it. The following descriptions focus on aspects of the laws, regulations, or institutional changes that could most affect drought-related water supply availability and water agencies' ability to respond to droughts.

- In 1992, the National Marine Fisheries Service issued its first biological opinion for winter-run chinook salmon, then listed as threatened under the Endangered Species Act. NMFS followed with a 1993 long-term biological opinion; winter-run were reclassified to endangered status in 1994. Both biological opinions incorporated changes to CVP operations to provide additional cold water in spawning areas downstream from Shasta Dam, and closures of Delta Cross-Channel gates. The 1993 opinion also provided for numerical take

Delta smelt, native to the Bay-Delta, have a one-year life span and a relatively low reproduction rate, making their population abundance sensitive to short-term habitat changes. CVP and SWP exports from the Delta must be curtailed when smelt congregate in the South Delta near the pumping plants. SWP export curtailments in 1999 to protect the smelt delayed San Luis Reservoir filling and resulted in an estimated loss of 150 taf of interruptible water for project contractors.

Castaic Lake Water Agency takes delivery of its SWP entitlement at Castaic Lake. CLWA recently purchased 41 taf of SWP entitlement from KCWA, pursuant to the SWP's Monterey Amendments, and has pending two additional purchases totaling about 19.5 taf.

limits at Banks and Tracy Pumping Plants, and for further temperature control operations at Lake Shasta. The CVP was required to maintain a minimum Shasta September storage of at least 1.9 maf, except in the driest years. (Shasta storage declined to 0.6 maf during the 1976-77 drought, and to 1.3 maf during the 1987-92 drought.)

- The Central Valley Project Improvement Act of 1992 reallocated 800 taf of CVP water supply from project contractors to fishery purposes, plus additional project supply to provide firm water for wildlife refuges. Annual Trinity River instream flows of at least 340 taf were to be provided until a flow study conducted by the U.S. Fish and Wildlife Service was completed, at which time new flow requirements would be established. The act directed the Secretary of the Interior to carry out structural and nonstructural environmental restoration actions, including water acquisition for fishery and wildlife refuge purposes. One major structural restoration project affecting river operations has been completed—the $80+ million Shasta Dam Temperature Control Device, which reduces the need to forgo power generation at Shasta to provide cold water for salmon. CVPIA also authorized transfers of project water outside the CVP's service area, subject to many conditions. Some conditions, such as right of first refusal by entities within the service area, expired in 1999. To date, no out-of-service area transfers have occurred. The Secretary was authorized to carry out a land retirement program, targeted at drainage problem lands in the San Joaquin Valley. USBR is working with Westlands Water District to implement a land retirement program within the district.
- Delta smelt were listed as threatened in 1993. The primary water management action associated with their listing has been reduction of CVP and SWP exports from the Delta.
- The 1993 Emergency Services Act required OES, in coordination with other State agencies, to have

a standardized emergency management system operational throughout California by the end of 1996. Local agencies are strongly encouraged to use SEMS, and must use it to be eligible for State funding of emergency response costs. SEMS incorporates the State's master mutual aid program. In response to a request from OES, or from a local agency via the mutual aid program, the Department must provide emergency response assistance, if resources are available. While drought *per se* is not an emergency, drought-related impacts, such as a local agency running out of water, could trigger a request for the Department to provide assistance in actions such as constructing a temporary pipeline.

- The Monterey Agreement, signed by the Department and SWP contractors in 1994, established principles to be incorporated in contract amendments (the Monterey Amendments) to be offered to the contractors. To date, all but two contractors (Plumas County Flood Control and Water Conservation District and Empire West Side Irrigation District) have accepted the amendments. The amendments changed the prior method of allocating water supply deficiencies, which reduced supplies to agricultural contractors before those of urban contractors were cut. Supplies are now to be allocated among contractors in proportion to their contractual entitlements. The amendments also reduced the SWP's total contractual commitment as part of transferring KWB lands to two contractors, and further provided that 130 taf of agricultural contractors' entitlements could be sold to urban contractors. Several amendment provisions gave contractors more flexibility in managing their SWP and non-SWP supplies. Contractors are allowed to store project water outside their service area boundaries and to have access to project facilities for wheeling non-project water. Agreements have already been executed with some contractors to enable storage of SWP water outside contractors' service areas. Examples include those with MWD, Santa Clara Valley Water District, ACWD, and Zone 7 Water Agency to allow them to store SWP water in SWSD's groundwater bank. The amendments allowed contractors participating in repayment costs of Castaic and Perris Reservoirs to conditionally withdraw water from the reservoirs, subject to replacement of the water within five years. The amendments also created a turnback pool (first operated in 1996) for internal annual reallocation of project water among project contractors, and provided dry-year rate relief for agricultural contractors.
- SWRCB adopted Decision 1631 in 1994, amending the City of Los Angeles' rights to divert from the Mono Lake Basin, in order to increase Mono Lake levels. The decision restricted diversions from the basin to 16 taf/year until the lake level reached elevation 6391, at which time diversions would be allowed to increase to about 31 taf/year, about one-third of historical diversions. (As of May 2000, the lake's elevation is 6384.5 feet.) Los Angeles implemented an aggressive water conservation program emphasizing plumbing fixture retrofits—with substantial State financial assistance—to help compensate for the shortfall. The City estimated that it replaced 750,000 toilets during the 1990s. Between 1994 and 1999, the Legislature appropriated $17.5 million out of an authorized $36 million to help Los Angeles implement demand reduction measures.
- The Bay-Delta Accord, executed as a three-year agreement in 1994 and then subsequently extended, set forth the State-federal CALFED Bay-Delta Program's three chief activities—establishing water quality standards, coordinating operations of the CVP and SWP to meet water quality and environmental protection requirements, and developing a long-term solution to Delta problems. In 1995, SWRCB adopted a water quality control plan incorporating concepts contained in the Accord, followed by an interim order. Order WR 95-6 provided that the CVP and SWP would meet Bay-Delta Accord standards while SWRCB developed a new water right decision to apportion the responsibility for meeting standards among all users of Delta water. SWRCB's process to develop a new decision remains ongoing. Table 5 summarizes major changes from the former D-1485 to WR 95-6. CALFED released a first draft programmatic environmental impact report/environmental impact statement for a long-term Delta solution in 1998, followed by a redraft in 1999. A record of decision is scheduled to be signed in 2000, marking the end of CALFED's planning phase and a transition to initial implementation of some CALFED actions, including its environmental restoration program. Other CALFED actions will begin a period of more detailed planning studies. The CALFED June 2000 action frame-

—Table 5—

Major Changes in Delta Criteria from D-1485 to WR 95-6

Criteria	Change
Water Year Classification	From Sacramento River Index to 40-30-30 Index
Sacramento River Flows	Higher September to December 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 part per thousand salinity during February-June
Export Limits	35%-65% export-to-Delta inflow ratio, April-May

work document called for the Governor to appoint a panel charged with developing a drought contingency plan by the end of 2000.

- The Department developed a proposed SWP supplemental water purchase program as a follow-up to the 1994 SWP water purchase program operated jointly with the drought water bank, and released draft programmatic environmental documentation covering a proposed six-year program. The proposed program would have entailed purchasing about 400 taf in drought years, with about half the amount coming from groundwater substitution. The Department did not go forward with the program due to opposition to groundwater substitution transfers in rural Sacramento Valley counties.
- A 1996 Federal Energy Regulatory Commission settlement agreement among the City and County of San Francisco, Modesto Irrigation District, Turlock Irrigation District, DFG, and others provided for increased instream flows in the Tuolumne River. The agreement is estimated to reduce San Francisco's Hetch Hetchy Aqueduct supplies by about 65 taf annually.
- Proposition 218, approved by voters in 1996, changed procedures used by local government agencies for increasing fees, charges, and benefit assessments. Assessments, fees, and charges imposed as an "incident of property ownership" are now subject to a majority public vote. Water-related charges potentially affected by Proposition 218 include some meter charges, acreage-based irrigation charges, and standby charges. Not all post-Proposition 218 proposed assessments to fund water agency charges have succeeded in receiving voter approval. Most water agencies use a combination of fees for water service and other charges or property assessments to cover operating costs. Depending on an individual agency's fee structure, it could experience financial problems during a drought, when water sales revenues are down and the need for voter approval would limit ability to increase assessments.
- In 1996 and 1997, NMFS listed coho salmon in two coastal areas as threatened. In 1997, NMFS listed two coastal steelhead populations as threatened and one as endangered, followed by 1998 listing of Central Valley steelhead as threatened. In 1999, Central Valley spring-run chinook and coastal chinook were listed as threatened. USFWS listed Sacramento splittail as threatened in 1999, but a July 2000 federal district court decision found that listing to be arbitrary and capricious. The CALFED Operations Group has been serving as the forum for coordinating day-to-day CVP and SWP operations with requirements for

protecting listed species. Decisions have been based on use of near-real-time monitoring data to identify locations of listed migratory and resident species in the Delta and upstream rivers, together with take data at the pumping plants. The CALFED Operations Group has been following adaptive management techniques—selecting a strategy, evaluating its effectiveness, and then either refining the strategy or adopting another approach.

