JANUARY 2020

California's Most Significant Droughts:

Comparing Historical and Recent Conditions

State of California | California Department of Water Resources

Cover: A fallowed field on West Jayne Avenue, just east of Lassen Avenue, near Huron, on July 29, 2015.

Executive Summary

Water Year 2018 saw a return of dry conditions to California. In the decade prior to an unusually wet Water Year 2017, all but two years were drought years; the statewide drought of Water Years 2007–2009 was soon followed by the statewide drought of 2012–2016. In February 2015, in response to questions regarding relative drought severity and changed conditions since prior major droughts, the California Department of Water Resources released *California's Most Significant Droughts: Comparing Historical and Recent Conditions*. That report compared then-current drought hydrology and impacts with those of California's largest historical droughts. This 2018 update builds on the previous report and puts the 2012–2016 drought in context with California's other large historical droughts.

During the 20th century, California experienced three significant historical statewide droughts: the six-year event of 1929–1934, the two-year event of 1976–1977, and the six-year event of 1987–1992. These droughts are exceptional in the observed record because of their duration or severe hydrology. The 1929–1934 event occurred within the climatic context of a decades-plus dry period in the 1920s–1930s. Hydrology during those years rivaled that of the most severe dry periods in more than a millennium of reconstructed Central Valley paleoclimate data. That drought's impacts were small by present-day standards, however, because the state's urban and agricultural development was far less than it is today. The 1976–1977 drought, though lasting only two years, was notable for the severity of its hydrology. The 1987–1992 drought was California's first extended dry period since the 1920s–1930s, and provides the closest comparison for drought impacts under a present-day level of development.

Shortly into this century, California has experienced two statewide droughts: one in 2007–2009 and one in 2012–2016. The 2007–2009 drought marked the first time that a statewide proclamation of emergency was issued because of drought impacts. A statewide proclamation was repeated with the 2012–2016 drought.

The recent 2012–2016 event occurred in the context of record warmth in California and set numerous hydrologic and impact records: driest four consecutive water years based on statewide precipitation (2012–2015), lowest April 1 statewide snowpack water equivalent (5 percent in 2015), first-ever zero allocations to Central Valley Project agricultural contractors (2014 and 2015), and groundwater levels in many parts of the state below previous historical lows.

Drought is a gradual phenomenon and a recurring feature of California's climate. Over time, trends related to droughts and drought impacts can be observed, such as effects of a warming climate, increased populations in vulnerable areas, and greater competition for scarce resources. Understanding the impacts historically observed and lessons learned in our past large droughts can help Californians be better prepared for future droughts.

STATE OF CALIFORNIA
Gavin Newsom, *Governor*

CALIFORNIA NATURAL RESOURCES AGENCY
Wade Crowfoot, *Secretary for Natural Resources*

DEPARTMENT OF WATER RESOURCES

Karla A. Nemeth
Director

Cindy Messer
Chief Deputy Director

Michelle Banonis
Assistant Chief Deputy Director

Deputy Directors and Executives

Ted Craddock
State Water Project

Gary Lippner
Flood Management and Dam Safety

Kristopher Tjernell
Integrated Watershed Management Program

Michael Day
Security and Emergency Management Program

Katherine S. Kishaba
Business Operations

Taryn Ravazzini
Statewide Groundwater Management

Spencer Kenner
Chief Counsel

Erin Mellon
Assistant Director, Public Affairs Office

Kasey Schimke
Assistant Director, Legislative Affairs Office

Anecita Agustinez
Government and Community Liaison

Stephanie Varrelman
Office of Workforce Equality

David Whitsell
Internal Audit Office

Prepared by:

Jeanine Jones, *Interstate Resources Manager*

With contributions from:

Michael Anderson, *State Climatologist*

Francis Chung, *Principal Engineer*

Anna Fock, *Supervising Engineer*

Sean de Guzman, *Engineer*

Nazrul Islam, *Senior Engineer*

Rich Juricich, *Principal Engineer*

Barrett Kaasa, *Engineering Geologist*

Jennifer Kofoid, *Senior Engineer*

Boone Lek, *Senior Engineer*

Erik Reyes, *Supervising Engineer*

David Rizzardo, *Supervising Engineer*

Maurice Roos, *Principal Engineer*

Hyun-Min Shin, *Engineer*

Tara Smith, *Principal Engineer*

Bob Suits, *Senior Engineer*

Evelyn Tipton, *Senior Engineer*

Levi Warr, *Engineer*

Yu Zhou, *Engineer*

Production Services provided by:

Robert Stoltz, *Editor, Technical Publications*

Mike Miller, *Supervisor, Photography*

Bill Kelley, *Librarian, Photography*

Scott Olling, *Graphic Designer, Graphic Services*

Contents

Chapter 1. Introduction and Setting 1

Drought Background and Defining Drought 2
- *Sidebar: The Great Drought of 1863–1864* 2
- *Sidebar: The Water Year* 3

Drought Beginning and Ending 5
Drought and Drought Emergency 5
- *Sidebar: Agricultural Disaster Designations* 6

Drought Prediction and Frequency 7
- *Sidebar: Drought Frequency Analysis* 8

Drought Vulnerability and Resilience 8
California's Most Significant Historical Droughts 10
- *Sidebar: State-Level Drought Definition* 10
- *Sidebar: Shortage or Normal?* 12
- *Sidebar: For Further Information on Historical Droughts* 12

California Water Supply, An Overview 13
Imported Surface Water – The Colorado River 15
Groundwater 19

Chapter 2. Hydroclimate Background on Drought in California 25

What Causes Drought and is it Predictable? 25
- *Sidebar: Climate Teleconnections* 29

A Changing Climate 30
Droughts In and Near California – The Long-Term Picture 36
- *Sidebar: Adapting Snowpack Monitoring to a Changing Climate* 36

Measuring Droughts in California's Historical Record 39
- *Sidebar: The Medieval Climate Anomaly* 40
- *Sidebar: Land Subsidence* 43
- *Sidebar: Unimpaired Flow* 44

Chapter 3. Highlights of Past Droughts 45

1929–1934 45
- *Sidebar: Timeline of Selected Events* 46
- *Water Infrastructure Development* 47

Impacts 48
Ending the Drought 50
1976–1977 50
Sidebar: Conflict at Lake Tahoe 53
Sidebar: Trying to End the Drought 54
Water Supplies and Water Project Operations 54
Impacts 55
Sidebar: Cloud Seeding Activities 57
Institutional Actions 58
Ending the Drought 59
1987–1992 59
Water Supplies and Water Project Operations 59
Impacts 61
Sidebar: Extreme or Catastrophic Droughts 62
Institutional Actions 62
Ending the Drought 63
2007–2009 63
Water Supplies and Water Project Operations 65
Impacts 67
Institutional Actions 73
Ending the Drought 74
2012–2016 74
Water Supplies and Water Project Operations 76
Impacts 84
Institutional Actions 91
Ending the Drought 94

Chapter 4. Comparison of Recent Conditions to Past Droughts and Lessons Learned 95

A Changing Climate 95
Changes in Institutional Setting – Water Project Operations 96
Changes in Institutional Setting – State Financial Assistance 100
Changes in Major Water Infrastructure 102
Changes in Water Use Conditions 103

Comparison of Drought Impacts *104*
Unmanaged Systems *104*
Managed Systems *105*
Sidebar: Defining Small Water Systems *106*
Other Observations from Past Droughts *108*
Evaluation of Statewide Groundwater Conditions *108*
Sub-seasonal to Seasonal Precipitation Forecasting *108*
Improving Small Water System Drought Preparedness *111*
Sidebar: New Technology for Monitoring Land Subsidence *112*
Drought Resilience Challenges *112*
Integrating Climate Change Adaptation *114*

Appendix 117

Acronyms *118*
References *119*
Selected Drought Executive Orders and Emergency Proclamations *125*
Executive Order B-27-77 ..... *125*
Executive Order W-3-91 ..... *129*
Executive Order S-06-08 ..... *133*
Emergency Proclamation: Central Valley *137*
Emergency Proclamation: Water Shortage *141*
Executive Order S-11-09 ..... *147*
State of Emergency: Fresno County *149*
Executive Order B-21-13 ..... *151*
A Proclamation of a State of Emergency *153*
A Proclamation of a Continued State of Emergency *157*
Executive Order B-26-14 ..... *163*
Executive Order B-28-14 ..... *165*
Executive Order B-29-15 ..... *167*
A Proclamation of a State of Emergency *173*
Executive Order B-36-15 ..... *177*
Executive Order B-37-16: Making Conservation a California Way of Life *181*
Executive Order B-40-17 ..... *185*
Executive Order B-42-17 ..... *189*

Figures

Figure 1.1: Location Map 3
Figure 1.2: Examples of Reservoir Storage to Average Annual Flow Ratio for Selected Watersheds 4
Figure 1.3: Comparison of Counties with Emergency Proclamations 6
Figure 1.4: Historical Skill of NOAA Precipitation Outlooks 9
Figure 1.5: Drought Duration Based on Precipitation Reconstruction at San Gabriel Dam 9
Figure 1.6: Calculated Statewide Runoff 11
Figure 1.7: Contribution of Atmospheric Rivers to California Precipitation 14
Figure 1.8: Comparative Variability of California Precipitation 14
Figure 1.9: Average Annual Precipitation and Runoff by Hydrologic Region 15
Figure 1.10: California Water Projects 16
Figure 1.11: Sacramento River Unimpaired Runoff 17
Figure 1.12: San Joaquin River Unimpaired Runoff 17
Figure 1.13: Central Valley Watershed Elevations 18
Figure 1.14: Colorado River Unimpaired Flow at Lees Ferry 19
Figure 1.15: California Groundwater Basins 20
Figure 1.16: Historical Groundwater Use by Sector 21
Figure 1.17: Groundwater Contribution to Total Water Use by Hydrologic Region 22
Figure 1.18: California Water Wells by Type (1977–2010) 23
Figure 1.19: Characteristics of Fractured Bedrock Controlling Groundwater Availability 23
Figure 1.20: Groundwater Level Monitoring Coverage 24

Figure 2.1: Forecasted Versus Observed Precipitation During the Winter 2015–16 El Niño 26
Figure 2.2: El Niño–Southern Oscillation and California Precipitation 27
Figure 2.3: El Niño–Southern Oscillation and Colorado River Basin Precipitation 28
Figure 2.4: NOAA Statewide Average Temperature Ranks 30
Figure 2.5: California Statewide Mean Temperature Departure 31
Figure 2.6: Annual Elevation of Freezing Level Over Lake Tahoe, Departure From Long-Term Mean 32
Figure 2.7: April–July Sacramento River Runoff as Percent of Water Year Runoff 33
Figure 2.8: April–July San Joaquin River Runoff as Percent of Water Year Runoff 33
Figure 2.9: April 1 Historical Snowpack Water Content: Statewide 34
Figure 2.10: Experimental Estimates of Snowpack Water Content 36
Figure 2.11: Reconstructed Flows in Major Rivers 38
Figure 2.12: Driest 10-Year Periods in Reconstructed Records 39

Figure 2.13: Observed and Reconstructed Water Year Precipitation at Ojai (1391–2016) 40
Figure 2.14: Long-Term Perspective on Concurrent Dry Periods in Southern California's Water Supply Sources 40
Figure 2.15: Water Year Precipitation at Selected Cities 41
Figure 2.16: Northern Sierra 8-Station Precipitation Index for Selected Years 42
Figure 2.17: Southern Sierra 5-Station Precipitation Index for Selected Years 42
Figure 2.18: Tulare Basin 6-Station Precipitation Index for Selected Years 42
Figure 2.19: Sample Hydrographs of Wells in the Sacramento and San Joaquin Valleys 44

Figure 3.1: Historical California Estimated Population 46
Figure 3.2: Historical California Estimated Irrigated Acreage 46
Figure 3.3: Distribution of California's Population in 1930 47
Figure 3.4: Maximum Delta Salinity Intrusion, 1921–1943 51
Figure 3.5: Maximum Delta Salinity Intrusion, 1944–1990 52
Figure 3.6: Historical Salinity (Modeled and Observed) at Jersey Point 53
Figure 3.7: Temporary Salinity Management Facilities Installed in 1976–1977 56
Figure 3.8: Metropolitan Water District In–Service Area Storage 65
Figure 3.9: Statewide Runoff Comparison, 2007–2009 Drought 66
Figure 3.10: 2007 Southern California Wildfires 69
Figure 3.11: Landsat Images of the San Joaquin Valley in Summer 2006 and 2009 70
Figure 3.12: Harvested Acreage of Selected Crops in Fresno County, 1955–2011 72
Figure 3.13: San Diego County Avocado Acreage 72
Figure 3.14: State Water Resources Control Board Analysis of Sacramento-San Joaquin Flows Available to Satisfy Water Rights in June 2015 77
Figure 3.15: Historical San Luis Reservoir Monthly Storage 79
Figure 3.16: Lake Mead End-of-Calendar Year Elevation, Showing Shortage Trigger Elevations and Impacts of Institutional Actions 80
Figure 3.17: Cumulative Change in Statewide Groundwater Levels, 2012–2016 Drought 81
Figure 3.18: Estimated Subsidence in the San Joaquin Valley Between 1949 and 2005 82
Figure 3.19: San Joaquin Valley Land Subsidence, May 2015–September 2016 83
Figure 3.20: Growth of Subsidence Hotspot Adjacent to California Aqueduct 84
Figure 3.21: Land Idling Based on Satellite Imagery, September Comparison of a Wet 2011 with a Dry 2015 85
Figure 3.22: SWRCB Drought Assistance for Public Water Systems 87
Figure 3.23: Tree Mortality in 2016 90

Figure 3.24: CAL FIRE Wildland Fires, Number of Acres Burned 2007–2016 90
Figure 3.25: Atmospheric Rivers Reaching the West Coast in Water Year 2017 94

Figure 4.1: Comparing the Present Climate to the Past in the Sacramento Valley and Southern California 96
Figure 4.2: Historical Central Valley Project Allocations to Agricultural Contractors 99
Figure 4.3: Historical State Water Project Allocations to Project Contractors 99
Figure 4.4: Sources of City of Los Angeles Water Supply 100
Figure 4.5: Colorado River Total System Storage 101
Figure 4.6: Metropolitan Water District's Combined Reservoir Storage 102
Figure 4.7: Example of Increased Acreage in Permanent Plantings 103
Figure 4.8: Example of Potentially At-Risk Small Water Systems 109
Figure 4.9A: Satellite Imagery of the Central Valley in Summer 2011 111
Figure 4.9B: Satellite Imagery of the Central Valley in Summer 2014 111
Figure 4.10: Spatial and Temporal Scales Associated with Weather and Climate Predictions 113

Tables

Table 2.1: End-of-Water-Year Statewide Reservoir Storage for Selected Dry Years 43
Table 3.1: Driest Four Consecutive Water Years, Based on Statewide Precipitation 47
Table 3.2: Single Driest Years Based on Statewide Runoff 47
Table 3.3: Leading Crops in 1929 49
Table 3.4: CVP and SWP Allocations During 2007–2009 Drought 66
Table 3.5: CVP and SWP Allocations During 2012–2016 Drought 76
Table 3.6: Selected State Institutional Actions in 2012–2016 Drought 91
Table 4.1: California Anadromous Fish Species 97
Table 4.2: CVP and SWP Allocations in Selected Drought Years 98
Table 4.3: Typical Multi-Year Drought Impacts 104
Table 4.4: Storage in Selected Reservoirs in Dry Water Years 105
Table 4.5: Estimated Wildfire Damages 106

1

Introduction and Setting

Originally released in February 2015, *California's Most Significant Droughts: Comparing Historical and Recent Conditions* addressed the state's dry conditions of 2012–2014, particularly the very dry hydrology of Water Year 2014. At the time, Water Year 2014 ranked as the third driest on record in terms of statewide precipitation. Likewise, the three-year period of Water Years 2012–2014 ranked as the driest consecutive three-year period on record in terms of statewide precipitation. These conditions elicited comparisons to previous long-term droughts, and raised questions concerning water-related impacts created by increases in state population and changed institutional conditions.

On January 17, 2014, Governor Brown proclaimed a state of emergency because of drought conditions, in response to the exceptionally dry start of the 2013–2014 winter combined with two prior dry years. The initial proclamation was followed by a series of executive orders, including Executive Order B-29-15 on April 1, 2015, calling for mandatory statewide urban water use cutbacks. That executive order was announced at DWR's April snow course measurement at Phillips Station, where there was no snow to measure. Water Year 2015 set a record for lowest estimated statewide snowpack water content, at only 5 percent of the historical April 1 average.

This 2018 update to the 2015 report compares the recent 2012–2016 drought to other statewide historic droughts and answers questions about the relative severity of drought hydrology and drought impacts. This update also discusses observed trends, commonalities, and lessons learned during and after the state's largest historical droughts, focusing on information associated with managed urban and agricultural water supplies.

To provide context for the following chapters, this updated report begins with defining the terms "drought" and "water shortage" and provides a brief overview of the hydrologic framework for California's water supply. Chapter 2 summarizes hydroclimate conditions associated with historical droughts, reviews drought in the paleoclimate record, and discusses climate change considerations. Chapter 3 covers highlights of the hydrology and impacts experienced in the large historical

droughts, together with brief background on the physical and institutional setting in which they occurred. Chapter 4 compares the historical events to the present, describing changed conditions and comparing impacts; recurring themes observed in past droughts are also discussed.

DROUGHT BACKGROUND AND DEFINING DROUGHT

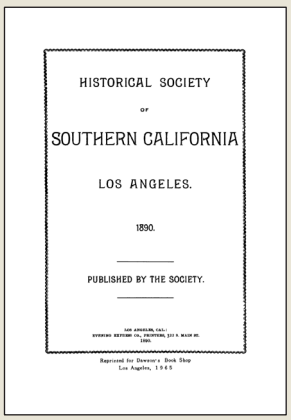
Drought is a recurring feature of California's climate, occurring sometimes on a localized or regional scale and other times on a statewide scale. Early accounts of California droughts include the Great Drought of Water Years 1863–1864, which contributed to the demise of the cattle rancho system, especially in Southern California. An often-quoted description of the impacts of that drought is provided in J.M. Guinn's account of early California floods and droughts (Guinn 1890).

"Drought" can be defined in many ways. Some ways can be quantified, such as meteorological drought (period of below average precipitation) or hydrologic drought (period of below average runoff); others are qualitative in nature (shortage of water for a particular purpose). There is no universal definition of when a drought begins or ends, nor is there a state statutory process for defining or declaring drought (see sidebar). Local water agencies develop criteria for defining drought specific to conditions in their jurisdictions, and urban water suppliers may issue drought watch or drought warning notices to their customers as a way of communicating drought conditions.

Drought is a gradual phenomenon, with slow onset. Impacts of drought are typically noticed first by those most dependent on annual rainfall, such as ranchers relying on dryland grazing or rural residents relying on wells in low-yield rock formations. Drought impacts increase with the length of a drought, as carryover storage in reservoirs is depleted and water levels in groundwater basins decline. Hydrologic impacts of drought to water suppliers may be exacerbated by other factors, such as regulatory requirements to protect environmental resources or to satisfy the rights of senior water right holders.

From a water use perspective, drought is best defined by its impacts to a particular class of water users in a specific location. 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. California's extensive system of water supply infrastructure greatly mitigates the effect of short-term (single year) dry periods to users of managed supplies, although impacts related to unmanaged systems (increased wildfire risk, stress on vegetation and wildlife) remain. A single dry year normally is not considered a drought for managed systems. Impacts of a single dry year are felt most by people who rely on unmanaged water sources, such as ranchers who graze livestock on non-irrigated rangeland.

Individual water suppliers may use criteria such as rainfall/runoff, amount of water in storage, decline in groundwater levels, or expected supply from a water wholesaler to define their water supply conditions. Criteria


HISTORICAL SOCIETY
OF
SOUTHERN CALIFORNIA
LOS ANGELES.
1890.
PUBLISHED BY THE SOCIETY.

The Great Drought of 1863–1864

An excerpt from
Exceptional Years: A History of California Floods and Droughts
J.M. Guinn, 1890

"… 1862–63 did not exceed four inches, and that of 1863–64 was even less. In the fall of 1863 a few showers fell, but not enough to start the grass. No more fell until March. The cattle were dying of starvation…. The loss of cattle was fearful. The plains were strewn with their carcasses. In marshy places and around the cienegas, where there was a vestige of green, the ground was covered with their skeletons, and the traveler for years afterward was often startled by coming suddenly on a veritable Golgotha – a place of skulls – the long horns standing out in defiant attitude, as if protecting the fleshless bones."

Figure 1.1: Location Map

used to identify statewide drought conditions – such as statewide runoff and reservoir storage – cannot address these localized circumstances. California is a large state and its river basins **(FIGURE 1.1)** experience diverse hydrology; Northern California watersheds may experience average to wet precipitation conditions while Southern California watersheds are dry.

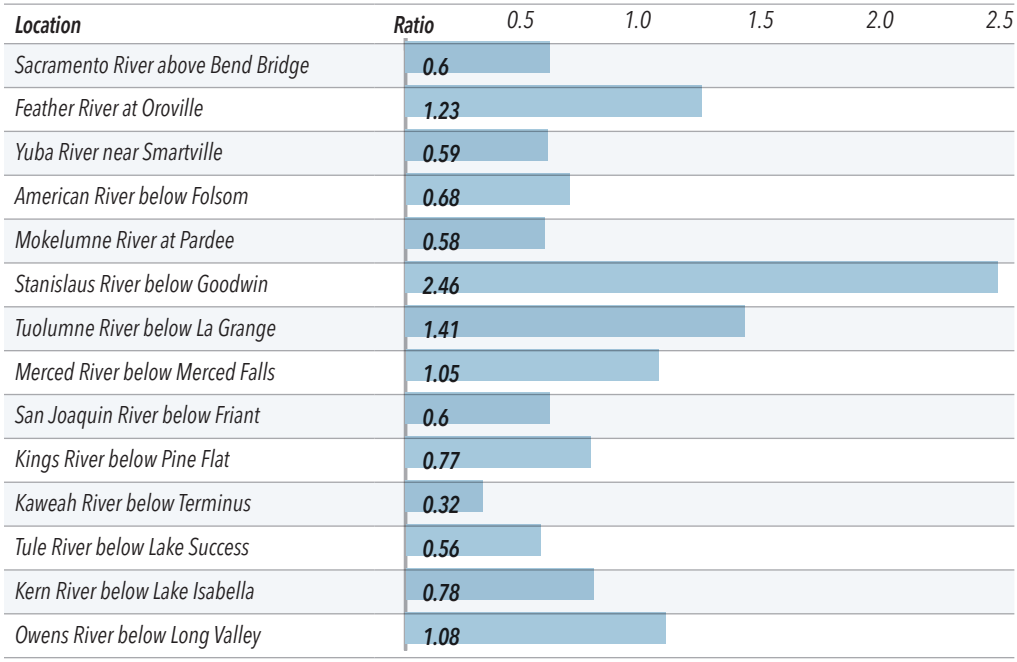
Historically, California statewide droughts have been commonly recognized as consecutive dry years, such as 1987–1992 or 2007–2009. This framing reflects the perspective of managing water on a year-to-year basis as dictated by annual hydrologic conditions. And because total reservoir storage capacity in most of California's major rivers is roughly equal to or less than the rivers' average annual natural flow, management of multi-year quantities of annual runoff is not possible, further reinforcing the focus on single-year hydrology **(FIGURE 1.2)**. In contrast, the 4:1 ratio of total reservoir storage to average annual flow on the Colorado River system allows for a multi-year outlook on reservoir operations and drought conditions.

However, drought also can be defined as aridity over a specified period that includes average or wet years as well as dry ones. Present conditions in the Colorado River Basin are an example, with the period from 2000 through 2018 being the driest 19-year period in the historical record (based on natural flow at Lees Ferry), even though the period included several wet or average years. Because of the river basin's substantial storage capacity, there have been no shortages to the U.S. Bureau of Reclamation's (Reclamation's) water contractors in the Lower Basin. But the significant reduction in system reservoir storage during this period is an impact sufficient enough to consider the period a drought.

The Water Year

Agencies such as DWR and the U.S. Geological Survey report hydrologic data on a water year basis. The water year extends from October 1 through September 30. Water Year 2018, for example, spanned October 1, 2017, through September 30, 2018. The 1987–1992 drought covers Water Years 1987–1992 and corresponds to the calendar year period of fall 1986 through summer 1992. Hydrologic data contained in this report are presented in terms of water years. Water project delivery data (e.g., State Water Project deliveries) are presented on a calendar year basis.

Figure 1.2: Examples of Reservoir Storage to Average Annual Flow Ratio for Selected Watersheds



Ratios illustrate total storage and include reservoirs used for flood risk management or hydroelectric power generation in addition to those that provide water supply.

Tule elk graze on the bottom of the 2 million acre-foot state-federal San Luis Reservoir on August 24, 2016, when the reservoir was at 13 percent of capacity.

DROUGHT BEGINNING AND ENDING

Defining when drought begins and ends is a matter of perspective. Droughts start slowly and most users of managed water supplies do not begin experiencing impacts until well after the onset of dry hydrologic conditions. Some of California's iconic droughts have ended rather abruptly after a significantly wet year, such as in 1993 (for the 1987–1992 drought) or 2017 (for the 2012–2016 event). When dry conditions persist and impacts begin, agencies or public officials may signal the beginning of drought, such as an urban water supplier calling for stage one water use restrictions or the Governor issuing an executive order. As described below, continued impacts of dry conditions may trigger the proclamation of a local or state emergency.

Defining when drought ends is often more obvious and is based on the moderation of impacts to water users. A local agency, for example, may define drought ending as when its reservoir is full or it has a full supply from a water wholesaler. A rancher may define drought ending as having enough precipitation to adequately support livestock grazing. Recovery from some drought impacts, such as declines in groundwater storage, can take multiple years.

Hindsight and a long-term perspective are useful in characterizing the relative aridity of longer-term dry periods. For example, the decade prior to a wet 2017 included the droughts of 2007–2009 and 2012–2016, with only two years that were not dry years (2010–2011). Given a dry 2018 and no ability to predict the outcome of future water years, 2017 might be viewed as either a wet outlier in an otherwise prolonged series of dry years, or as the wet year that ended a drought. This characterization can be determined only in hindsight.

DROUGHT AND DROUGHT EMERGENCY

Proclamations of statewide emergency in response to drought were issued pursuant to the California Emergency Services Act during the 2007–2009 and 2012–2106 droughts. It is important to distinguish between drought conditions and a state of emergency. The former is a condition of prolonged dryness that has resulted in impacts; the latter is a statutory finding that enables specified response actions. The California Emergency Services Act, Government Code Section 8550 et seq., establishes how conditions of emergency are declared and describes the authorities of public agencies to prepare for and respond to emergencies.

A state of emergency may be proclaimed pursuant to the act by the Governor or by a city or county. The governing body of a city or county proclaims a local emergency when the conditions of disaster or extreme peril exist. The proclamation enables the city or county to use emergency funds, resources, and powers, and to promulgate emergency orders and regulations. A local proclamation is normally a prerequisite to requesting a gubernatorial proclamation of emergency. The Director of the Office of Emergency Services (Cal OES) may issue a letter of concurrence to a city or county declaration of local emergency. Cal OES concurrence makes financial assistance available for repair or restoration of damaged public property pursuant to the California Disaster Assistance Act. **FIGURE 1.3** compares county-level proclamations of emergency issued in the driest year (based on statewide runoff) of the most recent of California droughts.

The Governor proclaims a state of emergency when local resources are insufficient to control the disaster or emergency, typically in response to a local proclamation of

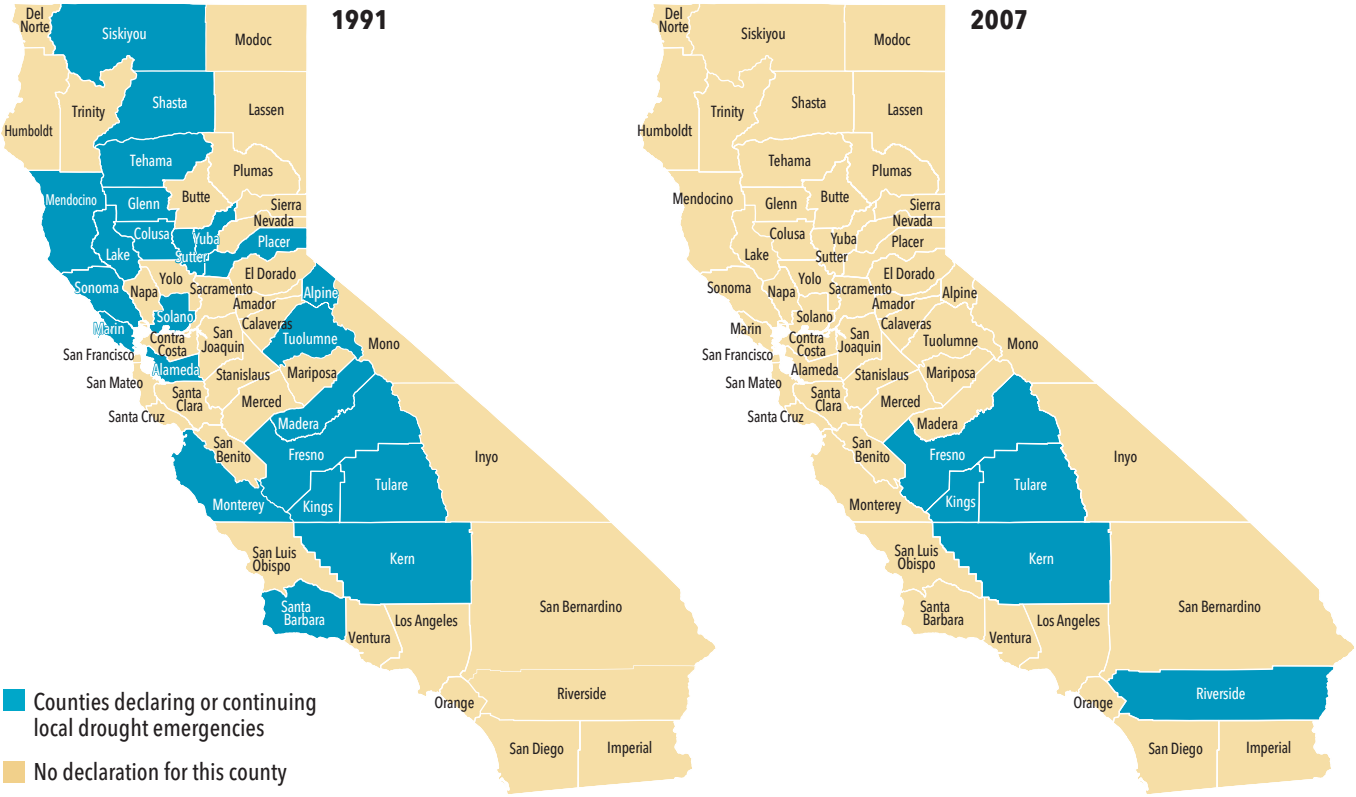
emergency. The Governor's proclamation makes mutual aid from other cities and counties and state agencies mandatory, permits suspension of state statutes or regulations, allows for state reimbursement (on a matching basis) of city and county response costs associated with the emergency, and allows property tax relief for damaged private property.

In addition to broad emergency powers provided under the Emergency Services Act, local water agencies have authority to ban new connections and manage water demands under emergency or shortage conditions. California Water Code (Water Code) Section 350 et seq. define the condition of a water shortage emergency, providing that the governing body of a public water supply (whether publicly or privately owned) may declare a water

Agricultural Disaster Designations

The U.S. Department of Agriculture's (USDA's) Farm Services Agency administers financial assistance programs to help farmers and ranchers recover from losses caused by drought, floods, other natural disasters, and quarantines. To be eligible for some programs, applicants' operations must be in a county declared by the President or designated by the Secretary of Agriculture as a disaster area. Criteria for a secretarial designation include a finding that a minimum 30 percent production loss of at least one crop has occurred in the designated county. USDA streamlined its drought disaster designation process in response to widespread Midwestern drought in 2012 to make listing nearly automatic once a county had been classified by the U.S. Drought Monitor as being in severe drought for eight consecutive weeks. This brief qualifying period reflects the importance of seasonal rainfall to activities such as livestock grazing on non-irrigated rangeland, and USDA's intent to provide rapid financial assistance.

Figure 1.3: Comparison of Counties with Emergency Proclamations



Data credit: California Office of Emergency Services

shortage emergency condition in its service area whenever it determines that *the ordinary demands and requirements of water consumers cannot be satisfied without depleting the water supply of the distributor to the extent that there would be insufficient water for human consumption, sanitation, and fire protection.* This declaration allows the water supplier to stretch its supplies by adopting regulations covering measures such as mandatory rationing or connection bans. Further, Water Code Section 71640 et seq. provide authority for water agencies to restrict the usage of water during drought or water shortages.

Special districts 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. Additionally, the State Water Resources Control Board (SWRCB) has the authority to impose terms and conditions on permits for public water systems to assure that sufficient water is available, including the authority to require a supplier to continue a moratorium on new connections adopted pursuant to Water Code Section 350 et seq.

DROUGHT PREDICTION AND FREQUENCY

Summer in California, a predictably dry period, lasting approximately half the year (characteristic of Mediterranean climates), would be considered a short-term drought in other states where year-round precipitation is the norm. As discussed in Chapter 2, the present scientific skill for forecasting California's winter precipitation, the key element to predicting drought, is minimal beyond the two-week time horizon of an operational weather forecast. Although the National Weather Service's Climate Prediction Center produces operational outlooks for precipitation on a national scale at lead times up to a year, the outlooks have historically shown little skill for California's winter precipitation. Improving the skill of this longer-term precipitation forecasting, known as sub-seasonal to seasonal (S2S) forecasting, remains a challenging science problem **(FIGURE 1.4)**. The Weather Research and Forecasting Innovation Act of 2017 directed the National Oceanic and Atmospheric Administration (NOAA) to begin producing operational weather forecasts at three- to four-week lead times for temperature and precipitation, marking a new step toward improving forecast skill at the longer lead times needed for drought preparedness and response. As discussed in Chapter 4, the California Department of Water Resources (DWR) is pursuing efforts to improve longer-term precipitation forecasting skill for California.

The paleoclimate record provides a tool for qualitatively or quantitatively assessing drought risk based on understanding drought duration and magnitude prior to California's relatively short period of measured record. Reconstructions of streamflow and precipitation for selected watersheds from dendrochronology data are presented in Chapter 2. These reconstructed records allow quantification

of key metrics (such as the number of droughts of specified duration over a period of many centuries) helping water agencies understand the costs and trade-offs between reliability and shortage risk. Previous state law for urban water management planning required specified water suppliers to plan for three-year droughts; Executive Order B-37-16 directed DWR to improve local drought resiliency by extending that length to a five-year drought duration, a requirement subsequently codified in 2018. California's longest drought in relatively recent times was the six-year event of 1987–1992, and the paleo record provides examples of longer past events as shown in **FIGURE 1.5.**

DROUGHT VULNERABILITY AND RESILIENCE

Drought reduces water supply reliability, potentially redefining areas that have had adequate water supplies under normal hydrologic conditions as areas of shortage under dry hydrology. The ability of water users to reduce the risk of shortage, or to minimize impacts if a shortage occurs, depends on the value of water to them and their willingness and ability to invest in a desired level of reliability. Two neighboring communities may be equally vulnerable to drought in terms of their hydrologic setting, but may differ in their resilience to drought depending on investments made to reduce vulnerability. Large urban areas typically demand a

Drought Frequency Analysis

The concept of flood frequency analysis (e.g., a 100-year flood) is a familiar one to hydrologists, having been widely used and having gained name recognition among the public as well, thanks to the National Flood Insurance Program. In contrast, the concept of drought frequency analysis is poorly understood and often misapplied.

Frequency analysis is a risk management tool for estimating the probability of an event that would have adverse consequences. In the case of floods, statistical analyses are used to develop a relationship between flood size and the annual probability of exceedance based on a record of historically observed floods. The results can then be used to balance the costs and risks of decisions such as sizing local stormwater infrastructure or delineating floodplains for land use planning.

Using a statistical flood frequency analysis requires satisfying certain assumptions, including ensuring that the data sample (the historical record) is representative of the population, that annual peak flows are independent of each other and occur randomly, and that peak flows are identically distributed, including over time. (This is the assumption of stationarity.) Today's commonly used flood frequency analysis technique dates to a 1966 congressional mandate in House Document 465, *A Unified National Program for Managing Flood Losses*, that called for creation of a panel under the federal Water Resources Council established pursuant to 42 U.S.C. Section 1962 to develop a standardized set of techniques for analysis. A standardized process using a specified probability distribution (log Pearson Type III) was subsequently published in 1976 as Bulletin No. 17, *Guidelines for Determining Flood Flow Frequency*, and later updated as Bulletin 17B in 1981. A limited update in the form of Bulletin 17C was published in 2018.

Nothing similar to this extensive framework for flood frequency analysis exists for drought. One inherent challenge is that floods are easily defined (an annual peak flow), but numerous possible ways exist to define and measure drought, as discussed earlier. Statistical assumptions used for flood frequency determination – for example, that individual years are hydrologically independent – do not necessarily hold true for long-duration events like drought. There is no generally accepted frequency distribution for use in drought frequency analysis, and the many advances in statistical methodologies and computing capacity since the adoption of Bulletin 17B make it unlikely that a log Pearson Type III distribution would be a default choice. Because the droughts of interest for water management are multi-year events, use of a long-term (i.e., paleo) record is needed to have a sample size that is meaningful for statistical analysis, and the assumption of stationarity becomes problematic. Observed warming seen in the historical record points to the need to consider nonstationarity.

Any representation that a particular drought or dry period is a 100-year event or 500-year event should be viewed with caution for the reasons described above. Unless and until a standardized protocol is developed and formally adopted, the concept of drought frequency analysis is an ambiguous one.

Figure 1.4: Historical Skill of NOAA Precipitation Outlooks

Seasonal (Lead 0.5 months) Precipitation Heidke Skill Score DJF Manual Forecasts from 1995 to 2019

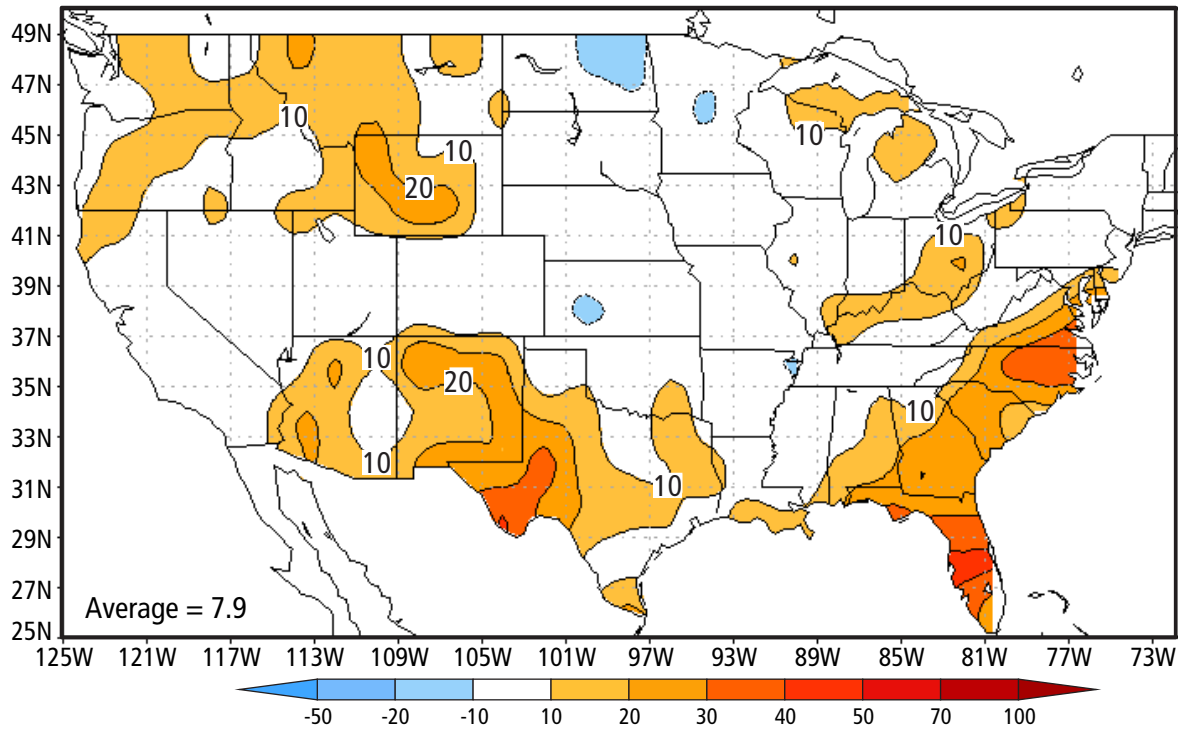


Figure credit: NOAA Climate Prediction Center

Figure 1.5: Drought Duration Based on Precipitation Reconstruction at San Gabriel Dam

Drought duration based on number of consecutive years below the historical mean precipitation at the San Gabriel Dam gauge. The historical record is based on measurements from 1900 to 2015 and the reconstructed record based on tree-ring data is from 1126 to 1899.

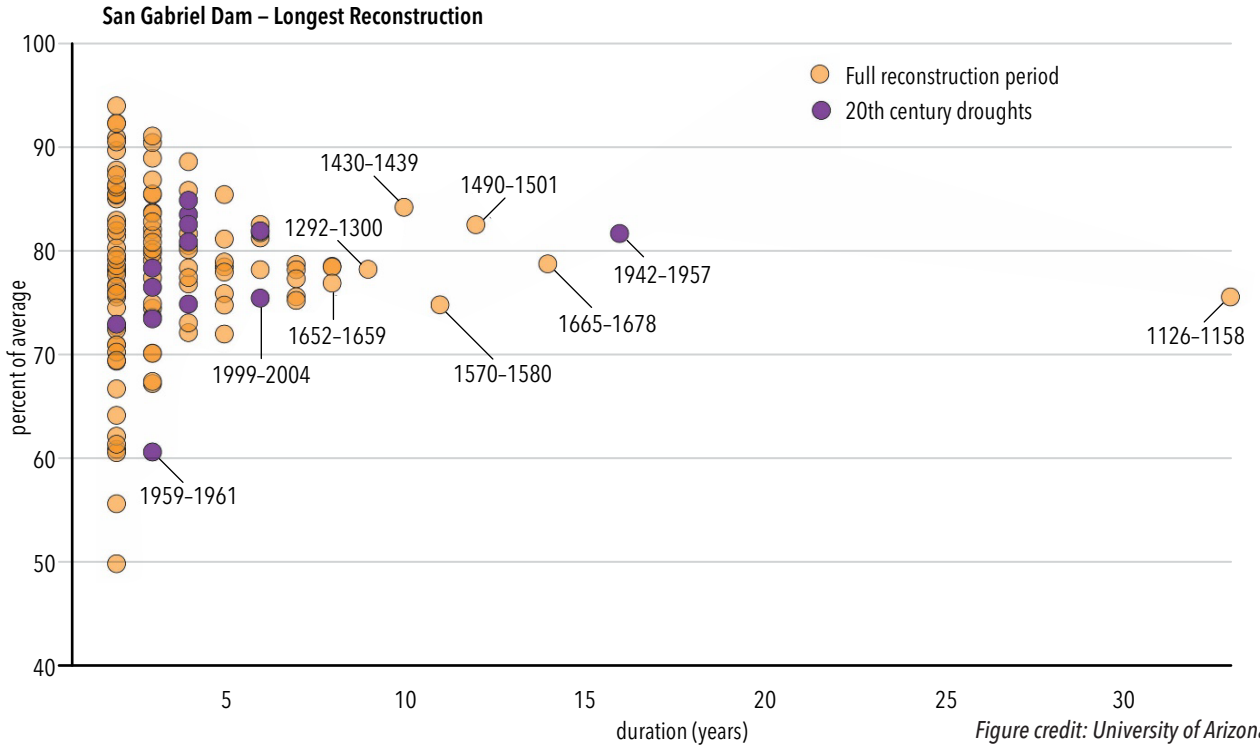


Figure credit: University of Arizona

high level of reliability and have the financial capability to ensure it. For farming businesses served by agricultural water agencies, it is typically not financially feasible to make the same level of investment in reliability as is done by urban agencies, and customers of agricultural agencies thus typically must expect a greater risk of shortage.

Vulnerability to shortage can change over time because of factors such as increasing population or changing cropping patterns in a water agency's service area, or reallocation of historically available water supplies for other purposes. Climate nonstationarity adds additional uncertainty. If increased vulnerability is not remediated through investments in improving reliability, then drought impacts can be expected to worsen. As illustrated in the sidebar, the concept of what constitutes normal or average water supplies is not necessarily static.

An example of changing drought vulnerability over time occurred during the 2012–2016 drought when numerous private residential wells were going dry in parts of Tulare County. Small water systems and residences on private wells in rural areas typically have a higher vulnerability to drought than do large urban water systems, because the large ratepayer base of urban systems permits investments in water source diversification and water supply reliability. In the Tulare County example, vulnerability was significantly increased when Reclamation made zero deliveries of irrigation supplies to its Friant Division in 2014 and 2015 – the first time in roughly 60 years that no imported supplies were brought into the service area. Without the incidental shallow groundwater recharge provided by imported irrigation deliveries and with growers deepening their wells to compensate for lack of surface water supplies, the impacts of below-average precipitation were exacerbated and many older shallow residential wells went dry.

CALIFORNIA'S MOST SIGNIFICANT HISTORICAL DROUGHTS

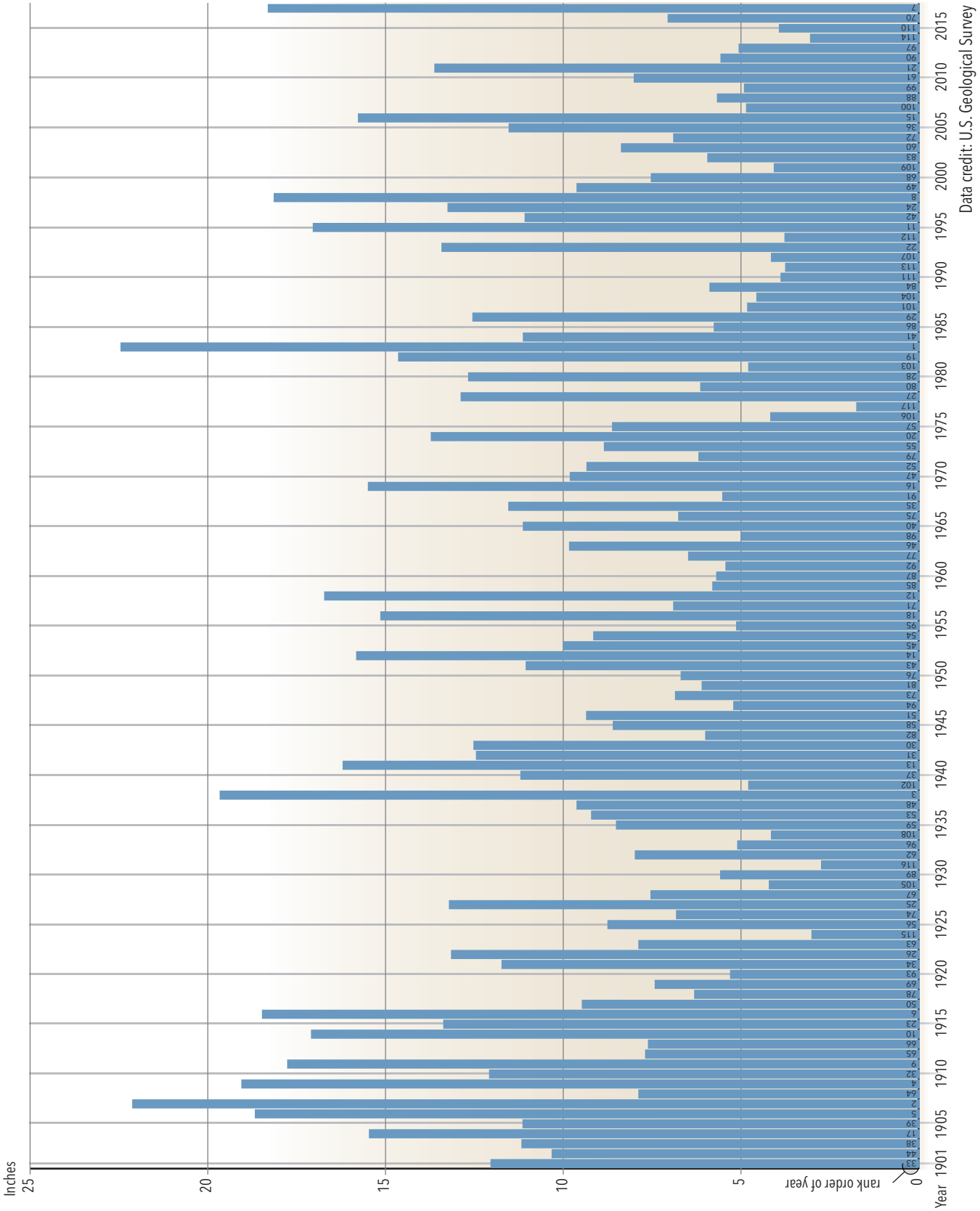
This report focuses on California's most significant statewide droughts in the historical record, because data are available to quantify drought hydrology and impacts, and that information can provide valuable lessons about drought vulnerability and resilience. It should be noted that there have been additional droughts of smaller spatial scale having more severe hydrologic characteristics at a localized level, but covering those regional events is beyond the scope of this report. **FIGURE 1.6** shows California's calculated historical statewide runoff, which is one metric for illustrating dry conditions at a statewide scale. This figure also well illustrates the high annual variability in California hydrology, discussed in more detail in Chapter 2.

State-Level Drought Definition

Most Western states, California included, do not have a state statutory definition or process for defining or declaring drought. The State of Washington is an exception; it defines a drought condition as when water supply for an area is below 75 percent of normal and the water shortage is likely to create undue hardships for various water uses and users (Revised Code of Washington chapter 43.83B.400).

During the 1987–1992 drought, DWR used statewide runoff and reservoir storage as general guidelines for identifying drought conditions, considering a drought threshold to be runoff for a single year or multiple years to be in the lowest 10 percent of the historical range and statewide reservoir storage during the same period at less than 70 percent of average. (These criteria were inherently biased toward depicting water supply conditions in the wetter northern part of the state, and would not necessarily be reflective of local conditions in Southern California.) No formal criteria were used in deciding to issue the 2009 statewide drought emergency proclamation; the driving factors cited in the proclamation were impacts of dry hydrology and cutbacks in State Water Project (SWP) and Central Valley Project (CVP) allocations resulting from changed Endangered Species Act compliance requirements. The 2014 statewide emergency drought proclamation was triggered by cumulative impacts of multiple dry year years and record or near-record low precipitation at the start of what would become a third consecutive dry year.

Figure 1.6: Calculated Statewide Runoff



The 1929–1934 drought occurred in a climatic context that included severe drought conditions over much of the western United States, including the Great Plains region affected by the Dust Bowl drought. As discussed in Chapter 2 and shown on **FIGURE 1.6**, the 1920s–1930s were a period of relative overall dryness (significantly dry years interspersed with some wetter ones) that rivaled similar extreme events in the paleoclimate record. California's level of development then was so different from today's conditions that this event cannot be compared to modern droughts in terms of impacts, but a repeat of this historical hydrology today would constitute a major water management challenge. This notable aridity of the 1920s–1930s was followed by several decades of relatively wetter conditions statewide, although droughts with a primarily regional focus (such as the 1959–1961 drought in Southern California) occurred.

Coming after this long period of relative quiescence with respect to water shortages, the 1976–1977 drought caught many water users by surprise and stands out for the widespread impacts experienced in only a two-year event. The drought began with a very dry 1976 that provided the antecedent conditions to help 1977 rank as the driest year of statewide runoff. Today's water conservation programs trace their origins back to this event, when local water suppliers who were unprepared for major reductions in their supplies rapidly implemented conservation actions as a coping strategy.

The 1987–1992 drought was characterized by the six-year duration of dry conditions, the longest significantly dry period since the 1920s–1930s. This event is an important benchmark for gauging drought impacts under a relatively modern level of development; California's population at the time was close to 80 percent of present levels, and there have been few changes in major surface water infrastructure since then. The extended dry conditions resulted in enactment of numerous California Water Code provisions relating to water conservation and water transfers; it is fair to say that the 1987–1992 drought signaled the beginning of widespread development of voluntary water transfer arrangements.

The three-year 2007–2009 drought featured markedly

Shortage or Normal?

Impacts of hydrologic drought can be measured in a variety of ways, but the metric of supplies available to CVP or SWP contractors is not a direct indicator of hydrologic conditions, as discussed in Chapter 4. CVP south-of-Delta agricultural contractors received 100 percent of their contracted supply amounts in only four years during the 26-year period from 1990 through 2017, and 75 percent or better in only nine of those years. Prior to 1990, these contractors received full supplies in all years except 1977. SWP urban and agricultural contractors received 100 percent of their requested Table A contractual amounts in only six years from 1990 through 2017. As with the CVP, SWP urban and agricultural contractors received full requested deliveries in all years prior to 1990, excepting 1977. Annual variability in project allocation and long-term trends in allocations reflect factors in addition to hydrology, including changes in service area demands over time and changes in environmental regulatory conditions.

For Further Information on Historical Droughts

Detailed information about California's historical droughts is available in DWR reports documenting the hydrology, impacts, and response actions associated with these events. The reports listed below are at the California State Library, Government Publications Section.

- *The California Drought – 1976.* May 1976
- *The California Drought 1977, An Update.* February 1977
- *The Continuing California Drought.* August 1977
- *The 1976–77 California Drought – A Review.* May 1978
- *California's 1987–92 Drought, A Summary of Six Years of Drought.* July 1993
- *Preparing for California' s Next Drought, Changes Since 1987–92.* July 2000
- *California's Drought of 2007–2009, An Overview.* November 2010

different institutional conditions than those in place during the state's earlier droughts and was the first instance in which a statewide emergency proclamation was issued for drought. Surplus Colorado River water was no longer available to California to help mitigate shortages in intrastate water supplies. Restrictions in CVP and SWP diversions from the Sacramento-San Joaquin Delta (Delta) to protect listed fish species were a regulatory circumstance that exacerbated the impacts of hydrologic drought, and served as a trigger for the drought emergency proclamation.

The five-year event of 2012–2016 set new hydroclimate records – driest four consecutive years of statewide precipitation, record low statewide snowpack, and record low groundwater levels in many areas – as well as marking the first-ever instance of zero deliveries to CVP agricultural contractors in the San Joaquin Valley. Satellite imagery revealed for the first time the broad scope of damaging land subsidence occurring throughout the San Joaquin Valley in response to drought-induced groundwater extraction. The dry hydrology necessitated response actions not seen since the 1976–1977 drought, such as installation of a temporary emergency salinity control barrier in the Delta and water rights curtailments on the state's largest rivers. This event marked the second time a statewide emergency proclamation was issued for drought.

The iconic Dust Bowl drought is typically associated with the Midwest, as shown in this 1938 photograph by Dorothea Lange, but much of the western U.S., including California, experienced drought during this time. California's overall dry cycle throughout the 1920s–1930s was on a par with the driest periods in a millennium, but its impacts were of less consequence because of the state's relatively low level of development at that time. Photo credit: Oakland Museum

CALIFORNIA WATER SUPPLY, AN OVERVIEW

California's proximity to the Pacific Ocean and major mountain ranges defines the state's hydroclimate setting. Most of the water vapor that provides the state's precipitation comes from the Pacific Ocean; as moist air moves over mountain ranges, like the Sierra Nevada or Transverse Ranges, the air is lifted and cooled, resulting in condensation and rain or snow. Snowpack in the Cascade Range and Sierra Nevada contributes to the runoff in the state's largest rivers and to the groundwater basin recharge that supports much of California's urban and agricultural water use.