- In 1997, the Colorado River Board released a draft plan outlining steps to reduce California's use of river water to the State's basic 4.4 maf apportionment, in years when surplus river water is not available. California water users have historically exceeded the basic apportionment by as much as 900 taf due to availability of surplus water and Arizona's and Nevada's unused apportionments. MWD is the most junior California water user; if the interstate apportionments were enforced in a year when surplus water was not available, the Colorado River Aqueduct would be only half full. Work to complete California's draft Colorado River Water Use Plan is continuing. The plan is based on the concept that the CRA will be kept full through transfers of conserved agricultural water (such as the Imperial Irrigation District/SDCWA transfer), water saved by lining the All American and Coachella Canals, and by implementing new groundwater storage projects. The groundwater storage projects would take surplus river water, when available, and recharge it in groundwater basins near the aqueduct.
- In late 1999, USBR and USFWS released a draft EIS identifying Trinity River instream flow alternatives. From 1981 to 1990, USBR provided instream flows of 287 taf in drought years and 340 taf in wet years. In 1991, the Secretary of the Interior directed that flows be increased to 340 taf per year, the amount subsequently required by

USBR's Parker Dam on the Colorado River impounds Lake Havasu, the point of diversion for MWD's Colorado River Aqueduct. Since the CRA is the only facility linking the river with urbanized coastal Southern California, its conveyance capacity is the limiting factor on the coastal region's use of river water.

THE NATIONAL DROUGHT POLICY COMMISSION

The National Drought Policy Act of 1998 (PL 105-99) called for creation of an advisory commission *to provide advice and recommendations on the creation of an integrated, coordinated federal policy designed to prepare for and respond to serious drought emergencies.* The commission was to be chaired by the Secretary of Agriculture and was charged with submitting a report on national drought policy to Congress. Factors contributing to enactment of the legislation included drought conditions experienced by southeastern and mid-Atlantic states in the latter part of the 1990s, and severe drought impacts to agriculture in states such as Texas and New Mexico in the same time period. The federal response to these agricultural impacts engendered discussion about the relative roles of the U.S. Department of Agriculture and the Federal Emergency Management Agency in providing financial and other assistance.

The National Drought Policy Commission released its report in May 2000. The report stressed planning response actions before droughts occur, to reduce the need for emergency relief actions. The federal role has historically focused on emergency relief actions, not on planning, especially in agricultural programs. The report noted that 88 drought-related federal programs had been funded within the last ten years, with USDA having the greatest federal responsibilities for drought response and assistance programs. Among the report's recommendations was one especially relevant to California—that USGS streamgaging networks be expanded and modernized.

CVPIA pending completion of USFWS' instream flow studies. Alternatives presented in the DEIS would substantially increase instream flows, correspondingly decreasing CVP water supplies. The federal agencies are currently considering public comments received on the DEIS.

- County groundwater management ordinances adopted in 1999 increased the percentage of California's counties with such ordinances to almost 30 percent. Most of the ordinances post-date the last drought. The numerous groundwater substitution transfers implemented as part of the Department's 1991 and 1992 drought water banks served to heighten local interest in use of county ordinances to control groundwater exports. In 1994, Butte County's ordinance withstood a legal challenge regarding the ability of cities and counties to issue such ordinances, encouraging other counties to consider this approach. The majority of county ordinances regulate groundwater exports from a county, typically by requiring a conditional use permit before export can occur. Permit issuance may be conditioned on findings that export will not result in groundwater overdraft, degrade groundwater quality, or otherwise impact local groundwater resources.

An observation that can be drawn from these changes in laws, regulations, and institutional conditions is that many of them reduce the amount of supplies historically available to agricultural and urban water users. Under either average water year or 1928-34 drought hydrology, for example, more than 1 maf of developed supply has been reallocated from urban and agricultural purposes to environmental purposes by CVPIA and Order WR 95-6. (This amount does not include reductions in Delta exports due to incidental take limits for listed fish species.) The loss of historically available Colorado River water will further increase the reduction in supplies, unless actions now in planning are implemented.

The long-term outcome of the CALFED Bay-Delta process is difficult to predict at this time. It is conceivable that fishery restoration and enhancement actions planned in the CALFED program, together with those mandated by CVPIA, could improve fishery conditions over the long-term to the point that water users would not experience further water costs due to environmental regulatory actions. In the near-term, CALFED's proposed environmental water purchase program is intended to lessen the impacts of fishery-related operational decisions on CVP and SWP water deliveries.

A significant CALFED-related uncertainty with regard to drought preparedness is the current process for coordinating CVP and SWP operations in the Delta with environmental protection requirements. Since its inception, the CALFED Operations Group has experienced a series of unprecedented wet years.

Its ability to simultaneously manage water and fishery goals has not been tested in a time of water shortage. Wet conditions have allowed CALFED to rely on short-term adaptive management techniques for fishery purposes, an approach not conducive to drought water operations, when multi-year operating plans for conserving reservoir storage are necessary.

NEW FACILITIES

California's extensive system of water supply infrastructure helps reduce drought impacts, by providing multi-year storage of water supplies and facilitating water transfers and exchanges. Most of California's major urban and agricultural production areas—with the exception of the Salinas Valley—are within reach of a regional conveyance facility or natural waterway that would provide access for water transfers. Table 6 shows new large-scale conveyance facilities constructed or under construction since the last drought. The Department's Coastal Aqueduct brings a new supply of imported SWP water into the Santa Barbara area, the most adversely affected major urban area during the last drought. Coastal Aqueduct deliveries began in 1997. Mojave Water Agency's two new pipelines convey SWP supplies into parts of its service area previously dependent entirely on limited groundwater resources. MWA additionally augmented its SWP supplies by purchasing 25 taf of entitlement from KCWA, pursuant to Monterey Amendment provisions. When completed in 2004, MWD's Inland Feeder pipeline will help improve water quality in parts of its service area, as discussed in Chapter 2.

Two large water supply reservoirs were constructed since the last drought—MWD's 800 taf Diamond Valley Lake and CCWD's 100 taf Los Vaqueros Reservoir. Both reservoirs are offstream storage facilities with a common purpose of providing emergency water supplies in or near the agencies' service areas, in the event that an earthquake or other natural disaster would make the agencies' imported

Completion of the remaining 100 miles of the SWP's Coastal Aqueduct from Devils Den to the Santa Maria area in Santa Barbara County links the southern half of the central coast region to California's system of major water infrastructure.

—TABLE 6—

New Large-Scale Conveyance Facilities Since Last Drought

Facility	Constructing Agency	Length (miles)	Maximum Capacity (cfs)
Coastal Branch Aqueduct	DWR	100	100
Eastside Reservoir Pipeline	MWD	8	1,000
East Branch Enlargement	DWR	100	2,100*
Mojave River Pipeline	MWA	70	94
Old River Pipelines (Los Vaqueros Project)	Contra Costa Water District	20	400
East Branch Extension**	DWR	14	104
Inland Feeder Project**	MWD	44	1,000
Morongo Basin Pipeline	MWA	71	100
New Melones Water Conveyance Project	Stockton East Water District/ Central San Joaquin Water Conservation District	21	500

* *This initial phase of the enlargement increased capacity of existing facilities by approximately 750 cfs.*

** *Under Construction*

supplies unavailable. CCWD's reservoir stores imported CVP supplies and improves service area water quality; it does not develop new water supplies. Conceptually, half the capacity of MWD's Diamond Valley Lake is to be reserved for emergency storage. The remaining capacity offers the opportunity to develop new supply, by providing storage for wet weather surplus flows or water purchases conveyed by the SWP or CRA. Initial filling of Diamond Valley began in late 1999.

There has been an expansion in groundwater recharge/storage capacity since the last drought. Figure 17 shows some of the larger groundwater recharge/storage projects operating in California today; the projects are described in Table 7. Projects becoming fully operational since the last drought are those operated by SWSD, Arvin-Edison Water Storage District, Kern Water Bank Authority, MWA, and Calleguas Municipal Water District. These new projects rely either wholly or in part on recharge supplies exported from the Delta. Projects' operations are thus subject to Delta export restrictions as well as to the availability of conveyance capacity. If water transfers provide a component of recharge supplies, availability of SWP conveyance capacity becomes a limiting factor on recharge, as discussed in the following section.

The 1987-92 drought enhanced local agency interest in constructing water recycling projects. The increased interest, combined with availability of substantial federal funding through PL 102-575 and PL 104-266, is being reflected in plans to implement projects of regional scale in the State's densely urbanized coastal areas. Accurate data on the statewide increase in new water supplies from recycling since 1990 are not available, but an order of magnitude value would be in the vicinity of 100 taf. Results of a survey of 1995-level recycled water use performed for the Department indicated that agricultural or landscape irrigation amounted to 49 percent of statewide use, and that groundwater recharge amounted to 27 percent.

CHANGES IN WATER PROJECT OPERATIONS

As discussed earlier, several key events affecting SWP and CVP operations have occurred since the last drought. Events of particular importance to water supply availability include CVPIA implementation, biological opinions for ESA listed fish species, listing of additional fish species, and the Bay-Delta Accord. For example, operations studies performed for the Department's Bulletin 160-98 evaluated the Bay-

—FIGURE 17—

Examples of Larger California Groundwater Storage Projects

Delta Accord's impact on CVP and SWP operations under 1995-level conditions as compared to similar conditions had D-1485 Delta standards remained in place. The studies, based on 73-year simulations (1922-94), showed that CVP (south of the Delta) and SWP delivery capabilities were significantly reduced. Under D-1485 and 1995 level demands, the CVP had a 40 percent chance of making full contractor delivery requests and a 95 percent chance of delivering 2.0 maf in any given year. Under WR 95-6 with identical demands, the CVP had a 20 percent chance of making full delivery requests 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 delivery requests and a 95 percent chance of delivering 2.0 maf in any given year. Under Order WR 95-6 with identical demands, the SWP had a 65 percent chance of making full delivery requests and an 85 percent chance of delivering 2.0 maf in any given year.

Together, the operations studies indicated 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 hydrology. The operations studies did not account for Delta export curtailments due to take of ESA listed species or use of CVPIA dedicated water for environmental purposes. Reduction in exports due to take limits can be significant, especially during drought periods, when the projects are unable to export unstored flows or reservoir releases providing required instream flows. The studies also did not account for day-to-day decisions now being made by the CALFED Operations Group regarding coordination of project operations with fishery protection objectives.

CVP operations to deliver the 800 taf of project water dedicated for CVPIA fishery purposes have been a subject of ongoing debate and litigation since enactment of the legislation. Issues have included, for example, the extent to which dedicated water may be used to meet ESA requirements and whether or not dedicated water is available for export when it reaches the Delta. CVP operations to provide the dedicated water, as well as the accounting processes used to identify provision of the water, have varied annually, reflecting the substantial disagreements over how the water would be managed. There is thus no fixed historical baseline from which to accurately measure

MWD's Diamond Valley Lake is being filled with a mixture of SWP and Colorado River supplies. Initial reservoir filling is expected to be completed by 2002 to 2004, depending on water supply availability. Photo courtesy of MWD.

—Table 7—

Details of Example Groundwater Storage Projects

Agency and Project Location	Comments
1. Alameda County Water District —Niles Cone, Alameda County	Seawater intrusion management. District recharges imported surface supplies from its SWP 42 taf annual contractual entitlement and from San Francisco's Hetch Hetchy Aqueduct.
2. Arvin-Edison Water Storage District —Kern County	A 350 taf banking program is being developed with MWD. Estimated extraction capability is 40-75 taf/year.
3. Calleguas Municipal Water District —Las Posas Basin, Ventura County	Uses injection wells to recharge its imported MWD supplies. Maximum storage capacity of 300 taf. At full implementation, maximum annual extraction rate estimated to be 72 taf. Providing local emergency storage is a major project purpose.
4. City of Bakersfield—Kern River fan area, Kern County	Initial operation of 2,800 acre recharge facility began in 1978. City has rights to Kern River water, and long-term contracts with three water agencies, who store and extract water in coordination with the city.
5. Coachella Valley Water District —Upper Coachella Valley, Whitewater River channel area	Recharge from local Whitewater River supplies and from MWD's imported Colorado River Aqueduct water exchanged for SWP contractual entitlements of CVWD and Desert Water Agency.
6. Kern Water Bank Authority—Kern River fan area, Kern County	3,000 acres of recharge basins. The Authority is a joint-powers agency which operates the project on behalf of local water agencies. Recharge supplies may be local surface water or imported supplies.
7. Los Angeles County Department of Public Works—Los Angeles River and San Gabriel River watersheds, Los Angeles County	Extensive recharge facilities employing about 2,400 acres of spreading areas, and injection wells at three seawater intrusion barriers (Alamitos, Dominguez Gap, and West Coast). County operates the river systems for the dual purpose of flood control and groundwater recharge, and also recharges imported and recycled water provided by others.
8. Monterey County Water Resources Agency—Salinas River Valley, Monterey County	Releases from MCWRA's Nacimiento and San Antonio Reservoirs are managed to provide recharge for upper valley. MCWRA distributes recycled water produced by the Monterey Regional Water Pollution Control Agency for in-lieu recharge in the lower valley, to help reduce seawater intrusion. MCWRA's 45-mile distribution system can convey 19.5 taf of recycled water.

—Table 7 cont'd—

Details of Example Groundwater Storage Projects, cont'd

Agency and Project Location	Comments
9. Mojave Water Agency—Mojave River Basin, San Bernardino County	Basin has been adjudicated by court. The ephemeral Mojave River is the only local surface supply. To reduce overdraft, MWA's two new 71-mile pipelines import SWP supplies for recharge in spreading areas in the river channel. MWA's initial SWP contractual entitlement of 50.8 taf annually was augmented by the 1997 purchase of an additional 25 taf of annual entitlement.
10. Orange County Water District —Santa Ana River watershed, Orange and Riverside Counties	Recharges Santa Ana River water regulated at Prado Dam, also recharges recycled water. Operates series of recharge basins along lower river and two seawater intrusion barriers. One barrier is jointly operated with Los Angeles County. Typically recharges about 300 taf annually.
11. Santa Clara Valley Water District —Santa Clara County	District formed in 1929 to combat declining groundwater levels and associated land subsidence. Has 20 recharge basins covering about 390 acres, and also recharges in stream channels. District typically recharges over 100 taf annually, with a combination of local and imported supplies. Estimated operational storage is 550 taf.
12. Semitropic Water Storage District —Kern County	Banking (in-lieu recharge) program with 1 maf storage capacity. Banking partners include MWD (350 taf), Santa Clara Valley WD (350 taf), Alameda County WD (50 taf), Zone 7 Water Agency (65 taf), and Vidler Water Company (185 taf).
13. United Water Conservation District —Santa Clara River Watershed, Ventura County	Operates Lake Piru on Piru Creek and Freeman Diversion Dam on the Santa Clara River in conjunction with spreading areas at Saticoy, El Rio, and Piru.
14. Zone 7 Water Agency—Alameda County	Recharges imported SWP water (46 taf annual contractual entitlement) in local stream channels.

impacts of implementing the requirement. The most apparent impact to CVP water users has been a reduction in deliveries to agricultural users in the Delta export service area on the west side of the San Joaquin Valley. To the extent that the SWP assists USBR in implementing dedicated water operation by forgoing export of unstored water otherwise available for SWP export in the Delta, there are also SWP water costs associated with CVPIA implementation. Water project operations associated with dedicated water remain a subject of discussion in the CALFED Operations Group.

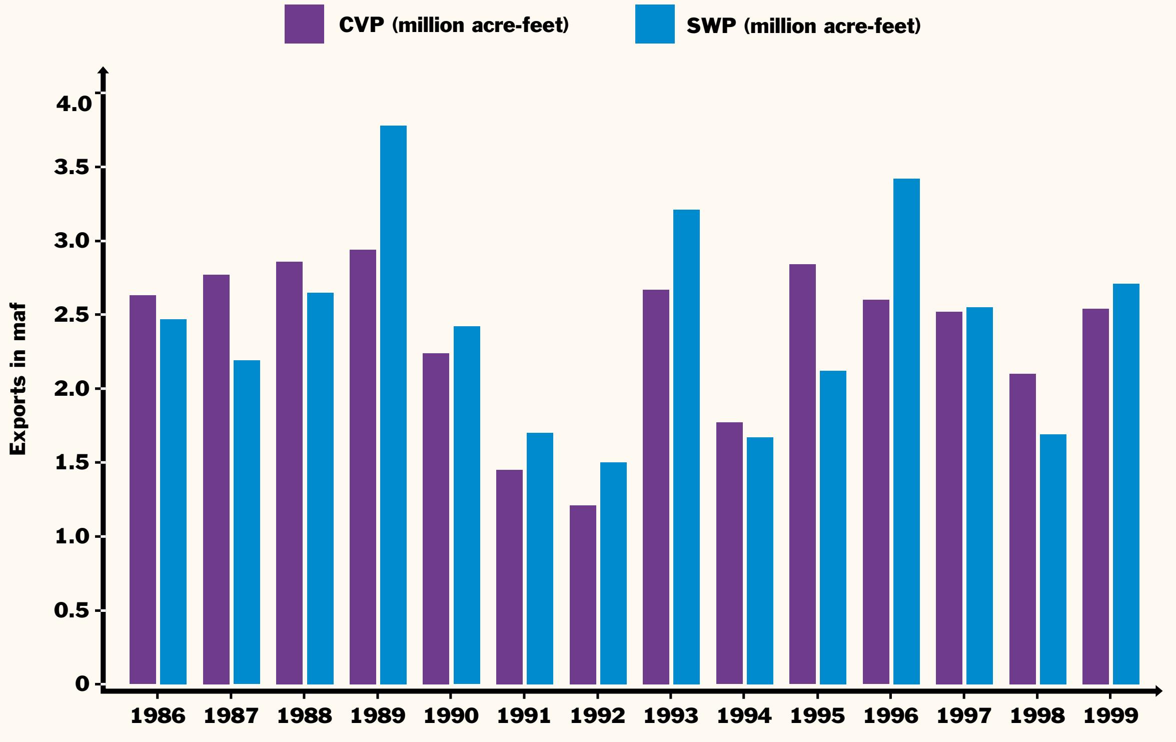
Under present CVP operations, agricultural contractors in the Delta export service area are expected to receive about 50 percent of contractual entitlements in above normal water years. Using the 2000 irrigation season as an example, the early forecast of deliveries to these contractors was at the 30 percent level due to the absence or rain through January. The forecast was subsequently revised to 50 percent in response to a wet February and early March. This allocation was later again increased to 65 percent partly as a result of the CVP's ability to use the recently obtained joint point of diversion permit with the SWP. (The SWP diverted water at Banks Pumping Plant during March and April for the CVP.)