Much of California experiences a Mediterranean climate with dry summers that are warm or hot, and wet winters that are cool or cold. Westerly winds transport water vapor that provides winter precipitation; summers are characterized by a blocking high-pressure zone that diverts atmospheric moisture away from the state. On average, approximately 75 percent of the state's average annual precipitation of nearly 22 inches falls between November and March, with about half that amount occurring between December and February. The state's annual water budget is typically determined by five to seven large storms (Dettinger et al. 2011). A shortfall of a few major winter storms results in a dry year; conversely, a few very wet storms leads to a wet year. The immediate cause of California's more severe droughts of statewide scale is a persistent Pacific high-pressure zone during the winter's normally wettest months.

Atmospheric rivers (concentrated streams of water vapor crossing the Pacific) can deliver large amounts of precipitation, especially as they rise over California's

mountains. NOAA's Hydrometeorology Testbed program and DWR's Enhanced Flood Response and Emergency Preparedness program have collaborated for more than a decade in installation and operation of an observing system for extreme precipitation designed to track atmospheric river storms, and in related research. Among the findings of the research is that atmospheric rivers are estimated to contribute approximately 40 percent of California's annual precipitation (Dettinger et al. 2013) **(FIGURE 1.7)**. California experiences high annual variability in precipitation, as illustrated by **FIGURE 1.8.** Much of this variability is determined by a relatively small number of storms that make up the state's water budget.

As illustrated in **FIGURE 1.9**, Northern California experiences more precipitation and runoff than Southern California. The imbalance between surface water supplies and the location of major population centers and agricultural production areas has been central to the history of water development in California, leading to development of major federal, state, and local water projects **(FIGURE 1.10)**. The state's two largest rivers, in terms of average annual runoff, are the Sacramento and the Klamath, respectively, reflecting their sizable drainage areas and locations in the water-rich part of the state. The Eel River is the next-largest in Northern California; south of the Delta, only the San Joaquin River is of comparable size to the Eel. The Sacramento and San Joaquin River watersheds supply (either directly as surface water or indirectly via groundwater recharge) much of the water used by California cities and farms. **FIGURES 1.11** and **1.12** show the variability of estimated annual unimpaired runoff in the Sacramento and San Joaquin River basins. The hydrology of these basins is often used as a benchmark for Northern California water year conditions because of their importance to California's developed water supplies.

Winter snowpack in the Sierra Nevada and Cascade Range is an important component of California's hydrology, and on a long-term average basis has been equivalent to

Sign in a Modesto almond orchard in 2014. The exceptionally dry December and January of Water Year 2014, when some Northern California communities went more than 50 days without measurable precipitation in what should have been the wettest part of the winter, spurred issuance of a statewide emergency proclamation due to drought. Photo credit: Debbie Noda/Modesto Bee/ZUMA Press

Figure 1.7: Contribution of Atmospheric Rivers to California Precipitation

Contributions to total precipitation of precipitation on days when atmospheric rivers made landfall on the California coast (or day after, to allow for differences between Coordinated Universal Time reporting of satellite data and local reporting of cooperative time series) at NWS cooperative weather stations, with atmospheric river days between October 1997 and September 2006.

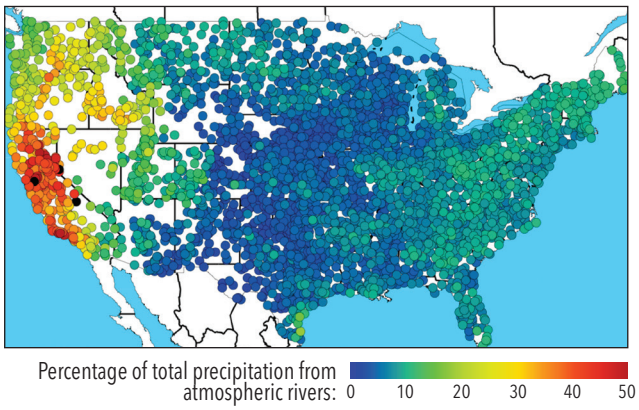


Figure credit: Mike Dettinger, U.S. Geological Survey

Figure 1.8: Comparative Variability of California Precipitation

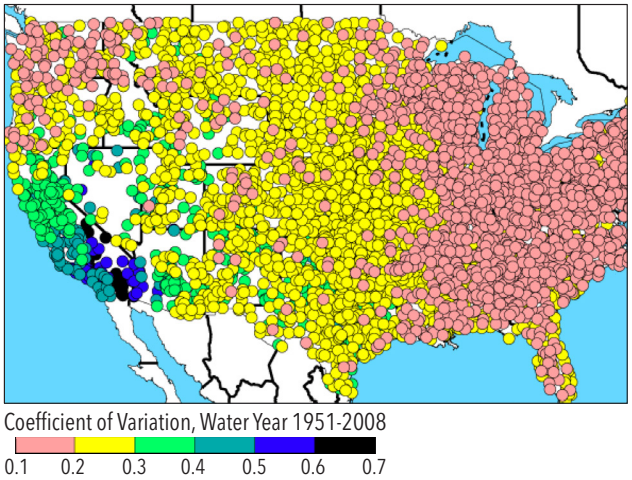
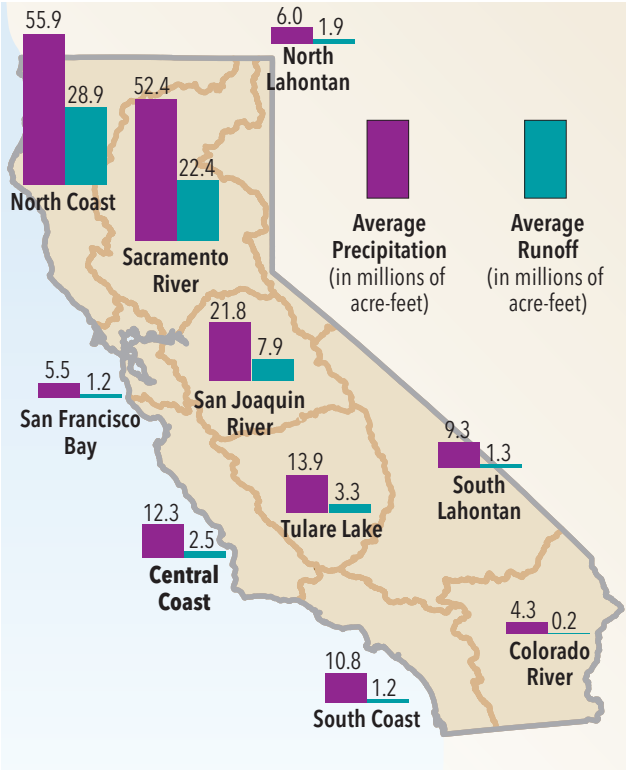


Figure credit: Mike Dettinger, U.S. Geological Survey

Figure 1.9: Average Annual Precipitation and Runoff by Hydrologic Region



El Capitan in Yosemite National Park in February 2014, with remarkably little snow cover.

approximately one-third of the statewide reservoir storage capacity, sometimes referred to as California's frozen reservoir. The large reservoirs along the Central Valley's rim were designed based on historical hydrology that considered the winter water storage provided in the mountains' frozen reservoir. This approach allows the reservoirs to provide downstream flood protection during the wet season and use spring snowpack runoff to support much of the water deliveries made to cities and farms.

In terms of the physical setting of Valley watersheds, 95 percent of the Sacramento River Basin's major watersheds (upper Sacramento, Feather, Yuba, and American) is below 7,500 feet in elevation, while 50 percent of the area of the San Joaquin River Basin's major watersheds (upper San Joaquin, Stanislaus, Merced, Tuolumne) is above 7,000 feet (FIGURE 1.13). Thus, the San Joaquin Basin can be characterized as a snowmelt-dominated basin, while the Sacramento Basin has a mixed rain-snow regime influenced by the characteristics of individual storms. A notable hydrologic aspect of the 2012–2016 drought was low statewide snowpack, with 2015 experiencing a record low of 5 percent of average April 1 statewide snowpack water content, and 2014 tying with 1977 for second place at 25 percent of average.

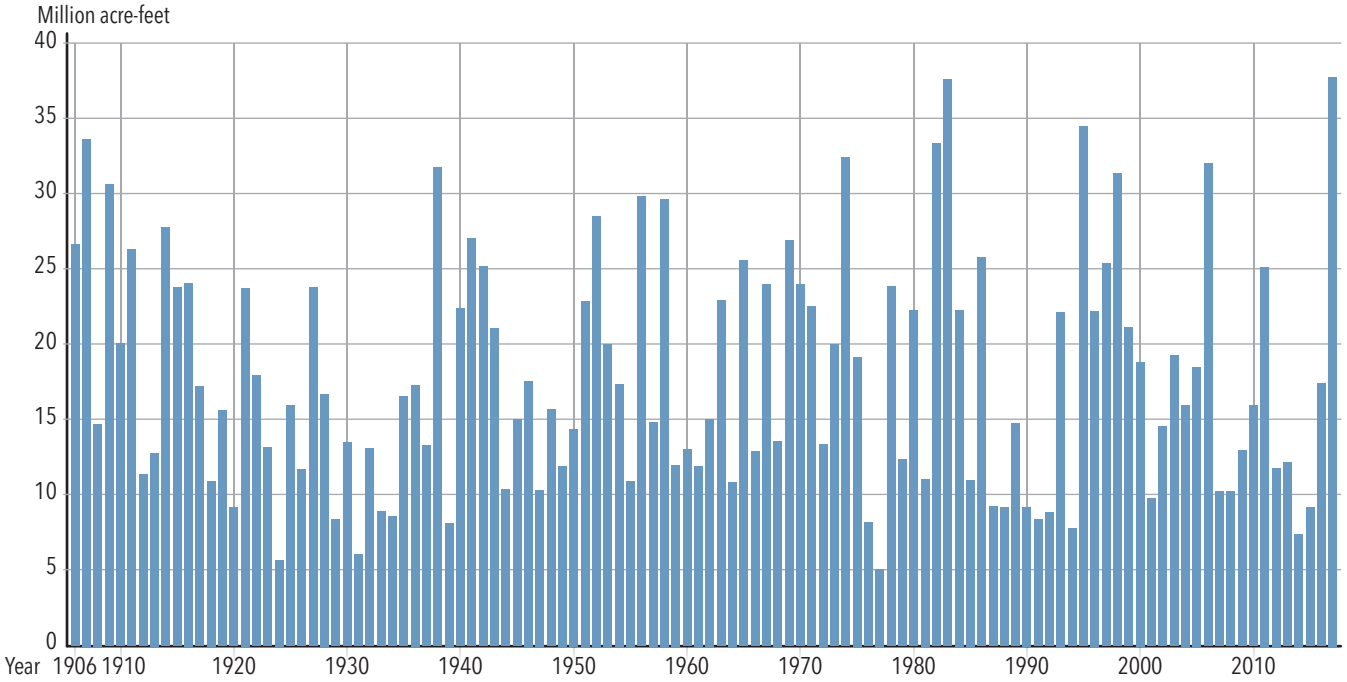
IMPORTED SURFACE WATER – THE COLORADO RIVER

Imported surface supplies make up only a small part of the state's water budget. The Colorado River is by far the largest source of imported surface water for California. The state has consistently received its basic interstate apportionment of 4.4 million acre-feet (maf) of consumptive use annually, and until 2003, was also able to receive additional water from hydrologic surpluses or from the unused apportionments of Nevada and Arizona. The Colorado River has been the most reliable of the three major sources of imported water used by urban Southern California, thanks to the ample storage capacity in the reservoir system.

Although persistent drought since 2000 has affected the Colorado River Basin, the river's substantial reservoir storage

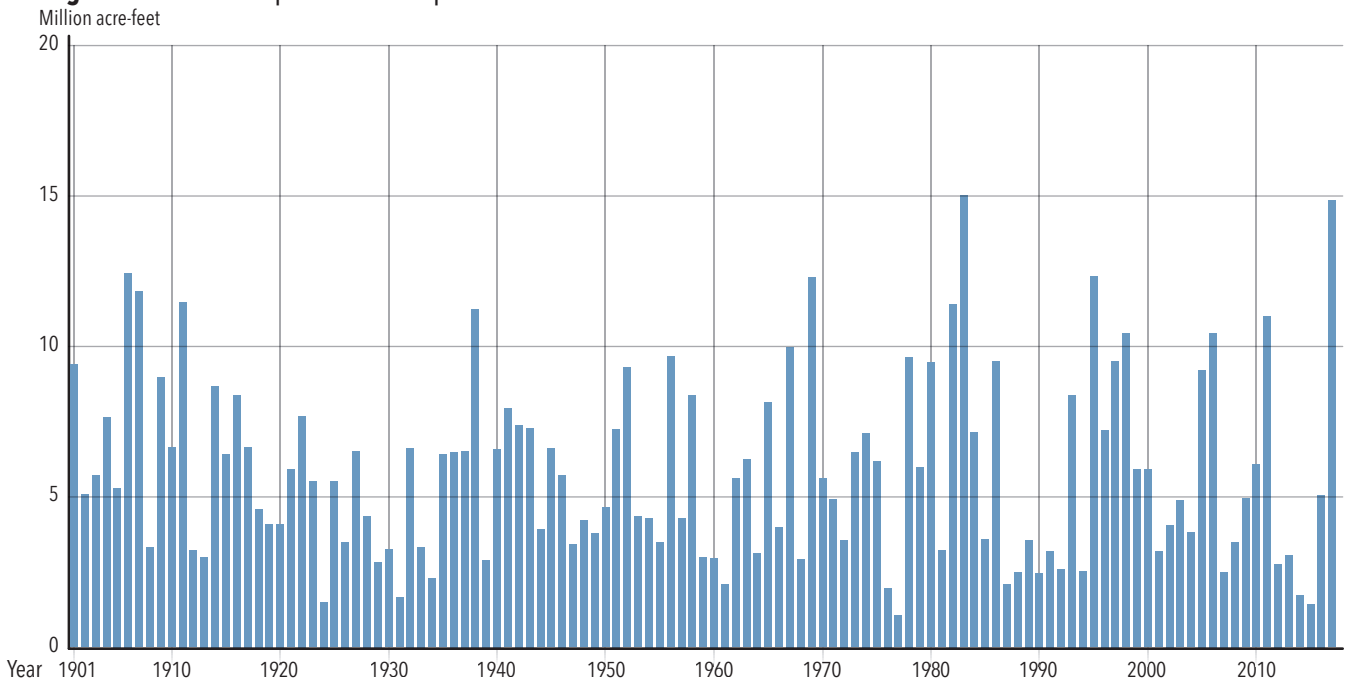
Figure 1.10: California Water Projects

Figure 1.11: Sacramento River Unimpaired Runoff



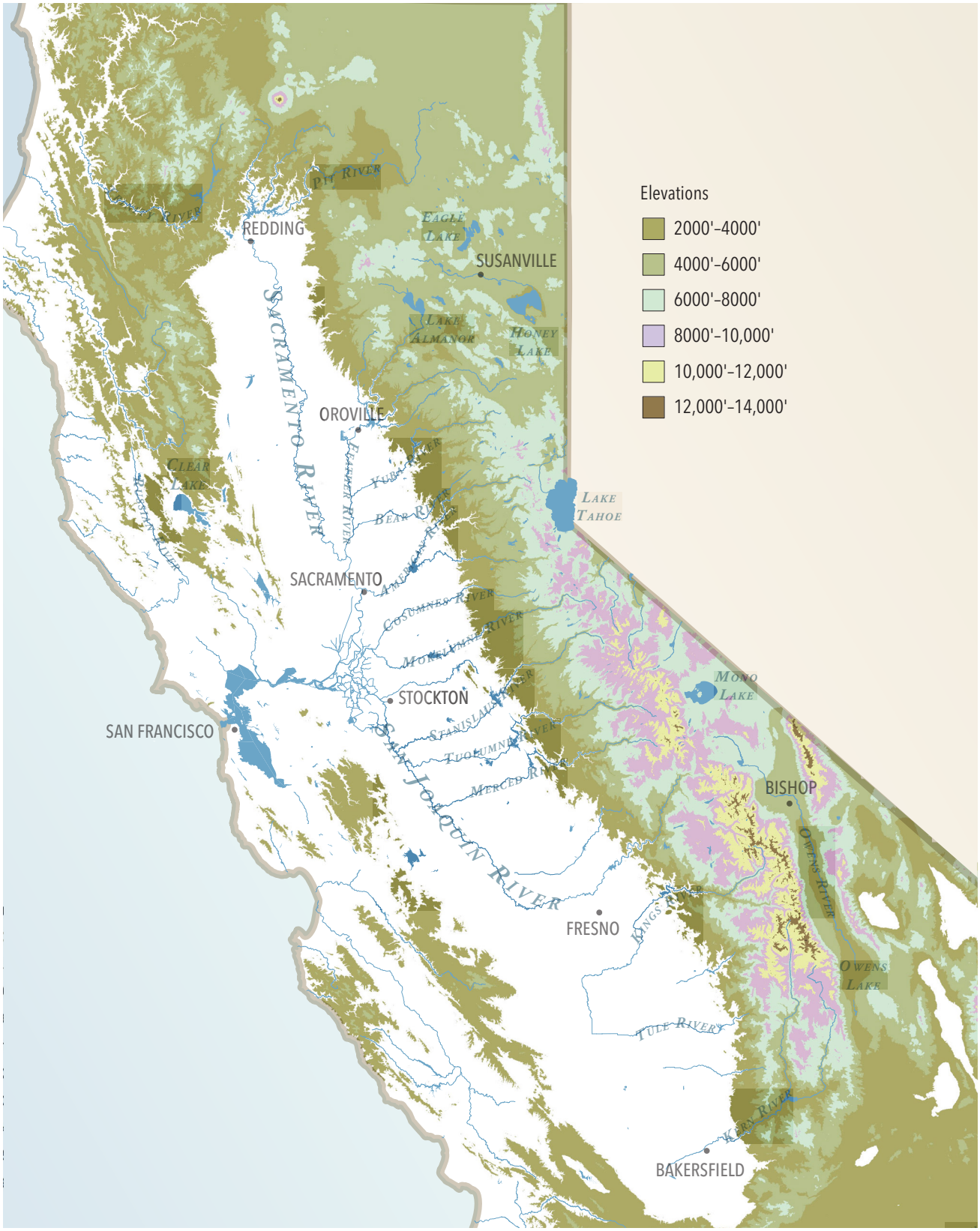
Sacramento River Runoff is the sum of Sacramento River flow at Bend Bridge, Feather River inflow to Lake Oroville, Yuba River flow at Smartville, and American River inflow to Folsom Lake.

Figure 1.12: San Joaquin River Unimpaired Runoff



San Joaquin River Runoff is the sum of Stanislaus River inflow to New Melones Lake, Tuolumne River inflow to New Don Pedro Reservoir, Merced River inflow to Lake McClure, and San Joaquin River inflow to Millerton Lake.

Figure 1.13: Central Valley Watershed Elevations



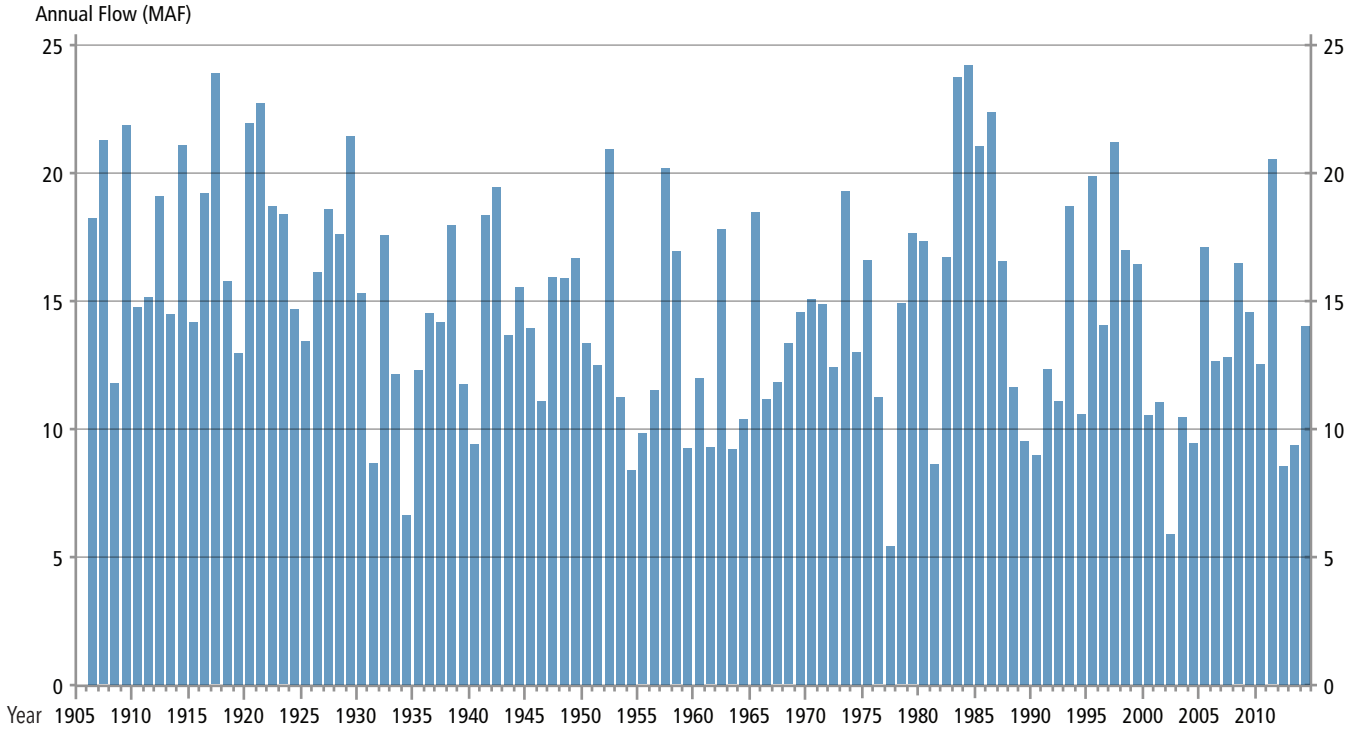
capacity has permitted full deliveries to the Lower Basin states (Arizona, California, and Nevada). The period from 2000 through 2018 was the driest 19-year period in the historical record based on natural flow at Lees Ferry (inflow to Lake Powell). **FIGURE 1.14** illustrates the historical variability of river flow. During the present prolonged dry conditions, total reservoir system storage has dropped to about half of capacity and has been continuing to fluctuate at around that level.

Present operations of Lake Mead and Lake Powell are based on Reclamation interim guidelines for Lower Basin shortages and coordinated operations of Lakes Mead and Powell adopted in 2007, and are in effect for operations in calendar years 2008–2025. The guidelines contain provisions for triggering a Lower Basin shortage declaration based on Lake Mead elevations; when the guidelines were negotiated, the prospect of hitting the trigger elevations seemed relatively remote. Subsequent continued dryness in the basin has increased the likelihood of triggering a first-ever shortage in the Lower Basin, and Reclamation's Lower Basin water contractors have been taking actions to avert or to prepare for shortage. These efforts include a program of extraordinary conservation measures to keep more water in Lake Mead to lessen the risk of hitting a shortage trigger elevation. Additionally, both the Upper Basin and Lower Basin have adopted drought contingency plans to address shortages more severe than those that had been expected in the interim guidelines.

GROUNDWATER

Under average hydrologic conditions, close to 40 percent of California's urban and agricultural water needs are supplied by groundwater. During dry years, however, that percentage increases when water users with reduced surface supplies turn to groundwater to help mitigate shortages. **FIGURE 1.15** shows the state's designated groundwater basins, the alluvial basins that support most of California's groundwater development. An estimated 90 percent of groundwater used in California is extracted from only 127 of these basins (California Department of Water Resources 2014). **FIGURE 1.16** provides historical background on groundwater use by sector, and **FIGURE 1.17**

Figure 1.14: Colorado River Unimpaired Flow at Lees Ferry
Provisional data through 2015, subject to change; estimated values for 2011–2014.



Data credit: U.S. Bureau of Reclamation

Figure 1.15: California Groundwater Basins

illustrates relative reliance on groundwater at a regional level. Private residential wells are the most numerous type of well in California **(FIGURE 1.18)**, although they account for only a small fraction of groundwater extraction in the state.

Although large alluvial basins support most of California's groundwater use on a volumetric basis, groundwater extracted from fractured bedrock (fractured rock groundwater) is the sole source of supply for many small water systems and private well owners in foothill and mountain areas. Generally speaking, fractured rock groundwater systems store far less water than do alluvial basins and are markedly dependent on annual precipitation for recharge. Yield of wells drilled in fractured rock can vary greatly over short distances because of highly site-specific geologic conditions, and are typically much less than those from wells drilled in alluvial deposits. **FIGURE 1.19** shows how local conditions affect wells drilled in fractured bedrock.

The amount of water stored in California's aquifers is far greater than that stored in the state's surface water reservoirs, although only a fraction of that groundwater can be economically and sustainably extracted for use. Sustainable groundwater basin management entails avoiding impacts of excessive pumping, such as land subsidence or migration of poor quality water, as will be required through long-term implementation of the Sustainable Groundwater Management Act (SGMA) of 2014. Groundwater usability may be additionally constrained by pumpers' water quality requirements, as in the case of small water systems or private residential well owners who are unable to afford treatment costs for sources having constituents that exceed drinking

Construction of Southern Nevada Water Authority's (SNWA's) third intake at Lake Mead. The new intake structure is being floated into position via barge to be lowered to connect to a 3-mile, 20-foot-diameter tunnel under Lake Mead. The $817 million intake was put into service in 2015 to allow SNWA to ensure water supplies for its customers if lake elevations drop below the level of an existing upper intake. The intake will also help address water quality issues associated with declining lake levels. Photo credit: SNWA

Figure 1.16: Historical Groundwater Use by Sector

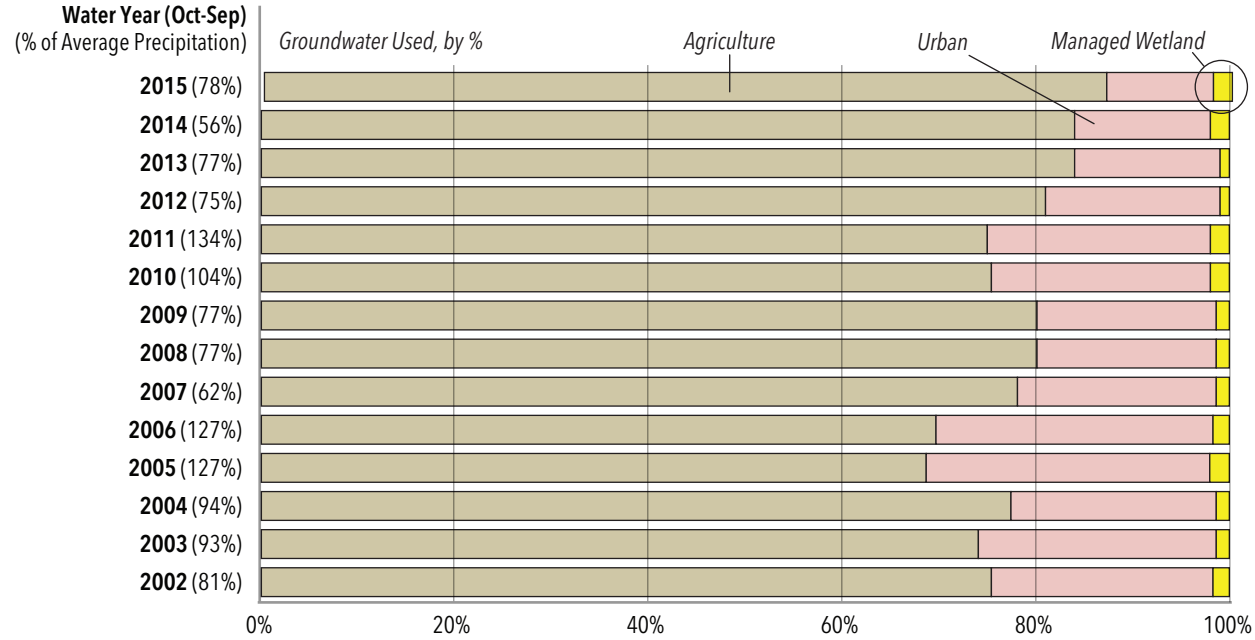
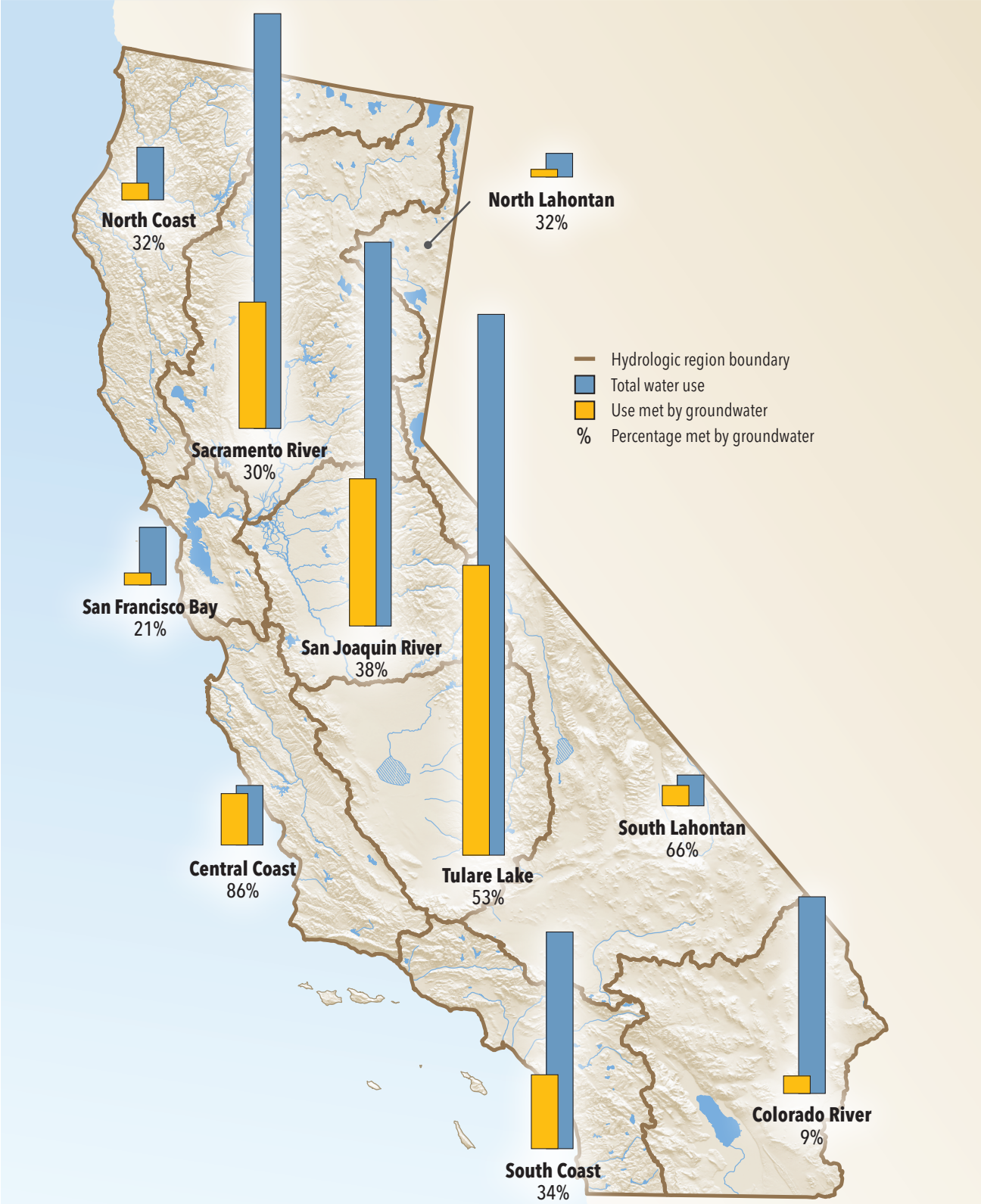


Figure 1.17: Groundwater Contribution to Total Water Use by Hydrologic Region

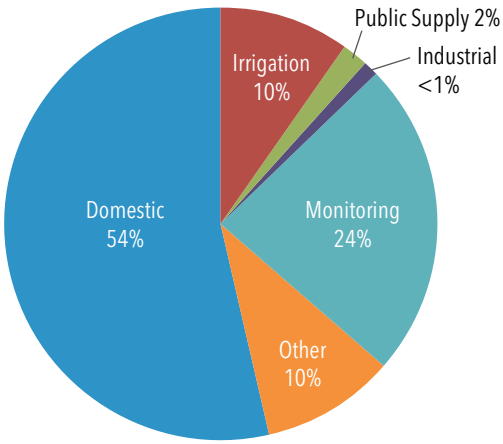


Data from California's Groundwater Update 2013, A Compilation of Enhanced Content for California Water Plan Update 2013.

water regulatory levels. Arsenic, nitrate, and radionuclides, for example, are often cited as sources of increased treatment costs for small water systems. Water level data are often used as a first-order screening tool for assessing drought impacts, but this information alone may not capture localized conditions that affect groundwater availability and usability.

Enactment of the California Statewide Groundwater Elevation Monitoring (CASGEM) legislation in 2009 for the first time allowed assessment of drought impacts on groundwater levels at a statewide scale, representing a major improvement over the information previously available. The intent of the CASGEM program is to track seasonal and long-term trends in groundwater basins statewide, focusing on basins identified by DWR as high- and medium-priority. The 2012–2016 drought was the first drought for which CASGEM monitoring data were available; **FIGURE 1.20** shows locations of wells recently used to track groundwater level conditions statewide.

Figure 1.18: California Water Wells by Type (1977–2010)
Based on well completion reports filed with DWR. Data from California's Groundwater Update 2013, A Compilation of Enhanced Content for California Water Plan Update 2013.



A typical example of fractured bedrock in the Sierra Nevada foothills, exposed in a spillway cut at Lake Success near Porterville. Groundwater from fractured rock sources can be an unreliable supply during droughts.

Figure 1.19: Characteristics of Fractured Bedrock Controlling Groundwater Availability

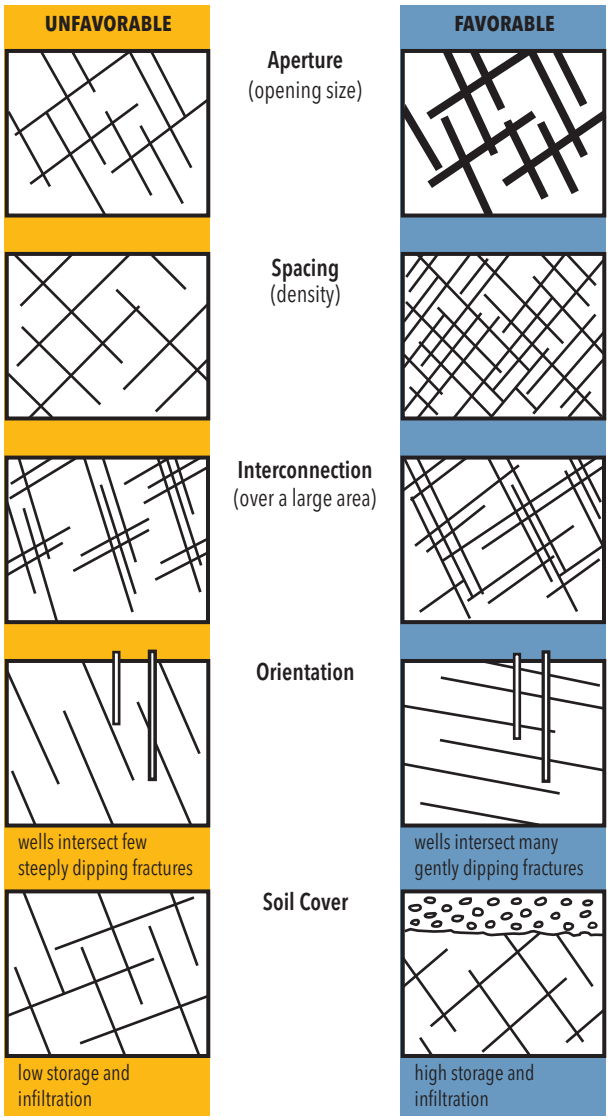
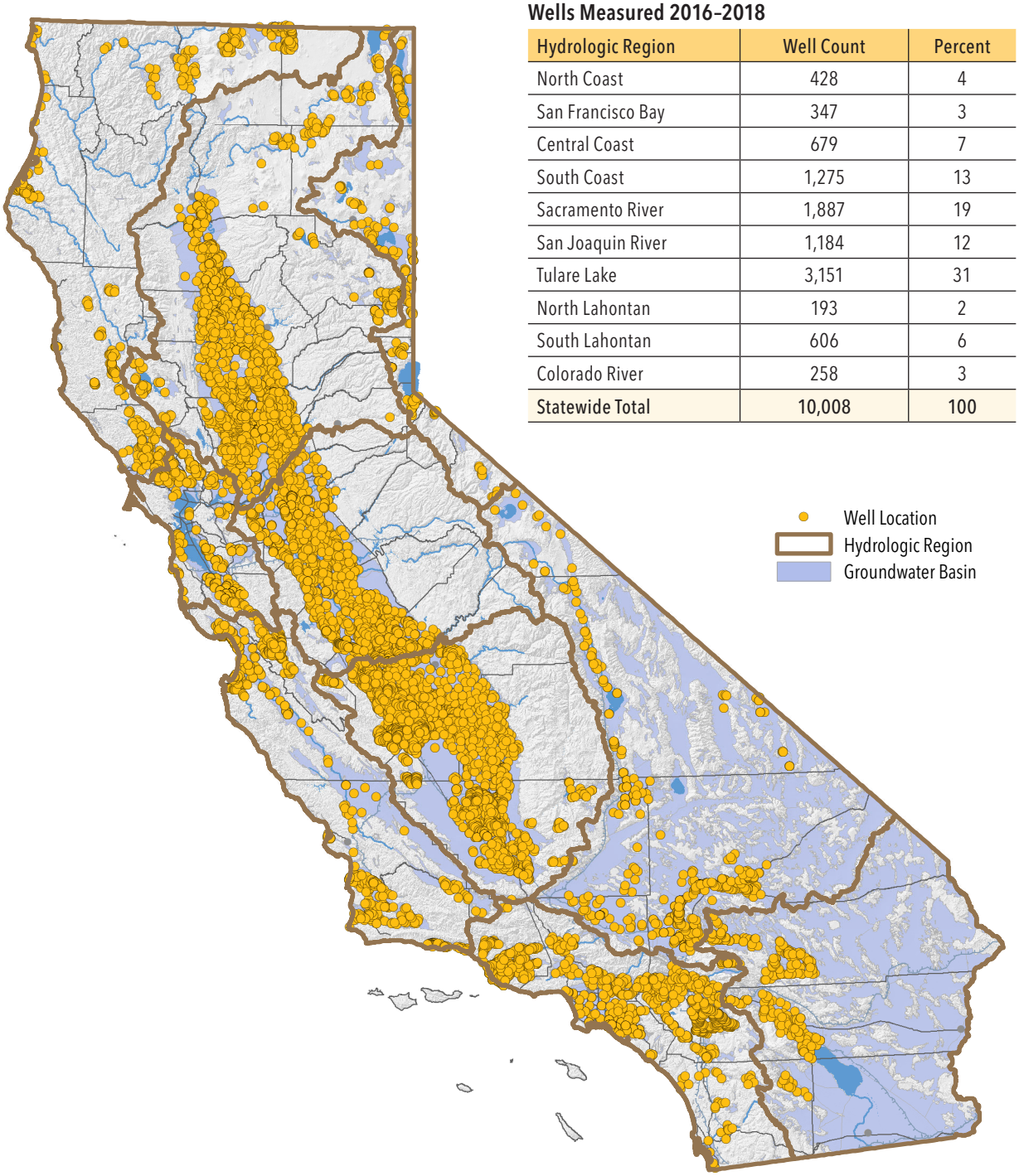


Figure 1.20: Groundwater Level Monitoring Coverage



Wells Measured 2016–2018

Hydrologic Region	Well Count	Percent
North Coast	428	4
San Francisco Bay	347	3
Central Coast	679	7
South Coast	1,275	13
Sacramento River	1,887	19
San Joaquin River	1,184	12
Tulare Lake	3,151	31
North Lahontan	193	2
South Lahontan	606	6
Colorado River	258	3
Statewide Total	**10,008**	**100**

Map displays California Statewide Groundwater Elevation Monitoring (CASGEM) and voluntary wells with water level data collected between January 1, 2016, and March 27, 2018.

2

Hydroclimate Background on Drought in California

This chapter briefly summarizes hydroclimate conditions associated with past California droughts. Drought is a normal part of the water cycle in California. Dry years happen periodically; occasionally dry conditions persist over multiple years, eventually resulting in sufficient impacts for these dry conditions to be termed a drought. Sustained multi-year dry periods have been relatively infrequent in the historical record. It is important to remember, however, that California hydrologic data cover a limited period of historical record; few stream gauges have a period of record of more than 100 years, and only a few precipitation records extend as much as 150 years. Efforts to go beyond the historical period must rely on tools such as paleoclimate analysis or climate models.

WHAT CAUSES DROUGHT AND IS IT PREDICTABLE?

Ultimately, drought in California stems from an absence of winter precipitation. At the weather timescale, this absence of precipitation occurs when an atmospheric high-pressure ridge blocks winter storms from reaching the state, shunting them to other areas. Moving from the weather to the climate timescale, many other aspects come into play; the chaotic interaction of atmosphere-ocean dynamics and land processes combine at varied spatial and temporal scales to set the stage for the weather we experience. Predicting drought entails understanding and predicting atmospheric processes at a sub-seasonal to seasonal (S2S) timescale. The S2S timescale – two weeks to one to two years – is sometimes referred to as the bridge between weather and climate, as it links short-term weather conditions with longer-term processes.

Although the ability to make skillful operational weather forecasts of precipitation (out to two weeks in advance) has greatly improved over the past several decades, the same cannot be said for making forecasts at the S2S timescale important for drought. S2S forecasting occupies a research gap between conventional numerical weather modeling and the decades- to centuries-long timescale of global climate change modeling. Substantial federal support since 1990 for the U.S. Global Change Research Program, for example, continues to result in major progress in developing increasingly complex climate models, but similar investment has not occurred at the S2S timescale. As described in Chapter 1, the historical skill of the Climate Prediction

Center's (CPC's) precipitation outlook for the winter months important to California's water supply has been minimal.

Investments in research needed to improve precipitation forecasting beyond a weather model timescale were described in two recent reports by the National Academy of Sciences (National Research Council 2010, 2016). These reports call for a broad suite of actions including improving observations, models, and data assimilation; and performing basic research on processes such as tropical convection. The 2016 report expresses a vision that with needed investments S2S forecasts could be as widely used as present-day weather forecasts within a decade. The Weather Research and Forecasting Innovation Act of 2017 is an initial step down this path. The act directed the National Oceanic and Atmospheric Administration (NOAA) to improve its S2S forecasts of temperature and precipitation, and to prepare a report to Congress identifying, among other things, the research, monitoring, observing, and forecasting requirements needed to carry out the legislation's S2S goals.

Many efforts have been made to identify climate patterns, or teleconnections (see sidebar on page 29), that could predict or diagnose drought conditions. NOAA defines a climate teleconnection as:

> *a recurring and persistent, large-scale pattern of pressure and circulation anomalies that spans vast geographical areas. … All teleconnection patterns are a naturally occurring aspect of our chaotic atmospheric system, and can arise primarily as a reflection of internal atmospheric dynamics. Additionally, some of these patterns, particularly those over the North Pacific, are also sometimes forced by changes in tropical sea-surface temperatures and tropical convection. … Teleconnection patterns reflect large-scale changes in the atmospheric wave and jet stream patterns, and influence temperature, rainfall, storm tracks, and jet stream location/intensity over vast areas. Thus, they are often the culprit responsible for abnormal weather patterns occurring simultaneously over seemingly vast distances* (National Oceanic and Atmospheric Administration 2014).

The El Niño-Southern Oscillation (ENSO) is an example of a teleconnection that has been extensively studied. The 1980s and 1990s were a time of numerous publications by the research community on ENSO prediction and relationships among ENSO and various aspects of the climate system. ENSO conditions became a chief factor used for making seasonal climate outlooks, such as those prepared by CPC. The limitations of relying on ENSO alone as an indicator of precipitation likelihood, however, were demonstrated during the strong El Niño event of 2015–2016 when forecasters predicted wet conditions throughout California based on the history of strong El Niño events such as those experienced in 1982–1983 and 1997–1998 **(FIGURE 2.1)**.

FIGURE 2.2 shows relationships between ENSO and historically observed California precipitation at the scale of

Figure 2.1: Forecasted Versus Observed Precipitation During the Winter 2015–2016 El Niño

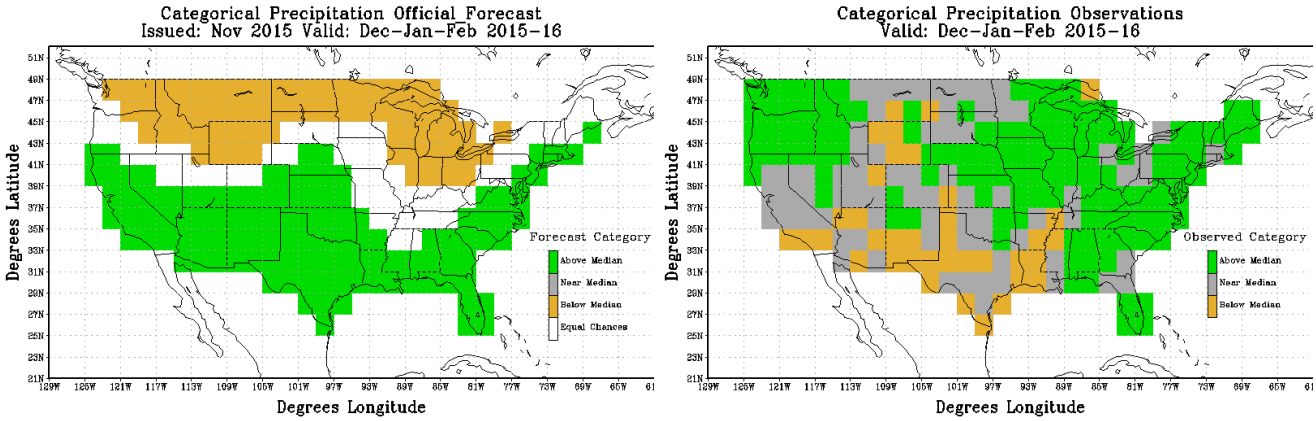


Figure credit: NOAA CPC

Figure 2.2: El Niño–Southern Oscillation and California Precipitation

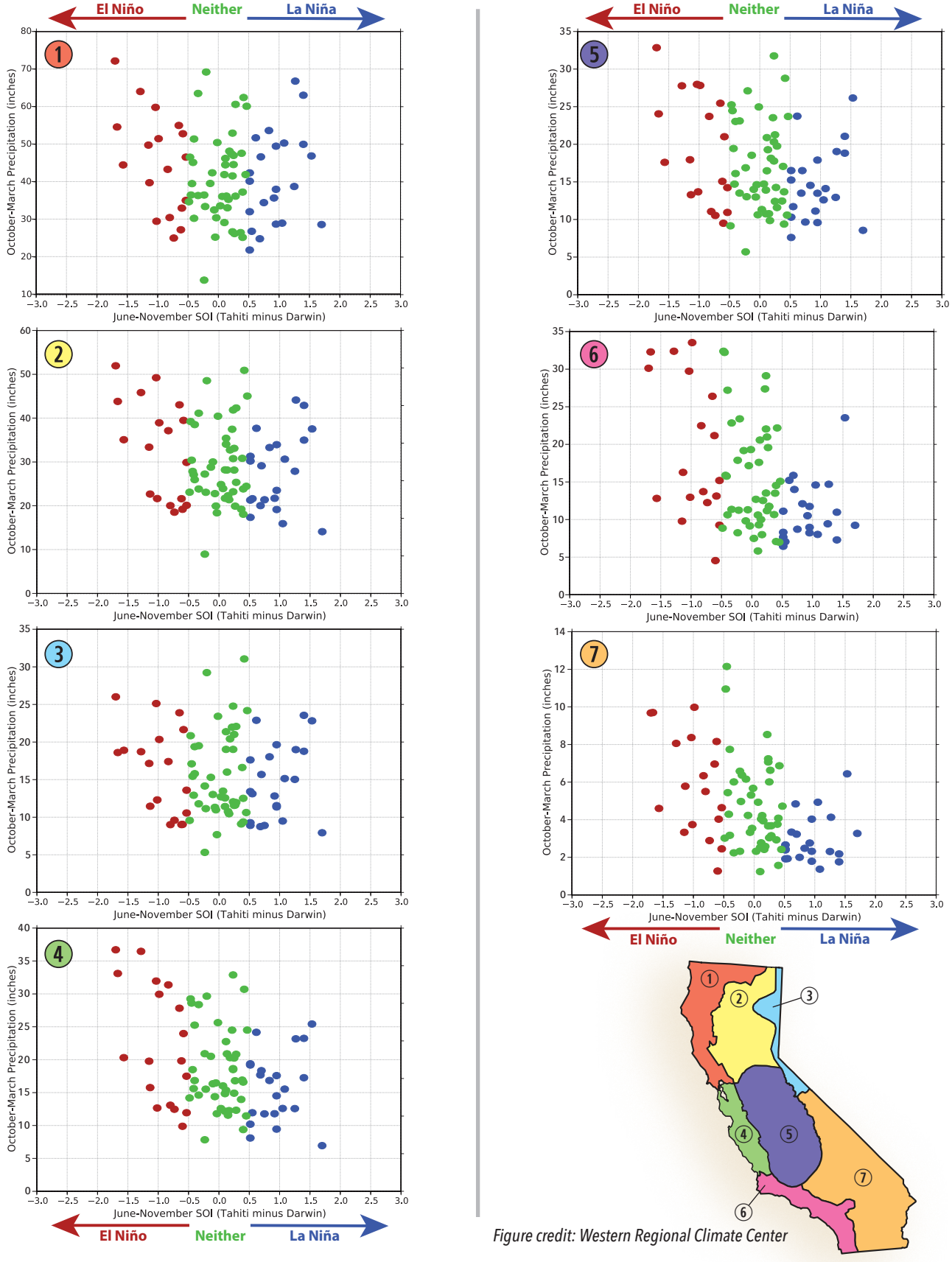
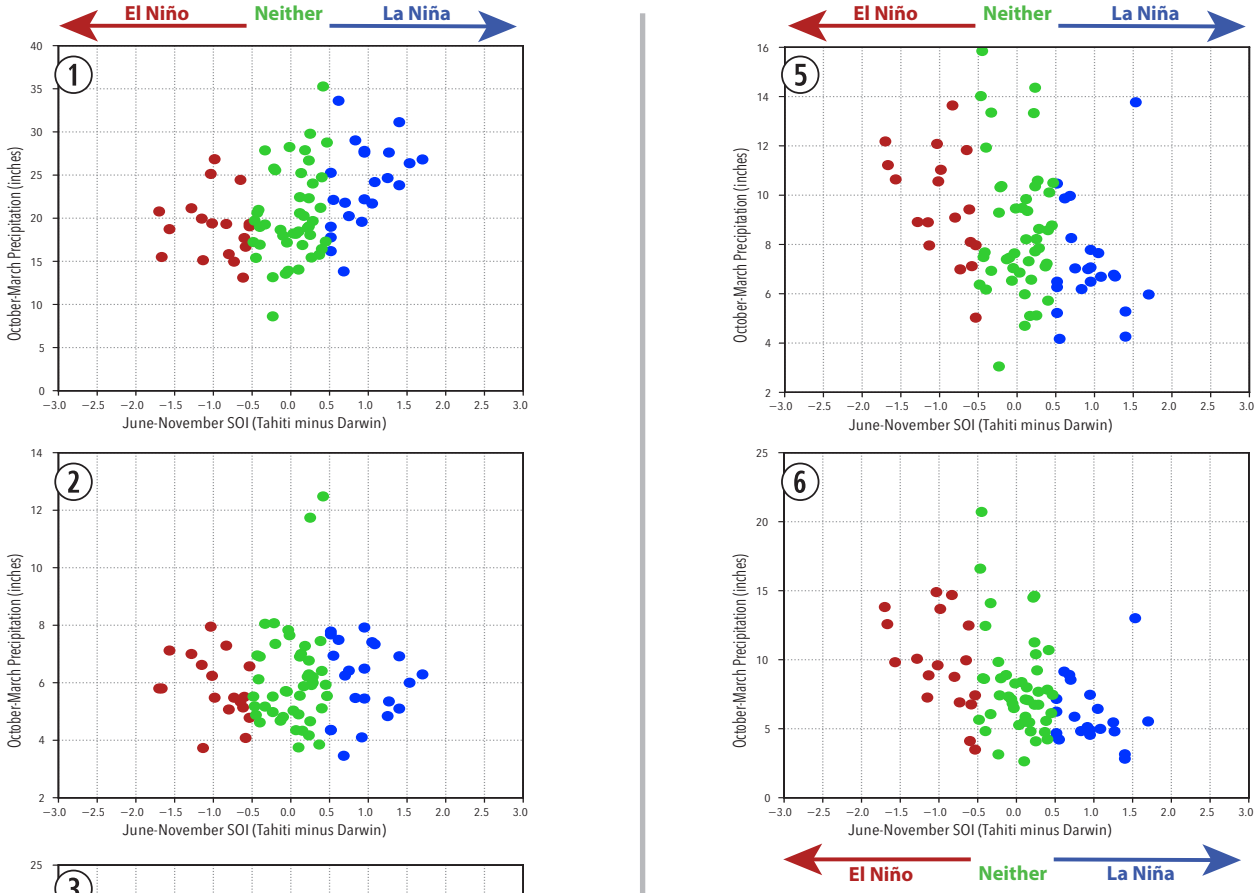


Figure credit: Western Regional Climate Center

Figure 2.3: El Niño–Southern Oscillation and Colorado River Basin Precipitation



NOAA climate divisions map: selected parts of Colorado River Basin highlighted.

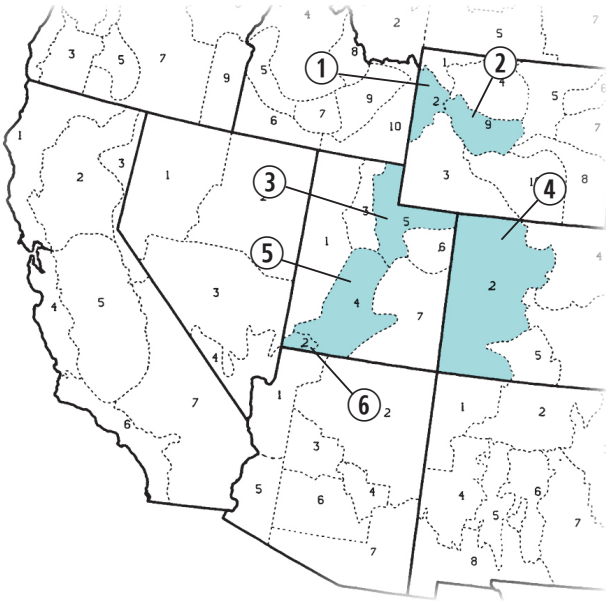


Figure credit: Western Regional Climate Center

Climate Teleconnections

Researchers have identified a variety of climate teleconnections that influence weather patterns in different areas of the globe. Listed below are examples of those relevant to North America and potentially useful for understanding weather patterns in California. Some of these teleconnections are being actively used or studied to provide predictive capability at weather or S2S timescales; others are primarily diagnostic in nature. Monitoring the status of these teleconnections is done through large-scale measurements of parameters such as ocean temperatures or atmospheric pressures; satellite observations are fundamental for this monitoring because of the global scale of meteorological processes. The historical record available for direct measurements is thus limited to the satellite era, although researchers have made efforts to reconstruct some earlier records through use of global climate models and limited direct observations (e.g., temperature records from ships).

The **Arctic Oscillation (AO)** is a pattern of fluctuating sea-level atmospheric pressure at polar and mid-latitudes. The positive phase of AO brings lower-than-normal pressure over the polar region and higher-than-normal pressure at mid-latitudes, steering storms to the north and potentially resulting in drier conditions for California. This pattern can persist from years to decades.

The **Atlantic Multidecadal Oscillation (AMO)** is a long-term fluctuation in sea surface temperatures in the Atlantic Ocean that can affect air temperatures and precipitation. The AMO has been in its warm phase since the mid-1990s; the Dust Bowl drought occurred during a warm phase.

The **El Niño-Southern Oscillation (ENSO)** characterizes year-to-year fluctuations in sea surface temperatures in the equatorial Pacific Ocean and concomitant fluctuations in sea-level air pressures between Tahiti and Darwin, Australia. ENSO conditions may provide some predictive guidance for precipitation in parts of the United States, as well as affecting West Coast sea levels and marine ecosystems.

Ocean temperatures needed for climate and weather modeling can be estimated by satellite-based remote sensing or directly obtained by measurements from buoys and ships. Real-time data collected from an array of moored buoys installed for the Tropical Atmospheric Ocean project is used for understanding and monitoring ENSO conditions. Photo credit: NOAA

The **Madden-Julian Oscillation (MJO)** is a sub-seasonal fluctuation (30–60 days) that is referred to as the bridge between weather and climate because of its short-term nature. The MJO occurs in the global tropics and is characterized by eastward propagation of areas of enhanced or suppressed tropical rainfall over the Indian and Pacific oceans. The MJO may speed or enhance ENSO episodes, and preliminary research suggests that it may be correlated to formation of atmospheric river storms that are important for California's water supply. Thus, it offers potential predictive capability (when active) at sub-seasonal timescales for drought onset or persistence, and provides a promising near-term research opportunity for improving drought prediction.

The **North Atlantic Oscillation (NAO)** is a fluctuation in atmospheric pressure between a low-pressure center located near Iceland and a high-pressure center located near the Azores. The NAO is closely related to the AO, in that both phenomena characterize pressure gradients that can affect storm tracks in North America.

The **Pacific Decadal Oscillation (PDO)** was originally developed as part of understanding relationships between salmon populations and Pacific Ocean temperatures. The PDO is an up to decades-long pattern of fluctuation in sea surface temperatures, similar to ENSO but at longer timescales. Since about 1998, the PDO has fluctuated from negative to positive temperature conditions at timescales of only a few years, in comparison to its prior multi-decadal cycle.

NOAA climate divisions. As illustrated in the plots, the only historically observed relationship between ENSO status and precipitation in California is for Southern California to tend toward dryness in most, but not all, La Niña years. **FIGURE 2.3** provides similar information for selected climate divisions in the Upper Colorado River Basin that provide much of the basin's runoff.

Interactions among teleconnections or other climate forcings influence the weather experienced in any given year, illustrating why ENSO conditions alone are not predictive. California's experience in Water Years 2011 (a wet year) and 2012 (a dry year) shows how multiple factors influence seasonal precipitation. Both were years of moderate La Niña conditions, with forecasters predicting drier-than-average conditions for much of California. Actual water conditions were dramatically different between the two years, with a major reason for the difference attributed to the Arctic Oscillation (AO). Predicting how multiple teleconnections may either amplify or cancel each other's expression at the scale of local weather remains a subject for research.

A CHANGING CLIMATE

California's 21st century droughts have occurred in a setting of increasing warmth. Calendar year 2014, for example, was California's warmest year on record in terms of statewide average temperature **(FIGURE 2.4)**, followed by 2015 as second warmest. **FIGURE 2.5** shows the warming in observed statewide temperatures. Increasing warmth is an expected result of anthropogenic climate change, and one that global climate model studies generally show good agreement on. Agreement among

Figure 2.4: NOAA Statewide Average Temperature Ranks
January–December 2014. Period: 1895–2014.

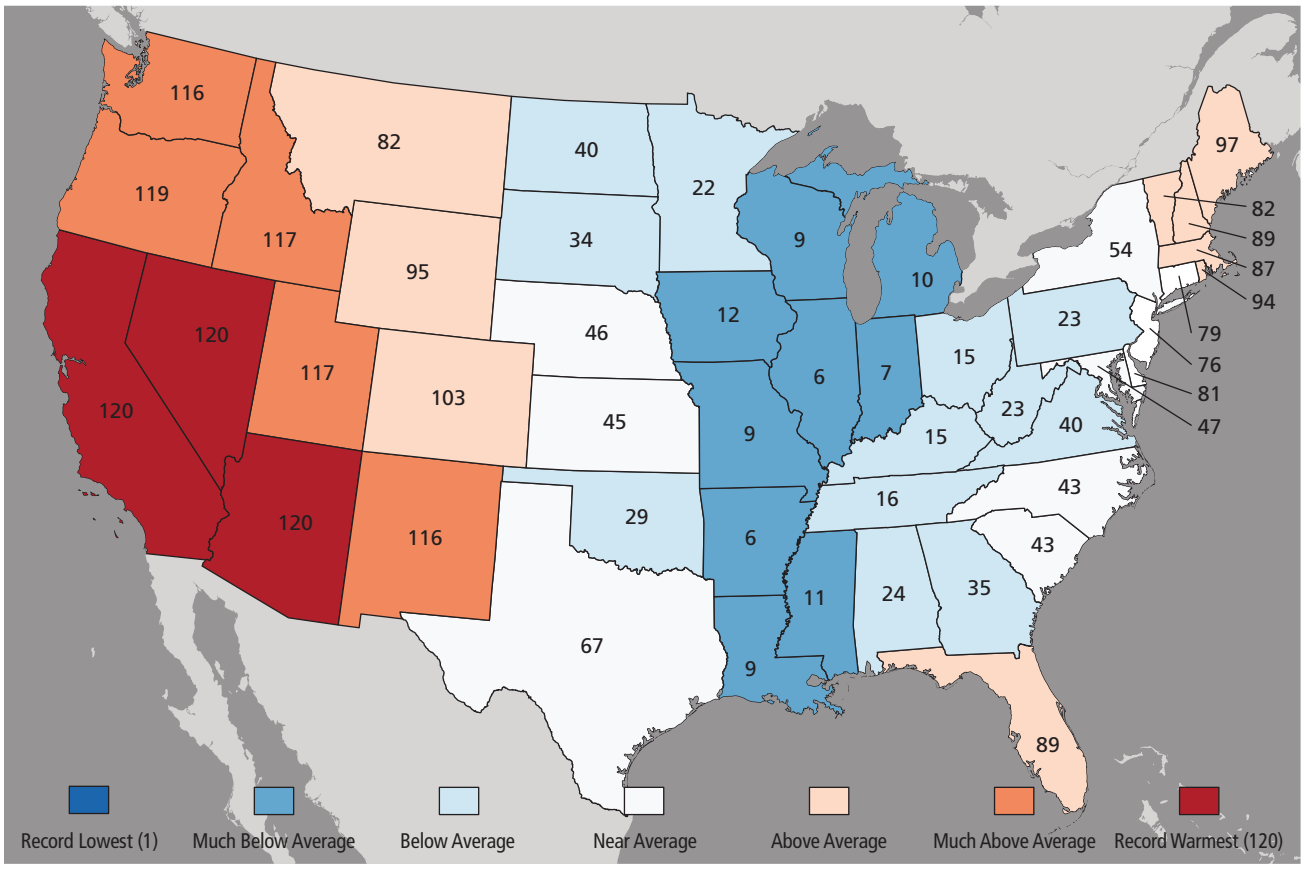


Figure credit: National Oceanic and Atmospheric Administration

climate model studies is not as reliable for precipitation as it is for temperature.

The 2013 Southwest Climate Assessment (Garfin et al. 2013) describes expected drought-related outcomes of climate change, and provides a few specific examples:

» Drought, as expressed in Colorado River flow, is projected to become more frequent, more intense, and longer lasting, resulting in water deficits not seen during the instrumental period (high confidence).

» Northern Sierra Nevada watersheds may become wetter, and in terms of flow, somewhat less drought-prone with climate change (medium-low confidence).

» In terms of soil moisture, drought is expected to generally intensify in the dry season due to warming (high confidence).

The 2013 Southwest Climate Assessment also notes that the period since 1950 has been warmer in the Southwest (including California and the Colorado River Basin) than in any comparable period in at least 600 years, and that the decade of 2001–2010 was the warmest and fourth driest of all decades from 1901 to 2010. A warmer temperature affects the percentage of precipitation that falls as rain or snow, and the spatial and temporal extent of mountain snowpack. **FIGURE 2.6** illustrates how warmer temperatures have affected the freezing level in the Sierra Nevada, using the Lake Tahoe area as an example. **FIGURES 2.7** and **2.8** show historical trends in the timing of spring runoff in the

Figure 2.5: California Statewide Mean Temperature Departure

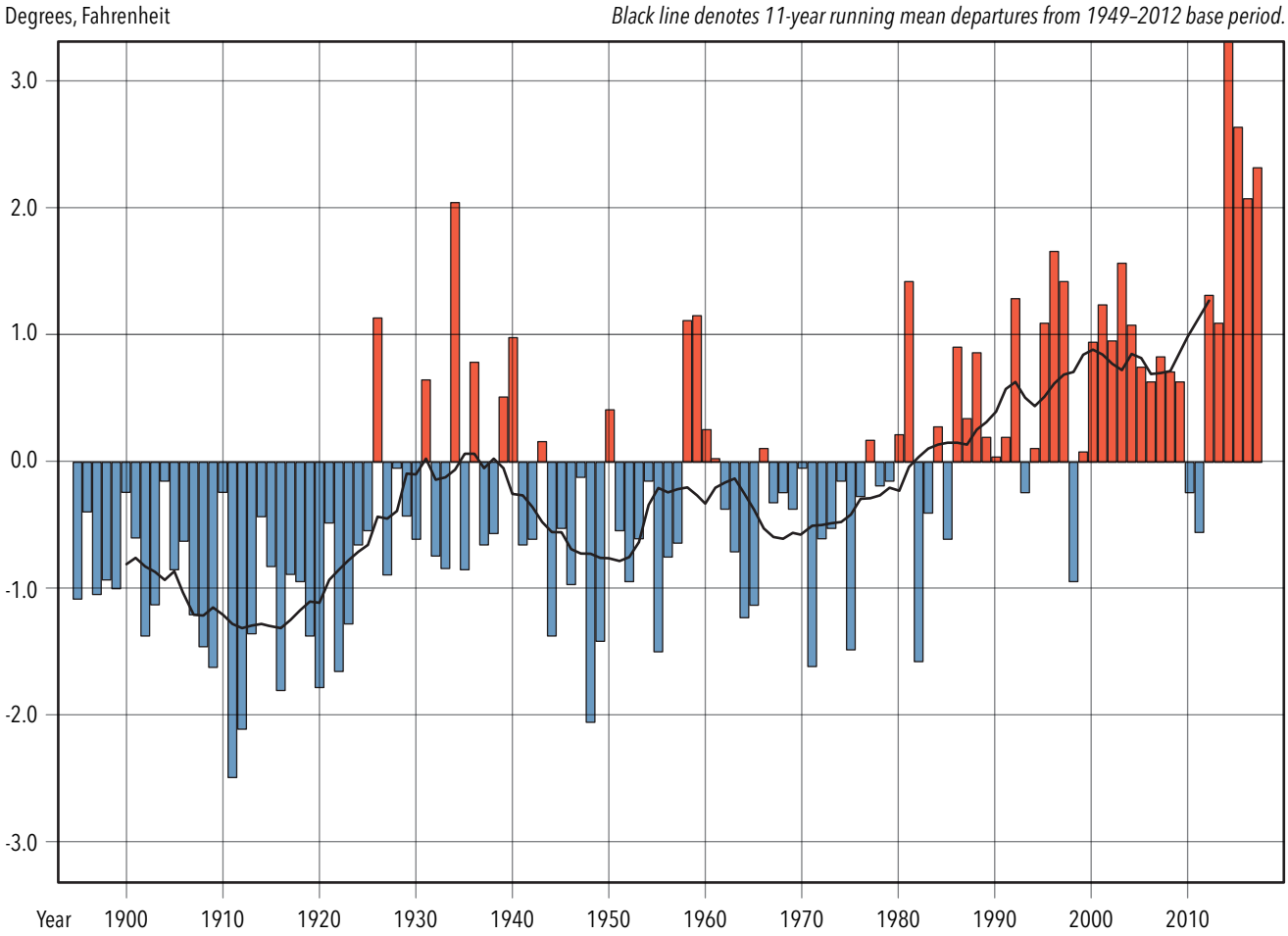


Figure credit: Western Regional Climate Center

Figure 2.6: Annual Elevation of Freezing Level Over Lake Tahoe, Departure From Long-Term Mean

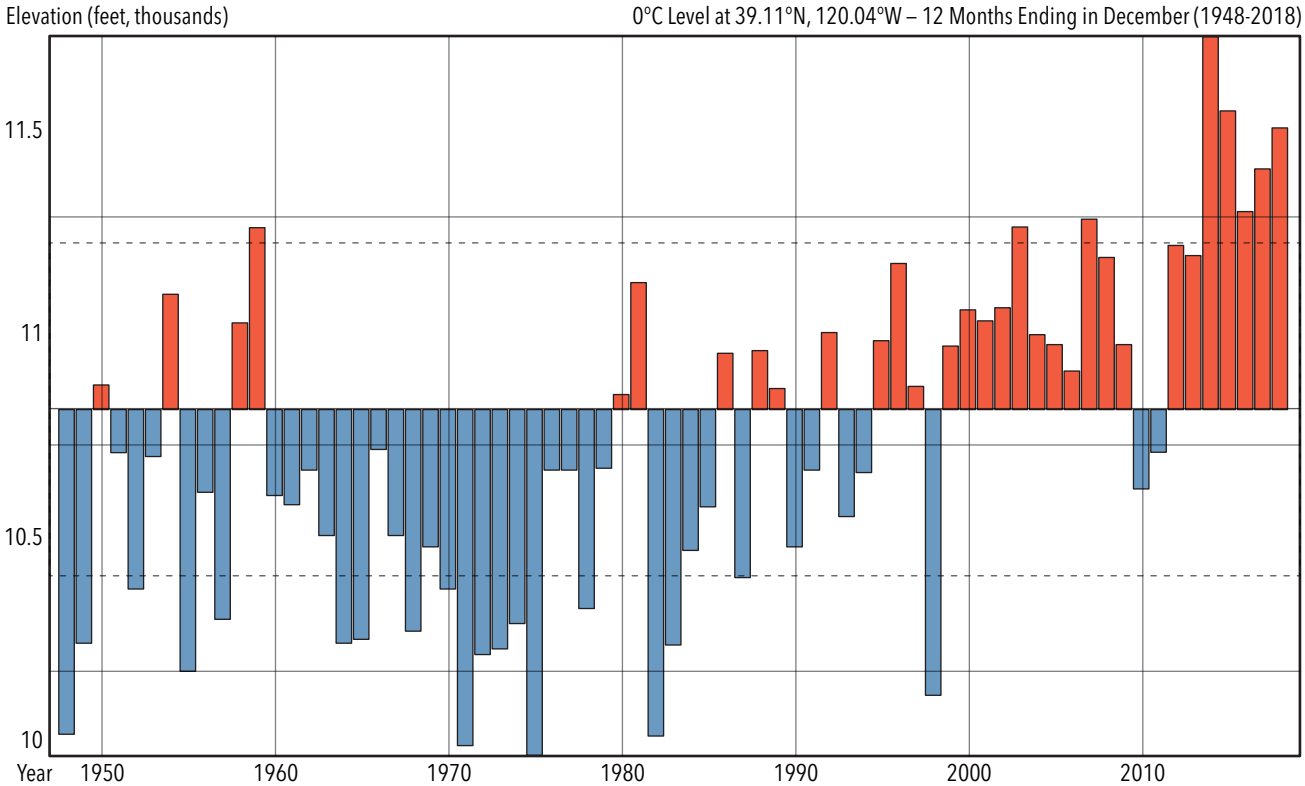


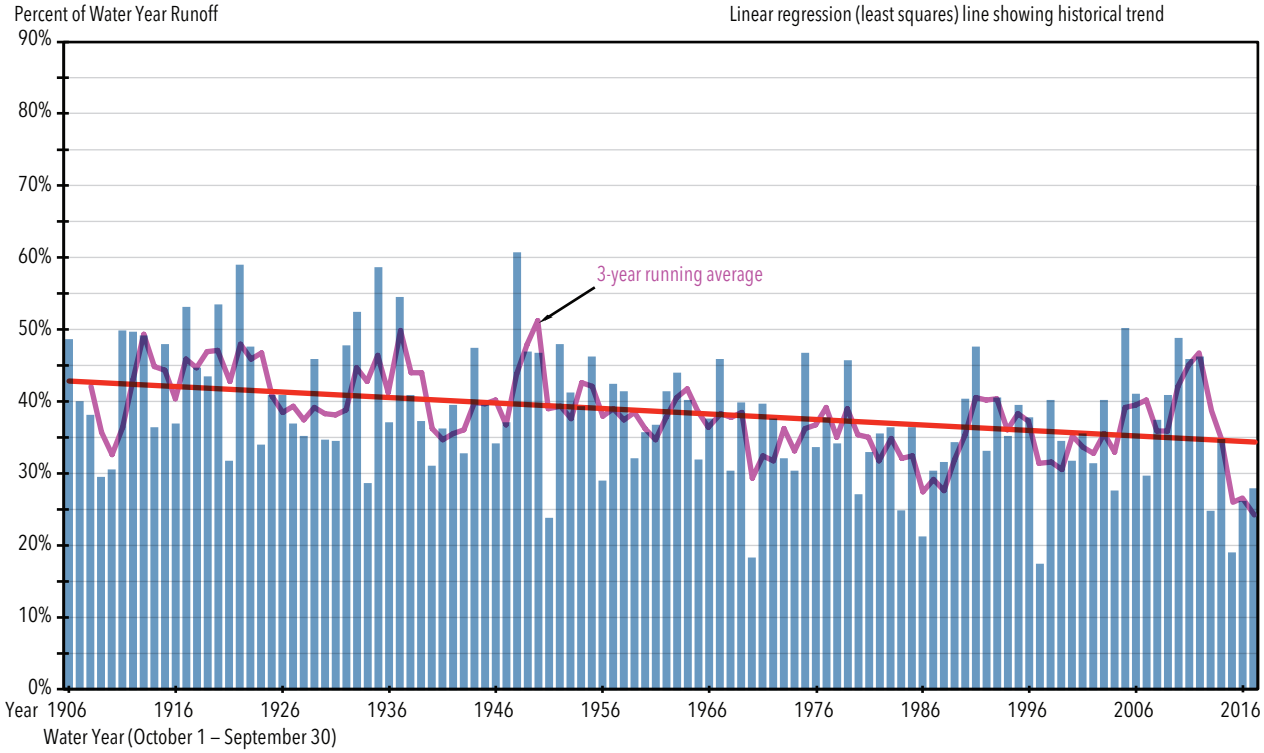
Figure credit: Western Regional Climate Center

Sacramento River and San Joaquin River basins. An expected long-term impact of warming is reduction of spring snowmelt runoff resulting from less precipitation occurring in the form of snow and earlier melting of snowpack. Historically observed snowpack water content is shown in **FIGURE 2.9**.

Extensive material has been published about expected impacts of future anthropogenic climate change in California – loss of Sierra Nevada and Cascade snowpack, increased aridity in Southern California, and increased water demands caused by warmer temperatures. In terms of timing of impacts, climate modeling generally shows very pronounced impacts – such as loss of half or more of Sierra Nevada snowpack – by the end of the century, with notable impacts being observed by mid-century (Knowles and Cayan 2002). Climate change impacts on water supplies and demands also have been estimated for the Colorado River Basin (U.S. Bureau of Reclamation 2012), where increased water demands resulting from warming and other factors are projected to result in a significant gap between 2060-level supplies and demands. Future droughts in California and the Colorado River Basin will occur in a climate setting that differs from the context experienced in the state's historical droughts.

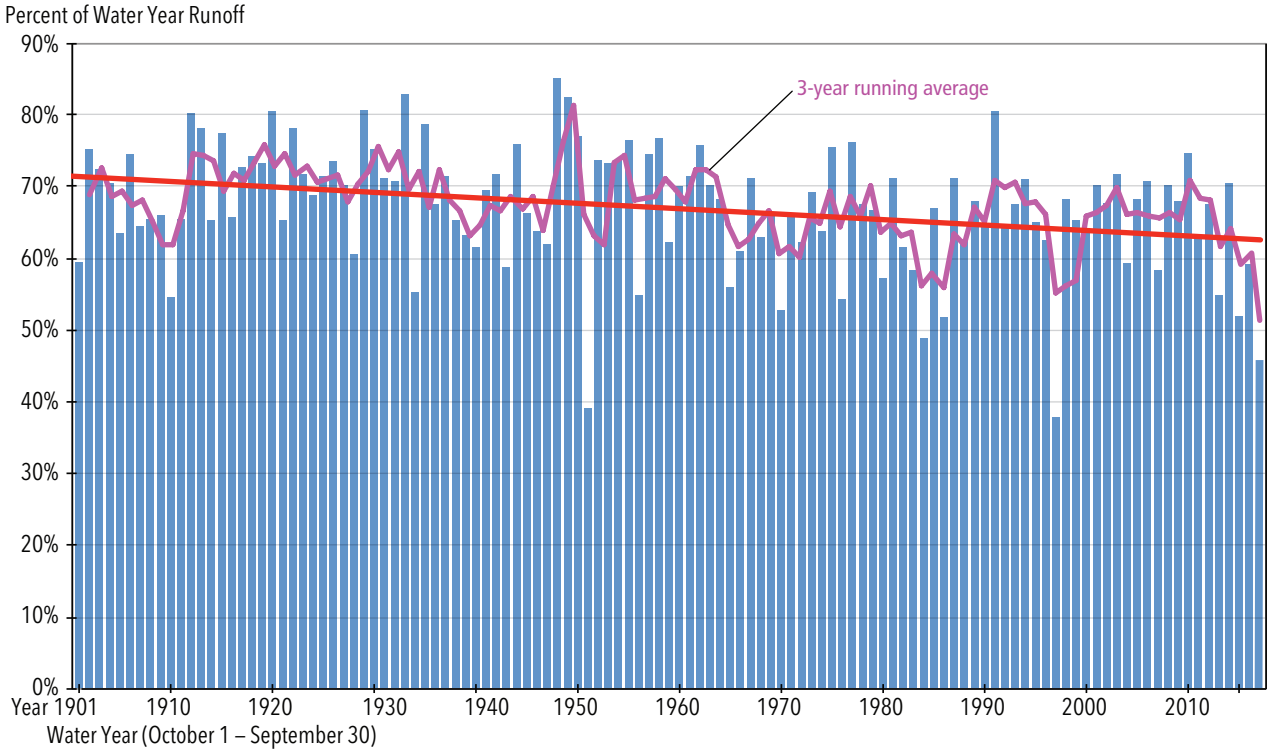
Trends in even the relatively brief historical record offer a cautionary message about using observed drought hydroclimate data for predicting the water supply impacts of future droughts at long-term planning timescales. It is important to recognize, however, that climate variability and change should be examined in the context of a defined part of the historical (or paleoclimate) record, whether the entire record or only some recent subset of it. As discussed below, paleoclimate records provide a long-term perspective on natural climate variability; in some cases, the natural variability seen in the long-term records shows drier conditions than those projected by climate models looking at late 21st century conditions.

Figure 2.7: April–July Sacramento River Runoff as Percent of Water Year Runoff



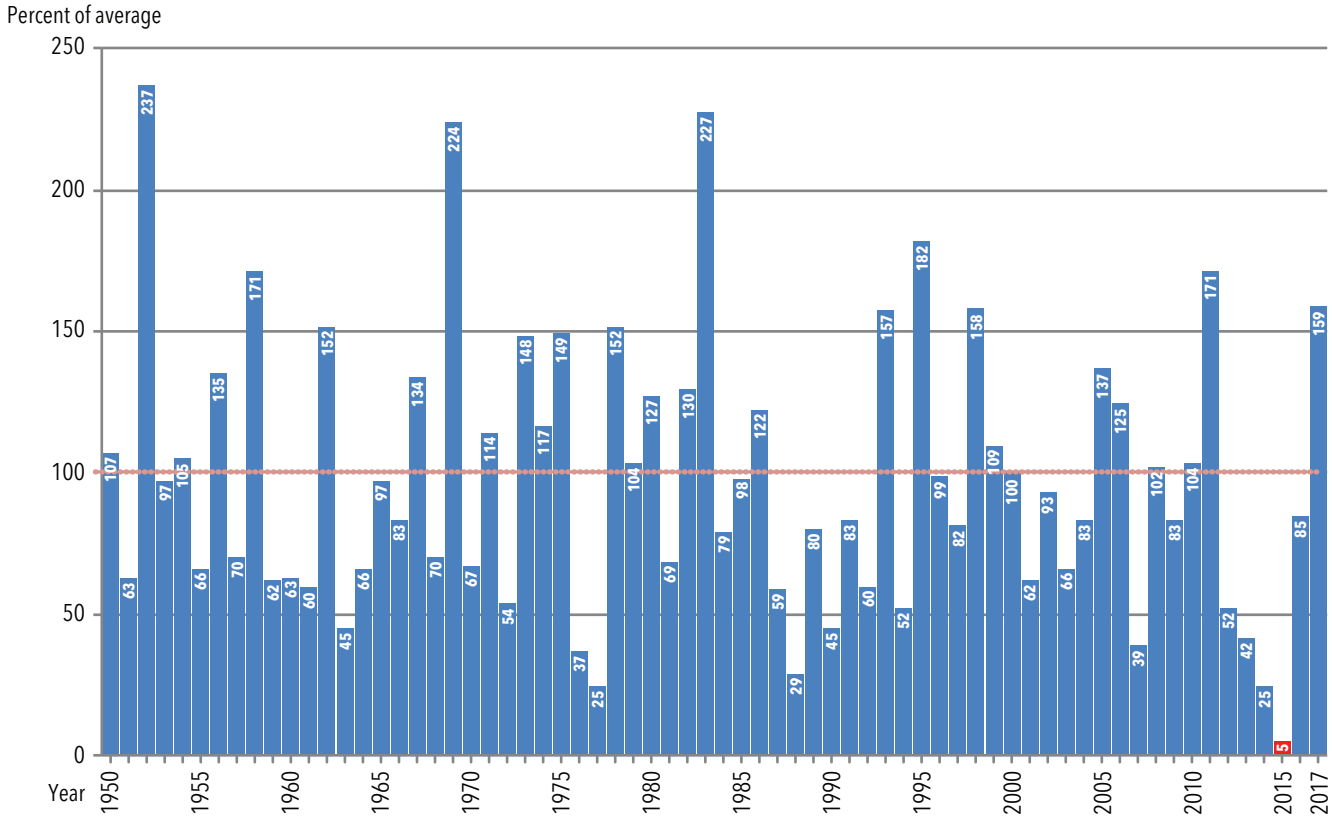
Sacramento River runoff is the sum of the unimpaired flow at the Sacramento River above Bend Bridge, Feather River at Oroville, Yuba River near Smartville, and American River below Folsom Lake.

Figure 2.8: April–July San Joaquin River Runoff as Percent of Water Year Runoff

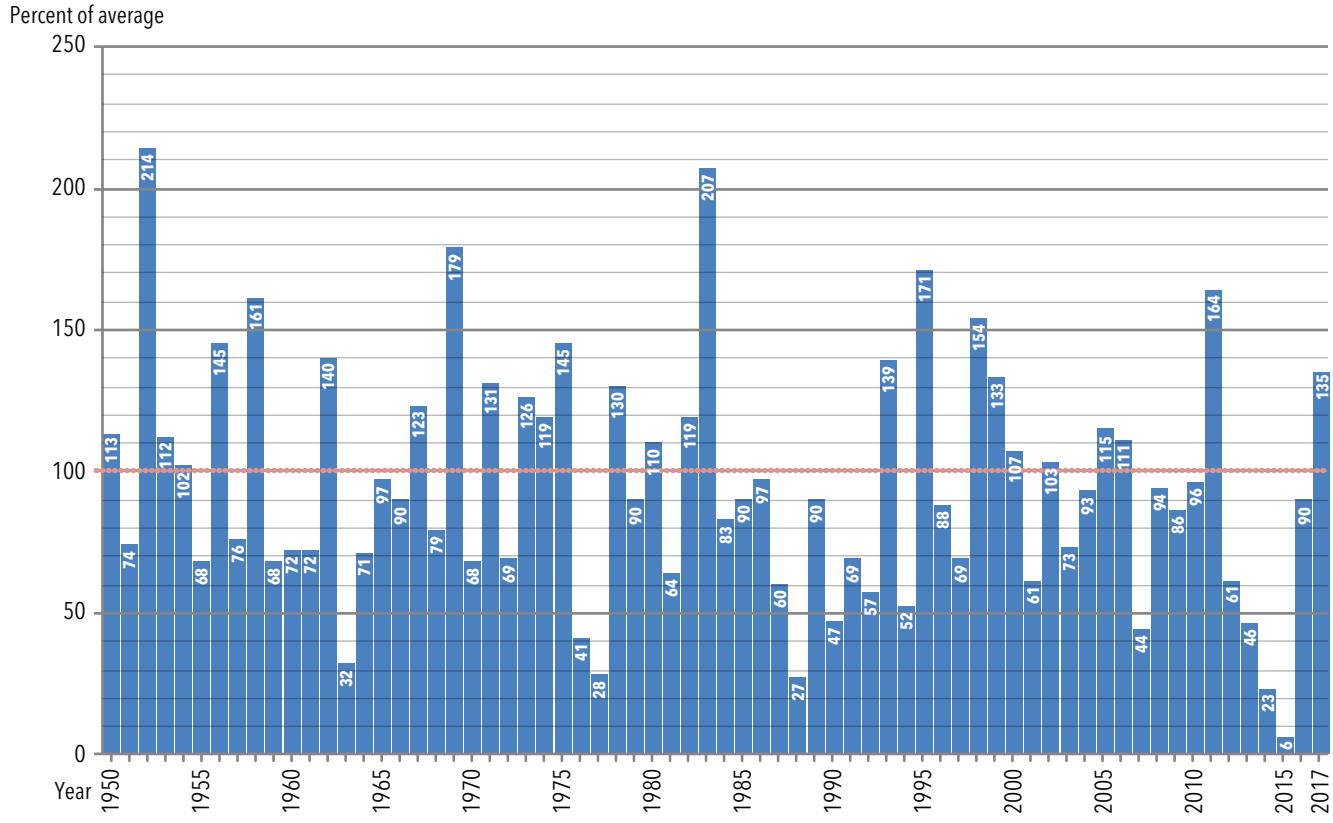


San Joaquin River runoff is the sum of the unimpaired flow at the Stanislaus River below Goodwin Reservoir, Tuolumne River below La Grange, Merced River below Merced Falls, and San Joaquin River inflow to Millerton Lake.

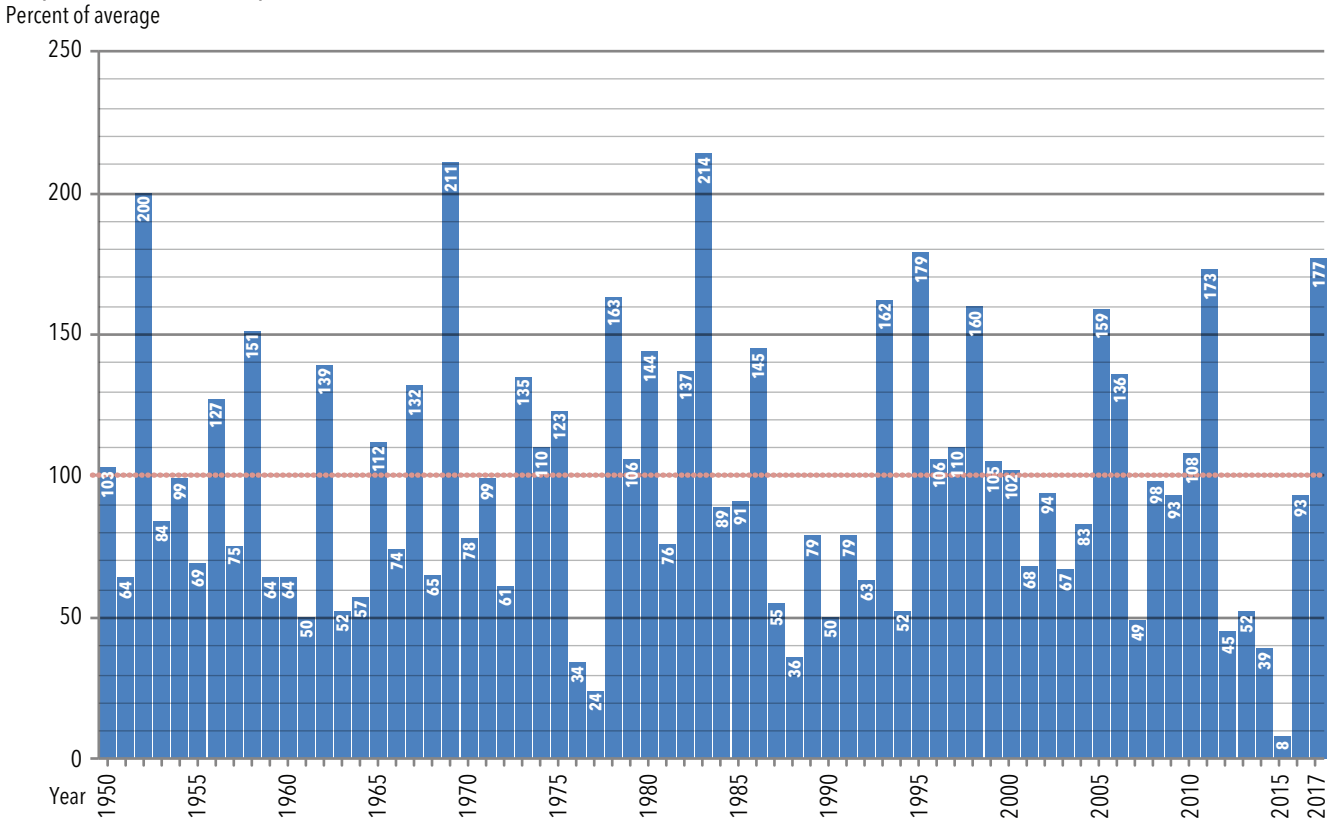
Figure 2.9: April 1 Historical Snowpack Water Content: Statewide



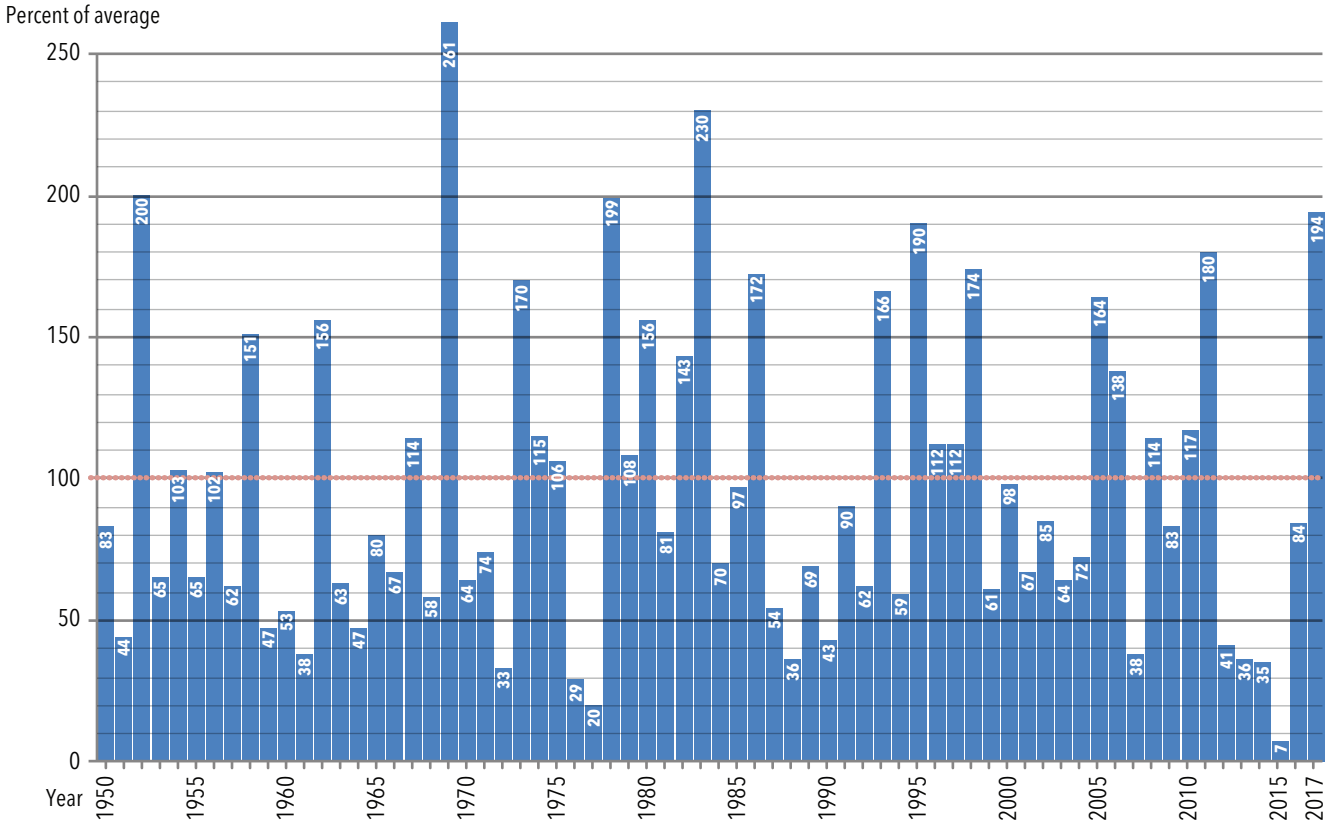
April 1 Historical Snowpack Water Content: North



April 1 Historical Snowpack Water Content: Central



April 1 Historical Snowpack Water Content: South



DROUGHTS IN AND NEAR CALIFORNIA – THE LONG-TERM PICTURE

Historically recorded hydrology of little more than a century does not represent the full range of natural variability of the global climate system. Paleoclimate reconstructions from sources such as tree-ring chronologies, lake sediments, or ice cores can provide a very long-term perspective on past climate conditions. Tree-ring data are especially useful for hydrologic studies, as this information can be used in statistical models to quantitatively reconstruct annual streamflow or precipitation values for as much as a thousand or more years.

Perhaps the earliest recognition of California's paleo droughts dates to the modern drought of 1929–1934, when Lake Tahoe dropped below its natural rim and exposed tree stumps rooted in place on the lake bottom. University of California, Berkeley professor S. T. Harding saw the stumps and recognized them as being indicative of much drier past conditions; many years later he used radiocarbon dating to estimate their age (Harding 1965). Subsequent refinement of his dates placed the age of the stumps at more than 5,000 years before the present, and other prolonged lowstands of Lake Tahoe dating to mid-Holocene times were also identified (Lindstrom 1990). Additional studies of relict tree stumps rooted in place in other central Sierra Nevada lakes, rivers, and marshes – including Fallen Leaf Lake, Independence Lake, and the West Walker River – have identified chronic dry periods (e.g., Stine 1994; Kleppe et al. 2011) prior to the modern record.

Paleo droughts have been particularly well studied in

Adapting Snowpack Monitoring to a Changing Climate

The concept of measuring snowpack water content for use in runoff forecasting dates to snow surveys began in 1908 by Dr. James Church at Mount Rose, overlooking Lake Tahoe. The manual snow course measurements he pioneered, later augmented with telemetered snow sensor data, supply the data reported through California's Cooperative Snow Surveys Program. Approximately 260 manual snow courses are measured for the April 1 estimate of snowpack water content, traditionally considered to represent the peak of seasonal snow accumulation. Both courses and sensors are largely located in lower-elevation portions of mountain snow zones because of issues such as difficulty of site access, weather damage to instrumentation on exposed high-elevation ridge tops, and restrictions associated with designated wilderness areas. Under warming temperatures and loss of mountain snowpack, these monitoring locations will become increasingly less representative of the conditions they have historically been used to model.

Figure 2.10: Experimental Estimates of Snowpack Water Content

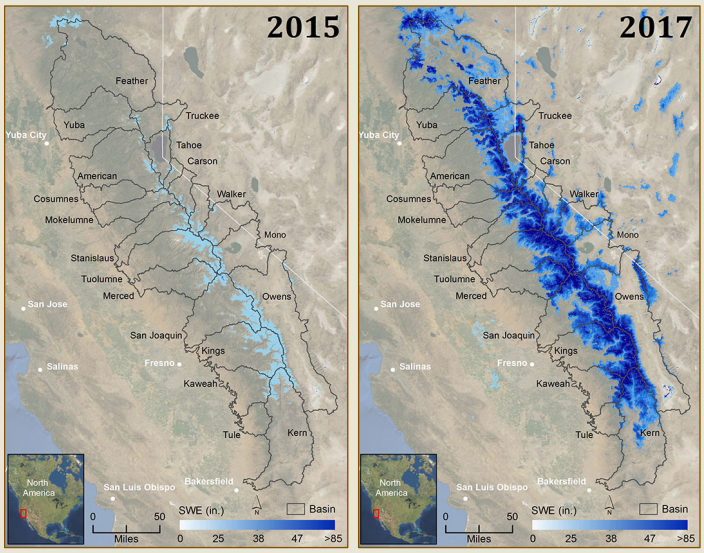


Figure credit: University of Colorado

Remote sensing technologies offer opportunities to improve snowpack monitoring by covering high-elevation areas that not are captured with in situ observations. **FIGURE 2.10** compares experimental estimates of Sierra Nevada snow water content in 2015 (record low year for statewide snowpack) and 2017 (wet year). This experimental research product uses data from a moderate-resolution imaging spectroradiometer sensor housed on National Aeronautics and Space Administration's (NASA's) Terra and Aqua satellites and measurements at existing ground-based sensors to estimate snowpack water content. As remote sensing approaches mature, future snowpack monitoring is likely to become a blend of the traditional in situ observations and remotely sensed data products.

National Geographic submersible examining relict tree stumps in situ on bottom of Lake Tahoe. Photo credit: National Geographic

the Colorado River Basin thanks to early interest in dating archaeological sites in the Four Corners area, and efforts to quantitatively relate dendrochronology data to hydrologic conditions were pioneered on the Colorado River. These quantitative reconstructions of Colorado River inflow to Lake Powell (at the Lees Ferry gauge) show multidecadal periods when flows were below the long-term mean **(FIGURE 2.11)**. The driest period in the Colorado's observed historical record (the present drought conditions from 2000 onward) is surpassed in severity by paleo conditions prior to the historical record. In terms of an overall water supply perspective, the Lees Ferry mean unimpaired flow in the historical observed period of 1906–2015 is slightly wetter than the mean for a long-term period of 1416–2015 (Meko et al. 2007, 2017).

The California Department of Water Resources (DWR) funded streamflow reconstructions for the Sacramento, San Joaquin, and Klamath river basins to improve the understanding of the severity of droughts in these basins and to support climate change sensitivity analyses (Meko et al. 2014); these reconstructions are also shown in **FIGURE 2.11**. **FIGURE 2.12** highlights the most severe 10-year periods in the records. The Sacramento and San Joaquin rivers share 1580 as their single driest year in the combined reconstructed and instrumental record; the reconstructed flow in 1580 was only about half of that of the driest year (1924) in the observed record. Considering both drought duration and estimated runoff magnitudes, the exceptional droughts that stand out in the reconstructed records for the Central Valley drainages are those of the mid-1100s, latter 1500s, and 1920s–1930s.

DWR also recently funded (Meko et al. 2017) reconstructions of streamflow or precipitation in selected Southern California local watersheds to help support drought risk analyses for local agencies that are updating water shortage contingency plan elements of their legislatively required urban water management plans. The study results showed that short-duration (two- to three-year) droughts are relatively common in Southern California, and that the 2012–2016 drought was either the driest or second-driest five-year drought for most of Southern California (depending on the location), in a reconstructed record dating to the 1400s. The value of paleo data in extending the historical record is illustrated in **FIGURE 2.13**, which shows

Collecting a tree-ring sample near Ebbetts Pass. Data from multiple trees at one site are combined into a single record representative of the site.

Figure 2.11: Reconstructed Flows in Major Rivers

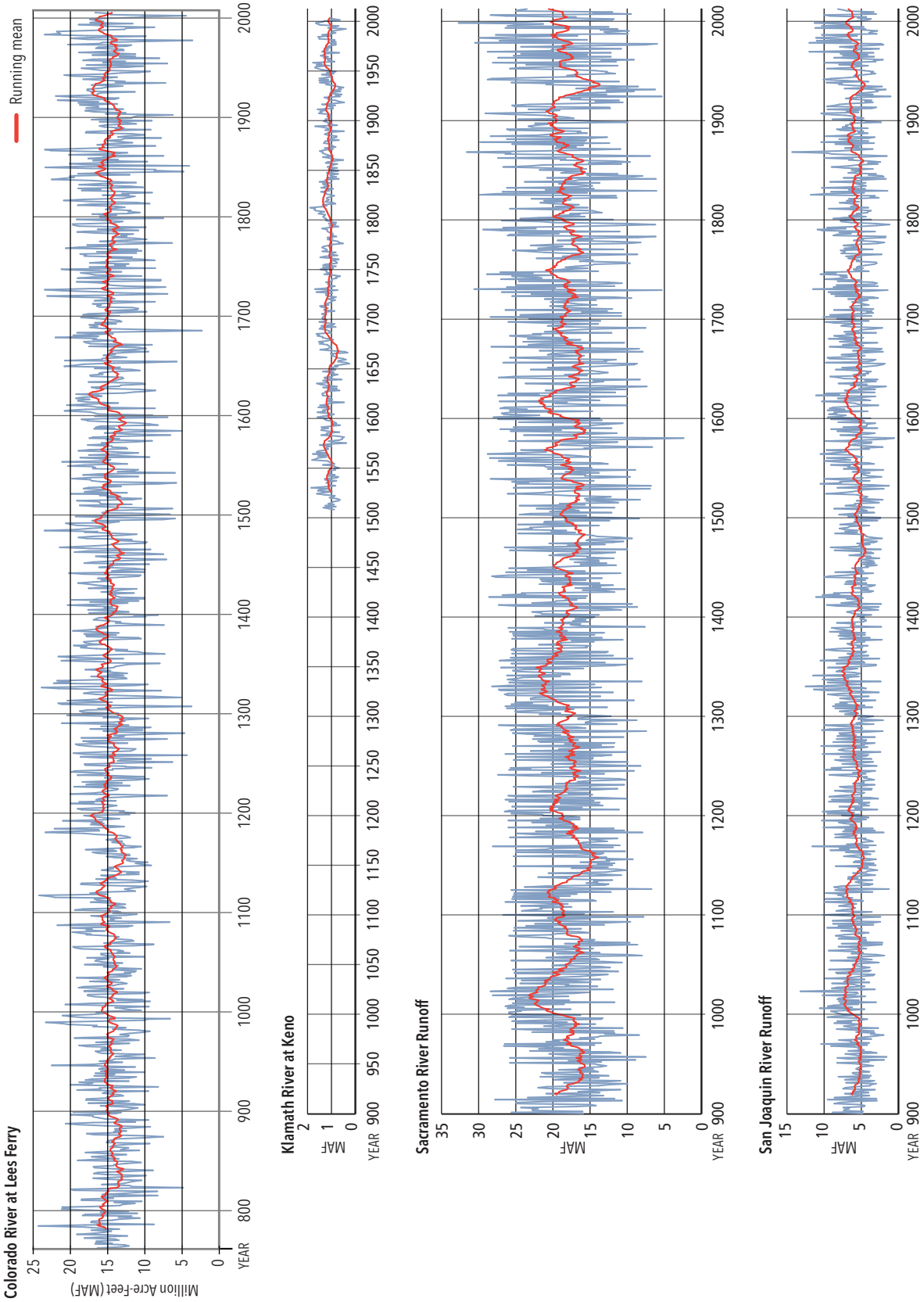


Figure credit: University of Arizona

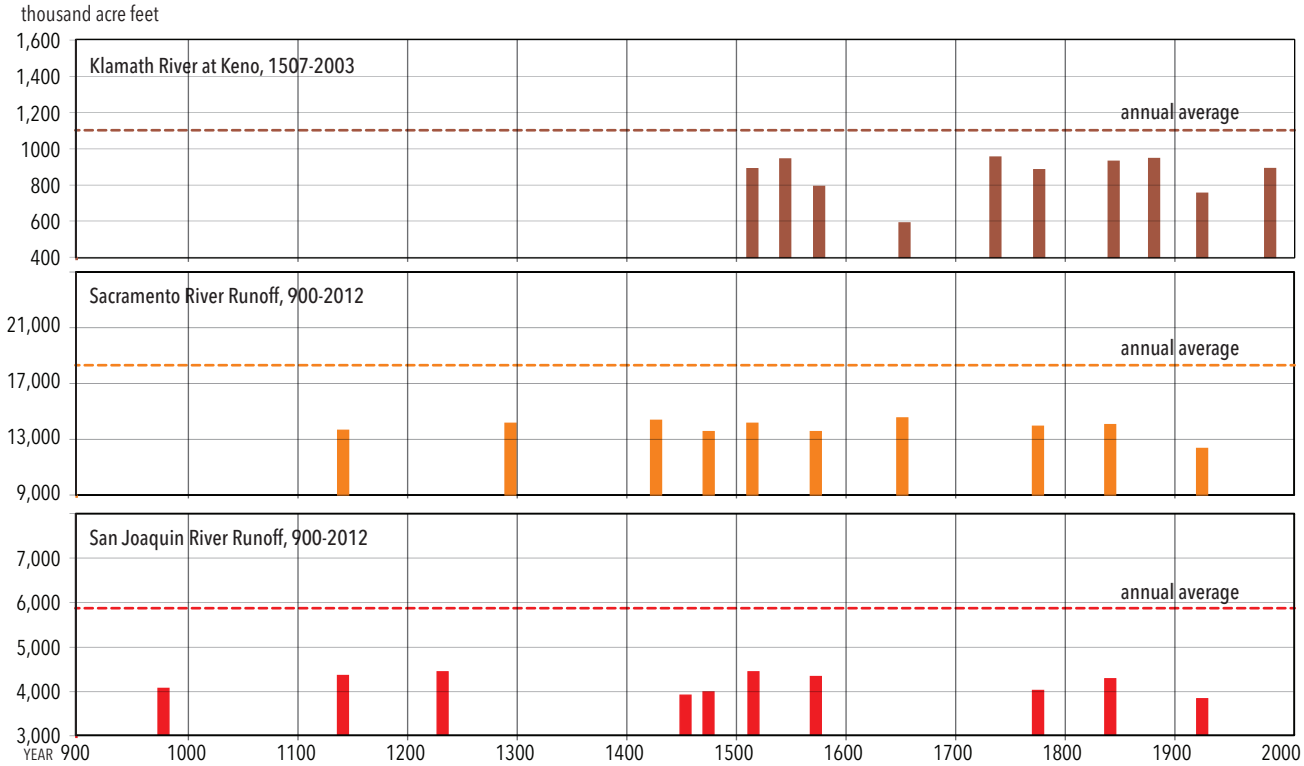
the severity of droughts in the mid-1400s and late 1500s. **FIGURE 2.14** (Woodhouse et al. 2017) illustrates times when all three of Southern California's water sources – the Colorado River, the Sierra Nevada (via the State Water Project [SWP]), and local precipitation – were concurrently dry.

MEASURING DROUGHTS IN CALIFORNIA'S HISTORICAL RECORD

Although the 1863–1864 drought played a major role in shaping the state's historical development by contributing to the demise of the cattle rancho system in Southern California, only sparse precipitation information is available to characterize the event and primarily anecdotal descriptions of its impacts. The widespread economic damage that this drought caused to California agriculture reflects the dominance of non-irrigated agriculture at the time, the limited extent of water infrastructure, and the absence of groundwater pumping technology.