Figure 18 shows historical CVP and SWP exports from the Delta. It is not possible to quantify the operational changes' drought year impacts to CVP and SWP delivery capabilities. Current project operations have been taking place in the context of wet year water conditions under a constantly changing regulatory framework (*i.e.,* fish protection decisions made in the CALFED Operations Group). The CALFED program is in a transitional state from planning to implementation. The Bay-Delta Accord will expire in September 2000; discussions remain ongoing as to the governance structure that could replace it, including how the function now performed by the CALFED Operations Group might be institutionalized. CALFED discussions on creation of an environmental water account are in progress. The success of this program, which entails acquisition of perhaps as much as 400 taf of water from willing sellers to use in meeting ecosystem goals, may affect regulatory decisions on water project operations, as well as the availability of

The Delta Cross Channel, a CVP facility constructed in 1951, was designed to help move water from the Sacramento River into the southern Delta. A gated inlet structure (left side of photo) on the Sacramento River about 1 mile north of Walnut Grove is operated to divert river water into a 4,200 foot-long channel connecting the Sacramento River to Snodgrass Slough, part of the Mokelumne River system. Maximum diversion capacity is about 3,500 cfs. SWRCB Order WR 95-6 requires that the Cross Channel gates be closed more frequently, to keep migrating salmon in the Sacramento River.

—FIGURE 18—

Historical CVP and SWP Delta Exports



water for future drought water banks. Also pending are petitions for reconsideration of SWRCB's Bay-Delta partial water rights decision, which continued the assignment of responsibility for meeting Order WR 95-6 water quality standards to the SWP and CVP, rather than sharing that burden among other Delta diverters.

CVP and SWP operations in 1999 and 2000 provide an example of uncertainties created by the changed regulatory framework. In 1999, SWP exports in late spring/early summer were curtailed due to high Delta smelt densities in the South Delta. The curtailment deferred San Luis Reservoir filling, subsequently resulting in a loss of about 150 taf of interruptible water for SWP contractors. In 2000, unusually wet conditions in February and early March were followed by dry weather. The initial wet conditions triggered the Order WR 95-6 X2 (salinity) requirement for Suisun Bay in April and early May, but natural runoff was subsequently insufficient to sustain the requirement. The SWP had to release water stored in Lake Oroville to meet the requirement. This additional release from storage, coupled with a lower runoff forecast, led to a reduction of ten percent in contractors' allocations.

CHANGES AFFECTING DROUGHT WATER BANK AND WATER TRANSFERS

Changed Delta operating conditions due to factors such as Order WR 95-6, CVPIA, and ESA also restrict the ability to use SWP (or CVP) facilities to wheel drought water bank deliveries or non-project water transfers across the Delta, in addition to reducing supplies available to both projects' contractors. Figure 19 shows historical levels of California Aqueduct wheeling, together with water year type. The majority of the Department's historical wheeling has been for the CVP, Cross Valley Canal water users, and SWP contractors. Future quantities of water wheeled for the CVP and for SWP contractors may increase, reflecting ability to use the DWR/USBR joint point of diversion permit and implementation of the SWP's Monterey Amendments. Implementing CALFED's environmental water account is also expected to entail use of aqueduct capacity.

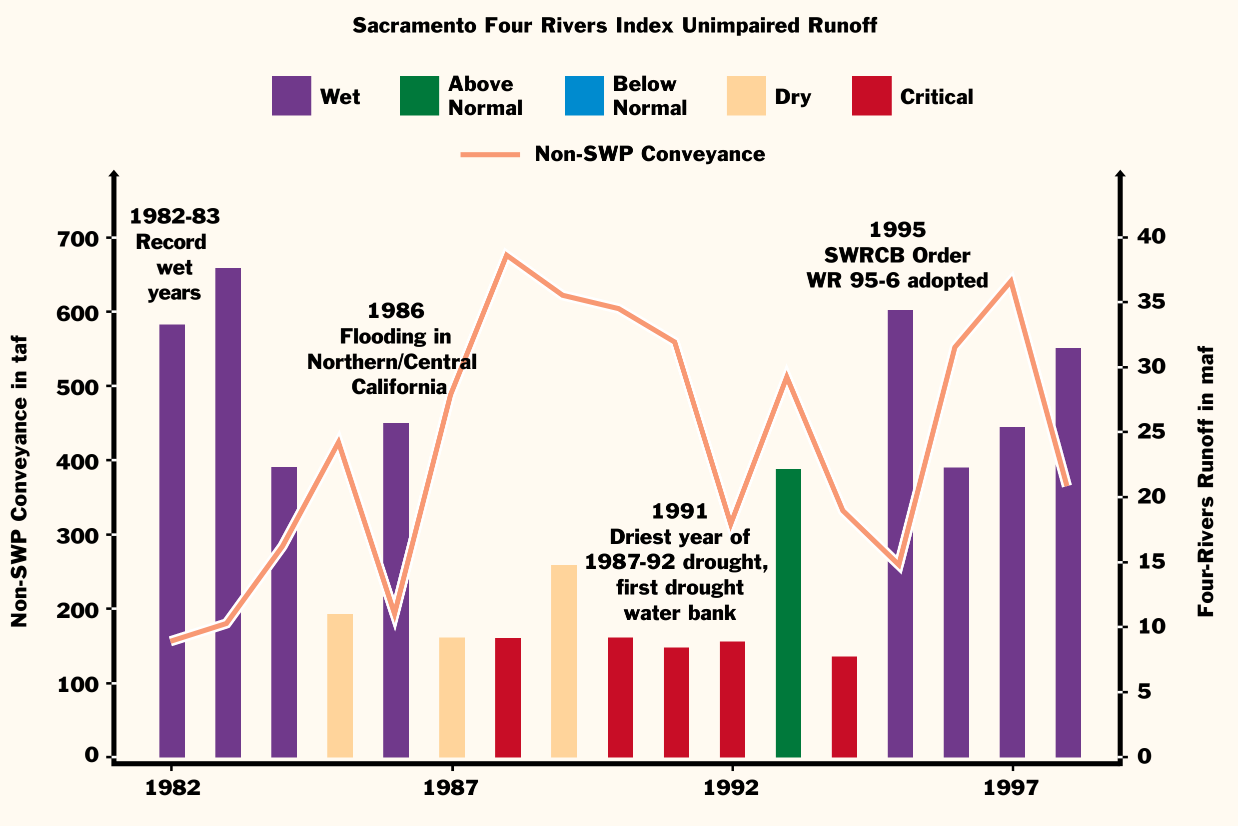
Drought water bank operations will probably be further constrained by lessened ability to acquire water through groundwater substitution transfers. Land fallowing and groundwater substitution, both of which created substantial local concerns over third-party impacts in 1991 and 1992, were the largest sources of water for those drought water banks. Enactment of county groundwater management ordinances and past local opposition to groundwater substitution transfers for the SWP suggest limited ability to acquire water from this source within the timeframe of this report. In the short-term, the most likely sources of drought water bank purchases would be water stored in reservoirs or ground water basins south of the Delta.

Water agencies' and private entities' plans for water transfers involving use of California Aqueduct capacity continue to increase. The development of additional groundwater recharge/storage projects south of the Delta will likely contribute to increased requests for wheeling non-project water. The Water Code requires that public agencies, including the Department, make available unused conveyance capacity of their facilities, subject to payment of fair compensation and other conditions (see sidebar). However, availability of unused capacity is significantly constrained, and the amount and timing of availability of future unused capacity cannot be predicted with any certainty. It may now be time for the Department to establish formal priorities for non-project wheeling, to help provide potential water transferors with a clear understanding of factors affecting availability of capacity.

Use of aqueduct capacity is first reserved for delivering SWP water. The quantities of project water to be delivered are established through an iterative process of matching contractors' requested delivery schedules against hydrologic conditions and facility delivery capabilities. This process is then balanced against constraints on moving water across the

—FIGURE 19—

Historical Wheeling in California Aqueduct



The Sacramento Four Rivers are:
Sacramento River above Bend Bridge, near Red Bluff;
Feather River inflow to Oroville; Yuba River at Smartville; American River inflow to Folsom

Delta—such as Order WR 95-6 export limits, incidental take provisions for ESA listed species, and other requirements of ESA biological opinions. Operational needs associated with existing agreements for conveyance of non-project water, such as those with Cross-Valley Canal water users, must also be considered. In 2000, for example, it is estimated that October will be the earliest time that unused capacity is available for new wheeling.

The magnitude of potential transfers involving SWP facilities is significant. SWP contractors are making greater use of aqueduct capacity to wheel non-project water, as provided in the Monterey Amendments. MWD, for example, issued a request for proposals in December 1999 for its "California Aqueduct Dry Year Transfer Program", a proposed program seeking purchases of 100 taf per year of transfer options. The program is intended to be operational by 2003. Transfers, including water purchases and exchanges for fishery purposes, are a component of CALFED program implementation. Development of groundwater storage and conjunctive use programs is currently an area of expanding interest—in addition to being a component of the Department's integrated storage investigations program, groundwater recharge and storage activities are authorized to receive $230 million in financial assistance from Proposition 13 bond funds. The majority of likely storage sites are located in the San Joaquin Valley and in Southern California, where implementing conjunctive use programs often entails use of California Aqueduct conveyance capacity.

CHANGES IN WATER USE CONDITIONS

Statewide or region-wide changes in actual water usage are best viewed over the long-term, because factors such as weather, hydrology, economic conditions, or regulatory changes can lead to significant annual fluctuations in water use, obscuring long-term trends. A notable example of annual water use fluctuation was the change in California agricultural water use between 1983 and 1984. In 1983, California irrigated acreage dropped by 900,000 acres (almost ten percent of total statewide acreage) due to widespread flooding and operation of the U.S. Department of Agriculture's Payment in Kind program, resulting in a corresponding drop in agricultural water use. Irrigated acreage subsequently rebounded by 800,000 acres in 1984, and water use likewise rebounded. Another example of annual influences on water use is spring hydrologic conditions—an unusually wet or dry spring can significantly influence both agricultural and urban water use in that year.

Demographic trends affect water use patterns. California's population has increased by more than 6 million people since 1987, the first year of the last drought. According to the Department of Finance, California's population growth is shifting from the State's densely urbanized coastal areas to inland regions. Urban per capita water use is higher in the State's inland regions than it is in coastal areas, reflecting higher landscape water use due to warmer and dryer climatic conditions. Regions expected to have the highest percent growth rates over the next 20 years are the Inland Empire, Central Valley, and Sierra Nevada foothills. As greater development occurs in these inland areas, the ex-urban ring around them also expands. From a drought management perspective, the flight from suburban areas to low-density rural developments in areas such as the Sierra Nevada foothills is significant.

Past drought experience demonstrated that genuine health and safety problems (running out of water for drinking, sanitation, and fire fighting) are most likely to occur in small, rural communities relying on marginal water sources, and for individual

THE 1994 CALIFORNIA AQUEDUCT PUMP-IN PROGRAM

The most recent drought was followed by a wet 1993, but 1994 reverted to critically dry conditions. Water users once again implemented strategies to augment supplies or reduce demands. To help meet water users' needs, the Department and USBR allowed local groundwater to be pumped into the joint State-federal San Luis Canal reach of the aqueduct. The program allowed water users to redistribute groundwater supplies within water districts, and allowed State or federal water contractors to receive supplies delivered from San Luis Reservoir in exchange for a like amount of groundwater pumped into the aqueduct. During calendar year 1994, aqueduct pump-ins within Westlands Water District and San Luis Water District totaled 99,390 af. The magnitude of the pump-ins subsequently raised concerns about water quality impacts to SWP contractors and increased rates of land subsidence. No subsequent pump-in programs have been conducted.

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.

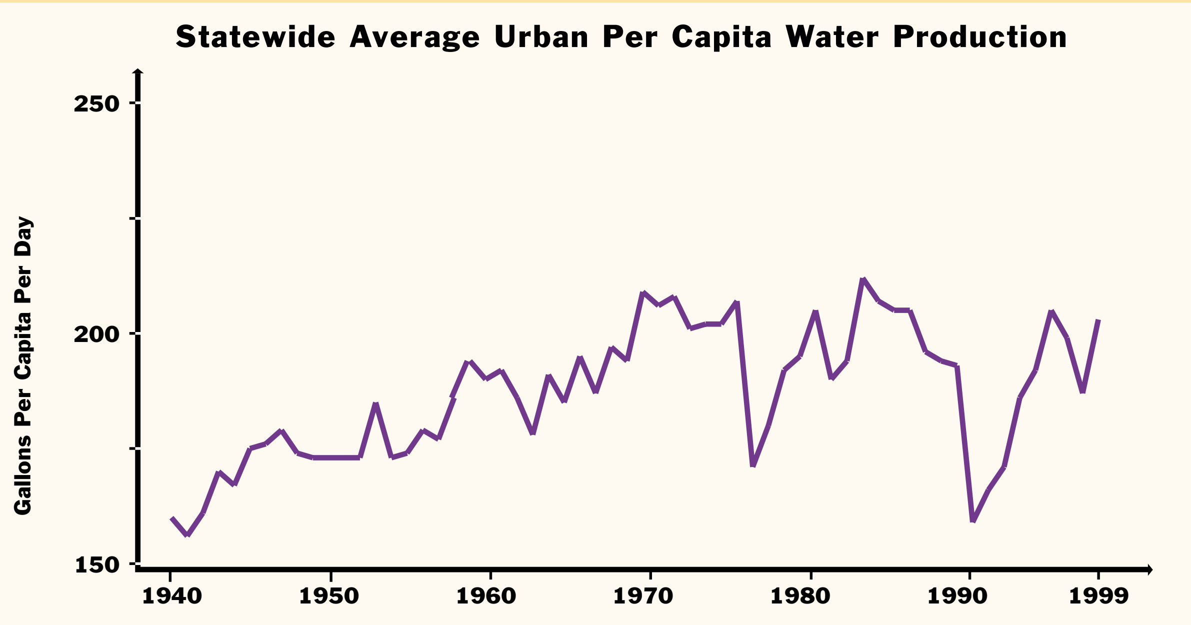
rural homeowners whose wells rely on groundwater in low-yield rock formations. Rural areas are typically characterized by small, geographically dispersed population centers and the absence of a financial base for major capital improvements or interconnection with other water systems. Groundwater resources from fractured rock sources in the Sierran foothills are highly variable in terms of quantity and quality, and are uncertain sources for substantial residential development. The substantial increase in the number of new wells constructed during the last drought—the majority of them for residential use—illustrates drought impacts to rural homeowners.

The potential for demand hardening in California's large urbanized areas is another trend to monitor. Demand hardening occurs when agencies implement water conservation programs that result in permanent reductions in water use, such retrofitting plumbing fixtures or installing low water use landscaping. These measures lessen agencies' ability to implement rationing to reduce water use during droughts, and can result in greater impacts to urban water users (*e.g.,* loss of residential landscaping) when rationing is imposed. For example, the extensive Los Angeles retrofit program helped the city maintain reductions in urban per capita water use it achieved during the last drought. These permanent water use reductions will make it more difficult for the city to duplicate its previous 15 percent water use reduction goal during a future drought.

Figure 20 shows statewide population-weighted average urban per capita water production over time, based on the Department's annual surveys of urban water retailers. The drop in per capita water production during both the 1976-77 and 1987-92 droughts is apparent, as is a post-drought rebound in production. Statewide per capita production declined by about 19 percent during the 1987-92 drought. Figure 21 contrasts total water production and population growth for two Southern California cities—Los Angeles and Ontario. Water production in Los Angeles declined during the drought and did not rebound, diverging from the trend of increasing population. Ontario's water production declined only during the driest year of the drought (1991), but otherwise continued to trend with population increases. The difference between the two cities is explained by Los Angeles' aggressive program to retrofit its older housing stock with low water use plumbing fixtures, aided by a substantial infusion of State financial assistance.