California's more recent severe droughts can be evaluated by metrics such as precipitation, streamflow, or storage in surface reservoirs or groundwater basins. It is important to recognize that although the longer droughts discussed in this report are all statewide in geographical extent, there can be significant variation in their hydrology at the regional or local scale. For example, California's historical climatology of a wetter Northern California and a drier Southern California is often intensified by drought, with parts of the San Joaquin Valley and Southern California being drier in terms of percent of average precipitation than the northern part of the state. Similarly, although most of the state may be experiencing drought, some areas affected by localized weather conditions may

Figure 2.12: Driest 10-Year Periods in Reconstructed Records



Sacramento River runoff is the sum of the unimpaired flow at the Sacramento River above Bend Bridge, Feather River at Oroville, Yuba River near Smartville, and American River below Folsom Lake. San Joaquin River runoff is the sum of the unimpaired flow at the Stanislaus River below Goodwin Reservoir, Tuolumne River below La Grange, Merced River below Merced Falls, and San Joaquin River inflow to Millerton Lake.
Figure credit: Connie Woodhouse, University of Arizona

Figure 2.13: Observed and Reconstructed Water Year Precipitation at Ojai (1391–2016)

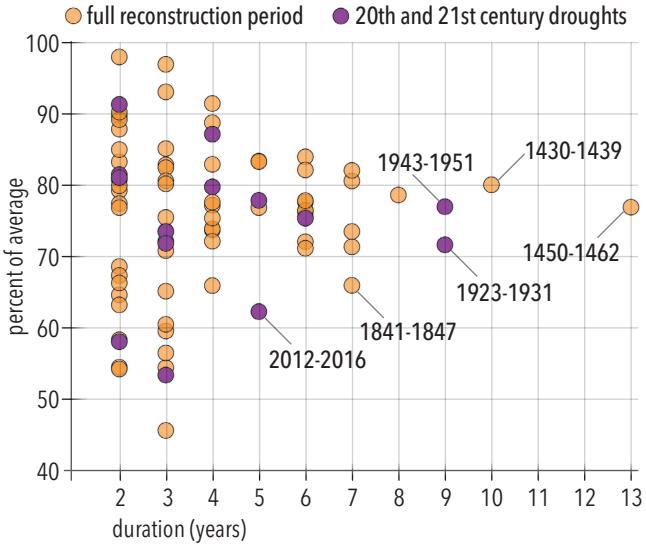


Figure credit: University of Arizona

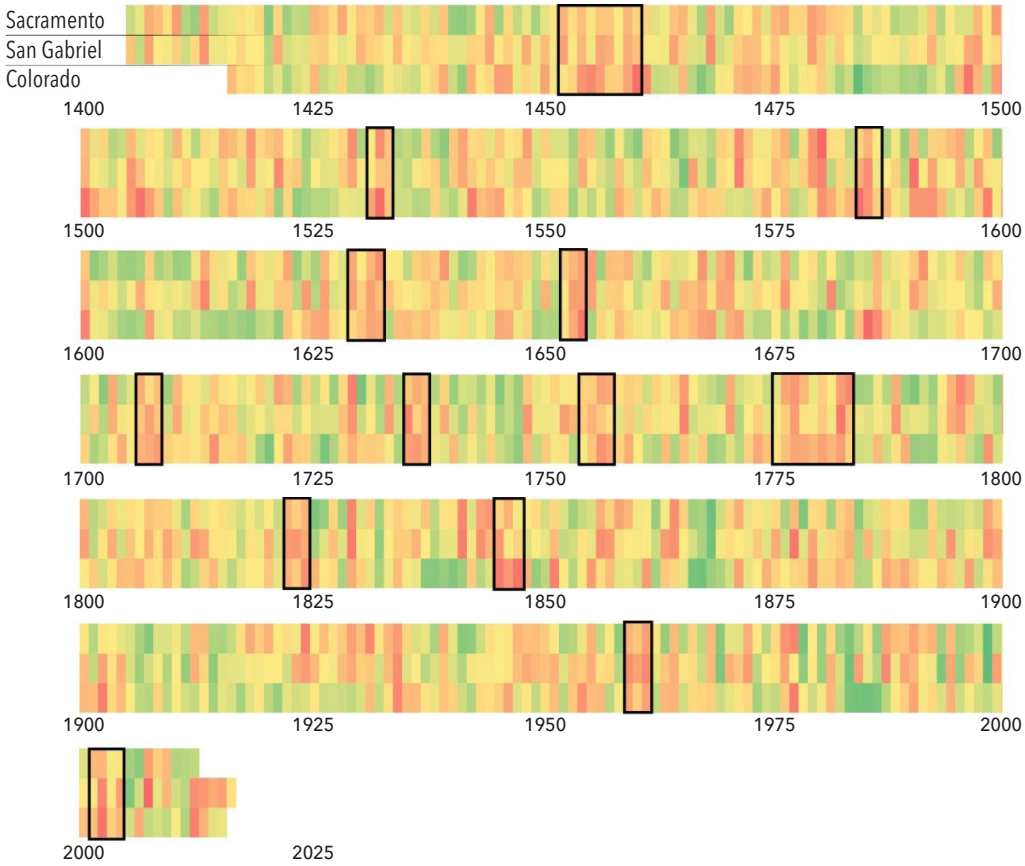
The Medieval Climate Anomaly

The Medieval Climate Anomaly in North America (sometimes called the medieval warm period or medieval climate optimum) is considered to span from as early as approximately 800 AD to as late as 1300 AD, depending on the specific location. The warmer (and in some places, drier) climate has been linked with historical events such as Norse settlement of Greenland and Iceland and changing settlement patterns in some Southwestern ancestral Pueblo communities whose agricultural production may have been affected by drought conditions. This period is associated with severe droughts in the Southwest and California. Paleoclimate data and climate modeling suggest that this period was characterized by cool surface waters in the eastern Pacific Ocean, or La Niña-like conditions (Seager et al. 2007).

Figure 2.14: Long-Term Perspective on Concurrent Dry Periods in Southern California's Water Supply Sources

Annual values for the Sacramento River Index (top row in each set of horizontal bars), San Gabriel precipitation (middle row), and the Colorado River at Lees Ferry (bottom row) reconstructions. Years are color coded, grading from wettest/highest flow (dark green) to driest/lowest flow (red). Sets of years in which values are 110 percent of average or less in all records, lasting three years or more, with an annual average value of 75 percent or less are shown with black outlines. The exception to this is the 11-year period, 1451–1461, with average annual values of 78 percent.

Figure credit: University of Arizona

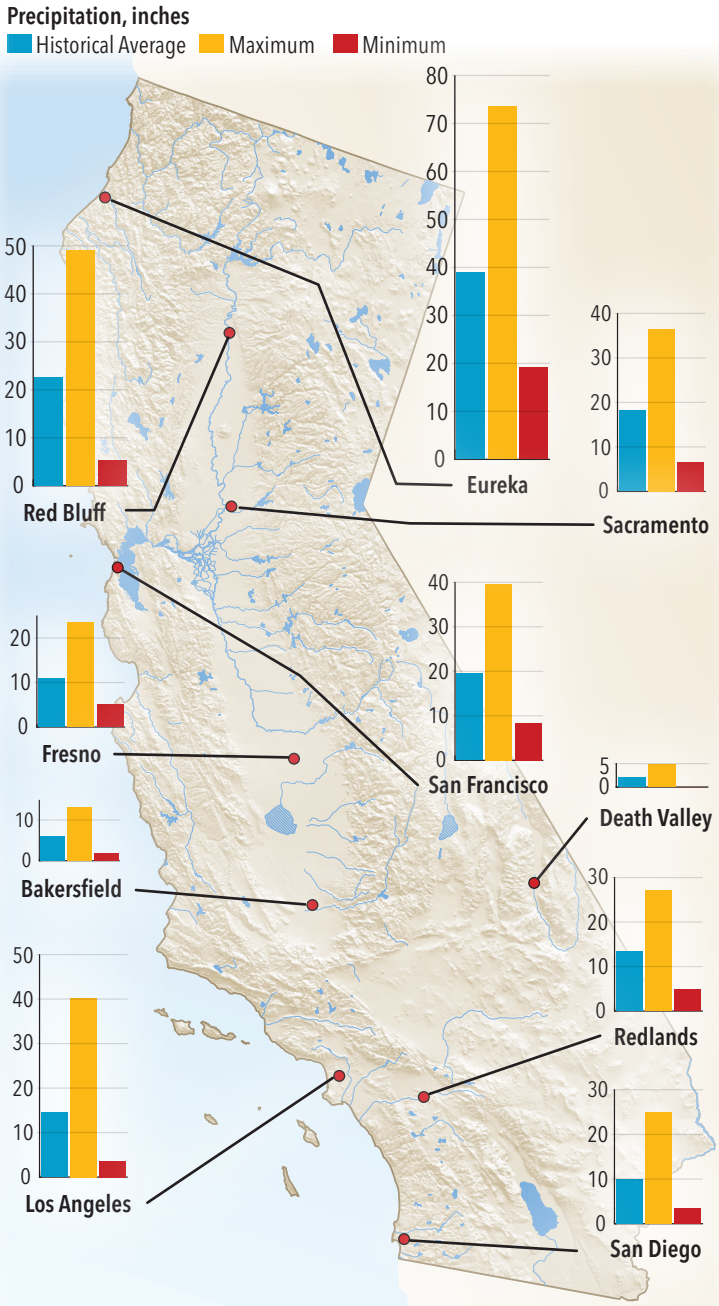


not be abnormally dry. This is often the case in California's southeastern desert region, where summer monsoonal moisture and the influence of tropical cyclones can contribute much of the region's relatively low average annual precipitation.

Spatial variation in precipitation for selected cities is shown in **FIGURE 2.15**. **FIGURES 2.16, 2.17,** and **2.18** show plots of the Northern Sierra 8-station index, San Joaquin 5-station index, and Tulare Basin 6-station index to illustrate the range of regional conditions in the Sacramento and San Joaquin valleys, where most of the state's developed water supplies occur.

FIGURE 1.6 (Chapter 1) shows the effects of droughts on calculated statewide runoff. Streamflow integrates the expression of drought hydroclimate conditions in that it reflects not only precipitation but also temperature-related effects such as melting of snowpack. Streamflow registers effects of drought duration through depletion of soil moisture; all things being equal, a given quantity of precipitation occurring at the beginning of dry conditions will result in more runoff than the same quantity of precipitation after multi-year dry conditions. Water Year 1977 ranks as California's driest year in terms of statewide runoff, although it was only the third driest year in terms of statewide precipitation, because of antecedent conditions of a very dry Water Year 1976.

Figure 2.15: Water Year Precipitation at Selected Cities



Data credit: National Weather Service

Comparing streamflows during California's major historical droughts is problematic because of changing levels of watershed development and changing regulatory requirements that affect flow. There are also different ways of expressing drought impacts on streamflow. A common approach used in hydrologic studies is to express streamflow at a specific point in terms of percent of average for a defined period (e.g., a day, a month, a year). This approach works well for major river basins where perennial flows are supported by upstream reservoirs. However, this approach can be less meaningful for resource managers in locations where drought may cause parts of the channel to go dry for extended periods, such as small watersheds that have little upstream storage, or ephemeral streams. Seasonal mean streamflows in small

Figure 2.16: Northern Sierra 8-Station Precipitation Index for Selected Years

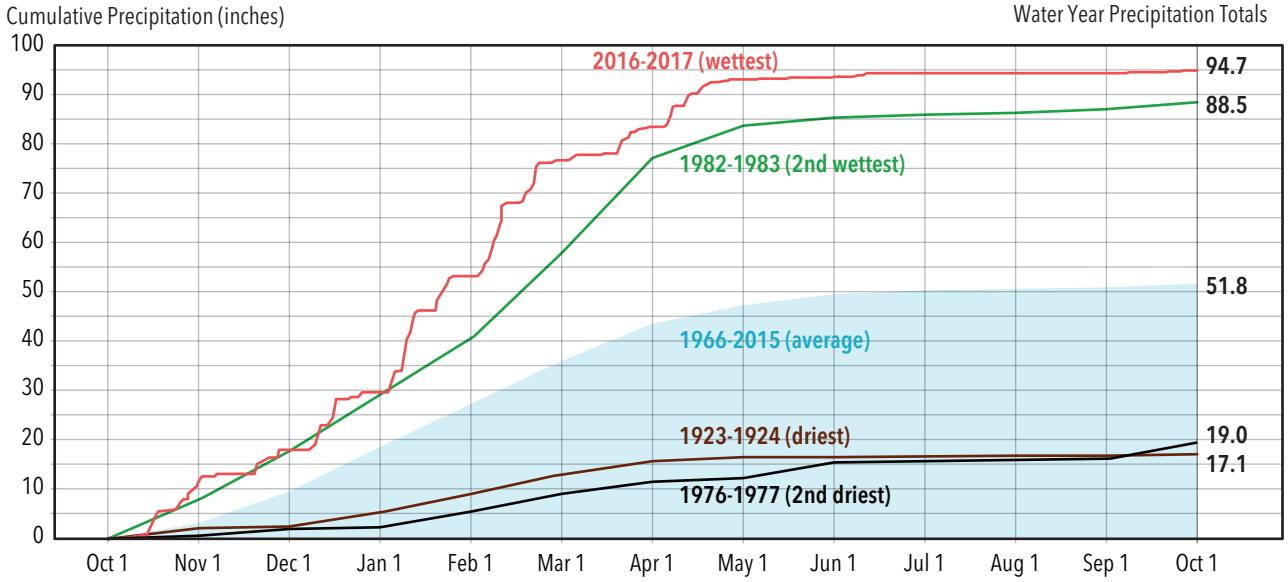


Figure 2.17: Southern Sierra (San Joaquin) 5-Station Precipitation Index for Selected Years

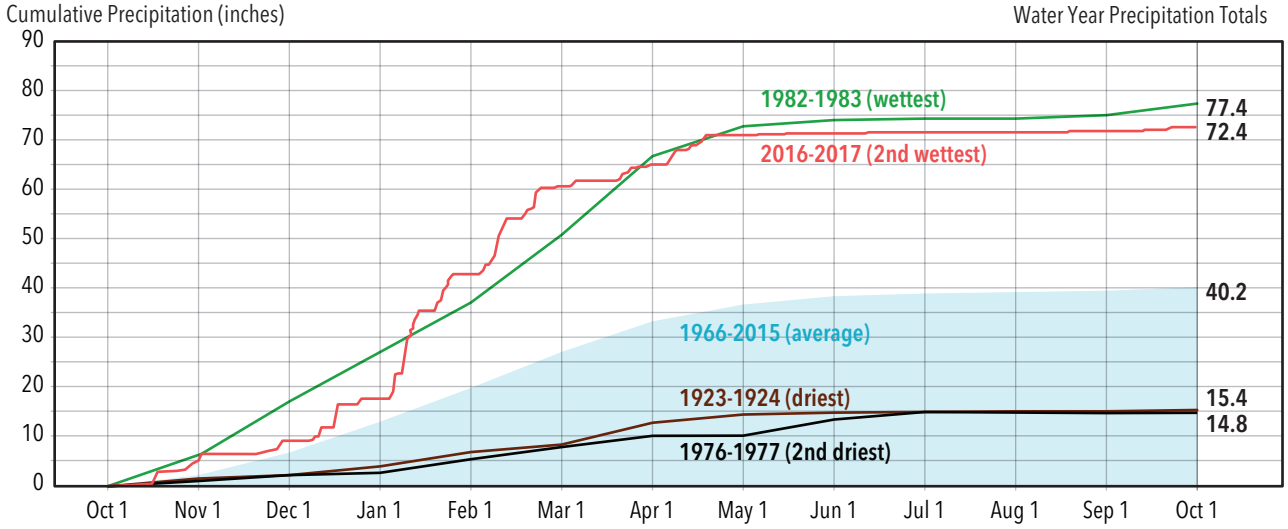
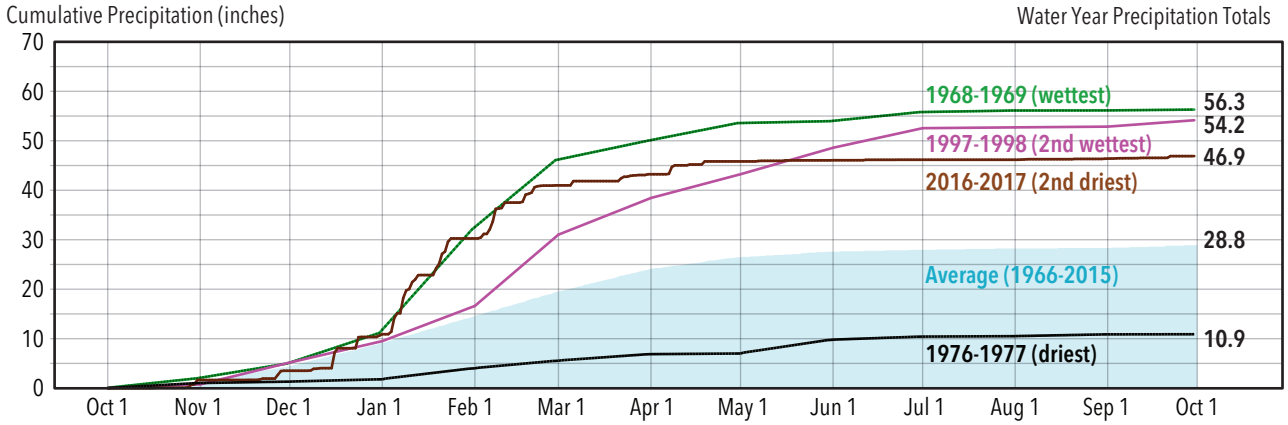


Figure 2.18: Tulare Basin 6-Station Precipitation Index for Selected Years



coastal watersheds, for example, may not be a useful metric for evaluating drought impacts on anadromous fish passage.

Reservoir storage, like streamflow, is another integrator of hydrologic drought impacts, although one that adds another layer of complexity – that of the institutional framework surrounding reservoir operations. End-of-season reservoir storage reflects multiple factors including hydrology, water rights, service area water demands, instream flow requirements, and other environmental regulatory requirements. Because the institutional framework for many California reservoirs has changed over time, comparisons of seasonal storage across historical droughts should be considered as only relative indicators of water supply availability. **TABLE 2.1** shows statewide reservoir storage at the end of selected dry water years.

Like reservoir storage, water levels in alluvial groundwater basins integrate drought impacts. Unlike reservoir storage, however, groundwater basin storage can be indirectly estimated only through complex and data-intensive models; but such information is available for a limited number of basins. Instead, groundwater level information is the key

The Cosumnes River in 1977. Parts of the Cosumnes River typically go dry during drought because there is no upstream storage to support streamflow during dry conditions.

Land Subsidence

Land subsidence in California resulting from extraction of subsurface fluids (oil and gas or groundwater) has been recognized for about 80 years (U.S. Geological Survey 1999), and has been historically observed in diverse geographical areas including the southern San Francisco Bay Area, coastal Los Angeles area, and Central Valley. The San Joaquin Valley has been an area of long-term ongoing subsidence caused by groundwater extraction. As the U.S. Geological Survey described in the 1970s (U.S. Geological Survey 1975), construction of the CVP and SWP to bring in imported supplies to help reduce groundwater overdraft had almost recovered water levels in much of the valley to predevelopment conditions, reducing the risk of continued subsidence. However, with imported CVP and SWP supplies becoming increasingly unreliable from about 1990 onward, growers turned back to groundwater to make up surface water deficiencies and to irrigate new plantings of permanent crops, resulting in further subsidence in some areas.

Increased subsidence was observed during the 1976–1977 and 1987–1992 droughts when pumping increased in response to surface water cutbacks. This subsidence was again seen during the 2007–2009 and 2012–2016 droughts. Observed San Joaquin Valley subsidence rates during the 2012–2016 drought matched the high rates seen prior to construction of the water projects. Significant adverse effects of subsidence include infrastructure damage, loss of capacity in water delivery canals and flood control channels, and changes in gradients of streams and rivers.

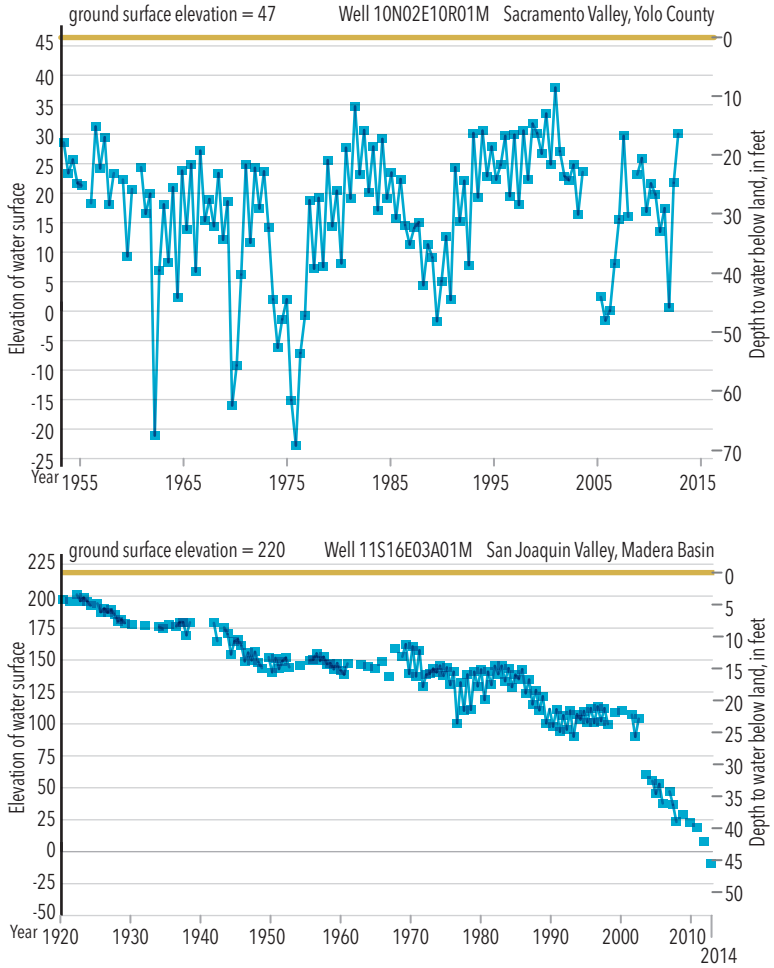
Table 2.1: End-of-Water-Year Statewide Reservoir Storage for Selected Dry Years

Year	*Percent of average*
2016	82
2015	55
2014	58
2009	79
2008	72
1992	58
1991	63
1977	36

proxy used to represent storage; it is well suited to the basins' subsurface heterogeneity and the local scale of groundwater management. Post 2009, CASGEM data allow statewide evaluation of drought impacts on groundwater.

There is limited availability of water-level data during historical (pre-CASGEM) drought periods at broad spatial scales, particularly for continuous long-term records that extend back to the 1920s–1930s. Such long-term records – dating to early development of groundwater resources – are important for understanding a basin's response to development and sustainable levels of groundwater extraction. Reliance on groundwater increases during droughts when water users with reduced surface supplies turn to groundwater to help mitigate shortages; the increased groundwater use is typically reflected in declining groundwater levels. **FIGURE 2.19** illustrates typical seasonal fluctuations in groundwater levels and longer-term trends associated with drought – a pattern of water-level drawdown during dry conditions and recovery during wet conditions – for sample wells in the Sacramento and San Joaquin valleys. The long-term overall decline in water levels for the San Joaquin Valley well shown is indicative of groundwater overdraft. Land subsidence (see sidebar) is one of the potential consequences of overdraft.

Figure 2.19: Sample Hydrographs of Wells in the Sacramento and San Joaquin Valleys



Unimpaired Flow

Unimpaired flow in a river or stream is a calculated value that reflects the amount of water that would be present in a watercourse without diversions or regulation of flow by reservoirs. Unimpaired flow is used as a metric for hydrologic conditions because it represents baseline conditions for streamflow. Measured (observed) flows typically change over time in response to development dependent on the watercourse. For example, storage provided by the Central Valley's major rim reservoirs supports downstream flows to meet water supply needs, water quality criteria, and fishery flow requirements. This results in higher observed low flows during dry years than would have occurred in predevelopment conditions. Because most of California's rivers support development, observing flows reflective of predevelopment baseline conditions is not possible.

3
Highlights of Past Droughts

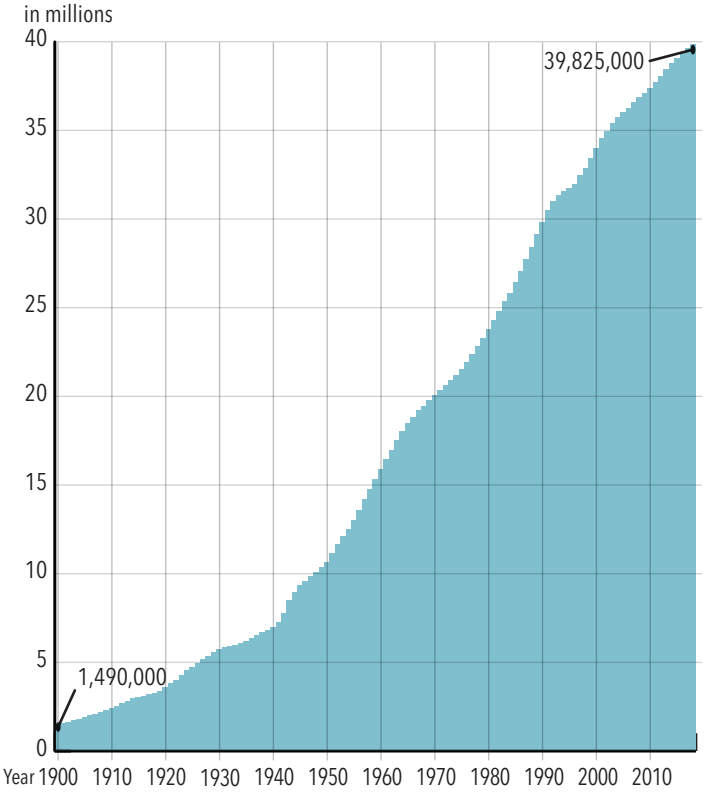
This chapter summarizes highlights from historical droughts, focusing on water management conditions and actions taken, and drought impacts. While the hydrology of past historical droughts can be compared from one event to another, the same cannot be said of their impacts, owing to the changes in California's institutional setting and level of development as described in this chapter. California experienced massive changes over the course of the 20th century, evidenced by dramatic population increases and land use conversion. **FIGURE 3.1** shows the state's population over time, illustrating the notably smaller size of California's population during the 1929–1934 and 1976–1977 droughts. **FIGURE 3.2** shows the historical extent of California's irrigated acreage which, after peaking in about 1980, has since declined slightly. **TABLES 3.1** and **3.2** illustrate relative severity of major droughts by highlighting the driest years of statewide precipitation and runoff. The sidebar on page 46 lists key dates to provide a frame of reference for the discussion of drought events that follows.

1929–1934

Beginning nearly 90 years ago and occurring as part of a longer period of sustained dry conditions, this drought is difficult to place in context in a modern setting because of the great differences in the level of development and institutional setting. California's population was estimated at 5.7 million in 1930, making it then the nation's sixth most populous state. Irrigated acreage was small in comparison to modern levels. Most major water infrastructure had not been constructed; work on initial facilities of the Central Valley Project (CVP) and on the Colorado River Aqueduct had just begun. **FIGURE 3.3** shows the geographic distribution of the state's population in 1930.

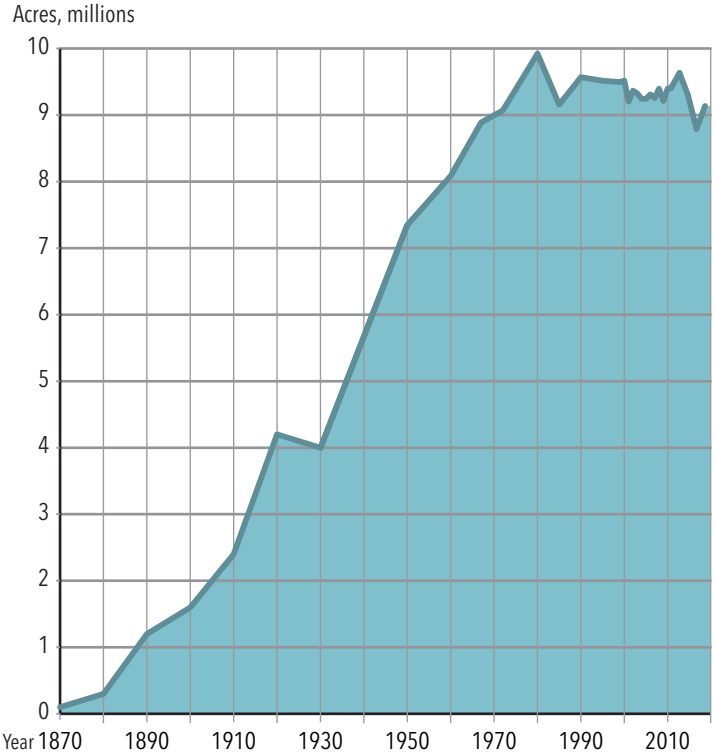
The drought was severe from a hydrologic perspective, especially in the context of its occurrence within a longer period during the 1920s and 1930s of clusters of notably below-average precipitation years briefly interrupted by wetter years. This longer-term dry sequence in the observed record stands out as being on a par with events of similar length in the paleoclimate record. In terms of calculated statewide runoff, Water Year 1931 ranks as second-driest after 1977.

Figure 3.1: Historical California Estimated Population



Data credit: Department of Finance

Figure 3.2: Historical California Estimated Irrigated Acreage



TIMELINE OF SELECTED EVENTS

1850	California admitted to the Union
1871	First reported construction of a dam on Lake Tahoe
1887	Legislature enacts the Wright Irrigation District Act, allowing creation of special districts
1902	Congress enacts the Reclamation Act, authorizing federal construction of water projects
1913	First barrel of Los Angeles Aqueduct completed
1922	Colorado River Compact signed
1929	Mokelumne River Aqueduct of East Bay Municipal Utility District is completed
1931	Legislature enacts the Water Conservation Act of 1931, spurring formation of many new special districts
1934	San Francisco's Hetch Hetchy Aqueduct completed
1940	All-American Canal completed
1941	Colorado River Aqueduct completed
1945	Shasta Dam completed
1968	Oroville Dam completed
1968	Congress enacts National Wild and Scenic Rivers Act
1971	New Don Pedro Dam completed (largest local-agency-owned dam in California)
1972	Legislature enacts California Wild and Scenic Rivers Act
1973	Congress enacts Endangered Species Act
1978	SWRCB adopts Water Rights Decision 1485 regarding CVP/SWP water operations criteria for the Delta
1984	Legislature enacts California Endangered Species Act
1992	Congress enacts Central Valley Project Improvement Act
1999	SWRCB adopts Water Rights Decision 1641 regarding CVP/SWP water operations criteria for the Delta
2003	Colorado River Quantification Settlement Agreement signed

Table 3.1: Driest Four Consecutive Water Years, Based on Statewide Precipitation

Years	Total Statewide Precipitation, inches
2012–2015	62.2
1917–1920	63.1
1923–1926	63.3
1928–1931	64.5
1931–1934	65.1
1921–1924	65.7
1922–1925	65.9
1918–1921	66.8
1929–1932	67.3
1987–1990	67.3
1930–1933	68.0

Data credit: Western Regional Climate Center

Table 3.2: Single Driest Years Based on Statewide Runoff, Based on 117 Years of Record

Year	Ranking	Year	Ranking
1. 1977	117th	7. 1990	111th
2. 1931	116th	8. 2015	110th
3. 1924	115th	9. 2001	109th
4. 2014	114th	10. 1934	108th
5. 1991	113th	11. 1992	107th
6. 1994	112th	12. 1976	106th

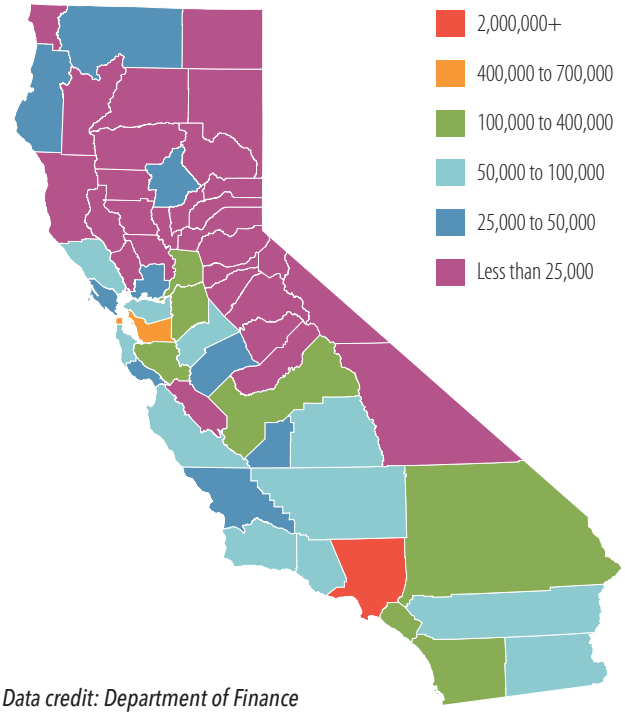
Data credit: U.S. Geological Survey

The 1935 barley harvest at the Mouren Farm in the Huron area, near the location of today's joint state-federal San Luis Canal. Prior to construction of the CVP to bring imported surface water to the San Joaquin Valley's west side, dry-farmed grain crops were a staple in the area. Photo credit: Coalinga Huron Library District

Water Infrastructure Development

The latter 1920s and 1930s were a period of accomplishment with respect to water supplies. Although only a few large-scale water projects were then extant or just coming on line, others were in the offing. The first barrel of the Los Angeles Aqueduct was completed well before the drought; construction of the Mokelumne River Aqueduct serving the East Bay was just completed at the drought's beginning. San Francisco had purchased the privately held Spring Valley Water Company in 1930 and subsequently completed construction of the Hetch Hetchy Aqueduct in 1934. The new supply of imported Tuolumne River water was needed on the Peninsula, where local supplies were stretched thin. The Santa Cruz Evening News included a short article on December 20, 1930, regarding San Francisco seeking a writ of possession for a 16-mile-long pipeline right-of-way between Newark and San Lorenzo for an emergency water line, because Spring Valley Lake (now known as Crystal Springs Reservoir) held only enough water for the first 100 days of 1931.

Figure 3.3: Distribution of California's Population in 1930



Data credit: Department of Finance

In 1930, State Engineer Edward Hyatt had completed the State Water Plan, which called for construction of a major public works project to develop the state's water resources. The plan was adopted by the Legislature in 1931, and then-Governor James Rolph issued a proclamation appointing a California Water Resources Commission and charging it with addressing the "real emergency" of "California's water problem" (California Department of Public Works 1931). Elements of the plan were implemented through California's Central Valley Project Act of 1933, which placed a bond measure before the voters to finance initial project facilities. Voters approved this $170 million measure at the height of the Great Depression, but the state was unable to sell bonds then and turned to the federal government to build the project. The state's focus on addressing water development needs also spurred 1931 legislation establishing new authority for formation of special districts, resulting in creation of many new local agencies.

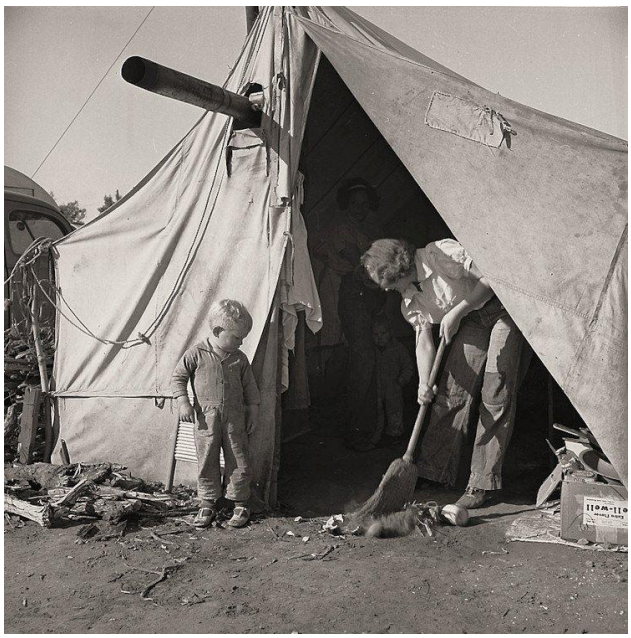
Progress had also been occurring on the Colorado River. The Boulder Canyon Project Act of 1928 authorized construction of Hoover Dam; the Seven-Party Agreement of 1931, ratified by the Legislature, divided up California's interstate apportionment of the river among the local contracting agencies. Metropolitan Water District (MWD) was formed in 1931 to contract for Colorado River water; it began construction of the Colorado River Aqueduct in 1932 and advanced funding to the U.S. Bureau of Reclamation (Reclamation) to begin construction of Parker Dam in 1934.

Construction of MWD's Colorado River Aqueduct in the 1930s, tunneling through the San Jacinto Mountains. Photo credit: Banning Library District

Also in 1934, Reclamation began construction of the All American Canal. Construction of these facilities, together with those of the CVP, provided sorely needed public works jobs during the Great Depression.

Impacts

Accounts of impacts of the 1929–1934 drought differ noticeably from those of more recent droughts in California. In part, these accounts represent the difference in the level of development between then and now. Impacts of the Great Depression – and of the extreme drought and societal impacts occurring in the Great Plains states at the heart of the Dust Bowl – overshadowed the dispersed and localized drought impacts occurring in California. Descriptions of drought in California during this period typically focus on the influx of migrants from the Dust Bowl states who came to California seeking farm jobs and often populated shanty towns or Hoovervilles in areas such as the San Joaquin Valley or Imperial Valley. John Steinbeck's *The Grapes of Wrath* immortalized this era, in which California was characterized as an Eden (a theme featured in a Woody Guthrie folk song of the time) in comparison to the Dust Bowl states. Demographers



Dorothea Lange photo of Dust Bowl migrants at a camp in the Imperial Valley. Photo credit: The History Place

Social conditions were the focus of attention for many during the Great Depression. This 1932 San Francisco scene shows jobless people living in pipes. Photo credit: San Francisco Public Library, San Francisco History Center

estimate that more than a million people moved to California during the 1930s from drought-affected states such as Oklahoma and Arkansas. This influx of people represented a large increase in the state's population in percentage terms, and one that, combined with economic conditions and labor market stresses, focused public attention on issues other than local water supply impacts.

Information about observed California impacts during the 1929–1934 drought is scattered and often anecdotal, reflecting the highly localized nature of impacts and relatively low level of statewide development. Reported statistics, notably agricultural crop production values, are difficult to compare to modern times because of the great difference in the scale of irrigated agriculture and in crop market conditions **(TABLE 3.3)**. Much has been written about agricultural production and policies during the Dust Bowl drought, but this material is largely focused on conditions in the affected Midwestern and Southeastern states and on commodity crops. Impacts on livestock production (reducing herds, selling cattle early) is the subject most frequently mentioned in California accounts of the time, and one of the impacts most similar to modern conditions. Then as now, livestock producers relying on seasonal grazing on non-irrigated rangeland were at the mercy of annual precipitation conditions. Responding both to drought in the Dust Bowl states and to the Great Depression's economic conditions, the U.S. Department of Agriculture (USDA) administered emergency drought relief programs designed to provide an outlet for producers to

Table 3.3: Leading Crops in 1929

Crop	Value ($)	% by Value of All Crops in State
Oranges	119,111,884	22.2
Hay, all types	65,207,035	12.1
Grapes	43,112,523	8.0
Lemons	43,035,390	8.0

Data credit: U.S. Department of Agriculture Census of Agriculture 1930

sell cattle whose meat would be canned and distributed through emergency food relief programs.

With respect to impacts from this period directly linked to water project operations, the so-called water wars at Lake Tahoe may have been the most well-publicized, as lakeshore property owners (dominantly on the California side) took issue with downstream uses of water in Nevada (see sidebar). Conversely, the lack of water management infrastructure to regulate streamflow during dry conditions also caused impacts, notably in terms of salinity intrusion in the Sacramento-San Joaquin Delta (Delta). Delta salinity levels fluctuated widely in response to hydrologic conditions prior to construction of the CVP and State Water Project (SWP). Because these projects are required to meet salinity targets at specified Delta locations for protection of beneficial uses of water (e.g., in-Delta agricultural diversions or fishery needs), the variability in salinity levels within the Delta has been greatly reduced. **FIGURES 3.4** and **3.5**, reproduced from the California Department of Water Resources' (DWR's) Delta Atlas (California Department of Water Resources 1993), show the contrast in upstream salinity intrusion under pre-project and post-project conditions. **FIGURE 3.6** shows a long-term record of salinity measured at a single point in the western Delta to illustrate the range of numerical values observed.

Ending the Drought

The dry cycle of 1929–1934 was followed by a Water Year 1935 that was near average in terms of computed statewide runoff. The three-year period of Water Years 1935–1937 was also in the near-average range in terms of statewide runoff. Subsequently, Water Year 1939 was one of the wettest in the measured record.

1976–1977

The institutional setting for the 1976–1977 drought differed significantly from the dry times of the 1920s–1930s. Although only a two-year event, its hydrology was severe; 1977 was the driest year of record for statewide runoff, in large part because it followed on the heels of a very dry 1976, which ranked as the 12th driest water year of record.

Low water levels at the City of San Diego's Morena Lake in 1930. Prior to construction of the San Diego Aqueduct to link the region to MWD's Colorado River Aqueduct, local drinking water supplies were almost exclusively dependent on reservoirs in the small watersheds of the Peninsular Ranges. Photo credit: San Diego History Center

An onion field near Indio in the Coachella Valley in 1929. California agriculture at the time of drought conditions during the 1920s and 1930s looked very different than it does today. Photo credit: Pomona Public Library

Low flow conditions are shown in this December 1932 photo of construction of the H Street Bridge over the American River in Sacramento. Photo credit: Center for Sacramento History

Figure 3.4: Maximum Delta Salinity Intrusion, 1921–1943

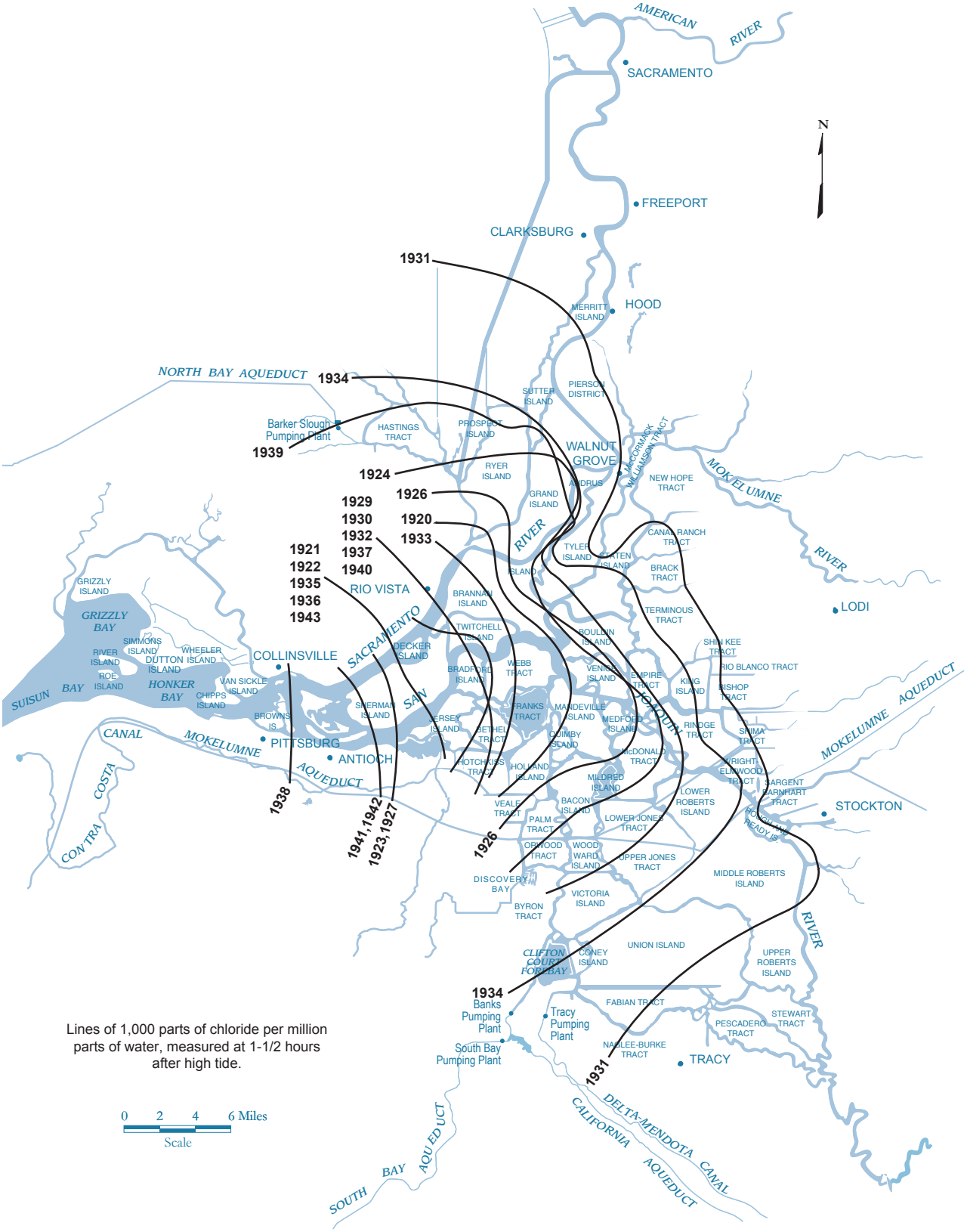


Figure 3.5: Maximum Delta Salinity Intrusion, 1944–1990

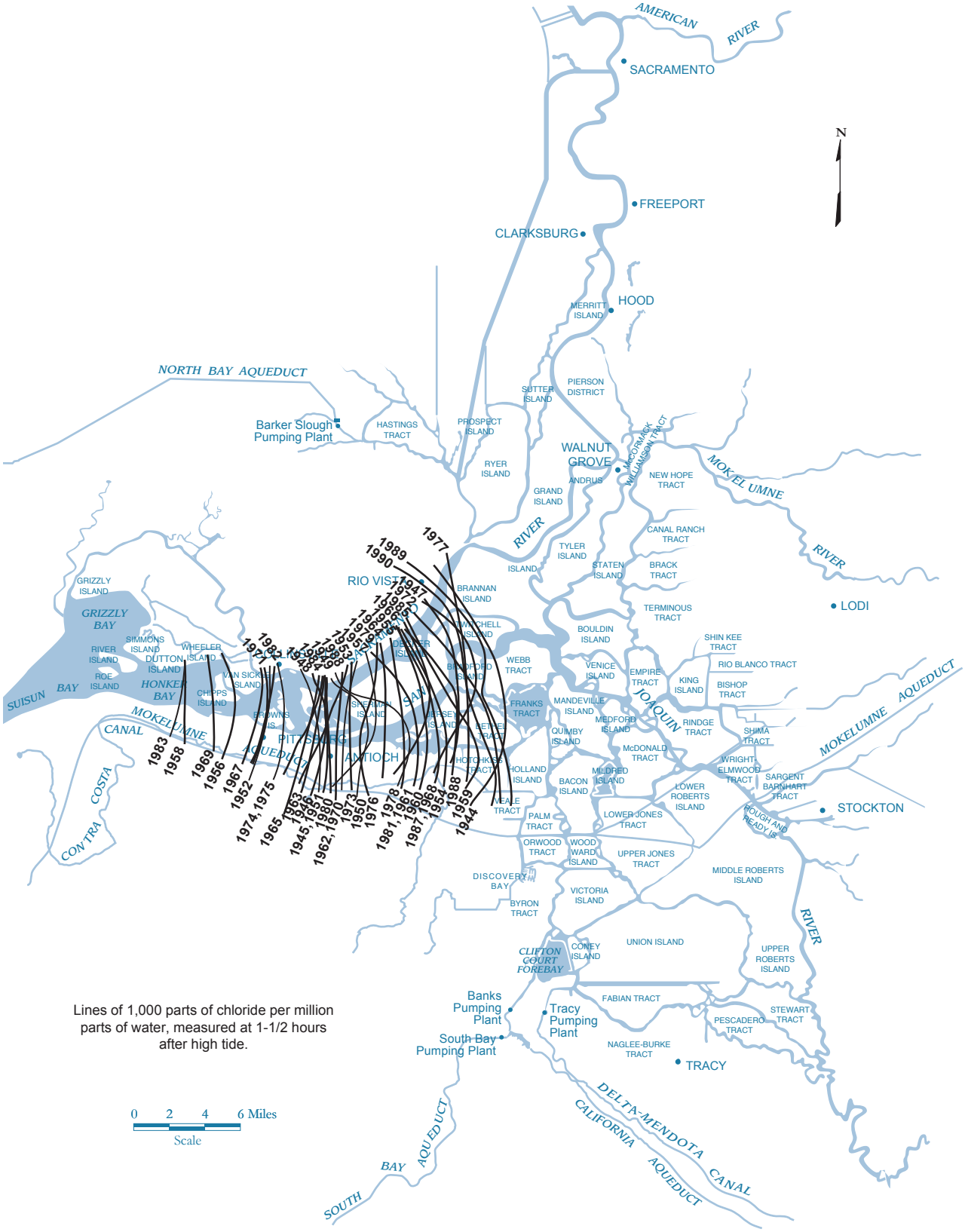
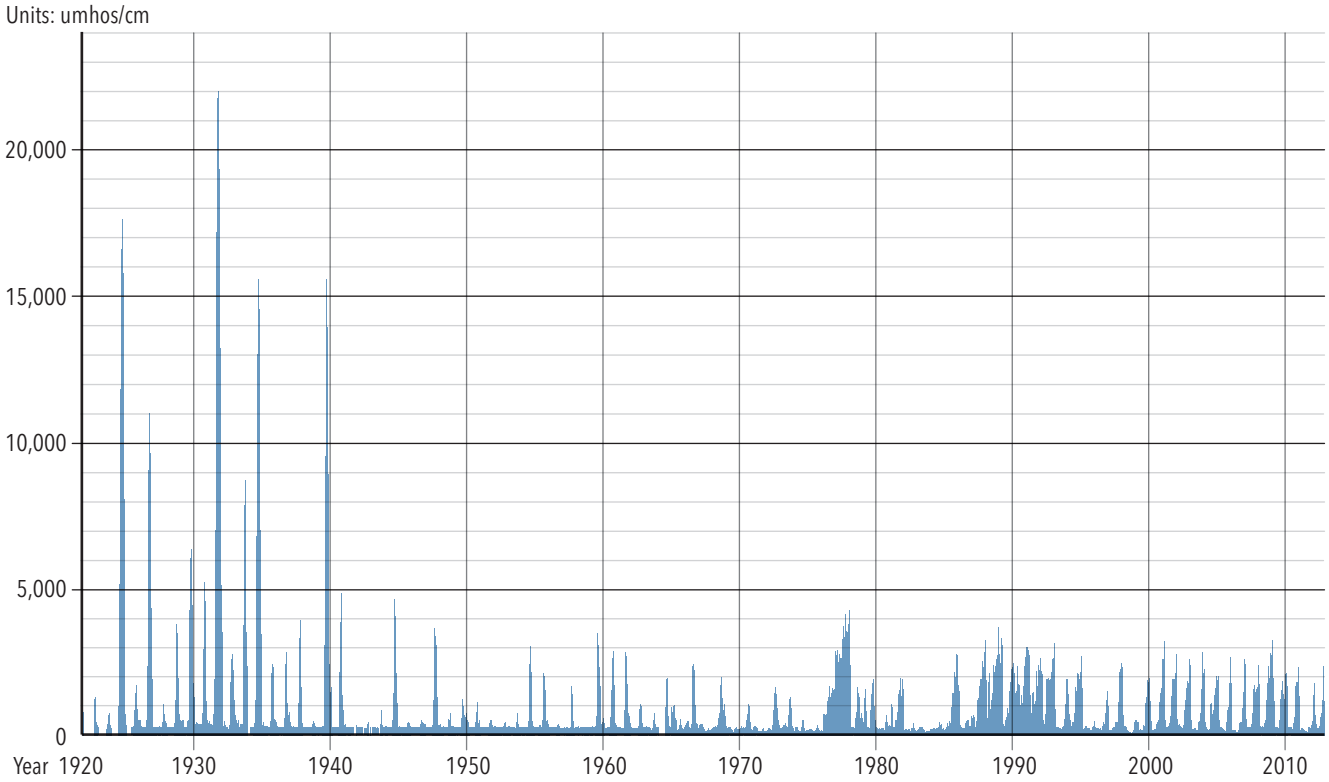


Figure 3.6: Historical Salinity (Modeled and Observed) at Jersey Point



Conflict at Lake Tahoe

The upper portion of Lake Tahoe – more than 744 thousand acre-feet (taf) of storage – is controlled by a small dam on the lake's natural outlet, constructed as part of Reclamation's Newlands Project to supply Nevada farms. During the dry conditions of the 1920s–1930s, the lake dropped below its natural rim in Water Years 1924 and 1929–1935. Severely reduced flows for downstream irrigators (and for the private power company whose hydropower plants relied on the Truckee River to generate power for the Reno-Sparks area) led to conflicts between the downstream water users and lakeshore property owners. In 1924, a group of Truckee Meadows farmers threatened to dynamite the lake's natural rim to release more water into the Truckee River. In 1930, a group of Nevada interests sent a steam shovel with a Reno police guard to the power company's property adjacent to the dam to start digging a diversion trench to the rim, and it was feared by lakeshore property owners that they would try to dynamite the dam itself. The local sheriff's representatives formed a posse and sought to stop the digging. A court injunction was ultimately obtained by landowner interests, and the diversion trench was backfilled. Arrangements were reached between landowner interests and downstream water users to allow lake water to be pumped over the natural rim in 1924, 1929, 1930, and 1934; amounts pumped were in the range of 25–34 taf annually.

Lake Tahoe periodically falls below its natural rim during drought conditions, leaving Reclamation's dam on the lake's outlet to the Truckee River high and dry.

Trying to End the Drought

Big Bear Lake in the San Bernardino Mountains was constructed to supply irrigation water for citrus and other crops in the Redlands area. Runoff to the lake is limited by the small size of the watershed. Newspaper articles from the spring and summer of 1931 report that the famous rainmaker Charles Hatfield, who used a secret mixture of chemicals that he would burn from the top of a tower, was hired by water users to make it rain to raise the lake by amounts variously reported as 10 to 29 feet. Hatfield had employed his technology at several locations, initially becoming famous for a flood he was said to have caused at San Diego's Morena Dam in 1916. Precipitation records in the San Bernardino area show an unusually wet late April in 1931, but the timing of Hatfield's work relative to those storms is unknown.

The drought was notable for the impacts experienced by water agencies unprepared for such conditions. One reason for the lack of preparedness was the perception of relatively ample water supplies in most areas of the state. The SWP's California Aqueduct had been completed less than 10 years before, bringing a new source of imported water for parts of the San Joaquin Valley and Southern California. Likewise, the state-federal joint-use facilities of the San Luis Canal brought new irrigation supplies for CVP contractors on the west side of the San Joaquin Valley. The new imported water took some of the pressure off overdrafted groundwater basins in parts of the valley; growers and irrigation districts took many of their wells out of service with the advent of the new supplies. California was receiving more than its basic interstate apportionment of Colorado River water thanks to unused apportionment of Nevada and Arizona and to hydrologic surpluses. There had not been major droughts in the recent past. (Although there had been multi-year dry periods of statewide scope in 1947–1950 and 1959–1961, the hydrology of these events was far less severe than that of the 1920s–1930s.) When the 1976–1977 drought did occur, it was a wake-up call for many water agencies.

California's population in 1977 was about 22 million. Irrigated acreage was essentially at present levels. Most of the state's major water infrastructure projects had now been constructed; the last major CVP reservoir (New Melones Lake) was under construction. There were no fish species listed pursuant to the Endangered Species Act (ESA) either migrating through or residing in the Delta; the striped bass index was being used by the then-Department of Fish and Game as a metric of Delta fishery conditions.

Water Supplies and Water Project Operations

The impacts of dry hydrology in 1976 were mitigated by reservoir storage and groundwater availability. The immediate succession of an even drier 1977, however, set the stage for widespread impacts. In 1977, CVP agricultural water contractors received 25 percent of their allocations, municipal contractors 25 to 50 percent, and the water rights or exchange contractors, 75 percent. SWP agricultural contractors received 40 percent of their allocations and urban contractors, 90 percent. Thanks to the availability of Colorado River water in excess of the state's basic interstate apportionment, MWD was able to reduce its use of SWP water, making more water from that source available for other project contractors.

Managing Delta salinity was a major challenge for the SWP, given the competing needs to preserve critical carryover storage and to release water from storage to meet Bay-Delta water quality standards. (At that time, the present-day Coordinated Operation Agreement between DWR and Reclamation was not in effect, and Reclamation was not operating the CVP to protect Delta salinity.) In February 1977, the State Water Resources Control Board (SWRCB) adopted an interim water quality control plan to modify Delta standards to allow the SWP to conserve storage in Lake Oroville. As extremely dry conditions continued that spring, SWRCB subsequently adopted an emergency regulation superseding its interim water quality control plan, temporarily eliminating most water quality standards and forbidding the SWP to export stored water.

As a further measure to conserve reservoir storage, DWR constructed temporary facilities in the Delta to help manage salinity with physical, rather than hydraulic, approaches (FIGURE 3.7). These facilities included:

» A rock barrier at Sutter Slough to help meet water quality criteria and enable increased SWP pumping.

» A rock barrier at the head of Old River for improving fishery conditions (this barrier had been installed annually to improve conditions for migrating salmon; its use was not specific to drought years).