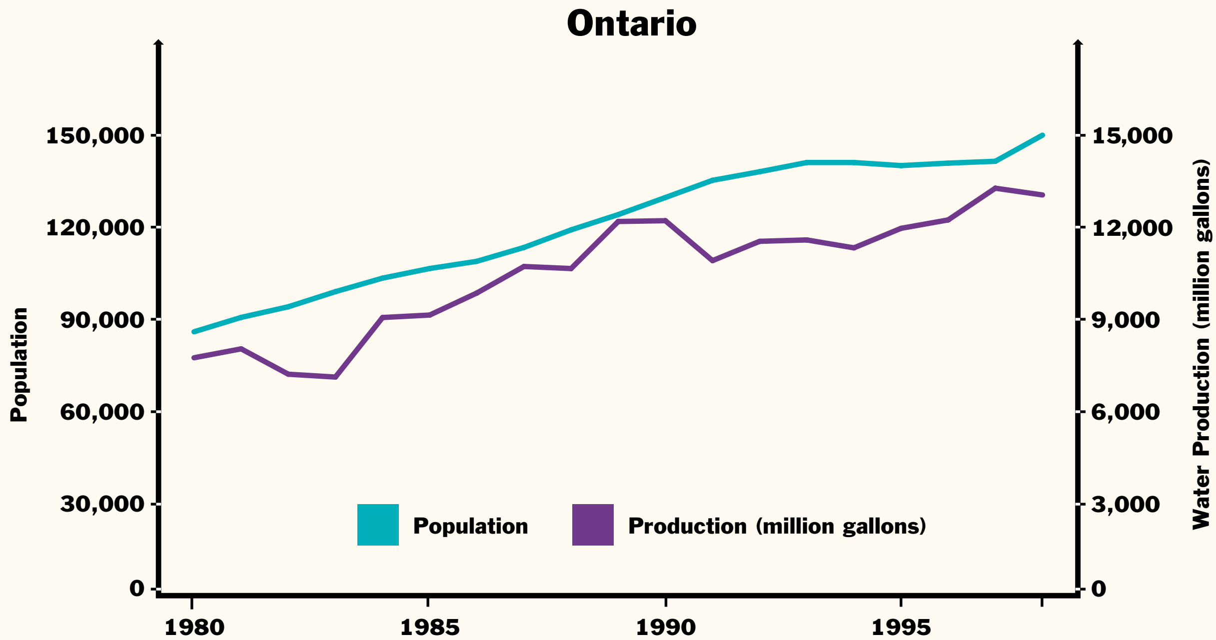
Demand hardening also applies to agricultural water use. Water demands harden as growers shift from field and row crops to permanent plantings of orchards and vineyards. A field normally planted in row crops can be fallowed in a water-short year. In contrast, withholding water from permanent plantings will ultimately result in loss of a grower's capital investment. California's acreage of permanent

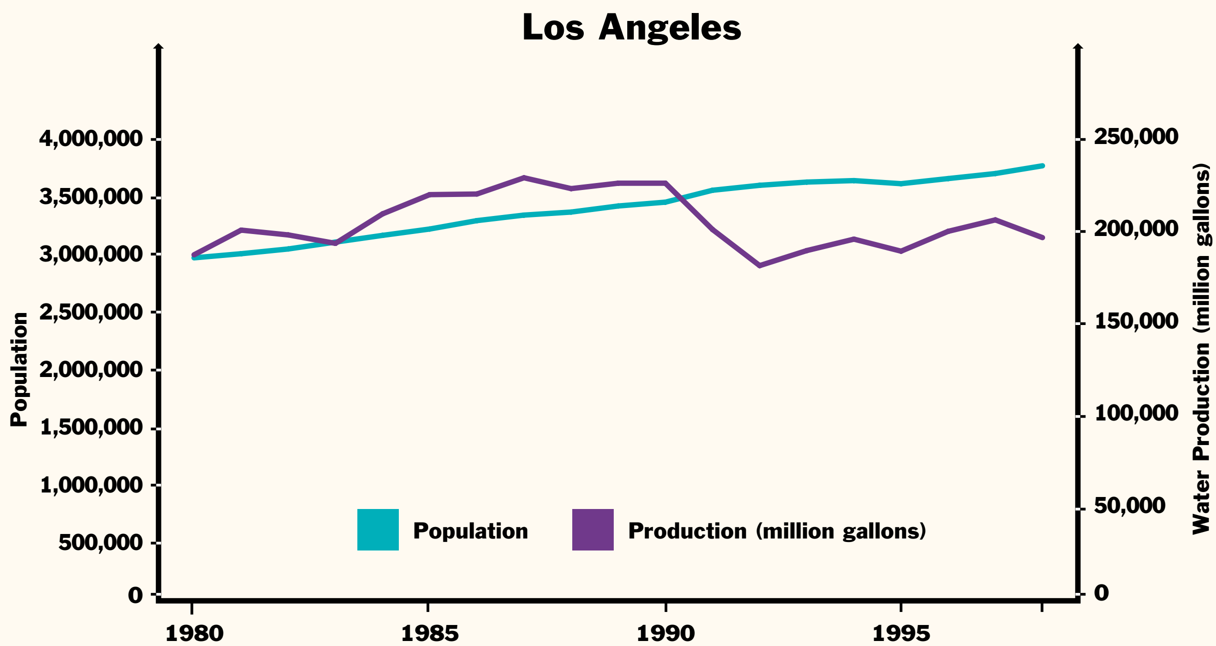
—FIGURE 20—



—FIGURE 21—

Examples of Water Production and Population Growth in Two South Coast Cities





—FIGURE 22—

Percent Increase in Acreage of Permanent Plantings

Harvested acreage data for orchards and vineyards from County Agricultural Commissioner reports, 1991-98. Excludes immature plantings and counties where the increased acreage was less than 640 acres (1 square mile).

plantings has increased since the last drought, as indicated in Figure 22. Much of this increase is in response to recent market conditions favoring production of grapes, almonds, and pistachios. The market for California's crops—internationally as well as nationally—is a driving factor in growers' planting decisions. A region's crop mix can change significantly over a time period as short as five to ten years, in response to changing market conditions.

From a drought planning perspective, two classes of permanent plantings stand out—vineyards installed in areas historically having limited agricultural water supplies, and most plantings in the San Joaquin Valley. Vineyard acreage in Amador and San Luis Obispo Counties, for example, is up by 36-37 percent since the last drought. Agricultural water users in the San Joaquin Valley rely significantly on Delta exports and on overdrafted groundwater basins. The San Joaquin Valley is also the area experiencing the greatest increase in acreage of permanent plantings since the last drought—more than 230,000 acres. Much of this increase has occurred on the Westside, within the water-short CVP Delta export service area.

NEAR-TERM ACTIONS NOW IN PLANNING

Some programs or actions now in planning stages could affect regional or statewide drought preparedness within the next five to ten years. The CALFED Bay-Delta program is one such example; water project operations uncertainties associated with its implementation and with SWRCB's Bay-Delta water rights proceedings were described earlier. This section highlights a few other programmatic actions now at or near an implementation stage, actions that have a bearing on drought preparedness planning.

Emergency Storage Programs

Urban water agencies at risk for seismic disruption of imported supplies have increasingly been evaluating emergency storage programs. These programs typically entail plans to store perhaps six months' to a year's worth of supplies in or near agencies' service areas; some are sized to provide supplies during prolonged droughts as well as during outages of lifeline facilities. Both MWD's Diamond Valley Lake and CCWD's Los Vaqueros Reservoir, for example, incorporate emergency storage functions in their operation. Calleguas Municipal Water District's aquifer storage program, now in initial implementation, is intended to provide storage within Calleguas' service area in the event of loss of supply from MWD's distribution system. (Calleguas is located at the western terminus of MWD's distribution system.) SDCWA is beginning construction of its emergency storage project, which entails construction of Olivenhain Reservoir in partnership with Olivenhain Municipal Water District and enlargement of Lake Hodges and San Vicente Reservoir. The project would provide about 90 taf of emergency storage. Emergency storage is particularly important to San Diego, because the county is highly dependent on imported supplies. Bay Area urban agencies such as EBMUD and the San Francisco Public Utility Commission have also performed appraisal-level studies to examine needs for in-service area emergency storage, but have not gone forward with projects.

From a lifeline engineering perspective, the potential need for emergency storage projects is demonstrated by Figure 23, which superimposes locations of some of California's significant fault zones on a map of regional water facilities.