» Rock barriers at Indian Slough and Rock Slough, along with a pumping plant on Middle River and temporary pipeline interconnection to one barrel of East Bay Municipal Utility District's Mokelumne Aqueduct, to move fresher water to the Contra Costa Canal intake.

» New diversions for Sherman Island agricultural water users.

» Facilities to provide better water quality for duck clubs in the Suisun Marsh.

» Rock barriers in Old River east of Clifton Court and in the San Joaquin River at Mossdale to protect South Delta agricultural water quality.

» A rock barrier on Dutch Slough in the West Delta to provide additional protection against salinity intrusion.

Illustrating the effects of greatly reduced Delta inflows, special tidal cycle monitoring conducted by DWR found reverse flows caused by tidal action occurring as far upstream on the Sacramento River as the mouth of the American River.

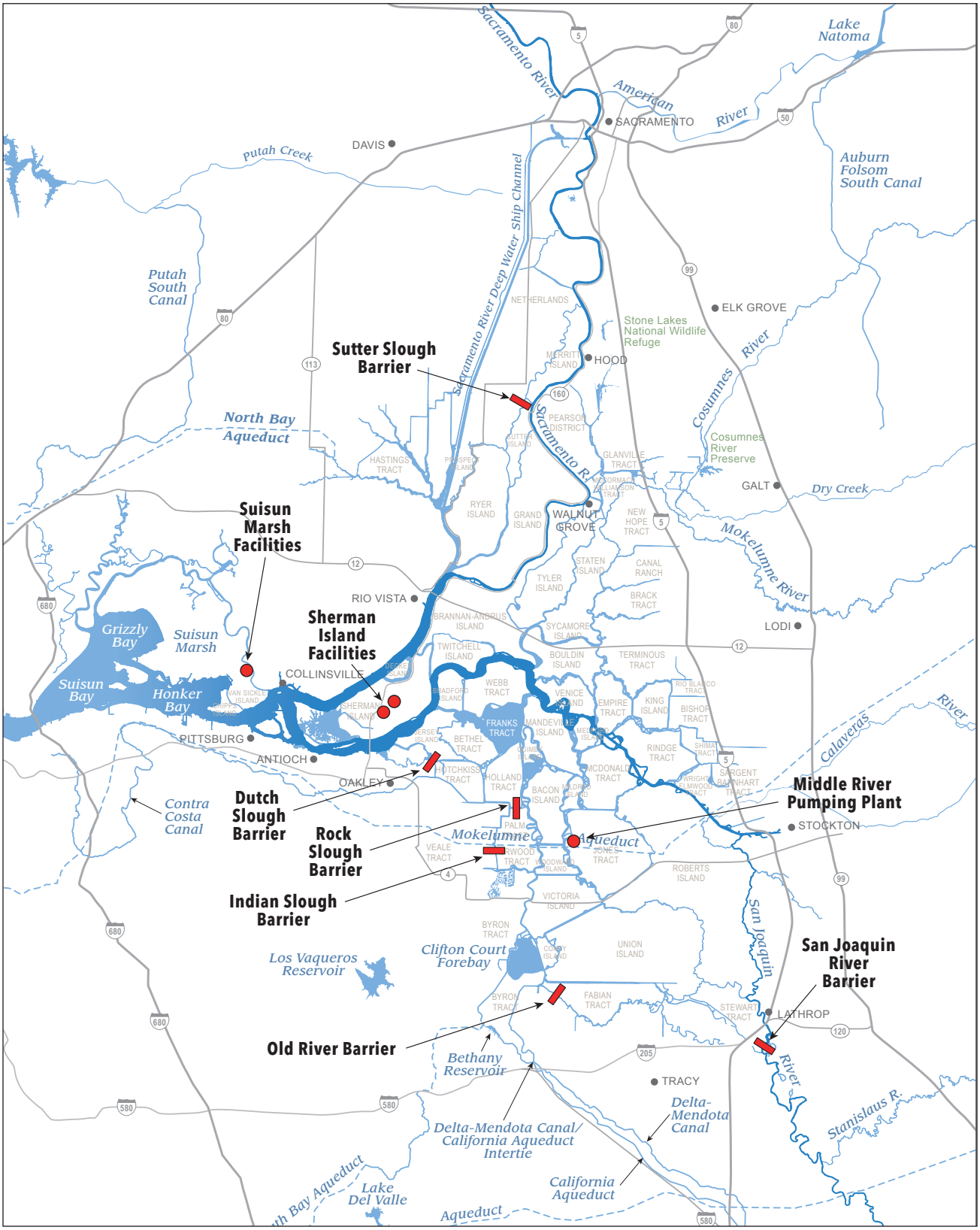
Water exchanges among SWP and CVP contractors were a tool used to respond to drought; one of the largest exchanges involved 435 thousand acre-feet (taf) of SWP supply made available by MWD and three other SWP Southern California water contractors for use by San Joaquin Valley irrigators and urban agencies in the San Francisco Bay area. The MWD SWP supply provided water to Marin Municipal Water District via an emergency pipeline laid across the San Rafael Bridge and a complicated series of exchanges under which DWR delivered the water to the Bay Area via the South Bay Aqueduct. Public Law 95-18, the Emergency Drought Act of 1977, authorized Reclamation to purchase water from willing sellers on behalf of its contractors; Reclamation purchased approximately 46 taf of water from sources including groundwater substitution and the SWP. Reclamation's ability to operate the program was facilitated by its CVP water rights that broadly identified the project's service area as the place of use, allowing transfers within the place of use. Institutional constraints and water rights laws were limiting factors in the transfer/exchange market at this time, and transfer activity outside of the SWP exchanges arranged by DWR and Reclamation's drought water bank was relatively small scale.

Impacts

Depletion of reservoir storage was a major impact. Statewide storage in California's major reservoirs was 57 percent of average on October 1, 1976, and had dropped to 37 percent of average one year later. (Storage in the North Coast hydrologic region was only 15 percent of average at this time.) The latter part of 1976 saw the start of a major

An emergency drought barrier being installed in Sutter Slough in August 1976.

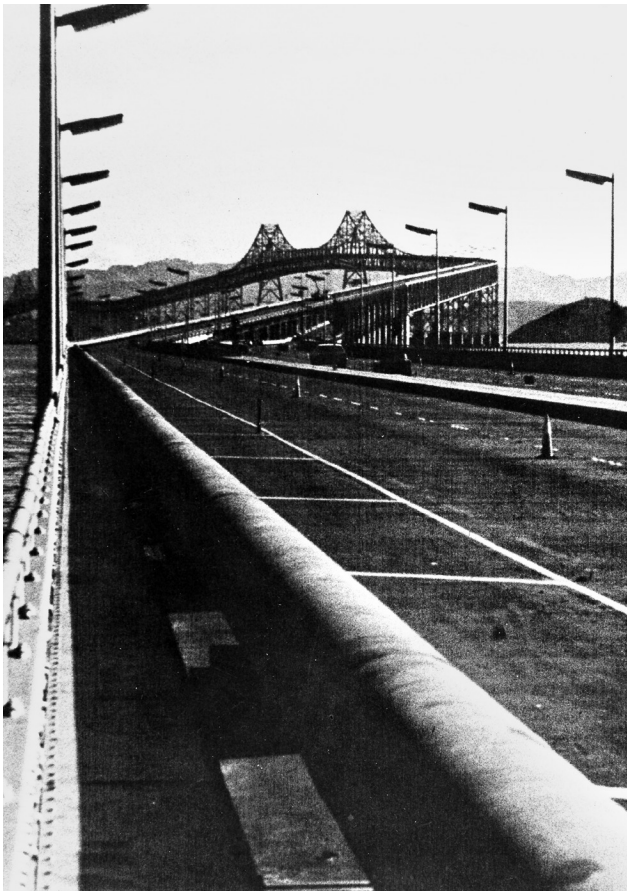
Figure 3.7: Temporary Salinity Management Facilities Installed in 1976–1977



state-level policy drive for urban water conservation. Widespread urban water conservation and mandatory rationing were hallmarks of the drought. Many communities achieved substantial savings, especially those where chronic water shortages (typically smaller communities outside major urban centers) led to cutbacks in water use of 50 percent or more. North and Central Coast communities had some of the highest conservation savings because of local water shortages.

Marin County was the large urbanized area most affected by the drought, with most communities in the southern part of the county limited to basic health and safety water consumption levels. The area has limited groundwater resources and at the time had only local surface water sources. (Completion of Warm Springs Dam/ Lake Sonoma in the Russian River watershed in the early 1980s subsequently provided a source of imported water.) Emergency response measures included the temporary pipeline to convey water exchanged from MWD's SWP supply, as well as state assistance with temporary storage tanks and connections for small water systems.

Outside of the Marin County problem, public water systems facing critical drinking water shortages were primarily small water systems in rural areas. State assistance was provided via loans or emergency response actions to support new wells, temporary storage tanks, temporary pipelines, interconnections, pumps and generators, and mobile treatment units. Some small water systems were able to arrange temporary interconnections to other systems or to industrial users (e.g., lumber mills). Water haulage was reported for small systems or for private residences on wells, especially throughout Northern California foothill areas and on the North Coast.



An iconic image from the 1976-1977 drought was the temporary emergency pipeline constructed across the San Rafael Bridge to bring imported water into southern Marin County.

Cloud Seeding Activities

Both DWR and Reclamation had active programs in 1977–1978 in what was then termed "cloud seeding." DWR awarded a $127,000 contract in July 1977 for an aircraft-based summer seeding program in parts of the Sierra Nevada, intended to improve soil moisture conditions and to reduce wildfire risk. In December 1977, Reclamation awarded a contract for $289,000 for winter seeding in parts of the Cascade Range and northern Sierra Nevada, using both ground-based propane generators and aircraft. Three additional small contracts were also issued for monitoring and research or analysis associated with the winter seeding program. The winter seeding was terminated in February 1978 because of heavy precipitation. DWR was to again conduct a weather modification program during the 1987–1992 drought, with a 1989 aerial seeding operation in the Feather River watershed and a demonstration ground-based propane generator project in the Middle Fork Feather River watershed in 1991.

Contemporaneous reports (U.S. Government Accountability Office 1977) describe most of the drought's economic impacts as being associated with the agricultural and forestry sectors. Idling of irrigated cropland caused by water shortage was reported as 125,000 acres in 1977 (California Department of Water Resources 1978), with most of the idled acreage located in Fresno and Kern counties. The majority of agricultural losses were ascribed to livestock production, with a geographic extent that covered most of the state. Agricultural production losses in 1977 were estimated at $566.5 million, composed of $414.5 million in livestock, $112 million in field crops, and $40 million in fruit and nut crops. Timber production losses resulting from wildfire and insect damage were estimated at $517.5 million (California Department of Water Resources 1978).

Institutional Actions

California was not alone in experiencing drought in 1976-1977; dry conditions affected many of the western states. The Western Governors' Conference named a western regional drought action task force in 1977 and used that forum to coordinate state requests for federal assistance. Multistate drought impacts resulted in federal response in the form of increased appropriations for traditional federal financial assistance programs (e.g., USDA assistance programs for agricultural producers), and in two drought-specific pieces of legislation. The Emergency Drought Act of 1977 authorized the U.S. Department of the Interior to take temporary emergency drought mitigation actions and appropriated $100 million for activities to assist irrigated agriculture, including Reclamation's water transfer programs. The Community Emergency Drought Relief Act of 1977 authorized $225 million for the U.S. Economic Development Administration's drought program, of which $175 million was appropriated ($109 million for loans and $66 million for grants) to assist communities with populations of 10,000 or more, tribes, and special districts with urban water supply actions. Projects in California received 41 percent of the funding appropriated pursuant to this act.

Within California, the Governor signed an executive order naming a drought emergency task force in 1977. Numerous legislative proposals regarding drought were introduced, about one-third of which became law. These measures included:

- Authorization of a loan program for emergency water supply facilities.
- Authorization of funds for temporary emergency barriers in the Delta (ultimately, the barriers were instead funded by the federal Emergency Drought Act).
- Prohibition of public agencies' use of potable water to irrigate greenbelt areas if SWRCB found that recycled water was available.
- Authorization for water retailers to adopt conservation plans.
- Addition of drought to the definition of "emergency" in the California Emergency Services Act.

In contrast to the present-day approach of using state general obligation bond measures to provide grants to local agencies, state-financed local assistance programs in the mid-1970s were primarily based on loans. Two bond-funded programs related to water supply were in effect: the Davis-Grunsky Act of 1960, which provided loans for local water supply projects, and a 1976 measure to provide loans for compliance with Safe Drinking Water Act requirements. Neither of these measures was drought-related, but both represented a potential source of assistance for local agency projects.

Water management issues highlighted by drought conditions – such as constraints on water transfers, potential forfeiture of water rights associated with conservation programs, or impacts resulting from over-extraction of groundwater – led to the Governor's appointment of a Commission to Review California Water Rights Law in 1977. The commission released its final report to the Governor in 1978, identifying many statutory changes that could be made and recommending proposed

legislative language (Governor's Commission to Review California Water Rights Law 1978). (Some of these recommendations were later addressed during the 1987–1992 drought, particularly those related to water transfers and to conservation programs.)

SWRCB was actively engaged in water rights administration during the drought, notifying diverters in Central Valley and Delta locations in 1977 that junior appropriators would be required to cease diverting as of specified dates, and that natural streamflows would be unavailable for riparian users and pre-1914 appropriators in some areas after specified dates. SWRCB conducted field inspections of Sacramento Valley diversions in 1977 to monitor compliance with its curtailment orders, with assistance from DWR staff. DWR carried out Sacramento Valley land and water use studies in 1976–1977 to quantify how the extremely dry conditions affected water use and diversion patterns. One finding of this effort was that for the first time in 30 years of DWR water use studies, the Sacramento River appeared to have a net loss of water to the groundwater basin.

Ending the Drought

The record dry Water Year 1977 was followed by a 1978 that ranked in the top quarter of the record for statewide runoff.

1987–1992

The six-year event of 1987–1992 was California's first extended dry period since the 1920s–1930s, and a closer analog to extended drought conditions under a modern level of development. All six years were dry, with four of them ranking in the top 10 percent in terms of driest statewide runoff. Water Year 1991 was the driest year of this drought, ranking in fifth place in the statewide runoff record.

California's population in 1990 was about 30 million. Irrigated acreage was essentially at present levels. Delta regulatory constraints affecting CVP and SWP operations were based on SWRCB water right decision D-1485, which had taken effect in 1978 immediately following the 1976–1977 drought. In 1992, the National Marine Fisheries Service (NMFS) issued its first biological opinion for the Sacramento River winter-run Chinook salmon, which had been listed as threatened pursuant to the ESA in 1989. The Central Valley Project Improvement Act of 1992 was enacted just at the end of the drought, so provisions reallocating project yield for environmental purposes were not in effect for 1992 water operations. California was continuing to receive more than its basic interstate apportionment of Colorado River water thanks to unused apportionment of Nevada and Arizona and to hydrologic surpluses. Access to Colorado River water above the basic apportionment helped mitigate impacts of SWP cutbacks in MWD's urban Southern California service area.

Water Supplies and Water Project Operations

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 because of reduced deliveries from reservoir storage. Statewide reservoir storage was down to approximately 40 percent of average by the third year of the drought, and did not return to average conditions until 1994, thanks to a wet 1993. 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. In 1991, the SWP terminated deliveries to agricultural contractors and provided 30 percent of requested urban deliveries. The CVP delivered 25 percent to agricultural contractors and 25 to 50 percent to urban contractors.

In addition to D-1485 requirements controlling SWP and CVP operations in the Delta, other operational constraints included temperature standards imposed 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 degrees Fahrenheit during periods when high water temperatures could be detrimental to survival of salmon eggs and pre-emergent fry. As part of managing salinity during the drought, DWR installed temporary barriers at two South Delta locations – Middle

River and Old River near the Delta-Mendota Canal intake – to improve water levels and water quality/water circulation for agricultural diverters. (In contrast to the 1976–1977 drought, the Coordinated Operation Agreement of 1982 was now in effect between DWR and Reclamation with respect to project operations to meet Delta regulatory requirements.)

In response to Executive Order W-3-91 in 1991, DWR developed a drought water bank that operated in 1991 and 1992. The bank bought water from willing sellers and made it available for purchase to agencies with critical water needs. Critical water needs were understood to be basic domestic use, health and safety, fire protection, and irrigation of permanent plantings. DWR purchased 821 taf of water for the bank in 1991 from land fallowing (approximately 50 percent), groundwater substitution (30 percent), and reservoir storage (20 percent). The 821 taf purchased yielded a net amount of 656 taf after accounting for Delta carriage water and instream flow requirements; 307 taf of this amount went to urban uses, 83 taf went to agricultural uses, and DWR purchased the remaining 266 taf for SWP carryover storage when needs of other buyers were satisfied. Building on lessons learned from the 1991 bank, DWR purchased 193 taf for the 1992 bank, obtained from groundwater substitution (80 percent) and reservoir storage (20 percent). Additionally, the then-Department of Fish and Game operated a purchasing program in parallel with the drought water bank, acquiring 75 taf for fish and wildlife purposes (primarily for refuge water supply) with state emergency drought relief funding. DWR monitored impacts in areas of groundwater substitution transfers to respond to

U.S. Bureau of Reclamation's 240 thousand acre-foot Twitchell Reservoir on the Cuyama River in San Luis Obispo County in 1990. The reservoir provides supplemental irrigation supplies for Santa Maria Valley.

concerns expressed by local water users and residents regarding third-party impacts.

Impacts

Effects of long-term dry conditions on reservoir storage were a concern, just as they were in 1976–1977. Among the state's largest urban areas, the City of San Francisco's system experienced the greatest impacts with only approximately 25 percent of total storage capacity remaining in 1991, a circumstance leading to its construction of two turnouts on the California Aqueduct to provide access for water transfers. The small reservoirs of Reclamation's Central Coast projects were another area of impact. The Santa Barbara area experienced the largest water supply reductions of California's larger municipalities; its limited groundwater and local surface supply (Reclamation's Cachuma Project) were unable to support residents' needs. (Although Santa Barbara had earlier contracted for SWP water supply, it had not at the time proceeded with construction of facilities to take delivery of its allocation and did not have access to imported water.) In 1990, the Governor declared a state of emergency in the City and County of Santa Barbara. The city was forced to adopt emergency measures that included a 14-month ban on lawn watering. Multi-agency water transfer and exchange agreements were used to make an emergency SWP water supply available to Southern Santa Barbara County via construction of a 16-inch pipeline between Ventura and Oxnard. Santa Barbara contracted for installation of a portable seawater desalination plant that was briefly operated in 1991.

This drought's extended duration resulted in widespread problems for small water systems in rural areas dependent on unreliable water supplies. Likewise, there were widespread reports of dry private residential wells. Some communities were able to construct temporary pipelines to a new surface water source (e.g., Markleeville and Willits). Water haulage was a common emergency response, occurring particularly in Northern California's foothill areas, the North Coast, and the Russian River corridor. Areas relying on fractured rock groundwater sources or shallow coastal

Just as the Marin County emergency pipeline over the San Rafael Bridge was an iconic image of the 1976–1977 drought, Santa Barbara's temporary emergency desalination project was emblematic of the 1987–1992 drought.

terrace groundwater basins (such as along the Central Coast) experienced many of the reported problems. In the town of Mendocino, for example, much of the water supply is provided by private residential wells. It was estimated that 10 percent of the town's wells go dry every year, and that amount increased to 40 percent during drought.

In the agricultural sector, estimated drought-idled acreage was on the order of 500,000 acres, representing approximately 5 percent of 1988-level harvested acreage. Some agricultural water districts experienced financial problems caused by reduced revenues from water sales but ongoing fixed costs for water. Financial problems experienced by Kern County Water Agency's member districts, for example, together with concerns about SWP water allocation rules, were an impetus for subsequent negotiation of the Monterey Amendments between DWR and its SWP contractors. When executed in 1994, the Monterey amendments provided that an equal annual allocation would be made to urban and agricultural contractors. The prior provisions in effect during the 1987–1992 drought called for agricultural contractors to take a greater reduction in their allocations during shortages than urban contractors, which had resulted in the zero allocation to the agricultural contractors in 1991. Statewide, estimated gross revenue loss to farms was approximately $220 million in 1990 and $250 million in 1991 (California Department of Water

Extreme or Catastrophic Droughts

What is an extreme drought? The Great Drought of 1863–1864 was an extreme event to early California settlers, because they had made no preparations and had no tools available for managing it. Overall, California coped relatively well through the six-year event of 1987–1992, the longest drought in recent times, thanks to major investments in water management infrastructure. Reconstructed paleo streamflows for the Sacramento River Basin do not show conditions markedly different from the present within the last 500 years (Meko 2014), although multidecadal droughts occurred earlier during the Medieval Climate Anomaly, when record drought gripped much of North America. As described in Chapter 2, severe sustained droughts are not particularly frequent in the last 1,000 years of observed plus reconstructed records.

From a resource management perspective, drought's slow onset offers time to take response actions. Historical experience shows that impacts of, for example, an initial five-year period of below-normal hydrology would be manageable at the statewide scale, although localized impacts could be significant for specific economic subsectors in vulnerable locations. Continuation of a subsequent five years of dry conditions likely would be more significant at a statewide scale, requiring response actions and policy decisions outside of those historically taken. It is typically better to take response actions sooner when conditions shift from a routine level of dryness to an extraordinary one, rather than waiting until reservoir storage is significantly depleted.

Resources 1994), with hardest hit commodities being grains, non-irrigated hay, and beef cattle. Geographically, impacts were greatest on the west side of the San Joaquin Valley.

DWR interviewed more than 60 entities associated with urban water uses to identify drought impacts to commercial and industrial water users. In administering their voluntary and mandatory water conservation programs, local urban water suppliers generally minimized cuts to commercial and industrial users in the interests of avoiding potential job losses, shifting the burden of water use reductions to residential customers. DWR's survey found only one sector within commercial and industrial users that had been impacted: the lawn and landscaping industry. Cutbacks in residential and institutional (e.g., parks and schools) landscaping and landscape maintenance were estimated to result in a loss of $460 million in gross revenues and 5,600 full-time jobs in this industry in 1991 (California Department of Water Resources 1994).

Widespread damage to Sierra Nevada timber resources was reported, caused by bark beetle infestation of drought-stressed trees. The drought's prolonged duration set the stage for a pattern that would emerge in future extended dry periods – the linkage between severe drought conditions and risk of major wildfire damage in densely populated urban areas located at the wildland-urban interface. The October 1991 Oakland Hills fire was the then-largest dollar fire loss event in U.S. history; 25 lives were lost and more than 3,000 structures were destroyed (Federal Emergency Management Agency 1991). Lessons learned from this fire led to formation of the California Water/Wastewater Agency Response Network to promote emergency preparedness, disaster response, and mutual assistance processes for water and wastewater utilities.

Institutional Actions

Executive Order W-3-91 established an Interagency Drought Action Team chaired by DWR to coordinate state response to the drought. Among other things, the order authorized DWR to implement the drought water bank. Facilitating water transfers and banking was a focus of state action during the 1987–1992 drought, and an extraordinary session of the Legislature held in 1991–1992 resulted in the following legislation:

» Technical and clarifying changes were made to California Water Code (Water Code) provisions governing temporary and long-term water transfers, including explicit authorization of groundwater substitution transfers and exemption of leases of water for up to five years from SWRCB jurisdiction.

- 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.
- DWR was directed 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.
- Water purveyors were required to meter new connections effective January 1992.
- A statewide goal was established of recycling 1 million acre-feet (maf) of water by 2010.
- Existing requirements for urban water management plans were amended to require that water suppliers estimate available supplies at the end of one, two, and three years and develop contingency plans for shortages of up to 50 percent.

Ending the Drought

Water Year 1992 was followed by a wet 1993, a year ranking in the top 20 percent with respect to statewide runoff.

2007–2009

The 2007–2009 drought marked the first time that a statewide proclamation of emergency was issued because of drought impacts. Statewide hydrologic conditions during this three-year event were less severe than those in prior droughts of statewide significance; the major difference between 2007–2009 and prior droughts was the severity of SWP and CVP delivery reductions, which began immediately in the first year of the drought. Water Years 2007–2009 marked a period of then-unprecedented restrictions in SWP and CVP diversions from the Delta to protect listed

Most homes were unrecognizable after the 1991 Oakland Hills fire, even if some evidence of the home remained after the blaze swept through the Oakland/Berkeley area. Photo credit: California Office of Emergency Services

Minimal 2009 CVP water deliveries on the west side of the San Joaquin Valley resulted in widespread concerns about socioeconomic impacts in the region.

fish species, a regulatory circumstance that significantly exacerbated the impacts of hydrologic drought for customers of those projects.

California's population was approximately 37 million by the drought's end, up from 30 million in 1990, and irrigated acreage was similar to that in the 1987–1992 drought. The impacts of a single dry year such as 2007 on water supplies typically would have been minimal from a statewide perspective; however, the new Delta export restrictions resulted in reduced CVP and SWP deliveries. Subsequently, a dry 2008 combined with restrictions on Delta diversions led to the issuance of Executive Order S-06-08 and a Governor's emergency proclamation for selected Central Valley counties in June 2008. A U.S. Fish and Wildlife Service (USFWS) biological opinion for Delta smelt released in December 2008 called for measures that would result in an estimated 20 to 30 percent reduction on average in SWP and CVP Delta diversions. Observed precipitation in January 2009 was only approximately one-third of average, indicating that the threat of a third dry year was already a possibility. These conditions, coupled with statewide reservoir storage of approximately 65 percent of average, led to the Governor's proclamation of a statewide water shortage state of emergency in February 2009.

The 2007–2009 drought was also the first (excluding consideration of the Dust Bowl drought) during which locally significant socioeconomic impacts resulted in emergency response actions related to social services programs (food banks and unemployment assistance). The greatest impacts of the 2007–2009 drought related to managed water supplies were observed in the CVP service area on the west side of the San Joaquin Valley, where hydrologic conditions combined with reduced CVP exports resulted in substantially reduced water supplies.

These water shortages resulted in land fallowing and other economic impacts to agriculture, and concomitantly to rural communities dependent on agriculture for employment. The drought coincided with the Great Recession, a time when employment in other sectors of the San Joaquin Valley's economy (such as construction) was down, and agricultural work opportunities that might have otherwise cushioned the recession's impacts were cut back. Demands for social services (food banks and unemployment assistance programs) stretched the ability

of local agencies to respond, and resulted in a first-ever state emergency proclamation for Fresno County linking drought with provision of social services.

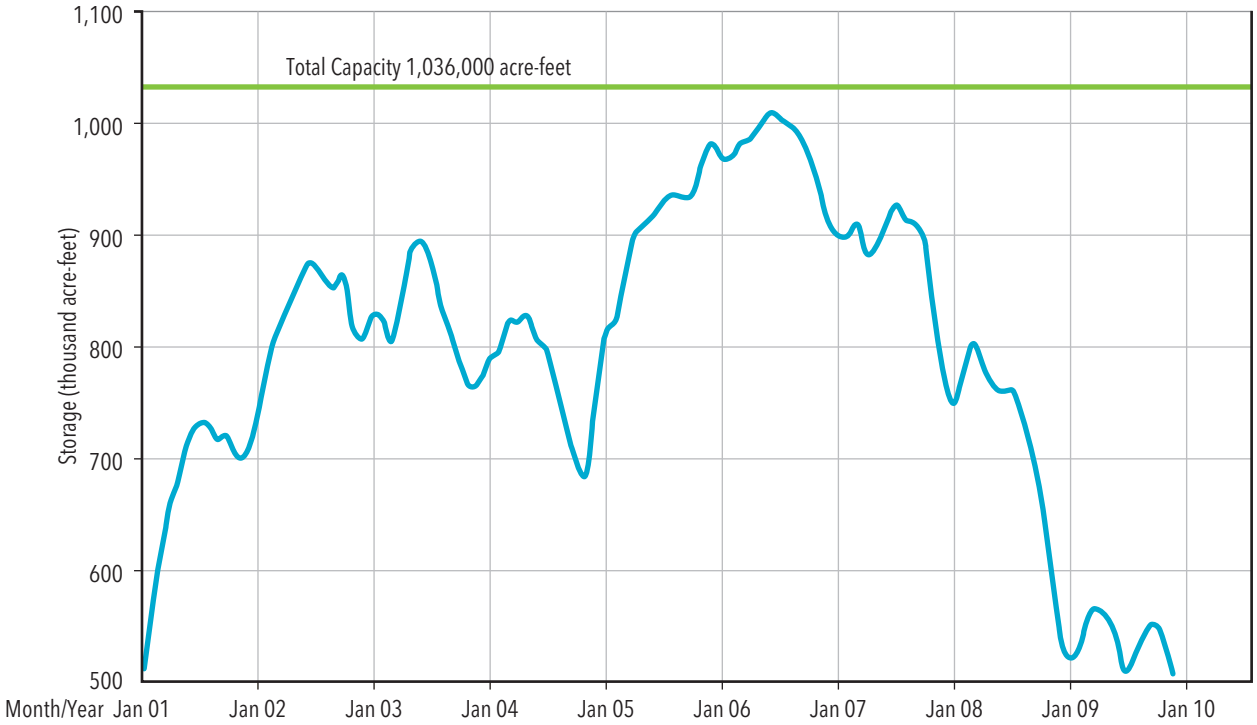
Water Supplies and Water Project Operations

Water Years 2007–2009 were the seventh-driest three-year period in the state's measured hydrologic record, based on statewide precipitation. Statewide precipitation was 64 percent of average in 2007, 78 percent in 2008, and 82 percent in 2009. Water Year 2007 was notably dry, with Central California experiencing about half or less of its average annual precipitation and Southern California receiving one-third or less. The very dry conditions experienced in the South Coast region in 2007 helped set the stage for the massive outbreak of wildfires experienced there in fall 2007. By the end of Water Year 2009, statewide reservoir storage was at 81 percent of average. The state's largest reservoirs, Shasta Lake and Lake Oroville, stood at 63 percent and 59 percent of average at that time, respectively. **FIGURE 3.8** shows the impact of drought on Southern California reservoir storage, using MWD facilities as an example (MWD's Diamond Valley Lake is the largest reservoir in Southern California.)

FIGURE 3.9 illustrates how statewide runoff during the 2007–2009 drought years compared to that during a wet 2006. April 1 statewide snowpack in Water Year 2007 was only 39 percent of average, similar to the 37 percent seen in 1976. Low snowpack and low runoff in the Sierra and Cascade watersheds feeding the CVP and SWP, combined with changed Delta environmental protection requirements for both projects, resulted in immediate impacts to CVP and SWP water supplies in the drought's initial year, as shown in **TABLE 3.4**. A wet 2006, when CVP and SWP contractors received full supplies, is again shown for comparison.

Eastern Sierra water supplies saw impacts similar to those affecting Central Valley watersheds. Owens Valley runoff, important for the City of Los Angeles' Owens River Aqueduct,

Figure 3.8: Metropolitan Water District In-Service Area Storage



Metropolitan Water District's Combined Reservoir Storage (Lake Skinner, Lake Mathews, and Diamond Valley Lake) as of November 1, 2009.

Data credit: Metropolitan Water District

was 60 percent of normal in the city's 2007–2008 runoff year. As with the CVP and SWP, supplies from the Owens Valley Aqueduct also had been reduced from their historical availability because of regulatory requirements, for a base flow in the lower Owens River beginning in 2007 and for Owens Lakebed dust control beginning in the early 2000s.

Executive Order S-06-08 had directed DWR to prepare to operate a dry year water purchasing program in 2009. DWR solicited interest in a 2009 program from potential buyers and sellers, receiving significantly greater interest in purchasing water than could be supported through the quantity of water offered for sale. Limiting factors in water bank participation included relatively high prices for rice in the Sacramento Valley, which made sales of water to DWR's program less economically attractive to growers, and constraints on being able to move purchased water across the Delta. Most of the water purchased was made available through groundwater substitution. DWR purchased water from sellers at $275 per acre-foot; buyers of the water from DWR paid this amount plus administrative and transportation costs, and were responsible for carriage and other losses associated with conveying the water to the place of use. DWR provided approximately 74 taf through the water bank in 2009. Operation of the bank was facilitated by SWRCB's issuance of Order WR 2009-0033, which allowed DWR and Reclamation to transfer up to 16 taf of bank water to the places of use of either the SWP or the CVP south of the Delta.

The CVP and SWP were also involved in conveyance of water for transfers initiated by local water agencies, and in approval of internal exchanges or transfers among each project's contractors. Conveyance of water for others in 2009 amounted to approximately 210 taf of water being moved from sellers upstream of the Delta to buyers in the San Joaquin Valley and in Southern California through the

Figure 3.9: Statewide Runoff Comparison, 2007–2009 Drought

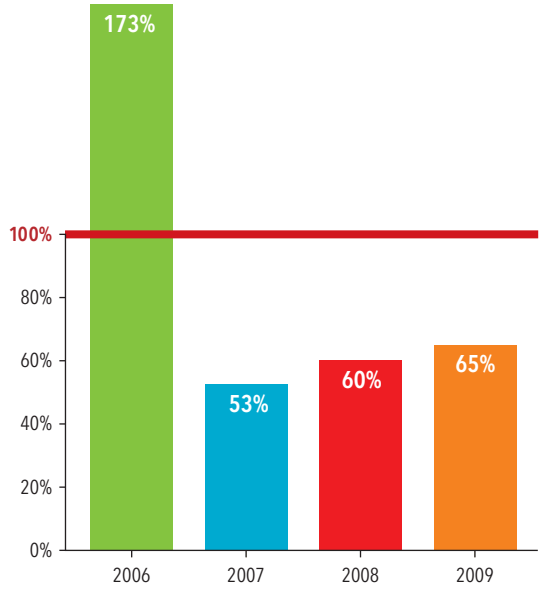


Table 3.4: CVP and SWP Allocations During 2007–2009 Drought

(Allocation in percent)

	SWP	CVP						
		North of Delta Ag	Urban	South of Delta Ag	Urban	Friant Class 1	Friant Class 2	East Side
2006	100	100	100	100	100	100	uncontrolled season	100
2007	60	100	100	50	75	65	0	29
2008	35	40	75	40	75	100	5	23
2009	40	40	75-100	10	60	100	18	12

Notes:

SWP allocations shown are percent of requested contractual Table A quantity.

For the CVP, Sacramento River water rights contractors, San Joaquin River exchange contractors, and wildlife refuges received 100 percent allocations (Level 2 supplies for wildlife refuges).

A wet Water Year 2006 is shown for comparison purposes.

projects' facilities, not counting the internal reallocations among CVP and SWP contractors.

The 2007–2009 drought was California's first statewide drought for which surplus Colorado River water was not available for Southern California. As provided by the 1922 Colorado River Compact, California's Colorado River water contractors previously had been able to use the unused annual interstate apportionments of Nevada and Arizona, together with water that was hydrologically surplus. Historically, California had been using as much as 800 taf annually in excess of the state's basic interstate apportionment of 4.4 maf of consumptive use annually. Increased water use in the other two Lower Basin states, combined with an absence of the high-flow years that produced hydrologic surpluses, had led to long-running discussions and litigation regarding how California would reduce its use of Colorado River water to the basic interstate apportionment. The Colorado River Quantification Settlement Agreement (QSA) and related agreements were executed in 2003 to resolve those matters; California has not subsequently taken water in excess of its basic apportionment as long-term drought conditions have precluded availability of hydrologically surplus water.

The Colorado River historically has been a highly reliable supply for Southern California, and the prior availability of surplus water had helped mitigate drought impacts in a broader geographic area thanks to coordination with SWP supplies. Dry Colorado River Basin conditions in the 2000s, however, signaled increasing drought risk in the basin, although not yet shortages for California. Average unregulated inflow to Lake Powell for the 10-year period of calendar years 2000–2009 was the then-lowest 10-year average since the reservoir's initial filling in 1963 (U.S. Bureau of Reclamation 2010), and calendar year 2002 set a record low of only 25 percent of average unregulated inflow. Total reservoir system storage in the basin was nearly full when drought conditions began in 2000, but then dropped to about half-full by 2004. The basin's overall condition of prolonged dryness has subsequently resulted in total system storage that fluctuates near the half-way mark, with storage in Lake Mead being helped in part by actions instituted through interim measures described below.

It was only shortly after QSA execution in 2003 that new discussions began on managing for shortages in the Lower Basin, with Reclamation subsequently adopting interim guidelines for Lower Basin shortages and coordinated operations of Lakes Mead and Powell in 2007 (U.S. Bureau of Reclamation 2007). The guidelines remain in effect through 2025 for operations in 2026, and were designed to reduce the probability of Lower Basin shortages by changing the historical flood control spill avoidance goal of reservoir operations and by allowing Reclamation's water contractors to take extraordinary actions to conserve part of their allocations and store the conserved water in Lake Mead. The guidelines define the circumstances under which Reclamation would reduce the annual amount of water available for consumptive use in the Lower Basin states below 7.5 maf (i.e., define circumstances triggering shortage). As provided for in the guidelines, reductions in Lower Basin deliveries triggered by specified Lake Mead elevations occur first for Arizona and Nevada before California is affected.

QSA execution enabled two large-scale, long-term local water agency water transfer agreements, for the Imperial Irrigation District/San Diego County Water Authority (SDCWA) transfer program and the MWD/Palo Verde Irrigation District (PVID) long-term fallowing program. The former agreement is an every-year transfer agreement providing SDCWA with access to water from Imperial Irrigation District's highly reliable Colorado River supplies, while the latter is an agreement for a base amount of agricultural land fallowing/water transfer plus an additional amount of fallowing and transfer that could be called by MWD as needed (e.g., for drought response). In 2009, MWD and PVID entered into a separate additional one-year, short-term fallowing agreement as a drought response measure.

Impacts

Damages associated with wildfires can be one of the largest impacts resulting from drought, as was seen in the October 2007 massive outbreak of fires in Southern California **(FIGURE 3.10)**, when a combination of dry vegetation and Santa Ana winds created conditions of high fire risk. The fires claimed the lives of 17 people, destroyed more than 3,000 structures, and displaced or forced the evacuations of as many as 900,000 people. Preliminary estimates placed U.S. Forest Service response costs at $62 million and California Department of Forestry and Fire Protection (CAL FIRE) response costs at $93 million (California Department of Forestry and Fire Protection, undated). Southern California had previously experienced a regional drought in Water Years 1999–2002 (followed by a devastating 2003 wildfire season), and dead vegetation remaining from the regional drought became a fuel source for the 2007 fires. Warmer-than-average annual temperatures over much of the recent past also contributed to an increased wildfire risk, leading to an almost year-round wildfire season in Southern California. Executive Orders S-09-04 (May 2004), S-06-05 (July 2005), S-10-06 (June 2006), and S-07-07 (May 2007) had all called for early/additional deployment of resources in Southern California to prepare for the increased wildfire risk. The 2008 and 2009 fire seasons were also active ones in California.

The most widespread impacts associated with managed uses of water were irrigation water shortages, especially on the west side of the San Joaquin Valley and the San Diego/Riverside County avocado/citrus growing area. Shortages also occurred in the Russian River service area (reduced vineyard water supplies) and the Tehama-Colusa Canal service area on the west side of the Sacramento Valley (reduced CVP deliveries). In areas such as the San Joaquin Valley, surface water shortages resulted in a notable increase in land fallowing as compared to a background level of fallowing for normal agronomic purposes (e.g., crop rotation or pest management), but surface water shortages were in some areas mitigated by increased groundwater pumping. The economic impacts of irrigation water shortages are difficult to compare from one drought to another because of the major role played by fluctuations in crop prices and markets for California's farm products (which reflect global-scale factors affecting food supplies). Favorable crop prices and markets during the 2007–2009 drought lessened the impacts of water shortages that might have otherwise occurred.

The Jesusita Fire in May 2009 in Santa Barbara County was an early-season fire that destroyed 80 homes.

Two factors were notable during the 2007–2009 drought as compared to the 1987–1992 drought: the increased acreage high-value permanent plantings (orchards and vineyards) in vulnerable areas, and the extended duration of major shortages (three years in the case of the west side of the San Joaquin Valley). Examples of both factors can be seen in Westlands Water District crop acreage reports. The crop reports showed that roughly 127,000 acres of the district's 568,652 cropped acres were in permanent plantings in 2009, and that land fallowing increased on the order of 100,000 acres between 2006 and 2009. **FIGURE 3.11** shows the contrast in San Joaquin Valley irrigated acreage in pre-drought (2006) and drought (2009) years.

FIGURE 3.12 illustrates a change in Fresno County cropping patterns over time, reflective of similar practices in other southern San Joaquin Valley counties. The widespread acreage of cotton present during the 1987–1992 drought declined dramatically, while almond acreage had more than doubled by the 2007–2009 drought. Acreage of row crops, like cotton, can be fallowed with lesser economic impacts to

Figure 3.10: 2007 Southern California Wildfires

Figure credit: California Office of Emergency Services, November 2007

Figure 3.11: Landsat Images of the San Joaquin Valley in Summer 2006 and 2009

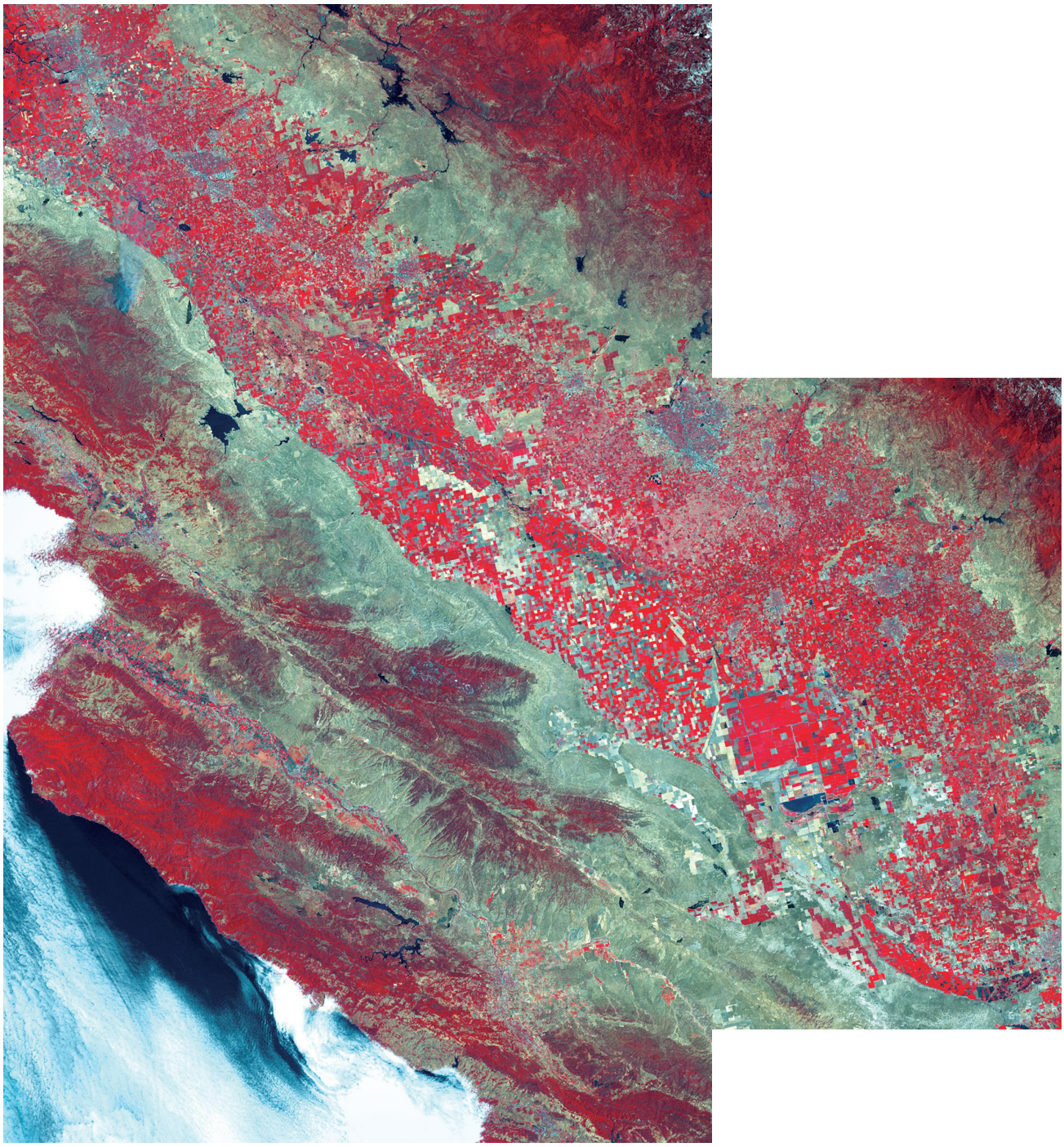


Image credit: U.S. Geological Survey Landsat Image. False-color infrared, irrigated areas in red.

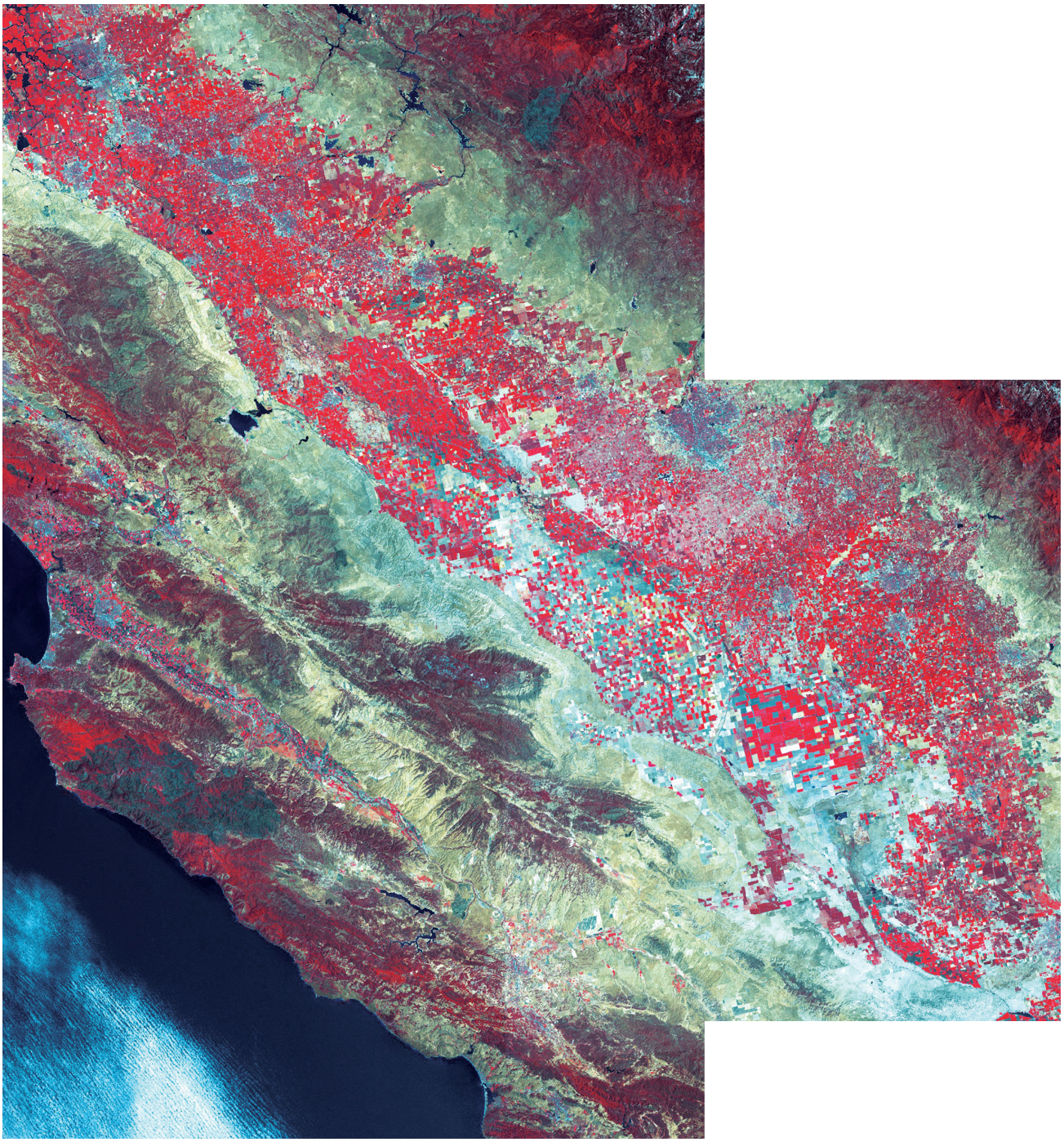
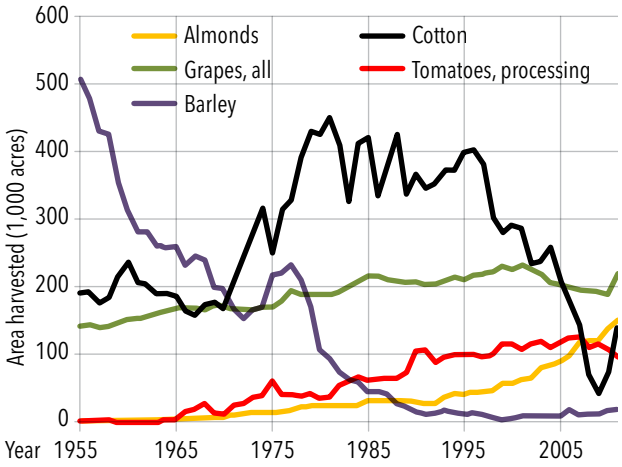


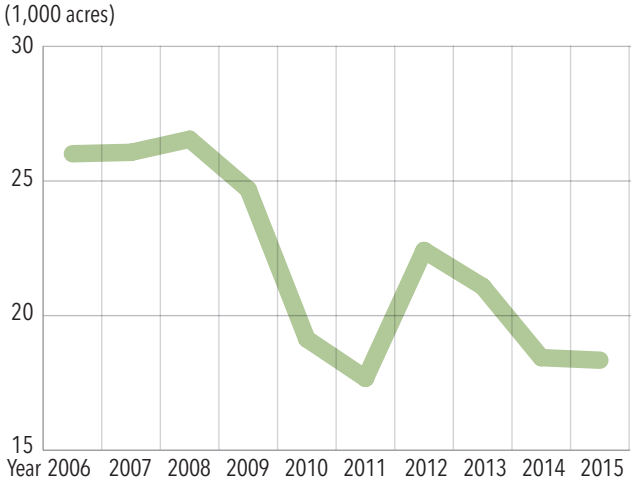
Image credit: U.S. Geological Survey Landsat Image. False-color infrared, irrigated areas in red.

Figure 3.12: Harvested Acreage of Selected Crops in Fresno County, 1955–2011



Data credit: California Department of Food and Agriculture

Figure 3.13: San Diego County Avocado Acreage



Data credit: San Diego County Agricultural Commissioner, harvested acres

growers than can the acreage of capital-intensive almonds and pistachios replacing cotton in many areas. The need to preserve acreage of permanent plantings during the drought led to increased San Joaquin Valley groundwater pumping and an active market for water transfers and exchanges in the CVP's south-of-Delta service area.

Locally significant agricultural impacts also occurred in the avocado/citrus growing region in northern San Diego/southern Riverside counties, where producers participating in MWD's interim agricultural water program were subjected to a 30 percent reduction in water deliveries beginning in January 2008. (Producers participating in the program, in effect since 1994, had received imported supplies at discounted rates in exchange for supply interruptions during times of shortages.) MWD subsequently phased out the interim agricultural program, ending the discounted water rate in 2012. **FIGURE 3.13** shows the change in San Diego County avocado acreage over time; avocados have long been an iconic crop in the region, and San Diego is the leading avocado producing county in the U.S.

Occurring as it did during the Great Recession, the loss of San Joaquin Valley agricultural jobs caused by water shortages was a locally significant impact, and one magnified by the region's high dependence on agriculture for employment (especially on the west side of the valley in the CVP service area). The University of California, Davis estimated that the incremental impact in the San Joaquin Valley from reduced Delta exports resulted in a loss of 21,000 jobs (16,000 jobs from drought alone and 5,000 from environmental pumping restrictions) (Howitt et al. 2009). Social services agencies on the valley's west side experienced dramatic increases in requests for assistance, leading Fresno County to proclaim a local state of emergency in April 2009 for drought-related unemployment food crisis. The County described its situation in that proclamation as: "… the demand on the local Community Food Bank continues to increase, where, they have provided food to residents on multiple occasions, only to run short each time. Thousands of people have been turned away during giveaways as supplies are not ample enough to meet the local need. During the Community Food bank's most recent neighborhood market distribution in the City of Mendota on February 2, 2009, 3,248 people were served."

Executive Order S-11-09 in June 2009 called for providing temporary supplemental assistance to local governments and non-profit organizations that provide food and other aid, in recognition of the continuing need for drought-related social services assistance, especially in the San Joaquin Valley. The Governor requested a presidential disaster

Food box distribution at the Valley Life Community Church in Selma in 2009. San Joaquin Valley agricultural communities were hard-hit by the combined effects of drought and economic recession. Photo credit: Heidi Schumann

Agricultural impacts of the drought were most visible in the San Joaquin Valley and in Southern California. Some growers in the Central Valley Project's service area on the west side of the valley abandoned orchards because of water shortages, and San Diego County avocado growers either abandoned groves or stumped trees as a temporary measure to reduce water use.

declaration for Fresno County in June 2009 because of the drought-related socioeconomic impacts. That request was denied, as was a subsequent appeal of the denial.

Rural areas also experienced the typical drought impacts associated with small water systems and private well owners dependent on unreliable sources. Reflective of this drought's active wildfire seasons, small community water systems in both Northern and Southern California additionally experienced fire-related shortages – either damage or destruction of water system infrastructure, or inability to operate because of a lack of electrical power to the systems. One of the lessons learned for some systems in the latter category was the need for auxiliary power sources to operate pumps.

Institutional Actions

Executive Order S-06-08 and an emergency proclamation for the Central Valley were issued in June 2008, followed by a statewide emergency proclamation in February 2009. (A subsequent Executive Order, S-11-09, and emergency proclamation for Fresno County, both issued in July 2009, focused specifically on social services assistance.) In addition to provisions in Executive Order S-06-08 calling for DWR to expedite water transfers and operate a dry year water purchasing program, the order also directed DWR to expedite grant programs for local agency water conservation/water use reduction programs and other programs capable of being implemented in time to reduce drought impacts in 2008 and 2009. Examples of drought-specific grants of statewide scope made pursuant to this provision were Proposition 50 grants totaling $984,800 to the California Rural Water Association for leak detection/water conservation and drought preparedness technical assistance for small water systems, and funding to the Association of California Water Agencies for developing the "Save Our Water" advertising campaign. New funding provided by voter approval of Proposition 84 in 2006 allowed the California Department of Public Health to award emergency drinking water grants to small water systems.

In October 2009, the Governor called a Seventh Extraordinary Session of the Legislature to deal with water issues; that session passed a five-bill package of water legislation intended to address Delta governance, provide for an $11 billion water bond measure on the November 2010 ballot (subsequently postponed), require groundwater level monitoring, require specified water conservation actions (commonly known as 20 percent by 2020), and require increased reporting of water diversions to SWRCB. The groundwater level monitoring legislation established the California Statewide Groundwater Elevation Monitoring (CASGEM) program, which was to greatly enhance the information available for future drought response and preparedness.

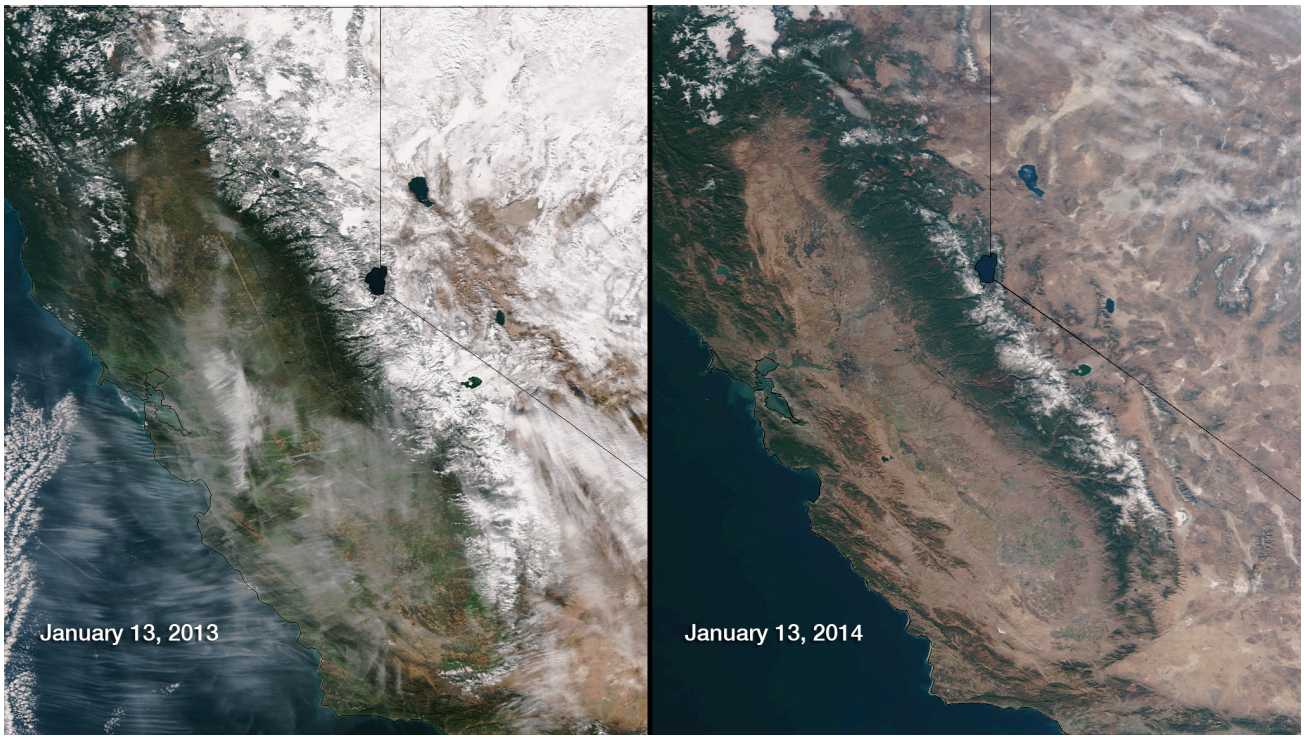
Ending the Drought

Late spring storms in 2010 brought statewide precipitation to slightly above-average levels and resulted in above-average runoff forecasts for all major Sierra Nevada watersheds. Storage in most major intrastate reservoirs had rebounded; among the major CVP and SWP reservoirs only two (Trinity Lake and San Luis Reservoir) had storage at less than 90 percent of average. Long-term dry conditions were continuing in the Colorado River system, but there were no shortages to Lower Basin water contractors.

Water Year 2010 was followed by a wetter Water Year 2011. In March 2011, Governor Brown terminated Executive Order S-06-08 and the 2008 and 2009 drought emergency proclamations that had been issued by his predecessor Governor Schwarzenegger.

2012–2016

California's three-year 2007–2009 drought was soon followed by the five-year 2012–2016 event. Only two years in the decade prior to a wet Water Year 2017 were not dry, prompting speculation regarding the possibility of a regime shift toward drier conditions. However, as with the Colorado River Basin's overall dry conditions since 2000, it is not possible to say if this is a statistically significant change or simply California's naturally high climate variability. It is also not presently within the research community's



Comparing Sierra Nevada snowpack in two Januaries, illustrating the extremely dry conditions in early 2014. Image credit: NASA

capabilities to glean useful predictive skill from these overall dry conditions that would improve near-term seasonal precipitation forecasting.

The 2012–2016 drought was notable for its hydrologic severity, setting records for driest consecutive four years of statewide precipitation (2012–2015) and requiring response actions not necessary since the 1976–1977 drought. California's population at the drought's end was 39 million, and the institutional setting was similar to that of the 2007–2009 drought. Continuing an observed 21st century trend, 2012–2016 occurred in a setting of record warm statewide temperatures. The 2014 April 1 statewide snowpack water content tied a record low of 25 percent of average set in 1977, a record that was then surpassed in 2015 with a new low of only 5 percent of average. For some areas in Southern California, this five-year period represented the driest or second-driest period, depending on the location, in a paleoclimate record dating to the 1400s (Meko et al. 2017).

Folsom Lake in January 2014. Although the impacts of a dry 2012 on reservoir storage were partly mitigated by a wet start to Water Year 2013, that water year's subsequent shift to record dry conditions combined with continuing dry conditions in the following winter resulted in substantially reduced reservoir storage in many Sierran reservoirs.

The drought's hydrologic severity set new records and metrics for impacts and response actions. This drought marked the second time that a statewide emergency proclamation was issued, and it set a record for the number of executive orders and emergency proclamations issued through its duration. Notable water supply impacts included first-ever zero water allocations to some CVP water contractors, record declines in groundwater levels, and rural areas with concentrations of dry private residential wells. Other impacts included equaling the prior historical record for San Joaquin Valley land subsidence rates, massive tree mortality in the central and southern Sierra, and record levels of wildfire costs (damages and state response costs).

Impacts of the drought's first year were cushioned by carryover storage from a wet Water Year 2011. Although year two of the drought began wet, a record dry January–May of Water Year 2013 led to the May 2013 issuance of Executive Order B-21-13, which directed DWR and SWRCB to expedite the review and processing of water transfers in response to reduced agricultural water supplies. With the advent of an exceptionally dry Water Year 2014, Northern California was now experiencing the significantly below normal precipitation that had characterized the southern part of the state in the prior two years. Some Northern California locations went for more than 50 consecutive days with no measurable precipitation at a time when the year's maximum monthly precipitation totals should have been registered. The record dry December 2013, when combined with the prior record dry January–May 2013, resulted in calendar year 2013 being the then-driest of record for many communities, including San Francisco, Sacramento, and Los Angeles.

The absence of significant precipitation in late 2013 led the Governor to form a state interagency Drought Task Force in December to provide a coordinated assessment of dry conditions and to provide recommendations on state actions. The continuing absence of precipitation led to an initial proclamation of statewide emergency in January 2014. The

initial proclamation was subsequently extended and followed by a series of executive orders as drought conditions persisted. These directives included a first-ever state requirement for mandatory emergency urban water conservation (to be achieved through SWRCB action). Water Years 2014 and 2015 were the driest years of the drought (and calendar years 2014 and 2015 were California's warmest and second-warmest, respectively, in terms of statewide average temperatures). Precipitation returned to near normal in Water Year 2016 for parts of Northern California, but Southern California remained dry, and runoff was well below average throughout the state because of prior dry conditions. A very wet Water Year 2017 ended the hydrologic drought, and Executive Order B-40-17 in April 2017 ended the proclamation of statewide emergency caused by drought, but kept emergency provisions in place in selected counties (Fresno, Kings, Tulare, and Tuolumne) where drought impacts remained.

Water Supplies and Water Project Operations

The dry hydrologic conditions described above resulted in unprecedented reductions in CVP and SWP supplies **(TABLE 3.5)**, most notably the zero allocations to CVP contractors in 2014 and 2015. (The SWP had a zero allocation to agricultural contractors in 1991, but the urban contractors who constitute most of the SWP's contractual commitments received 30 percent then.) CVP agricultural contractors used groundwater and water transfers, as available, to secure supplies to support their customers' investments in permanent plantings of orchards and vineyards, although the ability to do transfers was constrained by the very dry hydrology of 2014 and 2015, and by uncertainties then with allocation amounts to the CVP and SWP water rights settlement contractors who often participate as sellers in transfers. (The SWP's Feather River water rights settlement contractors were cut by 50 percent in 2015.) In contrast to the two prior droughts, DWR did not operate a drought water bank or dry year water purchasing program during 2012–2016, but did convey water for transfer initiated by local agencies. From 2012 to 2014, DWR conveyed 166,805 acre-feet of water made available through cropland idling/crop shifting transfers (there were no transfers from this source in 2015 and 2016). DWR also provided conveyance for groundwater substitution transfers that occurred during 2013–2015; these transfers amounted to 83,460 acre-feet. The CVP also facilitated groundwater substitution transfers in 2014 and 2015; an estimated 100,100 acre-feet of groundwater was pumped

Table 3.5: CVP and SWP Allocations During 2012–2016 Drought

(Allocation in percent)

		CVP						
	SWP	North of Delta Ag	Urban	South of Delta Ag	Urban	Friant Class 1	Friant Class 2	East Side
2012	65	100	100	40	75	50	0	100
2013	35	75	100	20	70	62	0	100
2014	5	0	50	0	50	0	0	55
2015	20	0	25	0	25	0	0	0
2016	60	100	100	5	55	75	0	0

Notes:

SWP allocations shown are percent of requested contractual Table A quantity.

For the CVP, Sacramento River water rights contractors, San Joaquin River exchange contractors, and wildlife refuges received 100 percent allocations (Level 2 supplies for wildlife refuges) in 2012, 2013, and 2016. The entities had 75 percent allocations in 2015, and in 2014 those north of the Delta had 75 percent while those south of the Delta had 65 percent.

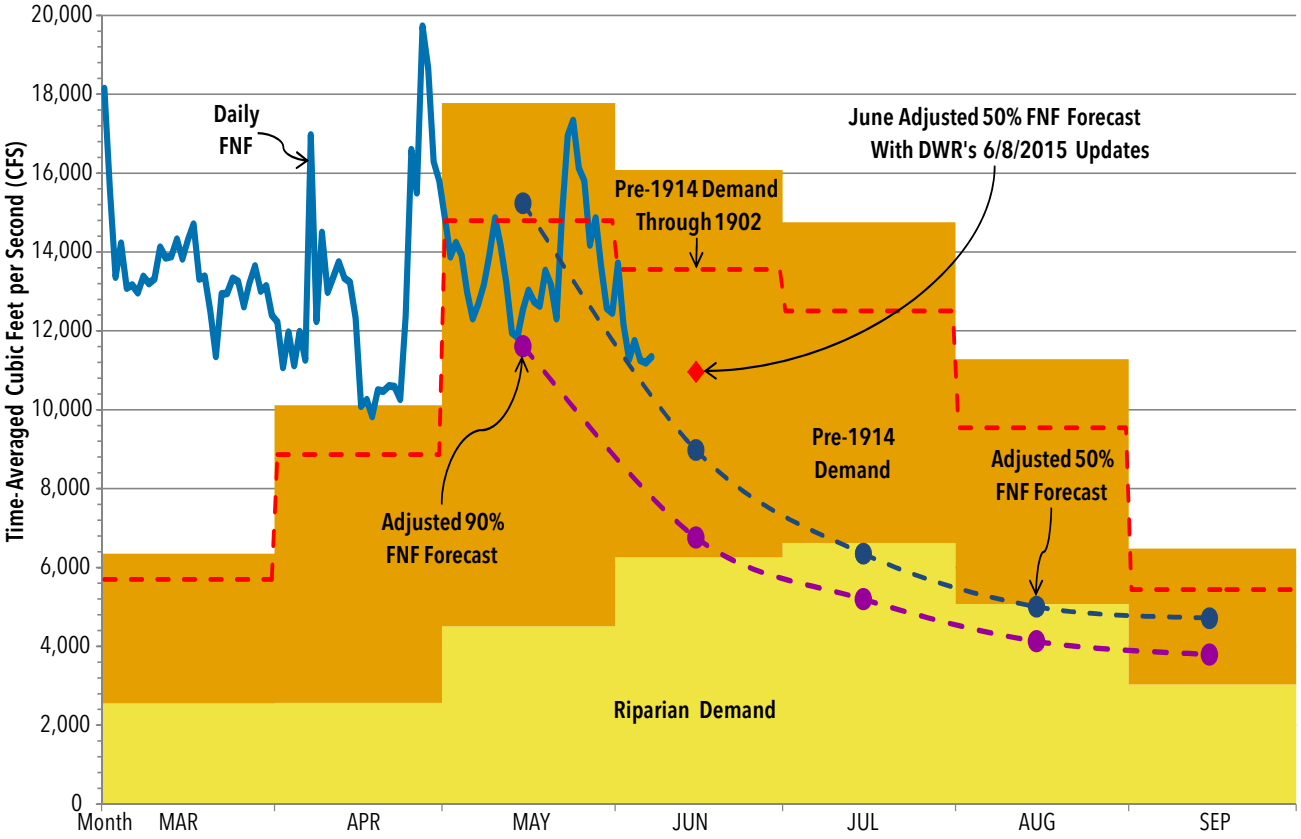
In 2015, CVP urban contractors received the greater of health and safety needs or 25 percent.

In 2016, a limited amount of Friant Class 2 water was released for flood management purposes.

then for conveyance by the CVP.

Water Year 2014's very dry start following on the heels of the two prior dry years prompted DWR and Reclamation to submit a temporary urgency change petition to SWRCB requesting modifications to Water Right Decision 1641 (D-1641) to provide operational flexibility for managing the SWP and CVP under significantly drier hydrologic conditions than those for which the decision had been designed. One element of the petition was forming a real-time drought operations management team, with representatives from DWR, Reclamation, SWRCB, the California Department of Fish and Wildlife, USFWS, and NMFS. This team would meet as often as weekly for managing water project operations to provide for meeting

Figure 3.14: State Water Resources Control Board Analysis of Sacramento-San Joaquin Flows Available to Satisfy Water Rights in June 2015



Notes:

Daily Full Natural Flow (FNF) from CDEC Stations BND, ORO, YRS, FOL, TLG, MRC, GDW, MIL, MKM, and MHB, current through 6/7/2015.

Monthly Adjusted FNF Forecast points include DWR's May 2015 FNF Forecasts for BND, ORO, YRS, FOL, MIL, GDW, LGR, EXC, MHB, and PAR, and estimated FNF of minor streams for the 90% exceedance level. DWR does not provide 90% exceedance values for MHB and PAR; therefore, the available 50% exceedance values were added to the 90% exceedance forecast values. Minor stream FNFs were obtained from DWR's May 2007 Unimpaired Flow Data report, tables UF 1, UF 2, UF 3, UF 4, UF 5, UF 7, UF 10, and UF 17. Water Year 1977 was used to reflect similarities in snowpack conditions.

Return flows were added to the 50% and 90% Adjusted FNF Forecast values as follows: For the San Joaquin Watershed, a percentage of the Riparian Demand as used in the 1977 Drought Report (20% in April, 10% in May and June, and 0% in July, August, and September). For the Delta contribution, an assumed 40% of the prorated Riparian and Pre-14 Demand was used as return flow.

Delta Riparian Demand includes Riparian-only and combination Riparian/Pre-14 Demand for both statements reporting under the Informational Order and those not. Basin Riparian Demand includes Riparian-only and combination Riparian/Pre-14 Demand for statements that did not report under the Order, and Riparian-only portion of the demand for statements that did report under the Order.

Delta Pre-14 Demand includes Pre-14-only Demand. Basin Pre-14 Demand includes demand from Pre-14-only statements that did not report under the Informational Order, and Pre-14-only portion of the demand for statements that did report under the Order.

Figure source: State Water Resources Control Board

essential health and safety water needs in the projects' service areas, controlling Delta salinity intrusion, managing cold water for salmonids, and maintaining minimum protections for endangered species and other fish and wildlife resources.

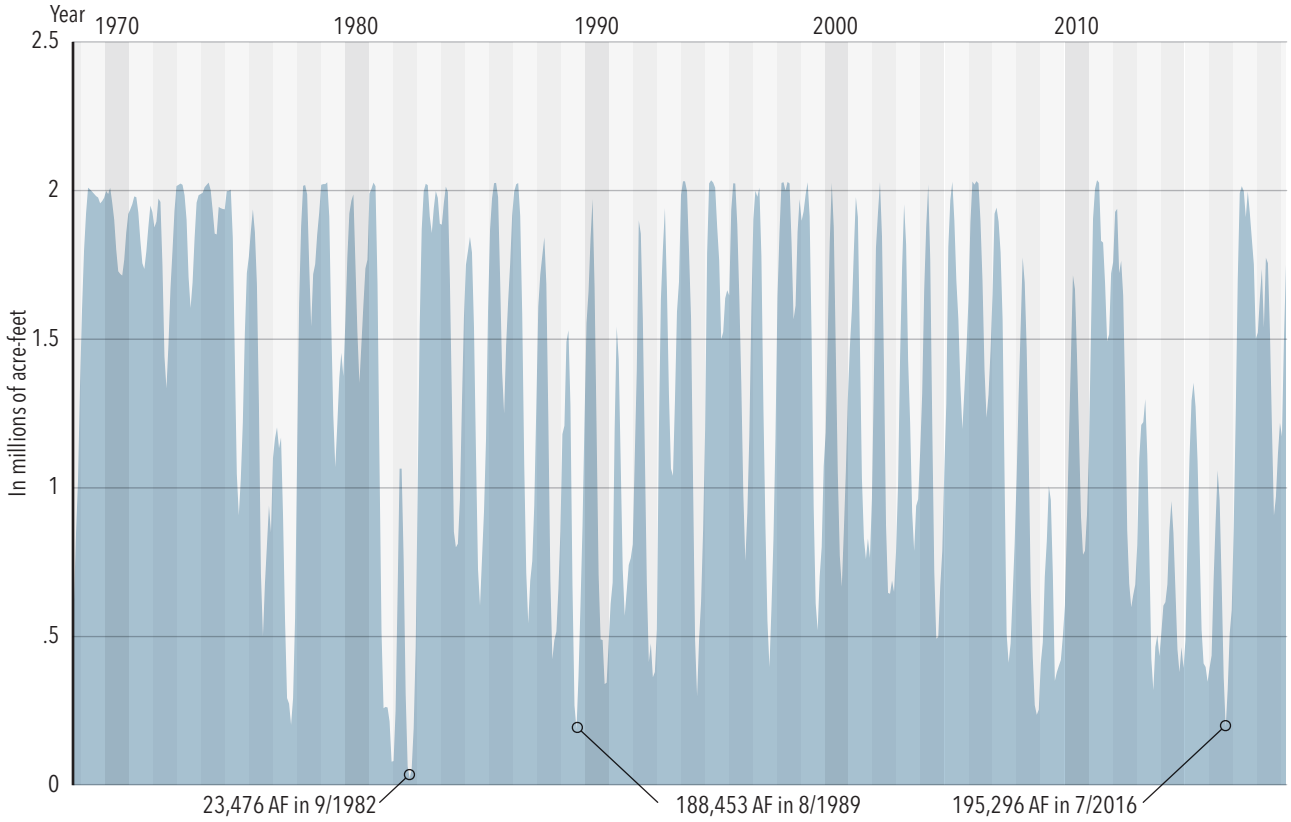
The very dry 2014 conditions followed by an also challenging 2015 prompted actions by DWR and SWRCB at a level of intensity not seen since the 1976–1977 drought. Following the January 2014 emergency proclamation, DWR began evaluating installation of multiple temporary emergency drought barriers in the Delta to aid in controlling salinity intrusion and to help conserve upstream reservoir storage. Barrier installation was not needed in Water Year 2014 thanks to above-average precipitation in the late spring; one barrier was installed on West False River in Water Year 2015. SWRCB issued more than 9,000 curtailment of diversion notices to holders of appropriative water rights in 2014 and adopted emergency regulations in July 2014 for statewide drought-related curtailment to protect senior water rights; more than 950 inspections were made to confirm compliance with 2014 curtailment notices. SWRCB issued curtailment notices to all post-1914 appropriators in the Sacramento-San Joaquin watersheds and in the Delta in the spring of 2015, followed in June by curtailment notices to pre-1914 diverters with a priority date of 1903 or later **(FIGURE 3.14)**. What the 2015 curtailment notices reflected was that almost all summer flow in the mainstem Sacramento-San Joaquin system was being sustained by reservoir releases to meet regulatory objectives or deliveries to water contractors; there was minimal natural flow in the system.

The CVP's and SWP's January 2014 temporary urgency change petition marked the beginning of a series of drought-related water rights administration actions and endangered species regulatory actions that would continue throughout the remainder of the drought. As part of the regulatory compliance and coordination, DWR and Reclamation prepared 2014, 2015, and 2016 CVP and SWP drought contingency plans for submission to SWRCB. Among other things, the plans defined minimum human health and safety water needs (55 gallons per capita per day for the SWP for consumption, sanitation, and fire suppression). An important aspect of the plans was provision for reservoir carryover storage in the event that

On the right, Lake McClure in February 2015 when the reservoir had dropped to only 6 percent of capacity, showing the temporary emergency pumping station (on a barge in the lake) used to divert water to the Lake Don Pedro Community Services District's intake after the intake was left dry by dropping reservoir levels. DWR and USDA Rural Development provided funding to the district for an emergency well drilling project to ensure water supplies for an approximately 3,500-person service area in the Coulterville and La Grange areas. In the photo on the left, the normally submerged old concrete arch Exchequer Dam can be seen adjacent to the New Exchequer Dam embankment.

Figure 3.15: Historical San Luis Reservoir Monthly Storage

San Luis Reservoir is an offstream storage facility used to meet demands of CVP and SWP contractors. Its lowest levels following initial filling occurred in 1981 and 1982 when the reservoir was drawn down in response to a slope failure on the upstream slope. Apart from this dam safety and repair period, July 2016 was its second-lowest monthly storage period, surpassed only slightly by low levels recorded in August 1989.



Low water levels at San Luis Reservoir in August 2016 exposed the upper intake structure for the CVP's San Felipe Division, which supplies water to Santa Clara Valley Water District and San Benito County Water District. The intake has also been exposed in other drought years. Low water levels in the reservoir in late summer lead to a problem known as "low point" for the San Felipe Division contractors, when reduced reservoir volume and warm temperatures contribute to algae growth. The algae create drinking water taste and odor problems for urban water users and clog drip irrigation systems for agricultural water users.

Construction of the temporary emergency drought barrier on West False River in the Delta in May 2015. The barrier, removed in November 2015, consisted of 92,500 cubic yards of rock, with sheet piling at the abutments and along the centerline of the levees adjacent to the barrier. Total project cost (installation, removal, monitoring, and mitigation) was approximately $36 million.

the following year was dry, particularly for preservation of a cold water pool at Lake Shasta for Sacramento River salmonids. One of the more operationally challenging events during the drought was associated with the CVP's Water Year 2016 operations for Sacramento River temperature management for salmonids. Faulty temperature measurements at Lake Shasta contributed to the water being warmer than expected. This discovery triggered NMFS to revise, in May, Reclamation's previously approved temperature plan that resulted in greatly reduced deliveries to CVP contractors during the peak summer season. Reclamation borrowed water from San Luis Reservoir, causing it to drop to near-record low levels **(FIGURE 3.15)**, and solicited water loans and exchanges from other agencies to avoid being unable to meet Delta

Figure 3.16: Lake Mead End-of-Calendar Year Elevation, Showing Shortage Trigger Elevations and Impacts of Institutional Actions
Since adoption of the 2007 interim guidelines, institutional actions have created special categories of water to be stored in Lake Mead, including intentionally created surplus water, deferred Mexican delivery water pursuant to International Boundary and Water Commission treaty minutes, and voluntary system conservation water.

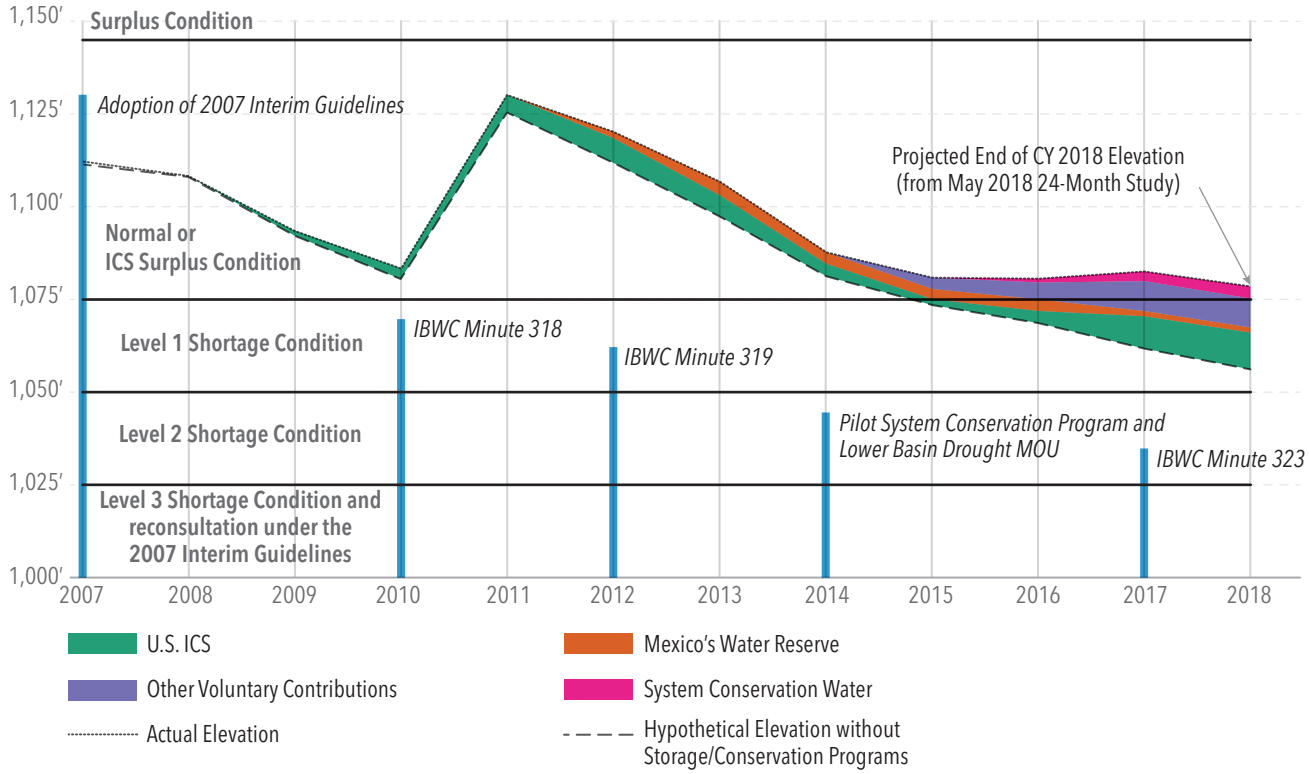


Figure credit: U.S. Bureau of Reclamation. Projected end-of-calendar-year 2018 elevation based on provisional data.

Figure 3.17: Cumulative Change in Statewide Groundwater Levels, 2012–2016 Drought

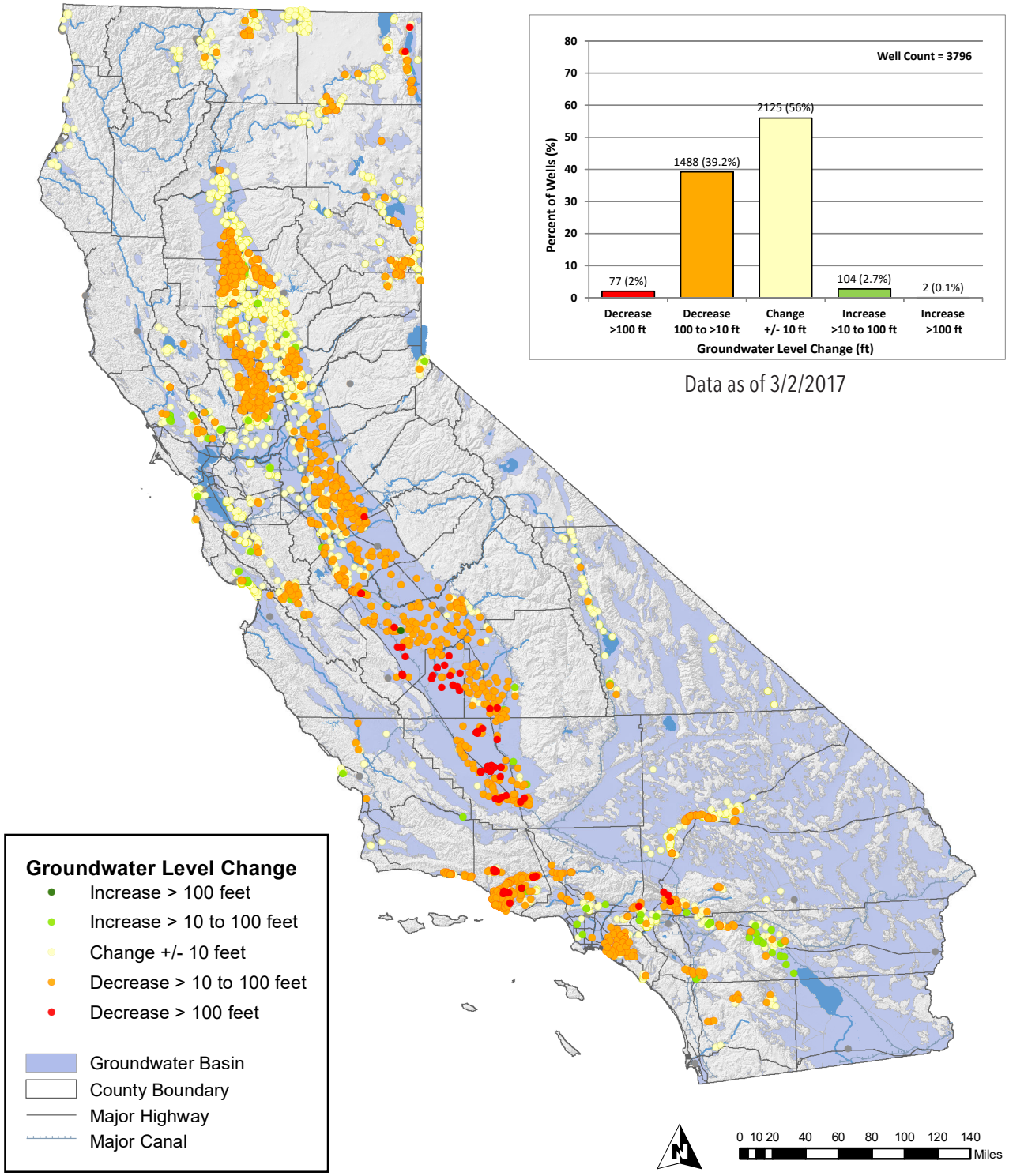


Figure 3.18: Estimated Subsidence in the San Joaquin Valley Between 1949 and 2005

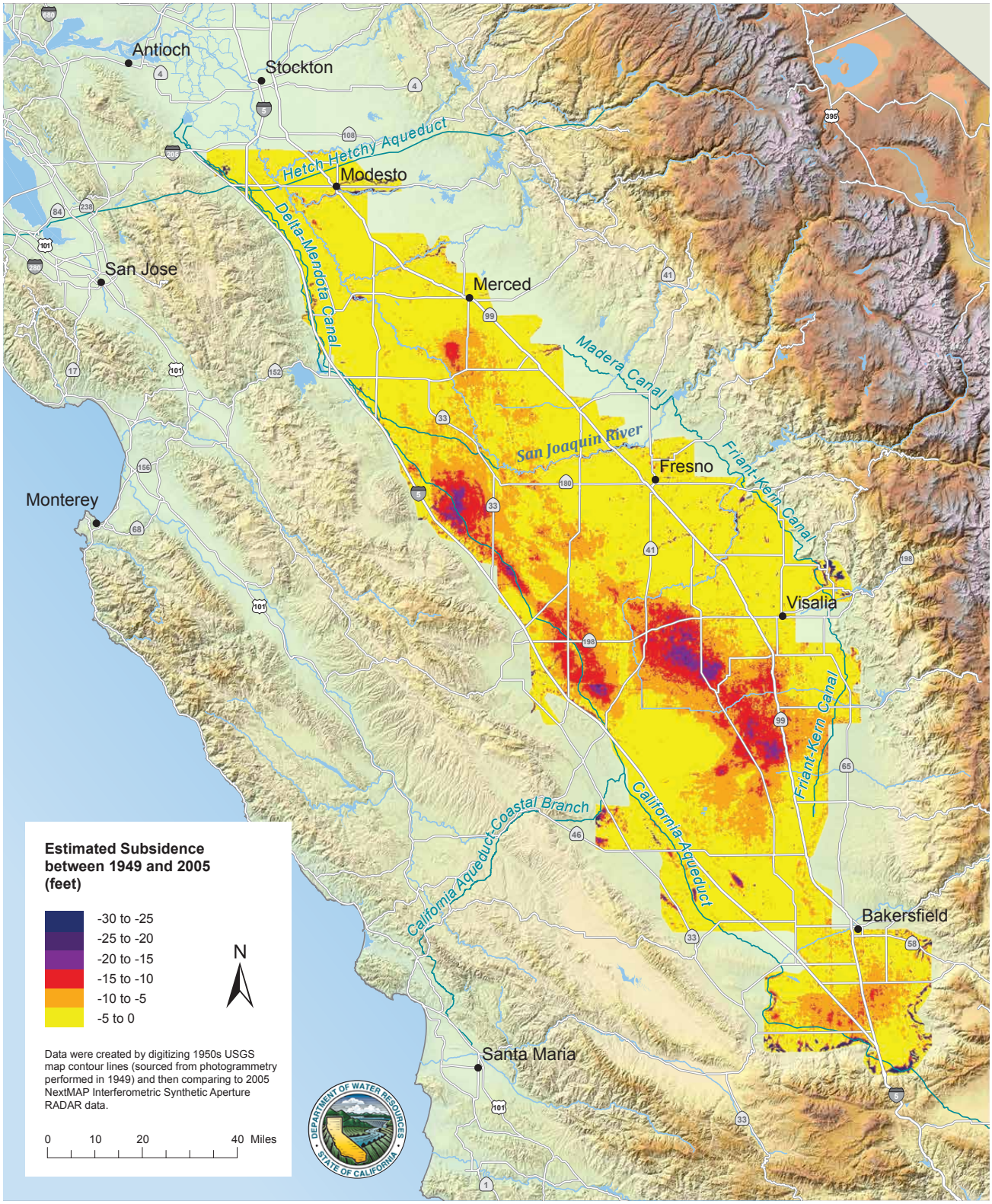


Figure 3.19: San Joaquin Valley Land Subsidence, May 2015–September 2016

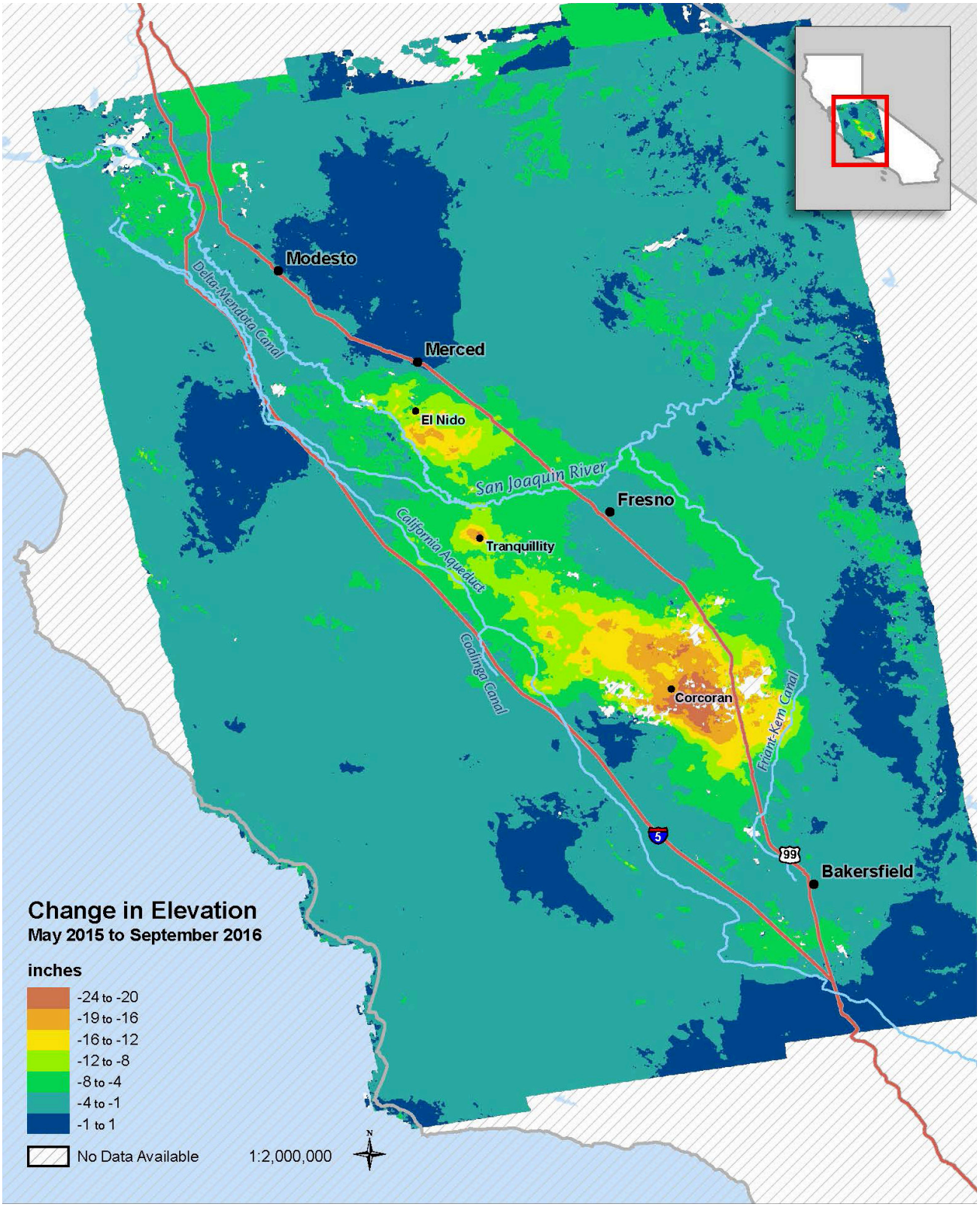


Figure crediit: NASA JPL

salinity requirements and having to shut off deliveries to south-of-Delta water users.

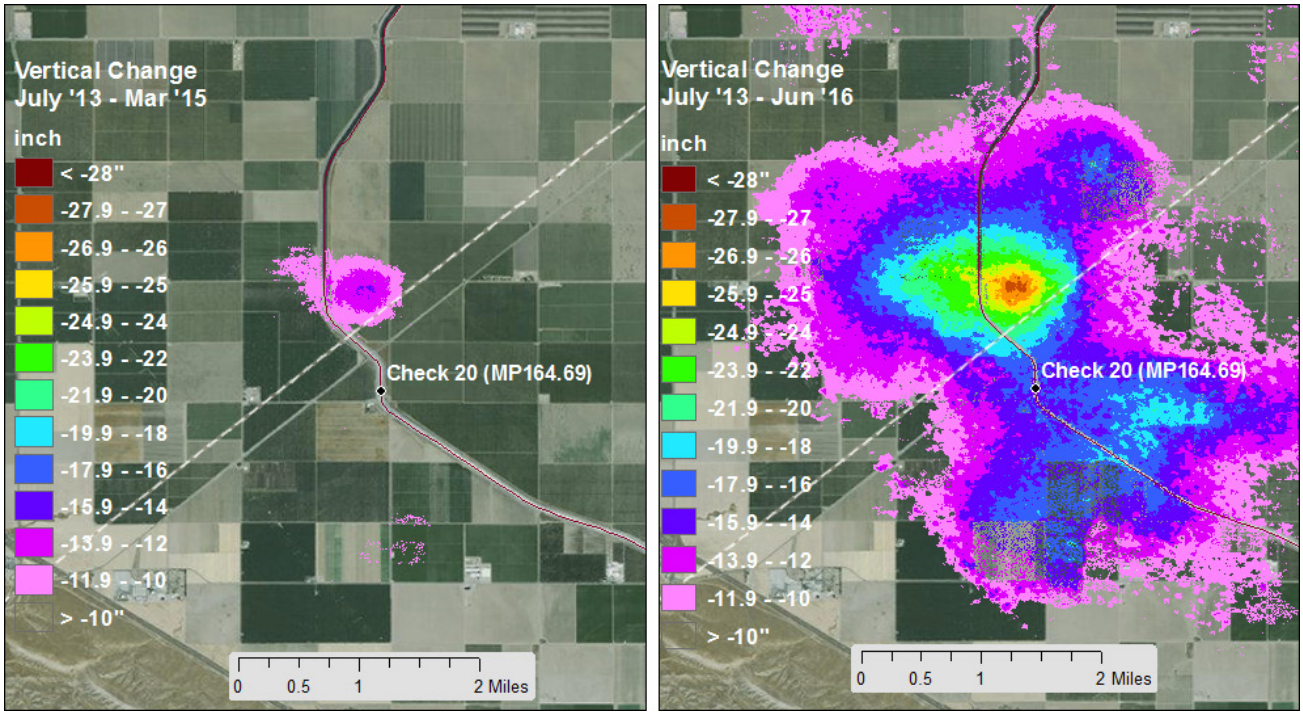
The Colorado River Basin continued in long-term dry conditions during California's 2012–2016 drought, although the basin's substantial reservoir storage permitted full water deliveries to Lower Basin contractors. Full supplies on the Colorado River were a welcome contrast to California's diminished intrastate surface water supplies throughout 2012–2016. With dry conditions continuing in the basin, however, it was becoming apparent that the risk of a Lower Basin shortage – considered to be low at the time the 2007 interim guidelines for operation of Lake Mead and Lake Powell were adopted – was increasing. Water Year 2012 and 2013 unregulated inflows to Lake Powell were 45 and 47 percent of average, respectively, generating discussions among Reclamation's Colorado River water contractors about the desirability of taking additional measures to avoid reaching the Lake Mead shortage trigger elevation. In 2014, Reclamation, MWD, Central Arizona Water Conservation District, Southern Nevada Water Authority, and Denver Water executed an $11 million agreement to fund a voluntary pilot project for water use reduction/water conservation measures that would help keep reservoir levels above critical target elevations. Reclamation, MWD, Central Arizona Water Conservation District, Southern Nevada Water Authority, and the States of California, Arizona, and Nevada additionally executed a 2014 memorandum of understanding regarding implementing further voluntary measures intended to increase storage in Lake Mead. The effectiveness of these measures is shown in **FIGURE 3.16**.

Impacts

Groundwater depletion was a significant impact. Thanks to the CASGEM program, for the first time statewide water level data were available for assessing this impact. DWR prepared an April 2014 report on the status of groundwater levels and gaps in groundwater monitoring in response to a requirement in the January 2014 emergency proclamation (California Department of Water Resources 2014); among

Figure 3.20: Growth of Subsidence Hotspot Adjacent to California Aqueduct

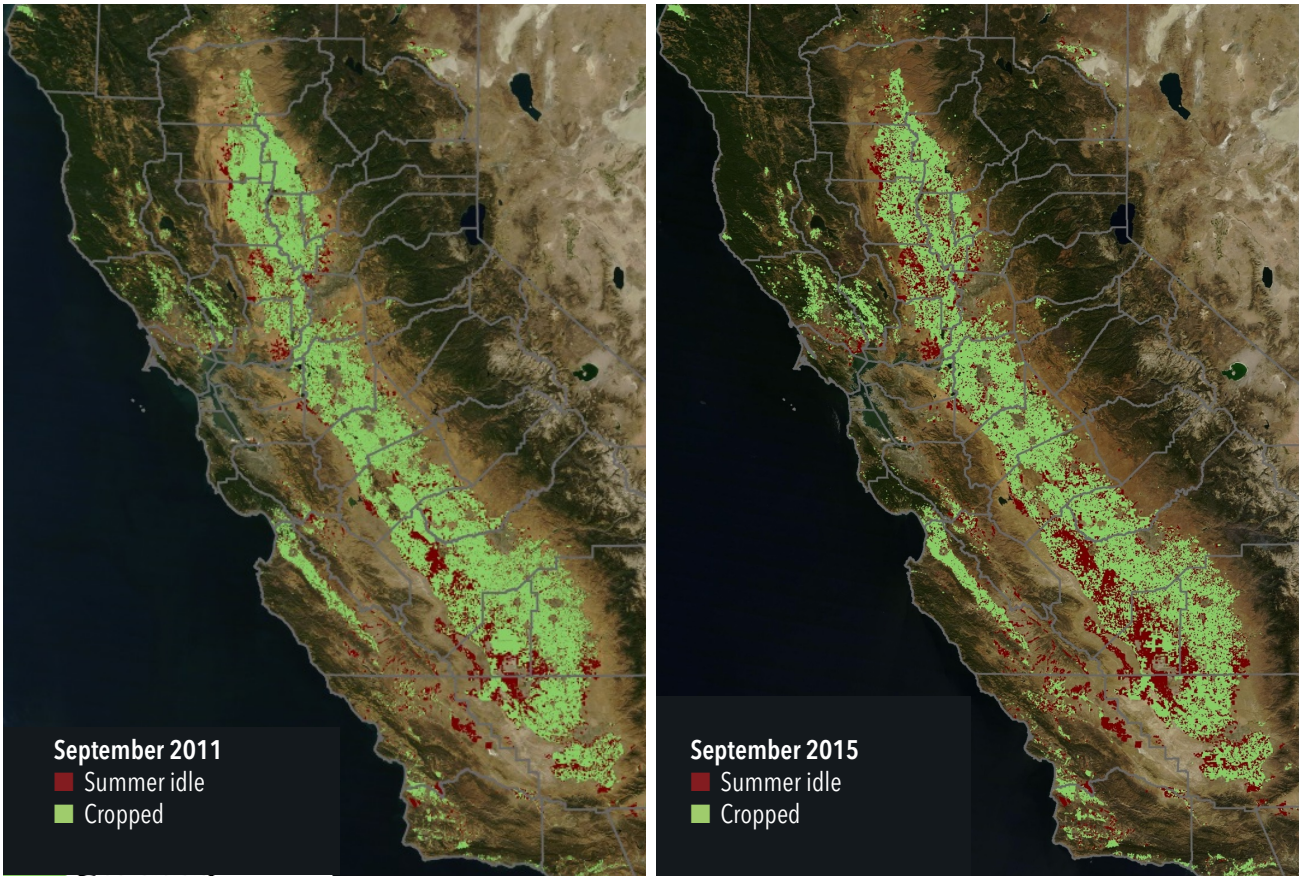
Subsidence north of Check 20 on the California Aqueduct near Avenal. DWR estimates that the aqueduct in this area has lost 20 percent of its original design capacity because of long-term subsidence. Figure credit: NASA JPL



the report's key findings were that recent groundwater levels in many areas in the San Joaquin Valley were more than 100 feet below previous historical levels. In other parts of the state, such as the northern San Francisco Bay Area, and South Coast and South Lahontan areas, groundwater levels were more than 50 feet below previous historical lows. **FIGURE 3.17** shows the drought's cumulative impacts on statewide groundwater levels. By the drought's end, the areas of most notable groundwater level decline were the San Joaquin Valley (especially the southern part) and the Ventura coastal plain.

The 2012–2016 drought was California's first drought for which regional-scale monitoring of land subsidence caused by groundwater extraction was available, thanks to a DWR contract with the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL). JPL acquired and processed satellite-based and aircraft-based interferometric synthetic aperture radar (InSAR) data to assess relative changes in land surface deformation (National Aeronautics and Space Administration 2016). The San Joaquin Valley was an area of particular interest because of the region's long-term history of subsidence **(FIGURE 3.18)**, and subsidence risks to critical water supply and flood risk management infrastructure. **FIGURE 3.19** shows a sample of the InSAR results. Observed annual San Joaquin Valley subsidence rates in some areas matched the record highs of approximately 1 foot per year recorded in the 1950s and 1960s, prior to construction of the CVP and SWP facilities that provided imported surface water to help mitigate groundwater overdraft. High rates observed during the drought reflect the historic zero allocations of project water to CVP contractors in 2014 and 2015. High-resolution, aircraft-based InSAR monitoring was able to detect impacts of pumping to infrastructure such as the

Figure 3.21: Land Idling Based on Satellite Imagery, September Comparison of a Wet 2011 with a Dry 2015. *Figure credit: NASA*



SWP's California Aqueduct **(FIGURE 3.20)**.

Agricultural operations were affected early in the drought, especially in the livestock industry where the impacts of a dry 2012 and 2013 were rapidly felt by producers relying on rangeland grazing. USDA had included all of California's counties in its drought disaster designations by the drought's first three years, either as primary counties or contiguous counties. Responding to reduced agricultural water supplies, particularly in parts of the San Joaquin Valley, the Governor issued Executive Order B-21-13 in May 2013, which directed DWR and SWRCB to expedite review and processing of water transfers.

Surface water shortages to agricultural water users resulted in increased land fallowing or idling, especially in the San Joaquin Valley. In a pilot project supported by NASA and the National Oceanic and Atmospheric Administration, NASA, U.S. Geological Survey, and USDA satellite imagery was used to prepare monthly updates of summer growing season land fallowing for DWR. This effort built upon work performed by USDA's National Agricultural Statistics Service for its annual cropland data layer product (National Aeronautics and Space Administration 2015). The pilot project's purpose was to make information available for near-term drought impact assessment; **FIGURE 3.21** shows a sample result. (USDA's annual cropland data layer product is released after the end of the year, providing an after-the-fact summary of conditions.) NASA estimated that there were more than 1.91 million acres of fallowed agricultural land in the Central Valley in the 2015 summer growing season, 522,000 acres more than estimated in 2011 (a wet year). As discussed previously, economic impacts of irrigation water shortages are difficult to compare from one drought to another because of the major role played by fluctuations in crop prices and markets for California's farm products. Where possible, growers turned to groundwater to make up for deficiencies in surface supplies, resulting in the large declines in groundwater levels observed in the San Joaquin Valley and Ventura coastal plain.

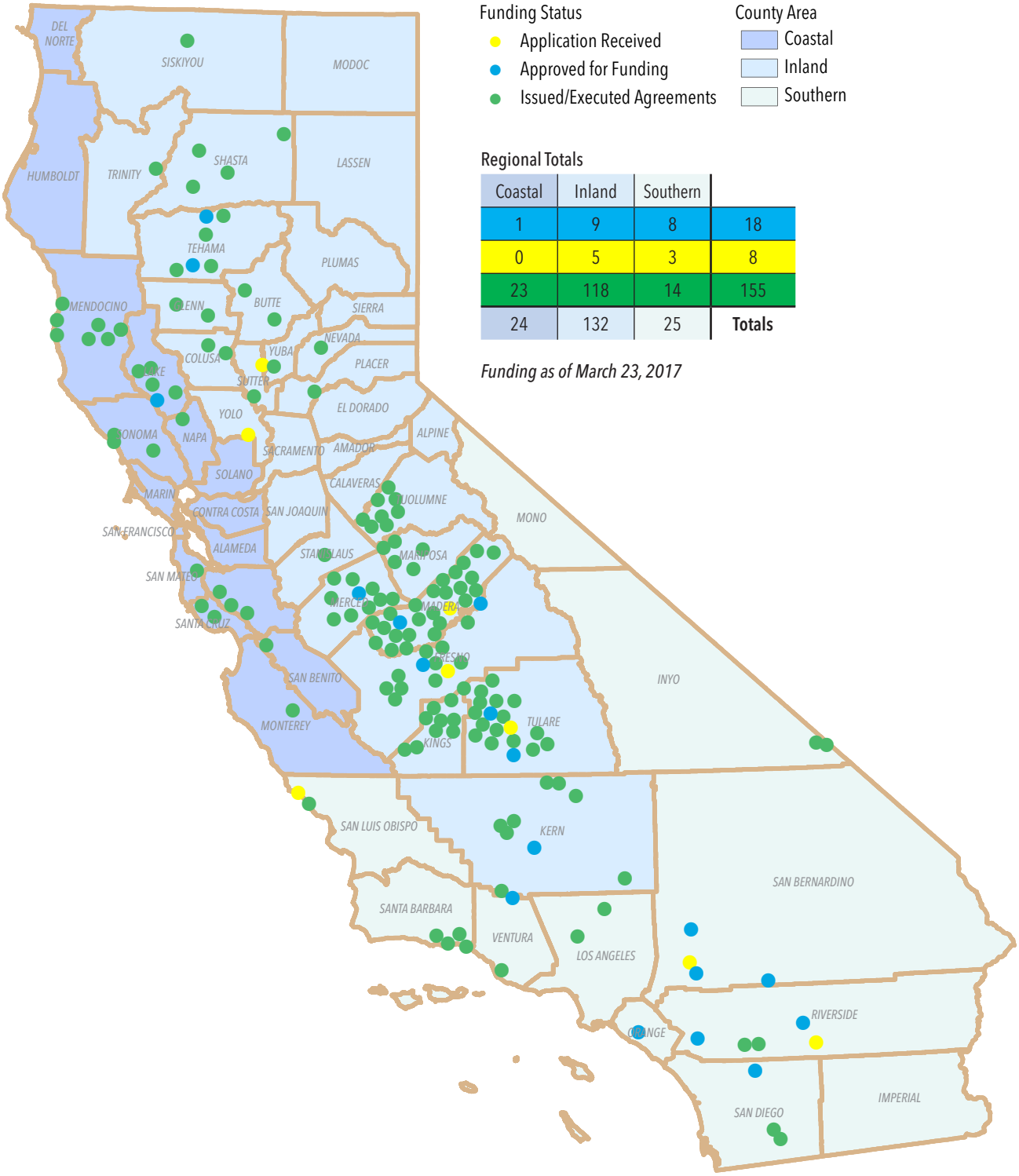
Impacts to drinking water supplies **(FIGURE 3.22)** were

Fallowed land in July 2015 in Westlands Water District near Huron, an area with a zero CVP allocation.

Drip irrigation lines and trees waiting to be chipped are all that remain where an orchard was torn out in 2015 because of drought, off Twisselman Road near Lost Hills.

A dead citrus orchard in 2015 near Lindsay. The first-ever zero allocations of Class 1 water in the CVP's Friant service area in 2014 and 2015 were unexpected and came with substantial impacts for local residents.

Figure 3.22: State Water Resources Control Board Drought Assistance for Public Water Systems



Regional Totals

Coastal	Inland	Southern	
1	9	8	18
0	5	3	8
23	118	14	155
24	132	25	**Totals**

Funding as of March 23, 2017

Figure credit: State Water Resources Control Board

State emergency assistance provided temporary water tanks and bulk water haulage for residents with dry private wells in San Joaquin Valley communities such as Monson in Tulare County. DWR subsequently provided funding to drill a municipal well for Monson, install a 60,000-gallon tank, and connect 22 private properties to the new water system. At the peak of the state emergency response effort, Office of Emergency Services costs for providing emergency potable water supplies in the San Joaquin Valley were approximately half a million dollars per month.