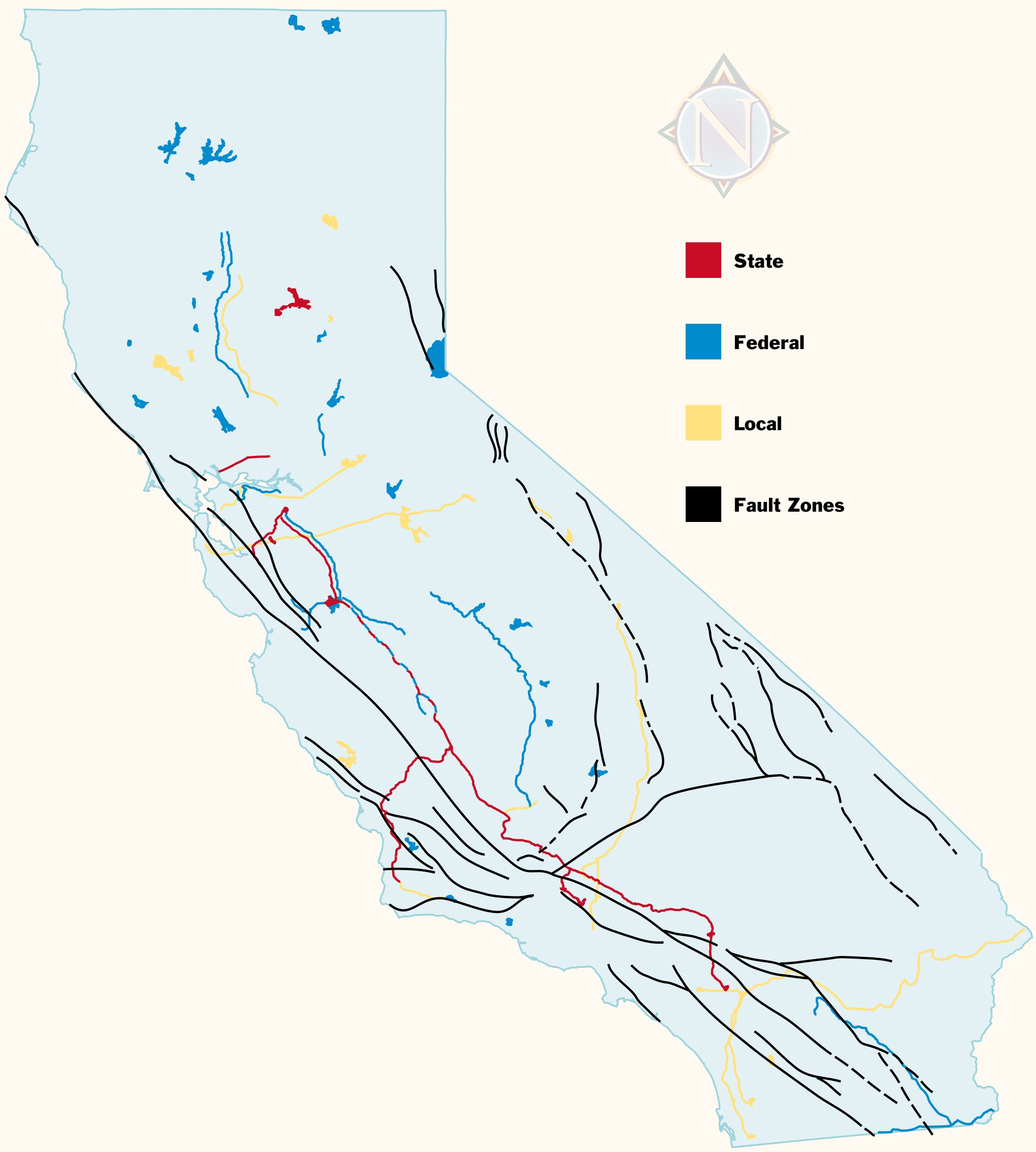
Groundwater Storage Projects

Large-scale groundwater recharge and storage projects now operating in California were described previously. Local agency projects now in various stages of planning include those associated with development of California's Colorado River Water Use Plan. Projects in this category are the Cadiz Valley/Fenner Valley project (draft environmental documentation released in 1999) and the Hayfield/Chuckwalla and lower Coachella Valley projects (both in testing stages). The projects would entail using MWD's aqueduct to convey surplus Colorado River water, when available, for recharge at the sites. The Cadiz/Fenner project would involve construction of about 35 miles of pipeline to link the valleys with the aqueduct. The project's estimated storage/extraction capacity would be about 150 taf per year, which could include extraction of some native groundwater together with stored Colorado River water. In Hayfield Valley, MWD is carrying out a demonstration project that would entail completing 100 taf of recharge this year. Implementing the full-scale project would require additional land acquisition. MWD estimates that the project could be fully operational in 2005, with 800 taf of water in storage by that time. In addition to investigating a new recharge site in the Lower Coachella Valley, MWD, Coachella Valley Water District, and Desert Water Agency are also considering expansion of the existing Windy Point recharge facilities in the upper valley.

The Colorado River Water Use Plan includes interstate groundwater banking in Arizona, pursuant to 1996 Arizona legislation allowing interstate banking under specified conditions. The Secretary of the Interior promulgated final regulations for interstate banking in 1999. Interstate withdrawals from the bank are limited to 100 taf per year; there is no limitation on annual deposits. Prior to enactment of the state legislation, MWD had established a test banking program in Arizona, storing about 89 taf there.

—Figure 23—

California's Major Fault Zones and Conveyance Facilities



San Joaquin Valley banking locations are also being investigated. For example, Azurix Corporation is attempting to develop a water bank at a site in Madera County previously considered by USBR. The project examined by USBR would have had a storage capacity of about 400 taf, with the recharge source being wet year surplus water conveyed through CVP facilities. In San Joaquin County, water users have engaged in discussions with EBMUD about storage of EBMUD's Mokelumne River supplies or its CVP supply from the American River in county groundwater basins. The $230 million of funding for groundwater recharge/storage programs provided by enactment of Proposition 13 will accelerate implementation of local agency projects now in planning stages. The Department's integrated storage investigations program also includes a component for cooperating with local agencies in developing groundwater storage projects.

Coordination of Land Use and Water Supply Planning at the Local Government Level

Interest in better coordination between land use planning performed by cities and counties and water supply planning performed by special districts is increasing, especially in areas experiencing significant development pressure. This subject was first addressed legislatively in 1995, with a requirement that cities and counties making specified land use decisions, such as amending a general plan, consult with local water agencies to determine if supplies are available, and to disclose findings through the California Environmental Quality Act process.

In its January 2000 report, *Growth Within Bounds,* the Commission on Local Governance for the 21st Century made several recommendations relating to orderly growth and the provision of infrastructure, including calling for a more proactive role by local agency formation commissions and for strengthening the linkage between local land use and water supply planning. In the context of drought preparedness, a stronger linkage would be particularly beneficial in the rural counties experiencing suburban flight from rapidly growing inland areas of the state. As indicated earlier, the low population densities and lack of ability to interconnect many small water systems makes these areas vulnerable to drought impacts.

Orange County Water District groundwater recharge facilities on the Santa Ana River. Proposition 13, approved by the voters in March 2000, provides $230 million of financial assistance for implementing local agency groundwater storage and recharge projects.

CHAPTER 4

RECOMMENDED ACTIONS

This chapter describes actions that the Department could take in preparation for the next drought, and in the early stages of response to a drought. These actions are necessarily based on California water and institutional conditions as they exist in mid-2000. The now-recommended actions should be periodically re-examined in light of the changes in water management conditions that will inevitably occur over time.

One dry year does not constitute a drought, but is a reminder of the need to plan for the occurrence of a second dry year. California's extensive system of water supply infrastructure and the planning performed by

—FIGURE 24—

Probable Impacts in a Single Dry Year

local water agencies mitigate impacts of short-term dry periods. Likely impacts in a single dry year are shown in Figure 24. Most impacts would be felt by water users relying on annual rainfall, such as rural homeowners on marginal wells or ranchers dependent on dryland grazing. Dry year hydrologic conditions would also exacerbate the shortages stemming from CVPIA implementation and Delta export restrictions experienced by CVP water users on the San Joaquin Valley's west side.

Defining when a drought occurs is a function of the impacts of dry conditions on water users. The Department used two primary criteria to evaluate statewide conditions during the 1987-92 drought—runoff and reservoir storage. A drought threshold was considered to be runoff for a single year or multiple years in the lowest ten percent of historical range, and reservoir storage for the same time period at less than 70 percent of average. These were not hard and fast values, but guidelines for identifying drought conditions. For example, the Department instituted a drought watch in 1994, based on forecasted statewide reservoir storage being at 75 percent of average. This decision took into account depleted groundwater storage conditions still remaining from the earlier six years of drought.

The following recommendations are divided into two categories—those dealing with general drought preparedness, and those intended to be implemented when dry conditions are being experienced. Implementation of this latter category of recommendations would be triggered in a dry year, with the intent of preparing for a second consecutive dry year. Deciding when to begin implementation, and with what level of effort, would be a judgement call based on considerations such as statewide reservoir storage or status of regulatory actions affecting Delta exports.

An example of the reason for drought preparedness planning. USBR's 240 taf Twitchell Reservoir on the Cuyama River in San Luis Obispo County, in 1990. The reservoir, a facility of USBR's Santa Maria Project, provides supplemental irrigation supplies for Santa Maria Valley.

LONG-TERM DROUGHT PREPAREDNESS PLANNING

One aspect of response planning is having information and resources available when drought conditions occur. Listed below are items that would contribute directly to Department drought response actions or would be useful in working with local agencies to develop drought response actions.

SWP Actions

- Work with the CALFED Operations Group or its successor entity to begin conceptual development of multi-year SWP and CVP operations strategies (*i.e.,* reservoir carry-over storage strategies). Such strategies would be useful not only for drought planning purposes, but also for evaluating possible responses to different fishery protection or regulatory requirements. This exercise would essentially extend CALFED's operations modeling process over a longer time period, and would be coordinated with preparation of the drought contingency plan called for in the June 2000 CALFED action framework document.