The emergency pumping operation and temporary pipeline at Reclamation's Lake Cachuma, shown here just before the pumping operation ended.

primarily felt in rural areas, among small public water systems and residents dependent on private wells. Some of the affected areas were locations of historical drought impacts caused by vulnerable sources of supply (e.g., fractured rock groundwater), such as Mendocino and Lake counties on the North Coast, or Sierra foothill counties such as Tuolumne and Mariposa. A new type of affected area emerged in the southern San Joaquin Valley, where

Tree die-off scenes like this were common in the central and southern Sierra Nevada. Foothill residents and county governments were challenged by the costs of removing dead and dying trees and disposing of the massive amounts of resultant biomass. Photo credit: CAL FIRE

Dead trees in Los Angeles' Griffith Park in 2016. Mature trees in residential and municipal landscapes suffered as irrigation was cut back and lawns were removed or allowed to die. The City of Los Angeles lost an estimated 14,000 trees in its parks in 2014 because of drought, according to the Los Angeles Department of Recreation and Parks. Bakersfield's Recreation and Parks Department estimated a loss of 1,500 trees in 2015, with 2,500 to 3,000 additional drought-stressed trees dying since then.

drought exacerbated pre-existing drinking water quality problems experienced by disadvantaged communities (DACs) on the valley floor, as well as causing private residential wells to go dry. A 2011 DWR grant to Tulare County for a Tulare Lake Basin DAC water study had been a catalyst for identifying the drinking water problems of DACs in the study area (352 communities), and bringing together communities with non-governmental organizations and social services providers. The outreach work performed in association with this grant set the stage for communities to seek governmental assistance when widespread problems with dry private residential wells began occurring, particularly in the CVP's Friant service area. The two consecutive years of zero CVP allocations there and increased agricultural pumping to keep orchards alive were apparent contributors to an unexpected area of concentrated impacts that resulted in a first-ever major state assistance effort to provide permanent water supplies (as opposed to temporary emergency supplies) to private well owners by connecting them to public water systems.

The Santa Barbara area was the only larger urban area at significant risk of drinking water impacts. Declining lake levels in Reclamation's Lake Cachuma forced the Cachuma Operation and Maintenance Board, a joint powers authority of local agencies that contract with Reclamation for Cachuma supplies, to install a barge-mounted temporary emergency pumping plant and more than 3,000 feet of temporary pipeline to convey water from a deeper part of the reservoir to the Tecolote Tunnel intake tower. The emergency pumping operation began in August 2015 and continued until February 2017; the reservoir dropped to 7 percent of capacity by early Water Year 2016. DWR and SWRCB provided $3 million in drought assistance for the emergency pumping operation. Subsequently, DWR provided a $10 million grant toward reactivation of the City of Santa Barbara's three-million-gallon-per-day desalination plant that had originally been constructed as a drought response measure in the 1990s. The total capital cost of plant reactivation, which began in 2015 and was

completed in 2017, was roughly $71 million.

Rural and urban areas both experienced tree mortality impacts. The drought's five-year duration set the stage for widespread tree mortality in the Sierra Nevada, with trees weakened by lack of water becoming vulnerable to bark beetle infestation, as occurred in similar large-scale Sierran die-offs during the 1987–1992 drought. Impacts were particularly acute in the central and southern Sierra **(FIGURE 3.23)**, and resulted in the October 2015 issuance of an emergency proclamation ordering state agencies, utilities, and local governments to remove dead and dying trees in high-hazard zones such as those adjacent to roads, power lines, and structures. The U.S. Forest Service's spring 2017 aerial survey estimated that 129 million trees had died in California's forests since 2010. Similarly, trees in urban areas suffered as municipalities cut back or eliminated irrigation of parks and street landscaping, and residents responded to water conservation messaging urging them to let lawns die and reduce their outdoor water use. The 2012–2016 drought was the first drought in which widespread tree mortality was reported in urban settings, in response to state requirements that urban water agencies reach mandatory water use reduction targets, typically through reduction of outdoor water use.

Figure 3.23: Tree Mortality in 2016

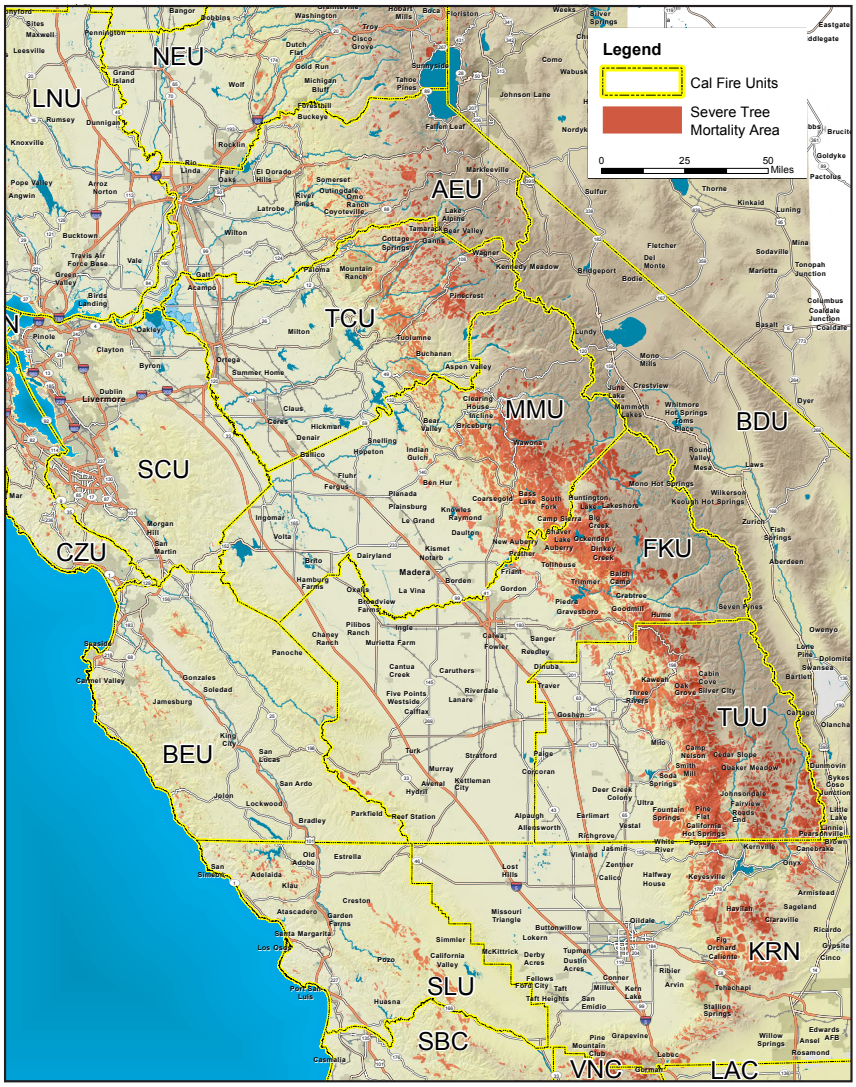
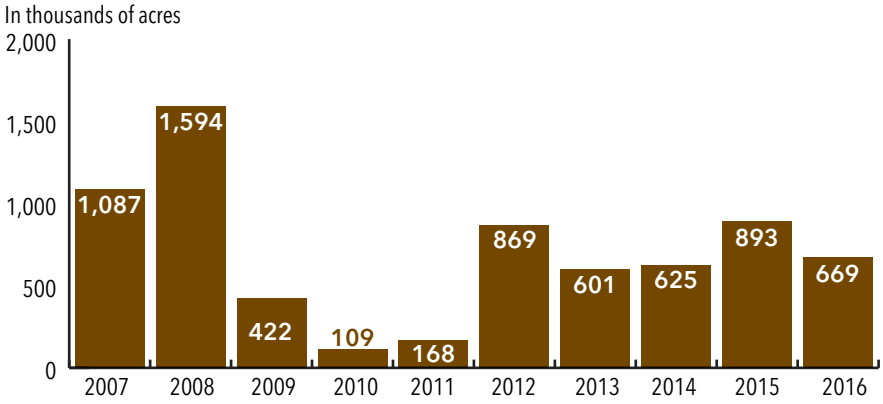


Figure credit: CAL FIRE

Figure 3.24: CAL FIRE Wildland Fires, Number of Acres Burned 2007–2016



Statistics include only wildland fire types from the California All Incident Reporting System database.

Data credit: CAL FIRE

A planned CAL FIRE urban forestry program update of its urban tree canopy survey may help quantify drought impacts. Presently, urban tree canopy assessment data are available on an ad hoc basis from some cities. A 2016 assessment for the City of Sacramento, for example, reported that 8 percent of the city's tree canopy was dead or dying and 11 percent was in poor condition.

FIGURE 3.24 provides a comparison of annual wildfire activity based on the metric of number of acres burned. According to CAL FIRE data through 2018, three fires during the drought period ranked on its list of top 20 largest wildfires: the Rush (Lassen County, 2012), Rim (Tuolumne County, 2013), and Rough (Fresno County, 2015) fires. Additionally, the Valley (Lake/Napa/Sonoma counties, 2015) and Butte (Amador/Calaveras counties, 2015) fires were ranked on CAL FIRE's list of top 20 most destructive wildfires. The Rim Fire was notable for watershed and infrastructure damage around the San Francisco Public Utilities Commission's (SFPUC's) Hetch Hetchy Reservoir, Cherry Reservoir, and Lake Eleanor, including the Lower Cherry Aqueduct and the Holm Powerhouse and power distribution lines. SFPUC's estimated emergency response and infrastructure repair costs were roughly $36 million.

The Save Our Water (SOW) outreach campaign, funded by DWR and carried out by the Association of California Water Agencies, began paid outdoor advertising in spring 2014 to promote urban water use reduction. Supplementing the paid campaign, no-cost media such as Caltrans' highway signs were also used. DWR provided more than $6 million for SOW during the drought.

Institutional Actions

The 2012–2016 drought stands out for the large number of institutional response actions taken at the state level **(TABLE 3.6)**. The initial action was Executive Order B-21-13 in May 2013, which directed DWR and SWRCB to expedite the review and processing of water transfers, a response

Table 3.6: Selected State Institutional Actions in 2012–2016 Drought

Date	Action
May 2013	Executive Order B-21-13, to expedite water transfers
December 2013	Formation of Governor's Emergency Drought Task Force
January 2014	Statewide drought emergency proclamation
March 2014	Amendment to Budget Act for $687.4 million for drought relief
April 2014	Proclamation of continued state of emergency because of drought
September 2014	Executive Order B-26-14, emergency drinking water assistance
December 2014	Executive Order B-28-14, continuing certain emergency proclamation provisions
March 2015	Amendment to Budget Act for more than $1 billion in emergency drought relief
April 2015	Executive Order B-29-15, mandatory urban water use reduction and other provisions
October 2015	Emergency proclamation on tree mortality
November 2015	Executive Order B-36-15, continuing urban water use restrictions, assistance for very small water systems/private well owners
May 2016	Executive Order B-37-16, to make urban water conservation a way of life, agricultural conservation planning
April 2017	Executive Order B-40-17, ending statewide drought emergency and calling for continued response to lingering impacts
September 2017	Executive Order B-42-17, continuing response to tree die-off

also employed in prior droughts. The dry start to Water Year 2014 subsequently caused the Governor to form a state interagency Drought Task Force in December 2013, soon followed by a January 2014 proclamation of statewide emergency based on continuing dry conditions. Among other things, the initial emergency proclamation called on Californians to reduce their water usage by 20 percent, as further discussed below. Ultimately, Executive Order B-40-17 in April 2017 marked the end of statewide drought emergency conditions by rescinding the earlier emergency proclamations and executive orders. That order, however, kept specified emergency response measures in place for Fresno, Kings, Tulare, and Tuolumne counties, primarily for continued response to drinking water shortages associated with small water systems and dry private residential wells, and directed continuing response to lingering drought impacts. The order also directed state agencies to increase efforts at building drought resiliency, including evaluating lessons learned from the drought and modernizing infrastructure for drought and water supply reliability.

State-mandated urban water use reduction was a primary feature of institutional response actions throughout the drought. This started with the initial request for a voluntary statewide 20 percent reduction in urban water use being followed by a directive to SWRCB in Executive Order B-29-15 in April 2015 that it impose mandatory restrictions to achieve a statewide 25 percent reduction in potable urban water use through February 2016. Executive Order B-36-15 in November 2015 directed SWRCB to extend the mandatory urban water use restrictions through October 2016 if drought conditions persisted. Executive Order B-37-16 in May 2016 shifted the focus on urban water use reduction from temporary drought reductions to a permanent reduction in use beyond the 20 percent by 2020 goal established by statute in 2009, directing DWR and SWRCB to develop new reduction targets as part of a permanent framework. That order further directed DWR to require agricultural water suppliers with more than 10,000 acres of land to prepare agricultural water management plans; the statutory requirement enacted in 2009 had applied to suppliers with more than 25,000 acres. Executive Order B-40-17 ending the statewide drought directed DWR and SWRCB to continue urban water use reduction efforts.

Institutional response actions taken during this drought built upon and expanded a theme first seen in the 2007–2009 drought, that of direct state social services assistance for drought impacts. The prior drought had seen limited-scale use of California Disaster Assistance Act (CDAA) funds to provide supplemental assistance to local governments and non-profit organizations for food bank programs in the San Joaquin Valley, to help mitigate impacts of the loss of

Dead lawns at state properties, including the Capitol, were a hallmark of the 2012–2016 drought. Eliminating lawns was also a message point in the Save Our Water campaign.

agricultural jobs caused by drought. Social services assistance was greatly expanded in the 2012–2016 drought, including state assistance to food banks. By December 2016, the Department of Social Service had provided more than 1.8 million boxes of food to community food banks in drought-affected counties. The Department of Community Services and Development provided assistance to drought-impacted, low-income households for residential water bills, and to farmworkers and other low-income agricultural workers for temporary housing and employment support services. Executive Order B-26-14 had authorized the Office of Emergency Services to use CDAA funds for provision of temporary emergency drinking water (bottled water or temporary tanks) to residents without water. However, for the first time, state assistance was also directly provided to residents in selected areas with dry private wells for development of permanent water supplies (connection to a public water system) to replace individual private wells. Executive Order B-36-15 in November 2015 authorized SWRCB to use up to $5 million of emergency drought funding to assist drinking water systems serving less than 15 connections (those too small to fall under state regulatory jurisdiction) and private well owners; this funding enabled, for example, several projects in Tulare County to connect private well owners to public water systems.

Standing dead trees killed by bark beetle infestations represented an immediate hazard to structures and roads, as illustrated by this 2016 example in Madera County, and increased wildfire risks. Fire prevention projects to remove dead trees included this 2016 example in Fresno County. Photo credits: CAL FIRE

The 2012–2016 drought marked the second time that special response action was taken for widespread tree mortality caused by bark beetle infestation brought on by drought conditions (the first instance was a 2003 emergency proclamation for Riverside, San Bernardino, and San Diego counties, following regional drought in Southern California). The Tree Mortality Task Force, bringing together state and federal agencies, counties, utilities, and others, was created following the October 2015 emergency proclamation on that subject, a proclamation that was subsequently extended by Executive Order B-42-17. The task force's initial focus was on removal of high-hazard (e.g., adjacent to roads, power lines, and structures) dead and dying trees, and identifying disposal options for the biomass removed.

A major legislative response action during the drought was provision of emergency drought response funding through two amendments to the enacted state budgets in 2014 and 2015. In March 2014, a budget amendment for the 2013–2014 fiscal year authorized $687.4 million for drought relief, with the largest amount of that funding ($549 million) being for accelerated expenditure of Proposition 84 and Proposition 1E bond funds for grants to local agencies for integrated regional water management projects. In March 2015, a budget amendment for the 2014–2015 fiscal year authorized more than $1 billion for additional relief, including water conservation and recycling assistance,

emergency food aid, and small system drinking water emergencies. Also in 2015, Senate Bill 88 (Statutes 2015, Chapter 27) amended the Health and Safety Code to give SWRCB authority to require consolidation of water systems consistently failing to provide an adequate supply of safe drinking water, and amended the Water Code to provide for more thorough measurement and reporting of diversions to SWRCB. Both provisions stemmed from resource management issues highlighted by drought conditions – the inability of some small water systems to have the technical, managerial, and financial capacity to provide reliable drinking water supplies to their customers, and a lack of accurate data on diversions for SWRCB to use in administering water rights in times of shortage. And, although not a drought response measure, it is likely that drought conditions contributed to adoption of the Sustainable Groundwater Management Act in 2014.

Ending the Drought

The 2012–2016 drought ended with a wet Water Year 2017 – the second-wettest year on record in terms of statewide runoff, and wettest year of record in the Sacramento River Basin as measured by DWR's 8-station precipitation index. Responding to the wet conditions, Executive Order B-40-17 in April 2017 terminated the statewide drought proclamation but kept in place drought emergency provisions for Fresno, Kings, Tulare, and Tuolumne counties to provide for response to continuing impacts, particularly for small water systems and dry private residential wells. **FIGURE 3.25** illustrates the cause of a wet Water Year 2017 – a significantly greater than normal number of atmospheric river storms reaching the West Coast.

Figure 3.25: Atmospheric Rivers Reaching the West Coast in Water Year 2017

Atmospheric River Strength	Atmospheric River Count*
Weak	12
Moderate	21
Strong	13
Extreme	3

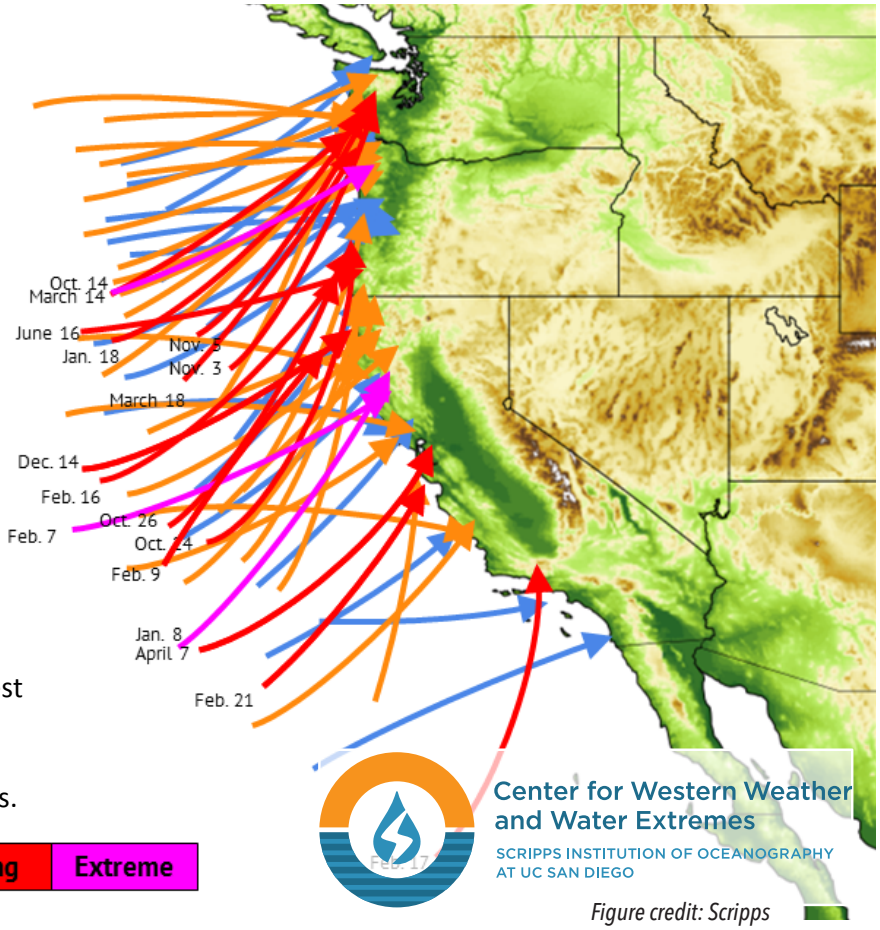


Figure credit: Scripps

4

Comparison of Recent Conditions to Past Droughts and Lessons Learned

This chapter examines the state's changed conditions, comparing California's most recent droughts – the three-year 2007–2009 event and the five-year 2012–2016 event – with the state's largest historical droughts. The state's population, now approximately 40 million, was near 36.6 million in 2007 and roughly 30 million during the 1987–1992 drought. Important aspects of the state's water management setting have changed significantly over the past few decades, as has the climate background in which droughts are occurring.

This chapter also addresses experiences documented during the large historical droughts and lessons learned from those events, highlighting gaps in information or tools for water-sector drought response and preparedness. The appendix contains copies of state executive orders and statewide emergency proclamations to illustrate typical response actions.

A CHANGING CLIMATE

Observed climate conditions have changed in the 21st century as compared to the longer historical record **(FIGURE 4.1)**. This century's droughts have occurred in a setting of increased warmth, which affects hydrologic conditions (snowpack, evapotranspiration) and drought impacts (wildfire risks, stream temperatures for anadromous fish). California's existing water infrastructure was largely designed based on the climate of the early to mid-1900s and is not optimized for the climate of the present. Increasing inter-annual precipitation variability, such as the transition from the 2012–2016 drought to an exceptionally wet 2017, is an expected outcome of climate change and challenges the ability to use existing infrastructure for adaptation strategies such as managed groundwater recharge.

Climate change also affects water management through altered water use or regulatory conditions, in addition to direct impacts on hydrologic processes. Populations of anadromous fish species protected pursuant to the Endangered Species Act, for example, have widespread geographic distribution in California **(TABLE 4.1)**. Warmer ambient air temperatures, as observed in the 2012–2016 drought, make it increasingly difficult to efficiently operate water infrastructure during times of shortage to provide required cold water for temperature-sensitive anadromous species such as salmonids, as was seen with Shasta Dam operations in 2016. This added stressor to water supplies

further complicates compliance with changed regulatory requirements that have significantly altered the institutional setting for water project operations in recent droughts as compared to prior ones, as discussed in the following section.

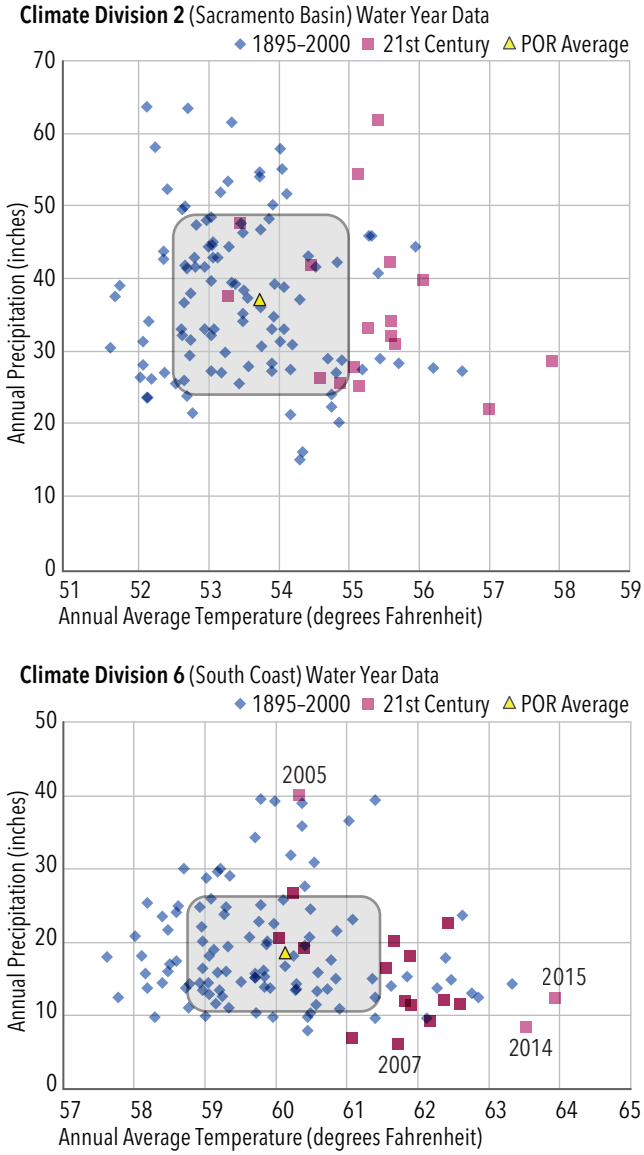
Changes in Institutional Setting – Water Project Operations

The institutional setting for water management has changed greatly since the 1987–1992 drought. Some of the most obvious changes have affected management of California's largest water projects, such as the Central Valley Project (CVP), State Water Project (SWP), Los Angeles Aqueduct, and Colorado River system, as described below. New listings and management of fish populations pursuant to the Endangered Species Act (ESA) have affected operations of many of the state's water projects, including the large projects affected by listing of Central Valley fish species as well as smaller projects on coastal rivers where Coho salmon populations were listed. During the 2007–2009 drought, for example, the State Water Resources Control Board (SWRCB) ordered urban water users in the Russian River service area to plan for conservation targets of 25 to 50 percent because of combined impacts of drought and multi-agency regulatory requirements for fish protection. Challenges of the 2012–2016 drought were exemplified by the difficulties in operating Shasta Dam to maintain cold water in the Sacramento River for salmon.

Challenges associated with managing CVP and SWP Sacramento-San Joaquin Delta (Delta) exports and conditions within the Delta have been consistently observed in California's largest droughts; only the specific details have changed. In the 1976–1977 drought, for example, major efforts were made to put in place temporary barriers and pipelines to manage Delta salinity and to enable emergency water deliveries. At the time, salinity was the primary management target, and the striped bass index was the primary metric used for tracking Delta fishery conditions. Fast forward to the 2012–2016 drought, and only one temporary emergency drought barrier was installed, in part because of environmental permitting difficulties associated with other proposed barrier sites. Today, Delta resource management criteria still include salinity, but fishery management requirements are driven by biological opinions for anadromous and resident fish species.

The present regulatory framework for CVP and SWP operations is distinctly different from that of 1987–1992. The first biological opinion for the then-threatened

Figure 4.1: Comparing the Present Climate to the Past in the Sacramento Valley and Southern California



Notes: Shaded box represents one standard deviation from mean
POR = period of record

Table 4.1: California Anadromous Fish Species

	Endangered Species Act Protection		California Salmonid Ecoregions					
Common Name	State	Federal	North Coast	North Central Coast	Klamath River	Sacramento-San Joaquin Rivers	South Central Coast	Southern California Coast
CHINOOK SALMON			X	X	X	X		
Central Valley fall-run ESU						X		
Central Valley late fall-run ESU						X		
Central Valley spring-run ESU	X	X				X		
Central Valley winter-run ESU	X	X				X		
California Coastal ESU		X	X					
Upper Klamath-Trinity Rivers Basin ESU				X	X			
Southern Oregon/Northern California Coastal ESU			X					
COHO SALMON			X	X	X		X	
Southern Oregon/Northern California Coasts ESU	X	X	X	X	X			
Central California Coast ESU	X	X		X				
CHUM SALMON [1]								
PINK SALMON [1]								
STEELHEAD TROUT			X	X	X	X	X	X
California Central Valley DPS		X				X		
Southern California DPS		X						X
South-Central California Coast DPS		X					X	
Central California Coast DPS		X		X			X	
Northern California DPS				X				
Klamath Mountains Province DPS					X			
COASTAL CUTTHROAT TROUT			X	X	X			
SOUTHERN GREEN STURGEON DPS		X	X	X	X	X		
WHITE STURGEON				X	X	X		
PACIFIC LAMPREY			X	X	X	X	X	X
LONGFIN SMELT	X	X[2]		X	X	X		
EULACHON		X		X	X			

1 Incidental to California, with no established populations or consistent occurrence.

2 Warrants protection under the federal Endangered Species Act. However, U.S. Fish and Wildlife Service determined that listing is precluded at this time because of the need to address other higher priority listing actions.

Notes: ESU = evolutionarily significant unit

DPS = distinct population segment

Table adapted from *California Department of Fish and Wildlife State Wildlife Action Plan 2015*.

winter-run Chinook salmon was issued just at the end of the 1987–1992 drought; in 1994, winter-run were reclassified as endangered. A significant provision of the initial 1992 biological opinion for winter-run salmon, and of subsequent opinions, was the requirement to provide additional cold water in Sacramento River spawning areas downstream of Shasta Dam, resulting in increased late-season reservoir storage. Delta smelt were listed as threatened in 1993. Other fish species subsequently listed pursuant to the federal ESA or the California ESA included the longfin smelt, Central Valley spring-run Chinook salmon, Central Valley steelhead, and green sturgeon.

The biological opinions for these species, together with changes in SWRCB Bay-Delta requirements, represent a major difference between 1987–1992 (when SWRCB's Water Right Decision 1485 (D-1485) governed the projects' Delta operations) and the present. SWRCB's Water Right Decision 1641 (D-1641) reduced water project exports to provide more water for Delta outflow. Requirements of the most recent U.S. Fish and Wildlife Service and National Marine Fisheries Service biological opinions for listed fish species modify D-1641 requirements, further reducing the water projects' delivery capabilities by imposing greater pumping curtailments and Delta outflow requirements. Additionally, the Central Valley Project Improvement Act of 1992 mandate to reallocate 800 thousand acre-feet (taf) of CVP yield for environmental purposes and to provide a base water supply for wildlife refuges was not in effect for 1987–1992 water operations.

FIGURES 4.2 and **4.3** illustrate a long-term perspective on CVP and SWP water supply availability; the projects' delivery capabilities over time are influenced by increases in service area demands and by regulatory requirements. Both projects have over time changed how they report allocation amounts; the U.S. Bureau of Reclamation (Reclamation) has significantly expanded the number of categories it uses for making allocations. To simplify data presentation for the CVP figure, only allocations to project agricultural contractors, as Reclamation uses that term, are presented; Reclamation's south-of-Delta agricultural water contractors typically receive the smallest percentage allocation of the federal water contractors. **TABLE 4.2** shows a more detailed breakdown of water project allocations in selected dry years.

All three sources of imported water supply for Southern California have been affected by changing institutional conditions; the SWP supplies as described previously, Los Angeles Aqueduct supplies by requirements such as dust control for Owens Lake, and Colorado River supplies by increased water use in Arizona and Nevada. **FIGURE 4.4** shows the long trend in water supplies used by the City of Los Angeles, illustrating how the city has increased its purchases of water from Metropolitan Water District (MWD) when its Los Angeles Aqueduct supplies were reduced.

During earlier droughts, California used water from the Colorado River in excess of the state's basic interstate apportionment – Lower Basin water that was either hydrologically surplus or unused apportionment of Nevada

Table 4.2: CVP and SWP Allocations in Selected Drought Years
(allocations in percent)

	1991	2009	2014	2015
SWP	30/0*	40	5	20
SWP water rights contractors	50	100	100	50
CVP north-of-Delta agricultural contractors	25	40	0	0
CVP south-of-Delta agricultural contractors	25	10	0	0
CVP Friant Division, Class 1	100	100	0	0
CVP water rights settlement contractors	75	100	75	75
CVP San Joaquin exchange contractors	75	100	65	75

*30 percent to urban contractors and zero to agricultural contractors.

Figure 4.2: Historical Central Valley Project Allocations to Agricultural Contractors

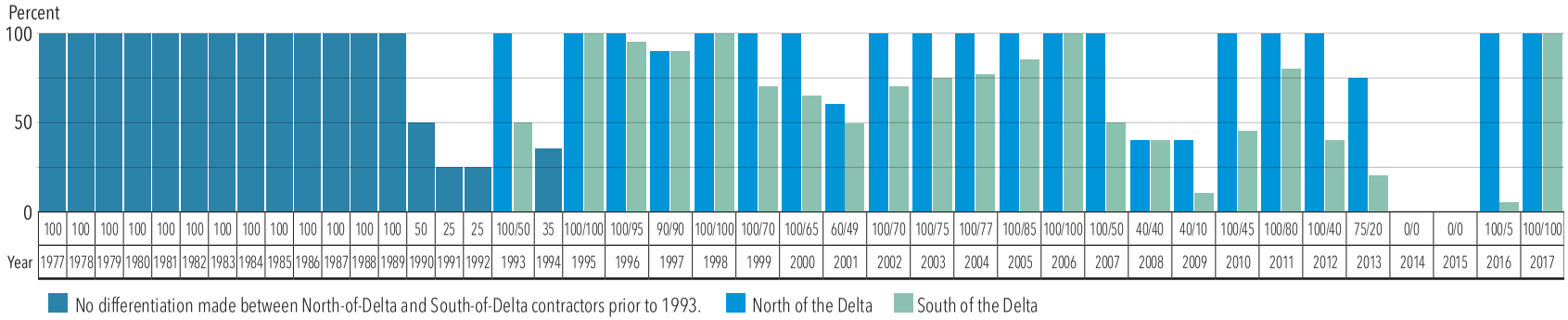
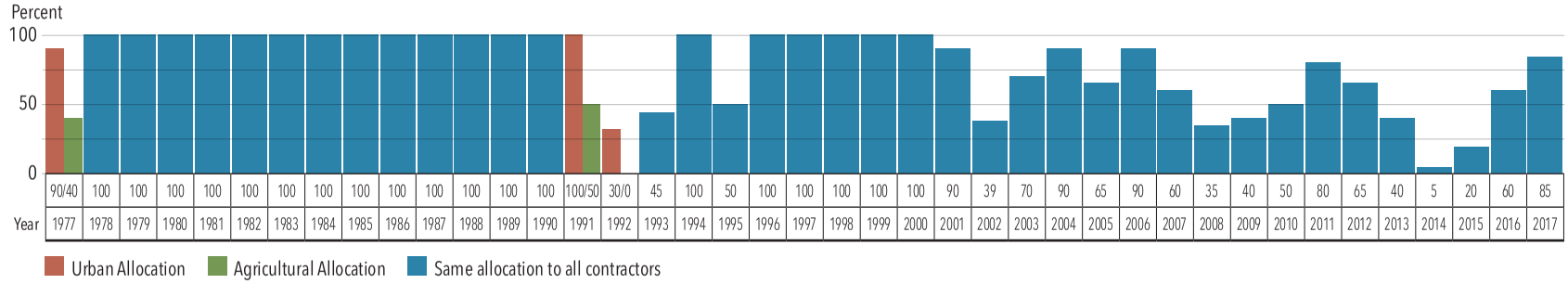


Figure 4.3: Historical State Water Project Allocations to Project Contractors



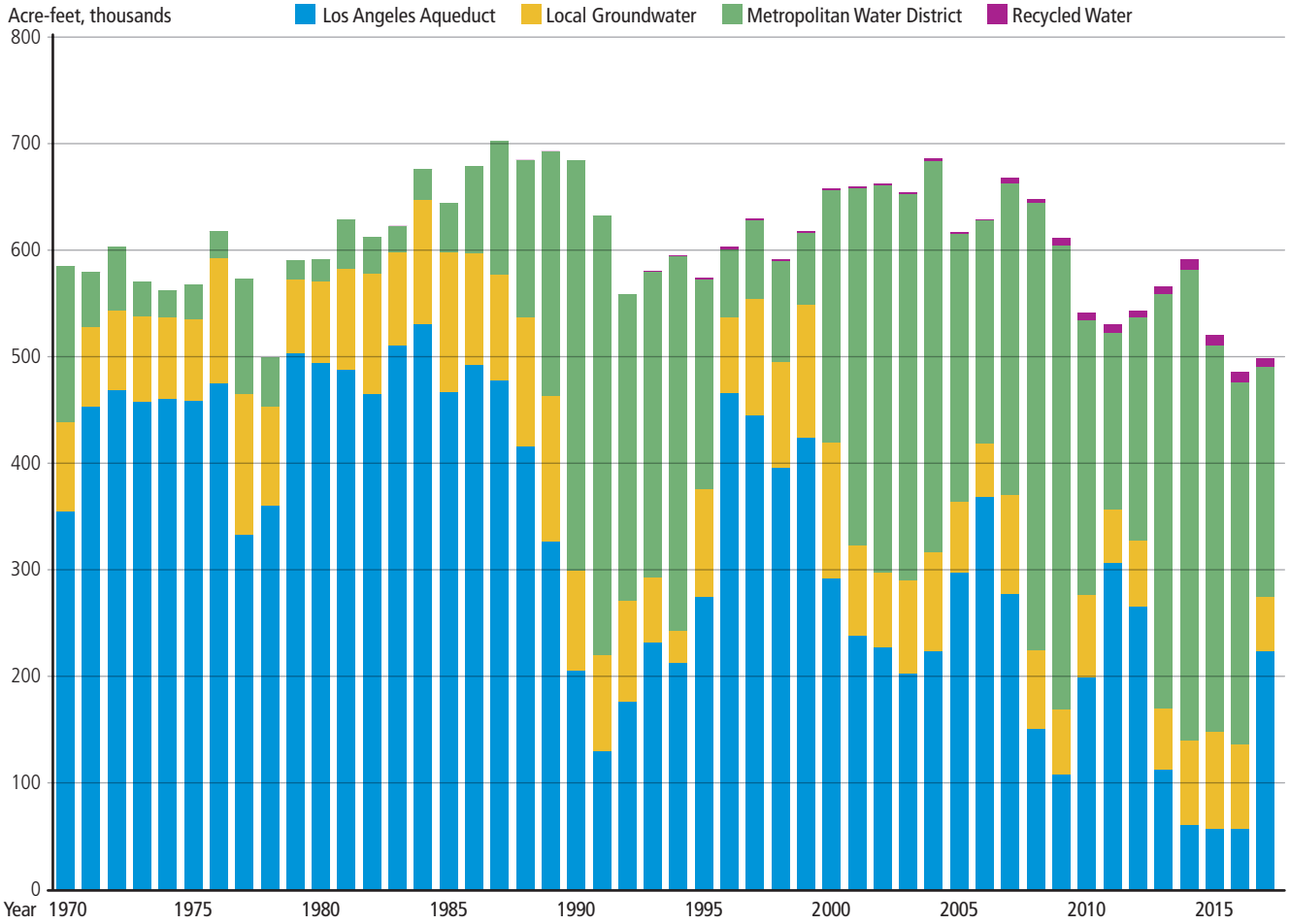
Prior to 1994, differential allocations could be made for urban and agricultural contractors. The few years for which separate allocations were made are highlighted in contrasting colors.

or Arizona. This additional supply helped protect the MWD service area against shortages and allowed MWD to participate in exchange agreements to assist other agencies experiencing critical shortages. Drought in the Colorado River Basin and increasing water usage by the other states brought this era of additional supplies to a close, and California was reduced to its basic interstate apportionment of 4.4 million acre-feet annually of consumptive use in 2003. Ongoing dry conditions in the Colorado River Basin and declining reservoir storage **(FIGURE 4.5)** subsequently led to Reclamation's 2007 adoption of interim guidelines for Lower Basin shortages and coordinated operations for Lake Mead and Lake Powell that remain in effect through 2025 for reservoir operations during 2026. The seven Colorado River Basin States have adopted drought contingency planning negotiations regarding additional shortage mitigation agreements that could be implemented before the 2007 guidelines expire, in response to ongoing dry conditions that increase the probability of a Lower Basin shortage.

Changes in Institutional Setting – State Financial Assistance

Beginning in the 1990s, California voters approved bond measures providing funding for actions such as improving water supply reliability, reducing flood risk, implementing conservation measures, or restoring fish and wildlife habitat. In contrast to prior smaller bond measures providing state financial assistance to local agencies, these

Figure 4.4: Sources of City of Los Angeles Water Supply



Data credit: Los Angeles Department of Water and Power

measures provided assistance primarily in the form of grants rather than loans. Many of the actions funded through these measures improve water supply reliability during dry or drought conditions. The bond measures were:

- Proposition 204 in 1996 for $995 million
- Proposition 13 in 2000 for $2.1 billion
- Proposition 50 in 2002 for $3.44 billion
- Proposition 84 in 2006 for $5.388 billion
- Proposition 1E in 2006 for $4.09 billion
- Proposition 1 in 2014 for $7.12 billion
- Proposition 68 in 2018 for $4.1 billion

Expediting processing of bond-funded grants and targeting grants to provide drought response benefits were approaches used in both the 2007–2009 and 2012–2016 drought periods. Executive Order S-06-08 in 2008 directed the California Department of Water Resources (DWR) to expedite grant programs for new or ongoing water conservation and water use reduction programs, and for projects capable of timely implementation to ease drought conditions in 2008 or 2009. Similarly, the 2014 drought emergency proclamation directed DWR and SWRCB to accelerate funding for near-term water supply projects; the March 2014 emergency drought relief legislation authorized use of existing Proposition 84 and Proposition 1E funds for grants for projects already planned or partially completed to increase local reliability, including recapturing stormwater, expanding use of recycled water, enhancing groundwater management/storage, and strengthening water conservation.

Figure 4.5: Colorado River Total System Storage

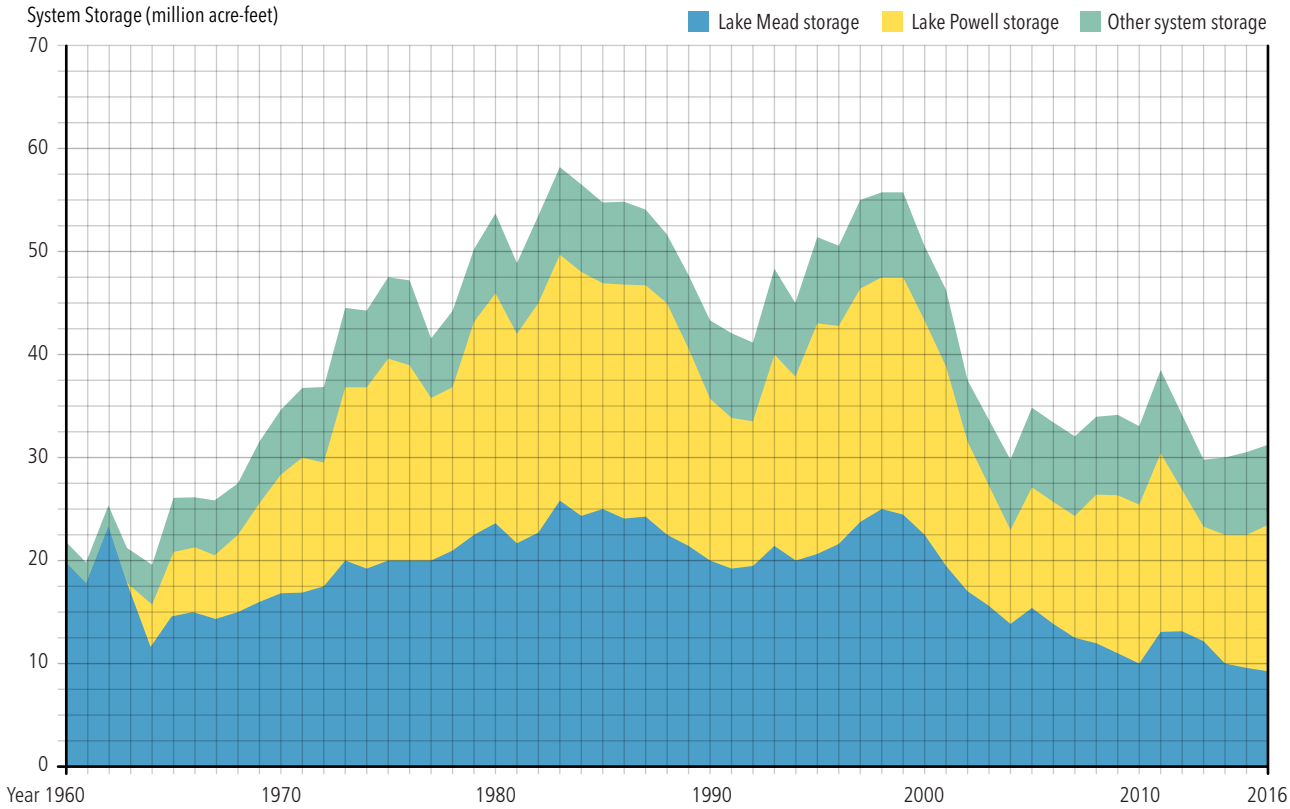


Figure credit: U.S. Bureau of Reclamation

Changes in Major Water Infrastructure

Two large water supply reservoirs have been constructed since the 1987–1992 drought: MWD's 800 taf Diamond Valley Lake and Contra Costa Water District's Los Vaqueros Reservoir (initially constructed at 100 taf and later expanded to 160 taf). Both reservoirs are offstream storage reservoirs with a common purpose of providing emergency water supplies in or near the agencies' service areas in an event that an earthquake or other disruption would make imported supplies unavailable. Half of the capacity of Diamond Valley is reserved for emergency purposes; the remainder can be used to buffer impacts of drought, as occurred during the 2012–2016 drought **(FIGURE 4.6)**.

The capacity of large-scale managed groundwater storage projects has also increased. Some of the largest new projects becoming fully operational since the 1987–1992 drought include those operated by Semitropic Water Storage District, Arvin-Edison Water Storage District, Kern Water Bank Authority, Kern County Water Agency, and Mojave Water Agency. These projects share a common feature of relying on recharge supplies exported from the Delta and are subject to the limitations and restrictions associated with these supplies. Water Year 2014 presented an operational challenge for some San Joaquin Valley banking agreements, as the water exchanges and wheeling agreements used by participating local agencies to manage water supplies at these projects had not been developed with the concept that zero or very low allocations from the CVP or SWP would occur.

From a drought perspective, one of the most significant large-scale conveyance facilities constructed since the 1987–1992 drought is SWP's Coastal Aqueduct, which made imported water available to areas of San Luis Obispo and Santa Barbara counties that had been hard hit in earlier droughts. Other major pipeline projects included enlargement and extension of the SWP's East Branch of the California Aqueduct to provide additional conveyance capacity into the Inland Empire area, and Mojave Water Agency's construction of two new pipelines to bring SWP

Figure 4.6: Metropolitan Water District's Combined Reservoir Storage

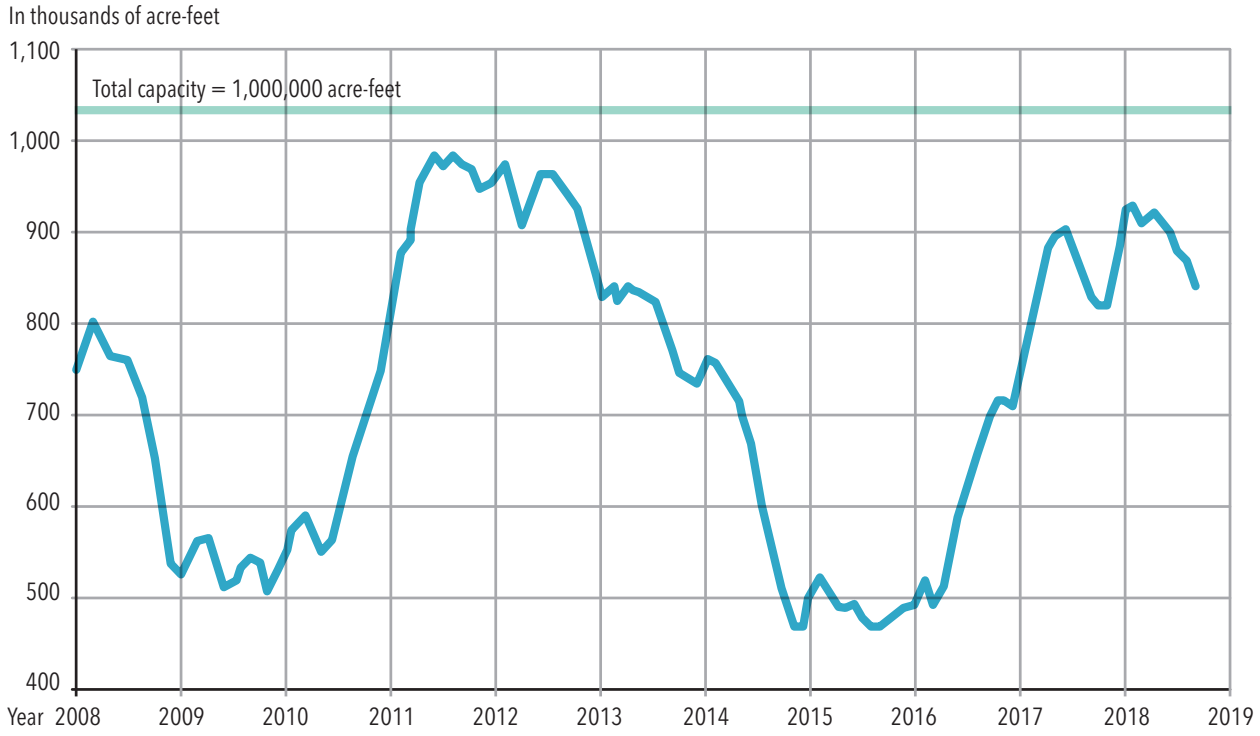


Figure credit: Metropolitan Water District

water into parts of its service area previously dependent entirely on local groundwater.

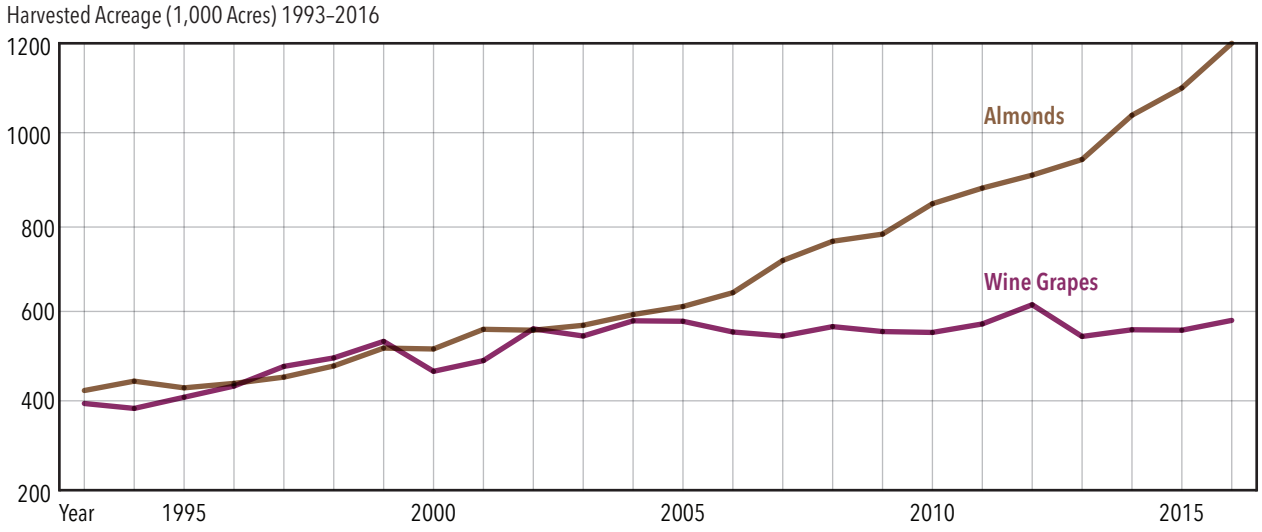
Changes in Water Use Conditions

Long-term actions to reduce urban per capita water demand have been underway for some time. California's 1990 Water Conservation in Landscaping Act was an initial effort to manage urban outdoor water use. The Water Conservation in Landscaping Act of 2006 subsequently expanded the concepts of the 1990 act. This required DWR to update its model water efficient landscape ordinance for new developments and retrofitted landscapes, and required local adoption of water efficient landscape ordinances. Regarding urban indoor water use, the federal Energy Policy Act of 1992 set efficiency standards for plumbing fixtures manufactured after January 1994. State legislation (the Environmental Water Act of 1989) had earlier authorized a DWR grant program to provide funding to the City of Los Angeles for replacement water to compensate for water supplies lost resulting from the Mono Lake public trust court decision. This program was implemented to fund plumbing fixture retrofit projects in Los Angeles; plumbing fixture retrofit programs were broadly implemented statewide during the 1987–1992 drought, and subsequently were further supported by state financial assistance programs during the 2007–2009 and 2012–2016 droughts.

The Water Conservation Act of 2009 (commonly referred to as the 20 percent by 2020 requirement) called for statewide reduction in urban per capita water use. Legislation enacted in 2018 established urban water use objectives and reporting requirements for indoor and outdoor residential and commercial use, and required SWRCB to coordinate with DWR in making recommendations and adopting long-term standards for efficient water use. The legislation set an urban indoor water use standard of 55 gallons per capita per day until January 2025, to be reduced to 50 gallons per capita per day in January 2030. An outdoor water use standard is to be developed.

In the irrigated agriculture sector, increased acreage is being devoted to permanent plantings of higher-value orchard and vineyard crops that require reliable water supplies during dry conditions. One example is expansion of almond and pistachio acreage, including acreage on the west side of the San Joaquin Valley where imported CVP and SWP supplies have become less reliable because of the changed conditions described previously. **FIGURE 4.7** provides an example of the statewide increase in acreage of

Figure 4.7: Example of Increased Acreage in Permanent Plantings



Data credit: California Department of Food and Agriculture and U.S. Department of Agriculture National Agricultural Statistics Service
Note: The California Department of Food and Agriculture reclassified its definition of wine grapes in 2013.

almonds and wine grapes since the 1987–1992 drought. The data shown is for harvested acres; actual planted acreage would be higher when including non-bearing trees and vines.

COMPARISON OF DROUGHT IMPACTS

TABLE 4.3 provides examples of drought impacts associated with managed and unmanaged systems. Unmanaged systems refer to conditions associated solely with precipitation and streamflow, where no water infrastructure is used to control or influence the outcome of water shortage. Managed systems are those where actions such as releases from reservoirs or pumping groundwater can be used to mitigate impacts. Some impacts can be associated with both unmanaged and managed systems; for example, impacts to anadromous fish habitat can occur either in free-flowing streams or in rivers controlled by major reservoirs. As discussed in Chapter 1, impacts increase with drought duration. **TABLE 4.4** illustrates how dry conditions have affected end-of-water-year storage in selected reservoirs. Persistent dry conditions reduce the water storage in reservoirs and groundwater basins used to mitigate drought impacts, and reduce the soil moisture that supports non-irrigated vegetation.

Unmanaged Systems

Economic impacts associated with unmanaged systems have historically been greater than those associated with managed systems. Some of California's largest directly quantifiable economic impacts of drought were associated with loss of timber resources and wildfires. Just as the 1991 Oakland Hills fire was at the time described as the costliest fire disaster in U.S. history, the same became true for the 2003 Southern California wildfires (which followed a multi-year regional drought in Southern California) (U.S. House of Representatives 2007). The October 2007 Southern California wildfires were of similar magnitude. **TABLE 4.5** shows costs in recent years associated with wildfires on lands under the jurisdiction of the California Department of Forestry and Fire Protection.

Table 4.3: Typical Multi-Year Drought Impacts

Unmanaged Systems	Health and Safety	Economic	Environmental
Risk of Catastrophic Wildfires	x	x	x
Non-Irrigated Agriculture (e.g., livestock grazing)	–	x	–
Fish and Wildlife Habitat	–	–	x
Managed Systems	**Health and Safety**	**Economic**	**Environmental**
Small Water Systems/Private Wells	x	–	–
Irrigated Agriculture	–	x	–
Green Industry (nursery and landscape)	–	x	–
Fish and Wildlife Habitat	–	–	x
Land Subsidence	x	x	x

Risk of catastrophic wildfire is also a public health and safety threat, especially for densely populated urban areas located adjacent to wildlands. Wildfires pose a threat for facilities of small water systems, as these systems are often located in rural areas where wildfire risk exists. The state's small system drought emergency drinking water grants made during the 2007–2009 and 2012–2016 droughts included grants for replacement of fire-damaged infrastructure. And as learned from the 2013 Rim Fire, large water systems in wildland settings can experience costly infrastructure damage as well as water quality impacts associated with watershed damage.