Local Assistance Actions

- Seek additional funding or partnerships to support the Department's basic water measurement programs—stream gaging and groundwater level measurement. Eroding federal financial support for the USGS state-federal cooperative stream gaging program has resulted in continued loss of gaging stations. Resource limitations have eliminated the Department's program for field measurement of groundwater levels in Southern California. Locations with increased water measurement needs include stream segments with fishery protection or other environmental goals, Central Coast groundwater basins subject to seawater intrusion, and Southern California groundwater basins not under active local agency management.
- Update and publish the Department's water well standards. The standards currently exist in two parts—Bulletin 74-81 (published in 1981) and a separately printed supplement. The two parts should be combined into one document, updated to reflect current Water Code requirements, and made available on the Web. Past experience demonstrates that the number of wells drilled or deepened during droughts increases substantially. There will be a corresponding increase in public requests for information on water well standards.
- Develop a fact sheet and Web page identifying county agencies administering water well standards. Provide telephone numbers and other contact information for each agency.
- Closely review the shortage contingency elements of the urban water management plans which suppliers serving more than 3,000 connections or 3,000 customers are required to submit to the Department by December 31, 2000. Identify plans needing more emphasis in this area, and work with the water suppliers to develop improvements.
- Develop an internal database-backed website for extracting information from urban water management plans, to make the information readily available for analysis. This action would facilitate responding to the numerous public and media information requests typically received during a drought.
- Continue efforts to site more California Irrigation Management System weather stations in urban areas, in coordination with the California Urban Water Conservation Council. Managers of large urban turf areas (*e.g.,* parks or schools) could use CIMIS climatological data to help respond to landscape irrigation restrictions commonly imposed during droughts. CIMIS stations have been installed in agricultural areas throughout the State, but have not been as widely distributed in urban areas due to the difficulty of finding suitable locations.
- Survey some of California's larger urban areas to determine the extent to which the Model Water Efficient Landscape Ordinance is being implemented, and estimate its effectiveness in reducing landscape water use as compared to pre-1992 conditions. Interest in demand reduction programs during the last drought led to enactment of this requirement, but there has been no evaluation of water savings resulting from its implementation. In general, actual data on residential landscape water use are minimal throughout the State. Knowing more about actual landscape water use would facilitate developing drought-related water education materials.
- Identify and fund research in the areas of long-range weather forecasting, global climate change, and paleoclimatology. The former would, as described in Chapter 1, be useful in operating water projects to take advantage of expected hydrologic conditions. The goal of paleoclimatology research would be to reconstruct past hydrologic sequences to allow at least qualitative, and preferably quantitative, simulation of

present-day water supplies under hydrologic conditions extending beyond the roughly 100 years of historical record. The Department is currently funding the University of Arizona 's Laboratory for Tree Ring research to perform a limited reconstruction of Sacramento River hydrology.

ACTIONS TO BE TAKEN WHEN DRY CONDITIONS OCCUR

Implementation of actions listed below would begin in a dry water year, to prepare for the possibility of a second dry year. Many of the actions would then be carried over into the second year, and subsequent years, if conditions remained dry. By January of the second year, consideration should be given to establishing a Department drought response team to coordinate response activities for a second dry year, if conditions remain dry. Continued dry conditions through April of the second year would suggest the desirability of creating an interagency coordination team, with representation from agencies such as SWRCB, DFG, and Department of Food and Agriculture.

SWP Actions—Water Year One

- If the early February Sierra Nevada snow survey data and resultant water supply forecasts indicate dry conditions, begin developing proposed multi-year SWP operations plans, in coordination with the CALFED Operations Group and CVP operators. Involve SWP contractors in the operations planning, with the goal that contractors' October preliminary delivery requests be reflective of proposed dry year operations plans. Several alternative plans could be developed, with alternative selection being triggered by forecasted water supply conditions as of some specified date.

SWP Actions—Early Water Year Two

- After reviewing the contractors' preliminary delivery requests and current water supply conditions/Delta conveyance restrictions, make a tentative selection of operational strategies for the coming year. Modify as needed based on subsequent snow survey information.

—Table 8—

Comparison of November 1993 Drought Water Bank EIR Conditions to Present Conditions

	1993	2000
Delta operations	D-1485	WR 95-6
Listed fish species	winter-run salmon	winter-run salmon fall-run salmon Delta smelt Sacramento splittail* coho salmon steelhead trout
CALFED operations	no	yes
CVPIA operations	no**	dedicated water/ supplemental water
Monterey Amendments	no	yes

* *Listing decision found to be arbitrary and capricious by the federal district court in July 2000. Further action by court is pending as this report goes to printing.*

** *CVPIA was enacted in October 1992. CVP operations to meet dedicated water requirements in 1993 were not available for analysis in the EIR.*

- Evaluate the need to increase the frequency or extent of subsidence monitoring along the California Aqueduct in the San Joaquin Valley, in expectation of increased groundwater extraction by local water users.
- Evaluate the extent to which drought-related water operations plans would facilitate or hinder major maintenance activities, inspections, or planned outages.

Local Assistance Actions—Water Year One

- In January of the first year, submit a request for funding in the Governor's May budget revision for the coming fiscal year, to update the programmatic EIR for the drought water bank. If the water year continues to be dry, work on a new EIR could then begin in July. As illustrated in Table 8, changed Delta operating conditions have made the 1993 programmatic EIR outdated.
- In January of the first year, submit a request for funding in the Governor's May budget revision for the coming fiscal year, to begin placing additional mobile irrigation management labs in the field. It would be desirable to maximize the number of operating labs during multi-year dry periods, to help growers make the best use of limited water supplies. In 1999, there were nine operating mobile labs. The Department's current funding for this program supports coordination activities only, not lab operation.
- In spring of the first year, promote CIMIS through workshops and media outreach. Growers or landscape managers can use CIMIS information to improve irrigation scheduling, a useful water management action even if the next year returned to normal water supply conditions.
- Also in spring, begin developing fact sheets and related information to facilitate responding to public and news media inquiries about dry conditions. Publicize weather and water supply conditions, and drought preparedness actions. Tabulate Department and other water conservation programs available to water users and make this information available on a Web page.
- In the summer of the first year, begin holding public workshops on water well construction fundamentals and the Department's well standards, targeting rural counties with large numbers of individual residences on wells. The workshops should also cover well maintenance and rehabilitation, subjects frequently unfamiliar to former urban residents who move to rural property served by a private well. Residential water users and small water systems experiencing the most problems in past droughts were those in the North Coast region and the Sierra Nevada foothills.

Local Assistance Actions—Early Water Year Two

- Near the start of the water year, evaluate water supply conditions and define conditions triggering different levels of drought response, such as enhanced public education and media outreach or opening a drought water bank.
- If conditions warrant a higher level of drought response, begin putting an enhanced education and outreach program in place, including publicizing drought response actions through the Department's Water Information Center and SWP visitor centers. Begin increasing local assistance efforts, such as holding leak detection workshops for local agencies and making all mobile lab irrigation system evaluations accessible via a central point of contact. Begin surveying selected local water agencies to identify any problem areas.
- Evaluate staff resources available for processing water bank contracts and contracts for other wheeling of non-SWP water in the California Aqueduct, and take measures to augment staffing if needed. Also evaluate the need for surface water or groundwater monitoring programs associated with bank implementation.
- For Department-operated Sacramento River flood control facilities, schedule major maintenance activities that would be facilitated by dry conditions.
- Evaluate the need for any new legislation to address drought-related conditions.

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Abbreviations And Acronyms

A

ACWD	Alameda County Water District
A.D.	*Anno Domini*
af	acre-foot, acre-feet

C

CALFED	State (CAL) and federal (FED) agencies participating in the Bay-Delta Accord
CCWD	Contra Costa Water District
cfs	cubic feet per second
CIMIS	California Irrigation Management Information System
CLWA	Castaic Lake Water Agency
CRA	Colorado River Aqueduct
CVP	Central Valley Project

D

DEIR/S	Draft environmental impact report/statement
DFG	Department of Fish and Game
DHS	Department of Health Services
DWR	Department of Water Resources

E

EBMUD	East Bay Municipal Utility District
EIR/S	Environmental impact report/statement
ENSO	El Niño Southern Oscillation
ESA	Endangered Species Act
ET_0	Reference evapotranspiration

K

KCWA	Kern County Water Agency
KWB	Kern Water Bank

L

LADWP	Los Angeles Department of Water and Power

M

maf	million acre-feet
mg/l	milligrams per liter
MWA	Mojave Water Agency
MWD	Metropolitan Water District
MWD	Municipal Water District

N

NBA	North Bay Aqueduct
NMFS	National Marine Fisheries Service

O

OES	Office of Emergency Services

P

PEIR/S	Programmatic environmental impact report/statement
PL	Public law
PUC	Public Utilities Commission

S

SEMS	Standardized emergency services system
SJR	San Joaquin River
SRI	Sacramento River Index
SWP	State Water Project
SWRCB	State Water Resources Control Board
SWSD	Semitropic Water Storage District

T

taf	thousand acre-feet
TDS	total dissolved solids

U

USBR	U.S. Bureau of Reclamation
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

W

WD	water district