Elevated wildfire risks persist after hydrologic drought has ended, because of the large fuel mass (dead and dying woody vegetation) remaining on the landscape. A wet year following drought promotes ample growth of grasses that, when they die down in the summer, provide additional fuel for starting fires. The 2003 Southern California fires (following a regional drought) and the catastrophic 2017 Tubbs Fire and 2018

Table 4.4: Storage in Selected Reservoirs in Dry Water Years

	1976		1977		1990		1991		1992		2008		2009		2013		2014		2015	
	% of capacity	% of average	% of capacity	% of average	% of capacity	% of average	% of capacity	% of average	% of capacity	% of average	% of capacity	% of average	% of capacity	% of average	% of capacity	% of average	% of capacity	% of average	% of capacity	% of average
Lake Shasta	28	48	14	23	36	60	29	49	37	62	30	51	39	65	42	70	25	42	35	59
Lake Oroville	52	67	26	42	33	53	40	64	37	60	31	50	38	61	46	75	30	49	30	48
Folsom Lake	43	75	15	27	18	32	52	92	18	31	28	49	42	74	37	65	35	62	18	31
Camanche Reservoir	43	70	13	22	41	68	27	45	27	45	35	58	77	128	61	102	32	53	24	39
Lake Berryessa	64	84	47	63	39	52	36	47	27	36	72	95	63	83	71	94	57	75	52	69
Lake Sonoma	–	–	–	–	38	74	47	90	56	108	53	103	51	100	50	97	39	75	47	90
Hetch Hetchy Reservoir	34	47	31	44	38	53	65	91	53	73	77	107	81	113	73	102	77	108	76	106
New Melones Reservoir	–	–	–	–	16	28	12	22	3	6	46	82	46	83	44	78	22	39	11	20
Lake Don Pedro	33	49	15	22	49	72	47	69	38	57	52	77	71	105	53	79	38	57	32	47
Lake McClure	23	52	9	19	10	23	19	42	13	29	27	60	42	93	29	65	12	26	9	17
Millerton Lake	87	215	38	94	35	87	34	83	32	78	38	95	67	167	61	151	35	88	37	92
Pine Flat Lake	23	68	8	24	3	9	4	13	3	9	12	36	20	59	15	46	11	34	12	35
Lake Isabella	12	37	6	19	9	26	17	53	15	45	21	65	18	55	10	30	9	27	5	16
San Luis Reservoir	40	84	13	29	24	51	32	68	23	50	12	25	21	44	25	53	23	49	19	42
Lake Casitas	80	96	72	86	54	65	58	69	75	90	84	100	74	89	63	76	53	64	45	54
Lake Cachuma	75	95	57	72	18	23	32	40	82	104	91	115	75	94	48	61	32	40	16	22

Note: End-of-water-year storage expressed as percent of capacity and percent of average.

Camp Fire (following the 2012–2016 drought) are examples of this post-drought risk. Both small and large water systems experienced significant water infrastructure damage in the 2017 and 2018 wildfire seasons.

With respect to non-irrigated agriculture, losses related to livestock production, which typically relies heavily on non-irrigated rangeland grazing, were characterized as most significant in the large historical droughts. Unlike the impacts to irrigated agriculture, which are concentrated in the Central Valley, impacts associated with livestock production are more geographically dispersed, affecting many rural and semi-rural counties. Prior to the recent revision in the U.S. Department of Agriculture's process for designating counties as eligible for drought disaster assistance, livestock-related impacts dominated the reasons for primary county designations in the big historical droughts.

Managed Systems

Public health and safety impacts associated with small water systems and private residential wells were common in past droughts. California has a daunting number of small water systems, many of which struggle for the resources to comply with basic Safe Drinking Water Act (SDWA) public health and safety requirements, and have unreliable water sources or facilities. California's small water systems have historically experienced the bulk of reported health and safety impacts, as well as the majority of water shortage emergencies – regardless of water year type. Drought is another stressor for small water systems, exacerbating the potential for problems in geographically vulnerable locations.

Although small water systems serve a low percentage of California's total population, they constitute the majority of the state's public water systems. Small water systems tend to be located outside the state's major metropolitan areas, often in lightly populated rural areas where opportunities

Table 4.5: Estimated Wildfire Damages

Fire Season	CAL FIRE Fire Suppression Cost Estimate ($M)	Damage Cost Estimate ($M)	Structures Destroyed
2000	124	30	130
2001	109	87	389
2002	135	174	327
2003	253	974	5394
2004	166	127	1016
2005	105	49	102
2006	206	60	431
2007	298	254	3079
2008	460	899	1027
2009	256	34	121
2010	90	5.2	94
2011	140	7.2	137
2012	310	28.2	248
2013	242	29.8	495
2014	402	20.0	434
2015	608	3061	3159
2016	534	148	1274

Notes:
1. CAL FIRE fire suppression costs are reported on its seasonal basis, not by calendar year.
2. Damage cost estimates and structures destroyed are only for CAL FIRE jurisdictional areas (wildlands).
3. 2015 costs are preliminary and subject to revision.

Defining Small Water Systems

Pursuant to the Safe Drinking Water Act, the U.S. Environmental Protection Agency (EPA) defines a public water system as a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such system has at least 15 service connections or regularly serves at least 75 individuals. EPA also classifies public water systems according to size:

- Very small water systems serve 25–500 people
- Small water systems serve 501–3,300 people
- Medium water systems serve 3,301–10,000 people
- Large water systems serve 10,001–100,000 people
- Very large water systems serve 100,001+ people

This report uses the term "small water system" in a loose sense to mean systems that EPA would define as very small to small, a size range that roughly represents the group of water suppliers not required to file urban water management plans under California law. In practical terms, however, there is no hard and fast delineation between small and medium systems with respect to drought vulnerability; systems at the smaller end of EPA's medium classification may share many of the same challenges as their smaller counterparts.

Hornbrook burning. The 2018 Klamathon Fire near the California-Oregon border left the small community of Hornbrook without potable water for more than two months after the Hornbrook Community Services District's main water tank was destroyed. Active fire seasons in Water Years 2017 and 2018 illustrated the ongoing wildfire risk faced by small water systems in rural areas. Photo credit: California Highway Patrol, Yreka

for interconnections with another system or water transfers are limited. Small systems also have limited financial resources and rate bases that constrain their ability to undertake major capital improvements. Financial assistance alone, even if such levels of support were available, would not be sufficient to address other technical and managerial capacity issues faced by small water systems (U.S. Environmental Protection Agency 2011), and concerted effort over time will be required to improve water supply reliability and drought preparedness for these systems. For many of the smallest systems, demonstrating the basic technical, managerial, and financial capacity required by SDWA regulations will be a needed first step toward improving drought preparedness.

Most small water system drought problems stem from dependence on an unreliable water source, commonly groundwater in fractured rock systems or in small coastal terrace groundwater basins. Historically, particularly at-risk geographic areas have been the foothills of the Sierra Nevada and Coast Range and inland Southern California, and the North and Central Coast regions **(FIGURE 4.8)**.

Ongoing recurrence of drought-related water shortage problems in the same locations has been observed for small water systems and some areas with high concentrations of private residential wells. DWR's August 1977 report (California Department of Water Resources 1977) on drought status featured a section on critical areas/special problems that identified 39 (mostly small) communities or areas and noted that:

> *Large areas of California have been affected by the 1976–1977 drought, and the effects will be intensified if the drought continues into 1978 with runoff conditions similar to those of 1977. Many cities and communities have had to resort to emergency measures, such as temporary importation of wells from other areas, drilling new wells, mandatory conservation measures and, in some cases, rationing to meet the essential water needs.*
>
> *Most of the more severely affected areas have developed, or are in the process of developing, contingency plans for 1978. There are, however, several cities and communities where local resources are inadequate to develop drought contingency plans or physical solutions. This is especially critical for small communities in the foothills and other areas where groundwater availabilty is limited.*

Many of the same communities or areas named in the 1977 report have continued to experience similar water shortage problems during later dry conditions in 1987–1992, 2007–2009, and 2012–2016. Even a single dry year can result in water haulage for vulnerable systems. Water Year 2001, for example, fell in the top 5 percent of dry years in terms of statewide runoff, and records for then-low precipitation were set in many Southern California communities. The region's larger water suppliers, supported by imported surface water and local groundwater sources, were relatively unaffected by the one singularly dry year. But there was a sharp upswing in the number of small water systems on fractured rock groundwater experiencing supply problems in areas such as the Tehachapi Mountains,

Following the 2017 Tubbs Fire, the City of Santa Rosa has been replacing destroyed or damaged water service lines and conducting extensive water quality testing in parts of its distribution system where contaminants from melted plastic pipes were detected. Photo credit: Office of Emergency Services

Inland Empire mountain and foothill areas, and eastern San Diego County. Local water suppliers in affected areas took actions, such as imposing mandatory water use restrictions, limiting new connections, and hauling water.

Large urban water agencies have a high capacity to prepare for and respond to drought, and most have historically experienced drought primarily in the form of financial impacts that are ultimately passed on to ratepayers. Urban water suppliers, particularly those serving larger metropolitan areas, normally provide reliable supplies for their customers, as they have the resources and the revenue base to prepare for and respond to drought impacts. During past droughts, large urban water agencies often took actions to assure full water supplies for their commercial and industrial water customers, as these customers typically constitute a relatively small percentage of urban water demand but are considered important contributors to local economies.

Lessons learned from prior droughts have spurred improved interconnections among urban water suppliers at both wholesale and retail levels. The capacity of California's larger urban areas to respond to drought is enhanced by the interconnectedness of much of California's water infrastructure, which facilitates actions such as water transfers and supporting improved emergency response to disasters such as wildfire or earthquake.

California's major water infrastructure continues to become increasingly interconnected, for example, the Delta-Mendota Canal/California Aqueduct intertie (2012) and the East Bay Municipal Utility District-Contra Costa Water District intertie (2007).

In the irrigated agriculture sector, the largest at-risk area has been the west side of the San Joaquin Valley, particularly the area supplied by Central Valley Project south-of-Delta exports. The impacts of reduced supplies were evident in the 2007–2009 drought, when growers abandoned permanent plantings, such as orchards, because of water shortages, a circumstance again observed in the 2012–2016 drought. The extent of Central Valley idled agricultural land in summer 2014 is shown in **FIGURE 4.9A**. A summer 2011 (wet year) image is provided for comparison **(FIGURE 4.9B)**.

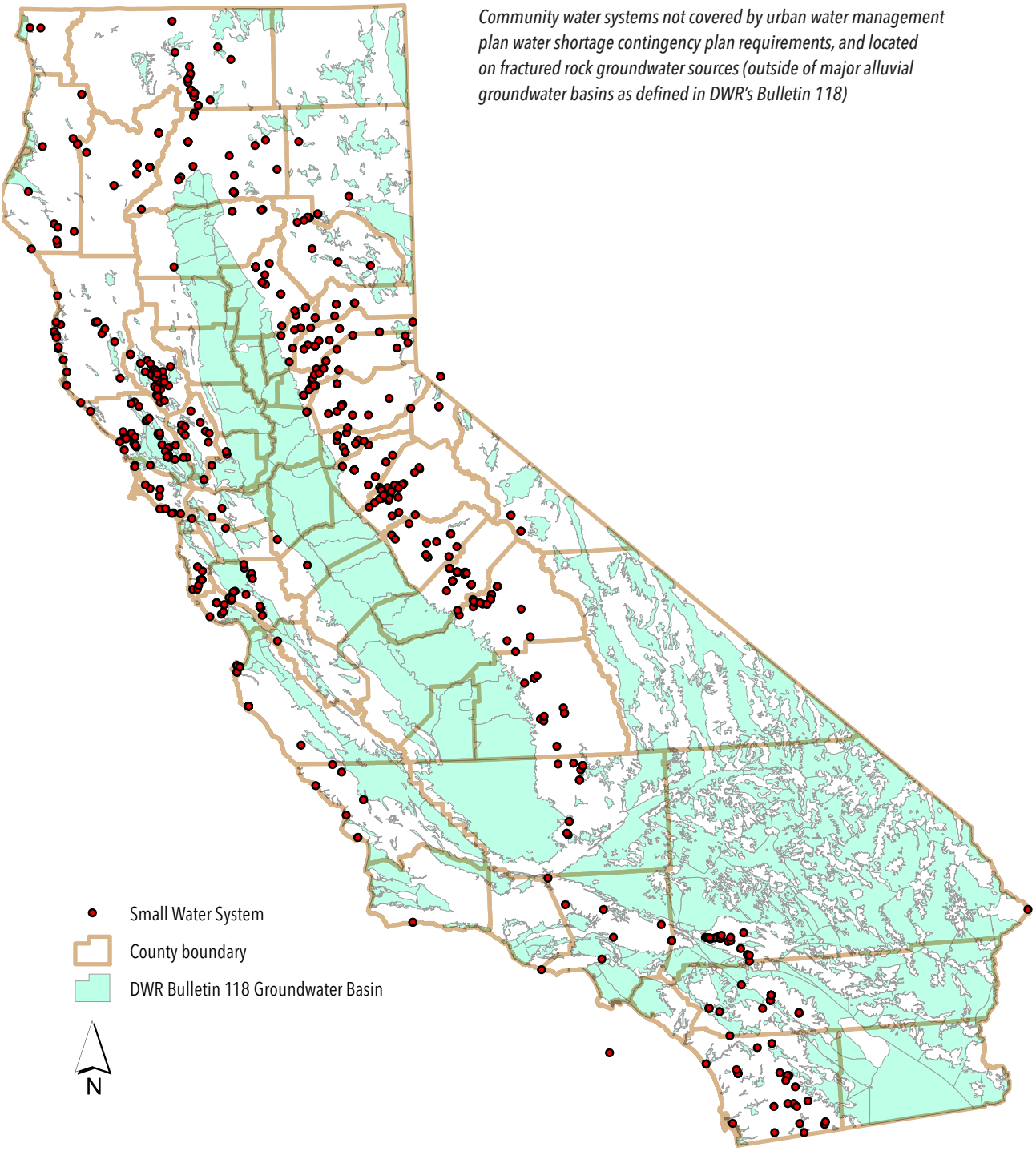
OTHER OBSERVATIONS FROM PAST DROUGHTS

California's largest historical droughts have shared some common themes and lessons learned applicable to drought response and drought preparedness. Progress has been made in some of these areas, but work remains to be done in others and new challenges are emerging. First, historically, there have been three important gaps in information or tools uniquely associated with drought–the ability to: (1) characterize statewide groundwater conditions, (2) predict whether the next months would be wet or dry, and (3) improve drought preparedness for small water systems. Second, California's largest droughts have highlighted a lack of drought resilience in some geographic areas where state emergency assistance has sometimes been provided to the same water suppliers in multiple events. And third, emerging challenges associated with climate change will require longer-term integration of adaptation and sustainability concepts into drought planning.

Evaluation of Statewide Groundwater Conditions

Understanding groundwater conditions is a key aspect of monitoring drought impacts and taking response actions as needed. Timely assessment of statewide groundwater conditions was not historically possible during past California droughts, but implementation of the 2009 California Statewide Groundwater Elevation Monitoring (CASGEM) legislation greatly enhanced the information available for drought preparedness and response, essentially filling this information gap. Implementation of the Sustainable Groundwater Management Act (SGMA) legislation over time will manage the risk of drought impacts (see sidebar on monitoring land subsidence on page 112) in the state's major alluvial groundwater basins and will provide for more sustainable use of the resource.

Figure 4.8: Example of Potentially At-Risk Small Water Systems



Community water systems not covered by urban water management plan water shortage contingency plan requirements, and located on fractured rock groundwater sources (outside of major alluvial groundwater basins as defined in DWR's Bulletin 118)

Sub-seasonal to Seasonal Precipitation Forecasting

Skillful sub-seasonal to seasonal (S2S) precipitation forecasting would be extremely useful in informing drought preparedness and response; calls for improving forecasting in the context of drought date back to attempts to predict the end of dry conditions in the 1920s–1930s. Weather models are run operationally out to two weeks ahead, but are most skillful for timeframes of less than five days. As discussed in Chapter 2, the present scientific capability for making skillful precipitation forecasts beyond the weather time domain, from a few months out (sub-seasonal) to the next water year (seasonal), is minimal. **FIGURE 4.10** shows the relationship between predictive skill and scale of weather and climate phenomena.

Sub-seasonal forecasting, if skillful, would be useful for supporting reservoir operations planning and for evaluating potential water project allocations in the spring months. Improved seasonal forecasting (to answer the question in the fall about the coming winter's outcome) has many potential applications, including providing lead time for implementing drought water banks or opportunistic wet year groundwater recharge projects. Improving prediction at longer timescales is also important for developing the ability to use forecast-informed reservoir operations as a tool for drought response and climate change adaptation. In its discussion of this subject for the 1976–1977 drought, DWR noted: *What is needed for operation and management of a complex water supply project is a long-term projection, at least a year in advance, with a high degree of reliability* (Department of Water Resources 1978).

While progress in improving useful skill of S2S precipitation forecasting at the Climate Prediction Center's national scale is likely a decade or more out (National

DWR constructed this well for the City of Porterville's system in 2015, as part of the project to connect dry private residential wells in East Porterville to a public water system.

A $29 million intertie was completed in 2012 to link the SWP's California Aqueduct and the CVP's Delta-Mendota Canal, to enable increased flexibility in the projects' operations.

Dead citrus trees in a San Joaquin Valley orchard during the 1929–1934 drought, an image similar to that seen on the valley's west side during the 2007–2009 drought. This photograph was printed from a booklet issued by Governor Rolph to the people of California calling for action on the state's urgent water development problems (Rolph 1931). Photo credit: Sacramento Public Library.

Research Council 2010), there are potential opportunities for improving skill at the spatial scale of California, making use of DWR's investment in the observing system for extreme precipitation and related research. DWR and the Scripps Institution of Oceanography have collaborated to explore forecasts of atmospheric river storms, initially at a two-week weather model lead time. Subsequently, DWR contracted with NASA's Jet Propulsion Laboratory for experimental forecasts of these storms at sub-seasonal lead times, and for sub-seasonal experimental forecasts of the persistent atmospheric blocking conditions that result in dry winters. Experience developed through these processes in combination with other research will develop capacity for making operational forecasts that could add skill to precipitation prediction at lead times of weeks to months.

Improving Small Water System Drought Preparedness

Water shortage problems with small systems on unreliable sources have been consistently observed in past droughts, and the requirements of shortage contingency planning associated with urban water management plans are not applicable to smaller systems. Many small water system problems are associated with fractured rock groundwater sources, and improvements in alluvial basin groundwater monitoring as a result of CASGEM are not applicable to this situation. The high spatial variability of groundwater conditions in fractured rock settings typically makes regional-scale monitoring impractical. For the smallest systems, lack of the basic technical, managerial, and financial capacity required by SDWA regulations is a significant impediment to improving drought preparedness, one that better drought planning and monitoring cannot overcome.

Concerted effort over time will be needed to improve small water system drought preparedness. In 2000, the Governor's Advisory Drought Planning Panel had recommended beginning a technical assistance and education program for rural homeowners on private wells and small water systems that would be implemented in

Figure 4.9A: Satellite Imagery of the Central Valley in Summer 2011

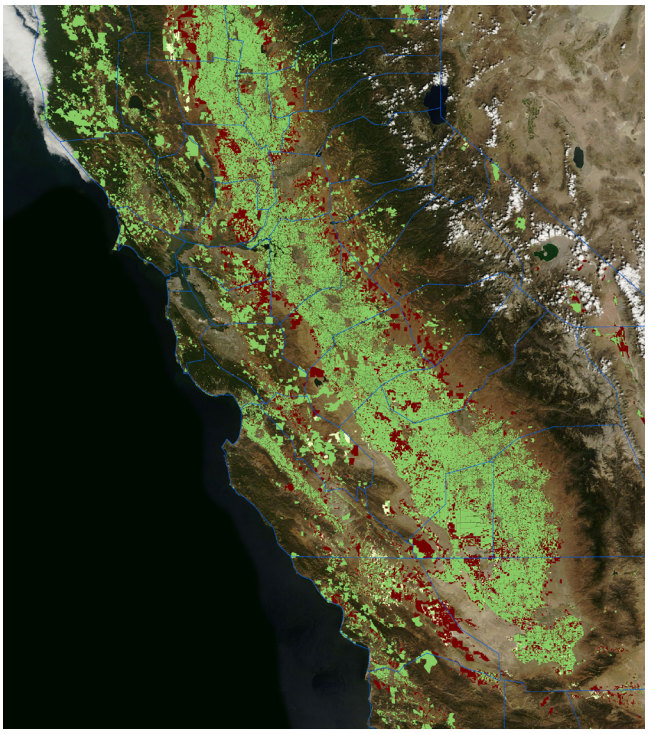
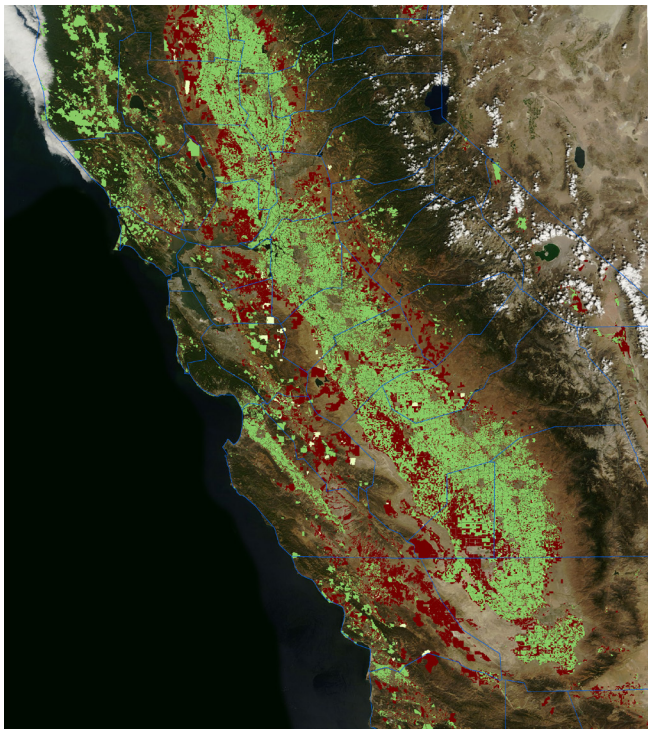


Figure 4.9B: Satellite Imagery of the Central Valley in Summer 2014



False color image. Estimated idled acreage shown in red. Image credit: NASA

New Technology for Monitoring Land Subsidence

Historical approaches for monitoring subsidence include use of conventional land surveying techniques and installation of borehole extensometers in conjunction with groundwater level monitoring. The availability of satellite-enabled global positioning systems has offered another tool in recent years. Satellite-based interferometric synthetic aperture radar (InSAR), a technology used by geophysical researchers for purposes such as monitoring relative land surface displacement along fault zones, is an emerging tool for identifying subsidence because of its ability to provide rapid coverage over a large spatial scale. The U.S. Geological Survey (USGS) used InSAR technology in an evaluation of subsidence in parts of the northern San Joaquin Valley in the early 2000s (U.S. Geological Survey 2013). The USGS work identified recent subsidence in an area outside of the historically at-risk region, prompting subsequent concerns about the effects of drought-related increased groundwater pumping, and impacts of subsidence on SWP and CVP facilities and local flood management infrastructure. As a drought response action, DWR initially contracted with NASA in 2014 for mapping recent subsidence with satellite-based InSAR imagery, and for experimental use of higher-resolution aircraft-based InSAR to map subsidence along parts of the California Aqueduct. The InSAR imagery has proved to be a valuable screening tool for cost-effective, rapid screening for land surface deformation over large-scale geographic areas. DWR is preparing to provide InSAR data as part of its technical assistance services for local agencies required to comply with SGMA.

coordination with county environmental health departments to improve awareness of drought risk mitigation (California Department of Water Resources 2000). As drought emergency funding has been available, DWR has historically partnered with the California Rural Water Association to provide technical assistance to small water systems, including drought planning, groundwater level monitoring, and leak detection. Most state financial assistance for small water system capital improvements has come through SDWA funding for achieving compliance with drinking water regulations, with additional drought emergency funding provided during the 2007–2009 and 2012–2016 droughts.

The 2018 legislation strengthening requirements for urban water management plans further required that DWR, in consultation with SWRCB, provide recommendations to the Governor and the Legislature for development and implementation of countywide drought and water shortage contingency plans for small water suppliers and rural communities by January 2020. The legislation also required DWR to identify small water systems and rural communities, such as the Tulare County communities affected in the 2012–2016 drought, at risk of drought and water shortage vulnerability. In addition to any actions that may be implemented through this process, SWRCB's new consolidation authority is a tool that will be available in future droughts.

Drought Resilience Challenges

Some regions and communities have experienced continued drought resilience challenges during the state's most significant droughts, requiring drinking water suppliers to call for severe levels of emergency conservation or connection bans, or to seek emergency assistance. Historically, California's North Coast and Central Coast regions have stood out in terms of risk, with communities such as Willits and Santa Barbara having obtained state emergency assistance in multiple droughts. The North Coast might appear to be a low-risk area for drought impacts because of its normally relatively wetter climate, but even a single particularly dry year on the North Coast can prove problematic because of the predominance of small water systems, many of which rely on fractured rock groundwater or small coastal terrace groundwater basins with little storage capacity. Small water systems with limited supplies during normal years, illustrated by historical bans on new connections at systems such as Redwood Valley County Water District in Mendocino County or the City of Cambria in San Luis Obispo County, face increased risk of shortage during drought.

The Central Coast is challenged by limited surface water

Equipment for an atmospheric river observatory being set up at Twitchell Island as part of the NOAA-DWR research observing system for extreme precipitation.

runoff in watersheds that feed reservoirs such as Lake Cachuma or Lake Casitas, as well as by relatively limited groundwater basin storage, or fractured rock groundwater, in many areas. Some coastal watersheds are additionally notable for their high sediment loading, which over time has resulted in significantly reduced storage capacity at sites such as Santa Barbara's Gibraltar Reservoir on the Santa Ynez River or Reclamation's Twitchell Reservoir on the Cuyama River. The 2017 and 2018 catastrophic wildfires on the North Coast and Central Coast illustrate risks of increased sediment loading in response to a more active wildfire regime enabled by a warming environment. Access to SWP supplies and SWP-wheeled water transfers in parts

Figure 4.10: Spatial and Temporal Scales Associated with Weather and Climate Predictions

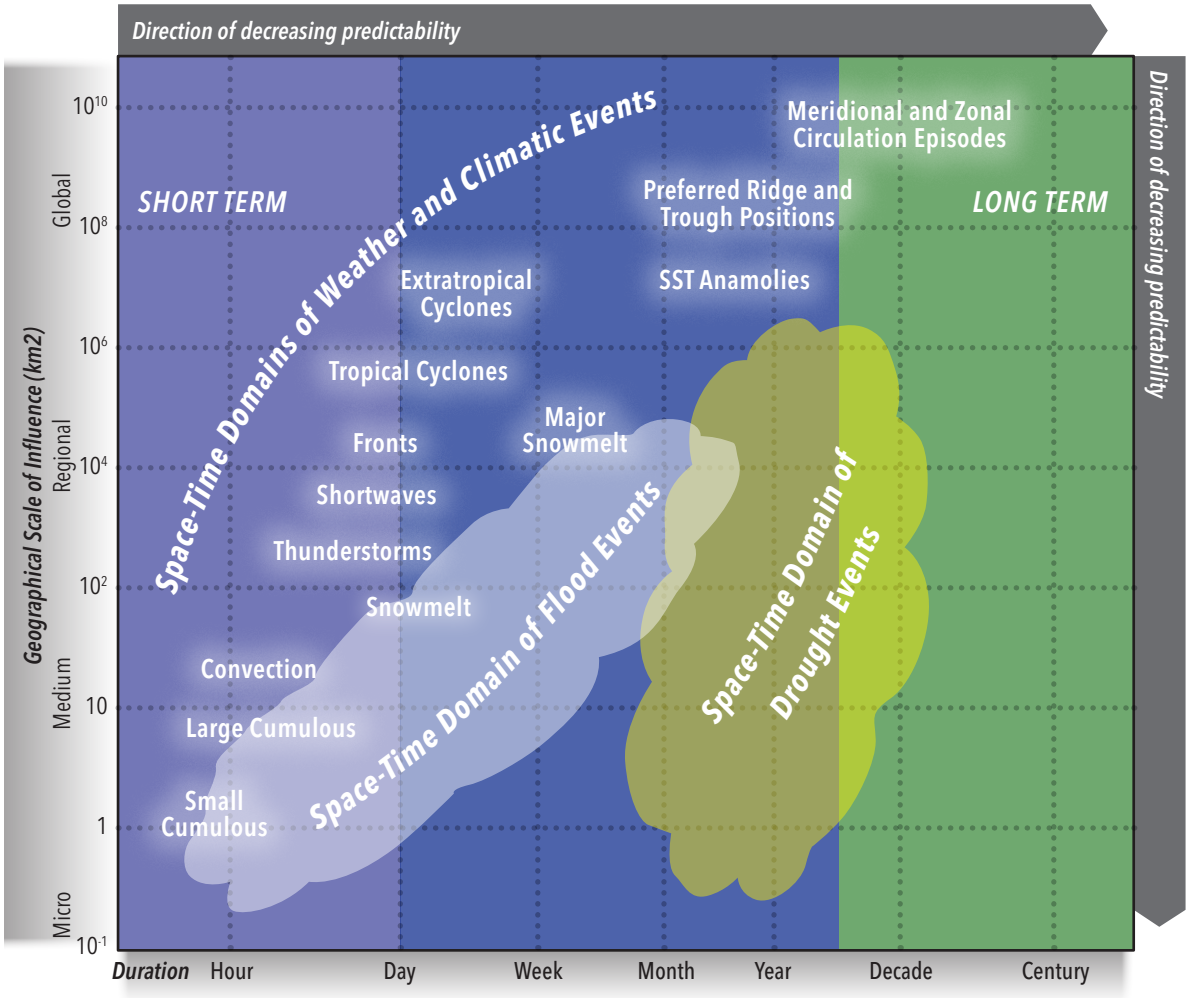


Figure credit: U.S. Bureau of Reclamation

of San Luis Obispo and Santa Barbara counties subsequent to construction of the SWP's Coastal Extension has helped lessen the risk of a water shortage emergency there. However, the prolonged dry conditions of 2012–2016 and the challenges of delivering imported supplies via Lake Cachuma during that time point out the continued risks for the Santa Barbara area.

Integrating Climate Change Adaptation

At the statewide scale, much of California's historical drought resilience has been fostered by major water infrastructure that can facilitate drought water transfers to most large urbanized areas, and by access to substantial groundwater resources, especially for irrigated agriculture. California's earlier droughts saw development of adaptive measures such as institutional frameworks for water transfers and water conservation/water use reduction, together with provision of substantial state financial assistance to local agencies. New challenges are emerging, however, and adaptive measures must now focus on additionally managing climate change impacts that directly affect water supplies through altered hydrologic processes as well as indirectly affecting water users via altered watershed conditions. Optimally, adaptive measures for drought also should be consistent with helping manage broader climate change impacts.

A transition to a warming climate in which more winter precipitation falls as rain rather than as snow will challenge the major Central Valley water infrastructure that manages the state's largest rivers for both water supply and flood risk reduction. Relatively lower-cost investments to improve forecasting – developing S2S precipitation forecasting capacity, new snowpack monitoring capabilities, new technologies for snowmelt runoff forecasting – can be done within 5 to 10 years and are an obvious early step toward adaptation. These investments will be necessary for taking another obvious adaptation step – maximizing the ability to use opportunistic groundwater recharge (wet year recharge, urban stormwater) for replenishing aquifer storage, building on major investments already made in the state's water infrastructure.

Looking out over a low Lake Cachuma in February 2017. Although much of California experienced wet conditions in 2017, the Central Coast remained drier and drought conditions persisted into the early part of 2019.

Montecito Water District's Juncal Dam and Jameson Lake prior to the December 2017 Thomas Fire, which burned most of the watershed. Subsequently, January 2018 mudslides caused by rain on the burned areas caused significant damage to the District's Jameson Pipeline and other water system infrastructure. Photo credit: Montecito Water District

Watershed-scale changes, notably wildfire damages and massive areas of tree mortality in upper mountain watersheds, can affect surface water runoff patterns and sedimentation in vulnerable coastal watersheds, and cause unexpected risks for water infrastructure in at-risk areas. An abrupt increase in Western U.S. wildfire activity was observed in the mid-1980s (Westerling 2016), and wildfire experts have described California's recent large catastrophic events as representing a shift to a new type of fire regime, one that has already resulted in increased

damage to water infrastructure (especially for small water systems in rural areas). In contrast to work already begun on adaptation related to better forecasting, present water agency drought preparedness planning has not focused on landscape-scale impacts such as increased wildfire risk.

Making drought preparedness and response measures consistent with goals for climate change adaptation and sustainability will entail focusing on a longer-term perspective than is typically considered in addressing immediate drought impacts. The immediate requirement, for example, to achieve a 25-percent mandatory reduction in urban water use during the 2012–2016 drought, was frequently messaged as letting lawns die, causing loss of urban shade trees and resulting in local turf replacement programs that allowed hardscapes to be substituted in place of lawns. These outcomes work against long-term adaptation goals of mitigating urban heat island effects and reducing stormwater runoff, and are inconsistent with California Model Water Efficient Landscape Ordinance criteria that recognize the many services that living landscapes provide in reducing stormwater runoff, replacing ecosystems lost to development, and realizing sustainability goals. As another example, the historical practice of high reliance on groundwater during drought will now have to be addressed within the context of SGMA implementation for jurisdictional basins. Groundwater sustainability plans adopted by local agencies for their basins may constrain the historical level of reliance on groundwater as a drought resource. Water suppliers preparing shortage contingency plans or other drought preparedness planning documents will need to consider that their future supplies can differ from historical baselines.

The 2018 Ferguson Fire in the Merced River watershed, where drought-related bark beetle infestation had resulted in high tree mortality, caused the closure of Yosemite National Park and evacuation of local communities. Parts of the Central Valley were blanketed for weeks by smoke from the concurrent Ferguson, Mendocino Complex, and Carr fires. The 2017 and 2018 wildfire seasons set new records for California wildfires, including the most destructive and largest fires. Photo credit: U.S. Forest Service

Appendix

Contents

Acronyms *118*
References *119*
Selected Drought Executive Orders and Emergency Proclamations *125*
- *Executive Order B-27-77* *125*
- *Executive Order W-3-91* *129*
- *Executive Order S-06-08* *133*
- *Emergency Proclamation: Central Valley* *137*
- *Emergency Proclamation: Water Shortage* *141*
- *Executive Order S-11-09* *147*
- *State of Emergency: Fresno County* *149*
- *Executive Order B-21-13* *151*
- *A Proclamation of a State of Emergency* *153*
- *A Proclamation of a Continued State of Emergency* *157*
- *Executive Order B-26-14* *163*
- *Executive Order B-28-14* *165*
- *Executive Order B-29-15* *167*
- *A Proclamation of a State of Emergency* *173*
- *Executive Order B-36-15* *177*
- *Executive Order B-37-16: Making Conservation a California Way of Life* *181*
- *Executive Order B-40-17* *185*
- *Executive Order B-42-17* *189*

Acronyms

AMO	*Atlantic Multidecadal Oscillation*
AO	*Arctic Oscillation*
CAL FIRE	*California Department of Forestry and Fire Protection*
Cal OES	*Office of Emergency Services*
CASGEM	*California Statewide Groundwater Elevation Monitoring*
CDAA	*California Disaster Assistance Act*
CPC	*Climate Prediction Center*
CVP	*Central Valley Project*
DAC	*disadvantaged community*
Delta	*Sacramento-San Joaquin Delta*
DWR	*California Department of Water Resources*
ENSO	*El Niño – Southern Oscillation*
EPA	*U.S. Environmental Protection Agency*
ESA	*Endangered Species Act*
JPL	*Jet Propulsion Laboratory*
InSAR	*interferometric synthetic aperture radar*
maf	*million acre-feet*
MJO	*Madden-Julian Oscillation*
MWD	*Metropolitan Water District*
NAO	*North Atlantic Oscillation*
NASA	*National Aeronautics and Space Administration*
NMFS	*National Marine Fisheries Service*
NOAA	*National Oceanic and Atmospheric Administration*
PDO	*Pacific Decadal Oscillation*
PVID	*Palo Verde Irrigation District*
QSA	*Colorado River Quantification Settlement Agreement*
S2S	*sub-seasonal to seasonal*
SDCWA	*San Diego County Water Authority*
SDWA	*Safe Drinking Water Act*
SFPUC	*San Francisco Public Utilities Commission*
SGMA	*Sustainable Groundwater Management Act*
SNWA	*Southern Nevada Water Authority*
SOW	*Save Our Water*
SWP	*State Water Project*
SWRCB	*State Water Resources Control Board*
taf	*thousand acre-feet*
Reclamation	*U.S. Bureau of Reclamation*
USDA	*U.S. Department of Agriculture*
USFWS	*U.S. Fish and Wildlife Service*
USGS	*U.S. Geological Survey*
Water Code	*California Water Code*

References

Chapter 1

California Department of Water Resources. 1976. The California Drought – 1976. Sacramento (CA): California Department of Water Resources. 115 pp. [Report]. Viewed online at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Water-Basics/Drought/Files/Publications-And-Reports/The-California-Drought-1976.pdf. Accessed: Oct. 9, 2018.

——. 1977. The California Drought 1977, An Update. Sacramento (CA): California Department of Water Resources. 161 pp. [Report]. Viewed online at: https://water.ca.gov/LegacyFiles/waterconditions/docs/12_drought-1977.pdf. Accessed: Oct. 9, 2018.

——. 1993. California's 1987–92 Drought, A Summary of Six Years of Drought. Sacramento (CA): California Department of Water Resources. 46 pp. [Report]. Viewed online at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Water-Basics/Drought/Files/Publications-And-Reports/Californias198792-drought.pdf. Accessed: Oct. 9, 2018.

——. 2010. California's Drought of 2007–2009, An Overview. Sacramento (CA): California Department of Water Resources. 46 pp. [Report]. Viewed online at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Water-Basics/Drought/Files/Publications-And-Reports/Californias-Drought-of-200709An-Overview.pdf. Accessed: Oct. 9, 2018.

——. 2014. Public Update for Drought Response – Groundwater Basins with Potential Water Shortages and Gaps in Groundwater Monitoring. Sacramento (CA): California Department of Water Resources. 46 pp. [Report]. Viewed online at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Library/Files/Maps/Statewide-and-Regional-Reports/DWR_PublicUpdateforDroughtResponse_GroundwaterBasins.pdf. Accessed: Oct. 9, 2018.

——. 2015. California's Groundwater Update 2013, A Compilation of Enhanced Content for California Water Plan Update 2013. Sacramento (CA): California Department of Water Resources. 12 pp. [Report]. Viewed online at: https://water.ca.gov/LegacyFiles/waterplan/docs/groundwater/update2013/GWU2013_FrontMatter_TOC_Final.pdf. Accessed: Oct. 12, 2018.

Dettinger MD. 2013. "Atmospheric Rivers as Drought Busters on the U.S. West Coast." Journal of Hydrometeorology 14(6): pp. 1,721–1,732. [Journal]. Viewed online at: https://journals.ametsoc.org/doi/full/10.1175/JHM-D-13-02.1. Accessed: Oct. 9, 2018.

Dettinger MD, Ralph FM, Das T, Neiman PJ, Cayan, DR. 2011. "Atmospheric Rivers, Floods and the Water Resources of California." Water 3, no. 2: 445–478. [Journal]. Viewed online at: https://www.mdpi.com/2073-4441/3/2/445. Accessed: Nov. 21, 2018.

Guinn JM. 1890. "Exceptional Years: A History of California Floods and Drought." Historical Society of Southern California, Los Angeles 1(5): pp. 33–39. [Journal]. Viewed online at: https://www.jstor.org/stable/41167825?seq=1#metadata_info_tab_contents. Accessed: Oct. 9, 2018.

Chapter 2

Climate Prediction Center Internet Team. 2014. "Teleconnection Introduction." National Oceanic and Atmospheric Administration: National Weather Service, Climate Change Center. College Park, MD. [Journal]. Viewed online at: http://www.cpc.ncep.noaa.gov/data/teledoc/teleintro.shtml. Accessed: Oct. 10, 2018.

Garfin G, Jardine A, Merideth R, Black M, and LeRoy S, eds. 2013. Assessment of Climate Change in the Southwest United States. A Report Prepared for the National Climate Assessment. Washington, DC: Island Press. Volume 1. 531 pp. [Book].

Harding ST. 1965. Recent Variations in the Water Supply of the Western Great Basin. Berkeley (CA): University of California Berkeley, Water Resources Center. Volume 1. 226 pp. [Book].

Kleppe JA, Brothers DS, Kent GM, Jensen S, Driscoll NW. 2011. "Duration and Severity of Medieval Drought in the Lake Tahoe Basin." Quaternary Science Reviews 30(23–24): pp: 3,269–3,279. [Journal].

Knowles N and Cayan CR. 2002. "Potential effects of global warming on the Sacramento/San Joaquin watershed and the San Francisco estuary." Geophysical Research Letters. 29(18). [Journal]. Viewed online at: https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2001GL014339. Accessed: Oct. 10, 2018.

Lindström S. 1990. "Submerged Tree Stumps as Indicators of Mid-Holocene Aridity in the Lake Tahoe Region." Journal of California and Great Basin Anthropology, 12 (2):146–157. [Journal]. Viewed online at: http://www.escholarship.org/uc/item/4s95f878. Accessed: Oct. 10, 2018.

National Research Council. 2010. Assessment of Intraseasonal to Interannual Climate Prediction and Predictability. Washington, DC: The National Academies Press. Volume 1. pp 192. [Book].

National Research Council. 2016. Next Generation Earth System Prediction, Strategies for Subseasonal to Seasonal Forecasts. Washington, DC: The National Academies Press. Volume 1. pp 290. [Book].

Meko DM, Woodhouse CA, Baisan CA, Knight T, Lukas JJ, Hughes MK, Salzer MW. 2007. "Medieval drought in the upper Colorado River Basin." Geophysical Research Letters. 34(10): 1–5 [Journal]. Accessed: Oct. 10, 2018.

Meko DM, Woodhouse CA, Touchan R. 2014. Klamath/San Joaquin/Sacramento Hydroclimatic Reconstructions from Tree Rings. 117 pp. [Report]. Prepared for: California Department of Water Resources, under Agreement 4600008850. Viewed online at: https://water.ca.gov/LegacyFiles/waterconditions/docs/tree_ring_report_for_web.pdf. Accessed: Oct. 10, 2018.

Meko DM, Woodhouse CA, Bigio ER. 2017. University of Arizona Southern California Tree-Ring Study, Final Report. 123 pp. [Report]. Prepared for: California Department of Water Resources, under Agreement 4600011071. Viewed online at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Water-Basics/Drought/Files/Publications-And-Reports/UofAZ-SoCal-tree-ring-report-dec-2017.pdf. Accessed: Oct. 10, 2018.

Seager R, Burgman R, Kushnir Y, Clement A, Cook E, Naik N, Velez J. 2007. "Tropical Pacific forcing of North American Medieval megadroughts: Testing the concept with an atmosphere model forced by coral-reconstructed SSTs." [Journal] Journal of Climate, 21(23): 6,175-6,190. Viewed online at: https://journals.ametsoc.org/doi/full/10.1175/2008JCLI2170.1. Accessed: Oct. 10, 2018.

Stine S. 1994. "Extreme and persistent drought in California and Patagonia during mediaeval time." Nature 369(6481): 546–549. [Journal].

U.S. Bureau of Reclamation. 2012. Colorado River Basin Water Supply and Demand Study. Washington, DC: U.S. Bureau of Reclamation. 34 pp. [Report]. Viewed online at: https://www.usbr.gov/watersmart//bsp/docs/finalreport/ColoradoRiver/CRBS_Executive_Summary_FINAL.pdf. Accessed: Oct. 10, 2018.

U.S. Geological Survey (Poland JF, Lofgren BE, Ireland RL, Pugh RG, eds). 1975. Land Subsidence in the San Joaquin Valley, California, as of 1972. Washington, DC: U.S. Government Printing Office. 87 pp. Professional Paper 437-H. [Report]. Prepared by: U.S. Geological Survey. Prepared for: U.S. Department of the Interior. Viewed online at: https://pubs.usgs.gov/pp/0437h/report.pdf. Accessed: Oct. 10, 2018.

——. (Galloway D, Jones D, Ingebritsen SE, eds). 1999. Land Subsidence in the United States. Washington, DC: U.S. Government Printing Office. 15 pp. Circular 1182. [Report]. Prepared by: U.S. Geological Survey. Prepared for: U.S. Department of the Interior. Viewed online at: https://pubs.usgs.gov/circ/circ1182/#pdf. Accessed: Oct. 10, 2018.

Woodhouse C, Meko D, Bigio E, Frederick S. 2017. Using Tree-Ring Records for Understanding Droughts in a Long-Term Context: A Guidebook. 37 pp. [Report]. Prepared for: California Department of Water Resources, under Agreement 4600011071. Viewed online at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Water-Basics/Drought/Files/Publications-And-Reports/UofAZ-tree-ring-Guidebook-dec-2017.pdf. Accessed: Oct. 10, 2018.

Chapter 3

California Department of Forestry and Fire Protection, U.S. Forest Service, Office of Emergency Services, undated. California Fire Siege 2007, An Overview. 110 pp. [Report]. Viewed online at: http://www.fire.ca.gov/fire_protection/downloads/siege/2007/Overview_CompleteFinal.pdf. Accessed: Oct. 11, 2018.

California Department of Public Works. 1931. California Highways and Public Works. Sacramento (CA): California State Printing Office. 48 pp. [Booklet]. Viewed online at: http://libraryarchives.metro.net/DPGTL/Californiahighways/chpw_1931_oct.pdf. Accessed: Oct. 11, 2018.

California Department of Water Resources. 1978. The 1976–1977 California Drought – A Review. Sacramento (CA): California Department of Water Resources. 239 pp. [Report]. Viewed online at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Water-Basics/Drought/Files/Publications-And-Reports/The-1976-1977-California-Drought.pdf. Accessed: Oct. 11, 2018.

——. 1993. Sacramento San Joaquin Delta Atlas. Sacramento (CA): California Department of Water Resources. 134 pp. [Report]. Viewed online at: https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/exhibit3/rdeir_sdeis_comments/RECIRC_2646_ATT%203.pdf. Accessed: Oct. 11, 2018.

——. 1994. Bulletin 160-93, the California Water Plan Update. Volume 1 of 2. Sacramento (CA): California Department of Water Resources. 359 pp. [Report]. Viewed online at: https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/wq_control_plans/1995wqcp/admin_records/part05/328.pdf. Accessed: Oct. 11, 2018.

——. 2014. Public Update for Drought Response – Groundwater Basins with Potential Water Shortages and Gaps in Groundwater Monitoring. Sacramento (CA): California Department of Water Resources. 52 pp. [Report]. Viewed online at: https://water.ca.gov/LegacyFiles/waterconditions/docs/DWR_PublicUpdateforDroughtResponse_GroundwaterBasins.pdf. Accessed: Oct. 11, 2018.

Federal Emergency Management Agency. 1991. The East Bay Hills Fire, Oakland-Berkeley, California. U.S. Fire Administration/Technical Report Series. Washington, DC. 130 pp. USFA-TR-060/October 1991. [Report]. Viewed online at: https://www.usfa.fema.gov/downloads/pdf/publications/tr-060.pdf. Accessed: Oct. 12, 2018.

Governor's Commission to Review California Water Rights Law. 1978. Governor's Commission to Review California Water Rights Law: Final Report. California Agencies. Paper 426. 280 pp. [Report]. Viewed online at: https://digitalcommons.law.ggu.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1425&context=caldocs_agencies. Accessed: Oct. 12, 2018.

Howitt R, Medellín-Azuara J, MacEwan D. 2009. "Measuring the Employment Impact of Water Reductions." Environmental Water Caucus. Santa Monica (CA): Environmental Water Caucus. [Website]. Viewed online at: http://www.ewccalifornia.org/reports/MeasuringEmploymentImpacts-092909.pdf. Accessed: Nov. 11, 2018. Last updated: Nov. 10, 2018.

Meko DM, Woodhouse CA, Touchan R. 2014. Klamath/San Joaquin/Sacramento Hydroclimatic Reconstructions from Tree Rings. 117 pp. [Report]. Prepared for: California Department of Water Resources, under Agreement 4600008850. Viewed online at: https://water.ca.gov/LegacyFiles/waterconditions/docs/tree_ring_report_for_web.pdf. Accessed: Oct. 12, 2018.

Meko DM, Woodhouse CA, Bigio ER. 2017. University of Arizona Southern California Tree-Ring Study, Final Report. 123 pp. [Report]. Prepared for: California Department of Water Resources, under Agreement 4600011071. Viewed online at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Water-Basics/Drought/Files/Publications-And-Reports/UofAZ-SoCal-tree-ring-report-dec-2017.pdf. Accessed: Oct. 12, 2018.

National Aeronautics and Space Administration. 2015. "Fallowed Area Mapping for Drought Impact Reporting and Decision Making." [Website]. Viewed online at: https://nex.nasa.gov/nex/projects/1372/. Accessed: Oct. 12, 2018.

——. Jet Propulsion Laboratory. 2016. Progress Report: Subsidence in California, March 2015 – September 2016. 37 pp. [Report]. Viewed online at: https://water.ca.gov/LegacyFiles/waterconditions/docs/2017/JPL%20subsidence%20report%20final%20for%20public%20dec%202016.pdf. Accessed: Oct. 12, 2018.

U.S. Bureau of Reclamation. 2007. Final Environmental Impact Statement, Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Mead and Lake Powell. 2,157 pp. [Website]. Viewed online at: https://www.usbr.gov/lc/region/programs/strategies/FEIS/index.html. Accessed: Oct. 12, 2018.

——. 2010. Annual Operating Plan for Colorado River Reservoirs 2010. 75 pp. [Website]. Viewed online at: https://www.usbr.gov/lc/region/g4000/aop/AOP10.pdf. Accessed Nov. 21, 2018.

U.S. Government Accountability Office. 1977. California Drought of 1976 and 1977 – Extent, Damage, and Governmental Response. Washington, DC: Government Printing Office. 108 pp. CED-77 137. [Report]. Viewed online at: https://www.gao.gov/assets/130/120157.pdf. Accessed: Oct. 12, 2018.

Chapter 4

California Department of Water Resources. 1977. The Continuing California Drought. Sacramento (CA): State of California, Resources Agency. 148 pp. [Report]. Viewed online at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Water-Basics/Drought/Files/Publications-And-Reports/The-Continuing-California-Drought---1977.pdf. Accessed: Oct. 12, 2018.

——. 1978. The 1976–1977 California Drought – A Review. Sacramento (CA): State of California, Resources Agency. 228 pp. [Report]. Viewed online at: https://books.google.com/books?id=pJYRAQAAIAAJ&q=The+1976%E2%80%9377+California+Drought+%E2%80%93+A+Review.&dq=The+1976%E2%80%9377+California+Drought+%E2%80%93+A+Review.&hl=en&sa=X&ved=0ahUKEwis-4acyYHeAhUR0lMKHd17C2MQ6AEIMTAB. Accessed: Oct. 12, 2018.

——. 2000. Governor's Advisory Drought Planning Panel, Critical Water Shortage Contingency Plan. Sacramento (CA): California Department of Water Resources. 65 pp. [Report]. Viewed online at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/What-We-Do/Drought-Mitigation/Files/Publications-And-Reports/Governors-Advisory-Drought-Planning-Panel-Critical-Water-Shortage-Contingency-Plan.pdf. Accessed: Oct. 12, 2018.

——. 2000. Preparing for California's Next Drought: Changes Since 1987–92. Sacramento (CA): State of California, Resources Agency. 76 pp. [Report]. Viewed online at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/What-We-Do/Drought-Mitigation/Files/Publications-And-Reports/Preparing-for-California-Next-Drought-1987-92.pdf. Accessed: Oct. 12, 2018.

National Research Council. 2010. Assessment of Intraseasonal to Interannual Climate Prediction and Predictability. Washington, DC: The National Academies Press. Volume 1. pp 192. [Book].

Rolph J. 1931. Message of the governor to the people of California dealing with their water problem. California State Printing Office. 53 pp. [Report].

U.S. Environmental Protection Agency. 2011. National Characteristics of Drinking Water Systems Serving 10,000 or Fewer People. 104 pp. [Report]. Viewed online at: http://dnrc.mt.gov/divisions/cardd/docs/resource-development/w2asact-docs/REVFINALNatCharacteJuly2011508compliant.pdf. Accessed: Oct. 9, 2018.

U.S. Geological Survey (Sneed M, Brandt J, Solt M, eds). 2013. Land subsidence along the Delta-Mendota Canal in the northern part of the San Joaquin Valley, California, 2003–10. 100 pp. U.S. Geological Survey Scientific Investigations Report 2013–5142. [Report]. Viewed online at: https://pubs.usgs.gov/sir/2013/5142/pdf/sir2013-5142.pdf. Accessed: Oct. 12, 2018.

U.S. House of Representatives. 2007. House Hearing, 110th Congress – Insurance Claims Payment Process in the Gulf Coast after the 2015 Hurricanes. Hearing before the Subcommittee on Oversight and Investigations of the Committee on Financial Services. February 28. 314 pp. Serial No. 110-7. [Report]. Viewed online at: https://www.gpo.gov/fdsys/pkg/CHRG-110hhrg34677/pdf/CHRG-110hhrg34677.pdf. Accessed: Oct. 12, 2018.

Westerling AL. 2016. "Increasing western US forest wildfire activity: sensitivity to changes in the timing of spring." Biological Sciences: Philosophical Transactions of the Royal Society B 371(1696). [Website]. Viewed online at: http://dx.doi.org/10.1098/rstb.2015.0178. Accessed: Oct. 12, 2018. Last updated: June 5, 2016.

03/04/1977

Executive Order B-27-77

FILED
In the office of the Secretary of State of the State of California
MAR 4 - 1977
MARCH FONG EU, Secretary of State
By Deputy

Executive Department
State of California

EXECUTIVE ORDER NO. B-27-77

WHEREAS, it is necessary to provide for coordination of communications and directives to insure effective management and cooperative efforts by state agencies to combat the effects of the drought; and

WHEREAS, it is necessary to provide for coordination of communications between the state and other governmental agencies at the federal and local levels;

NOW, THEREFORE, I, Edmund G. Brown Jr., Governor of the State of California, by virtue of the power and authority vested in me by the Constitution and statutes of the State of California, do hereby initiate on an interim basis the following plan:

IT IS ORDERED that the Drought Emergency Task Force is hereby established. Said Task Force shall consist of representatives of the following state agencies and departments:

Agriculture and Services Agency
Business and Transportation Agency
Health and Welfare Agency
Resources Agency

Department of Finance
Department of Fish and Game
Department of Food and Agriculture
Department of General Services
Department of Health
Department of Housing and Community Development
Department of Navigation and Ocean Development
Department of Parks and Recreation
Department of Transportation (Caltrans)
Department of Water Resources
Division of Forestry
Employment Development Department
Military Department
Office of Emergency Services

The Task Force shall also consist of representatives of any of the following independent boards and commissions which are willing to participate and to voluntarily comply with this Executive Order:

California Coastal Commission
California Emergency Council
California Tahoe Regional Planning Agency
California Water Commission
Colorado River Board of California

Executive Order B-27-77, page 2 of 3

Executive Department
State of California

PAGE TWO

Commission on Housing and Community Development
Navigation and Ocean Development Commission
Public Utilities Commission
Regents of the University of California
San Francisco Bay Conservation and Development Commission
State Air Resources Board
State Board of Fire Services
State Board of Food and Agriculture
State Board of Forestry
State Energy Resources Conservation and Development Commission
State Park and Recreation Commission
State Personnel Board
State Reclamation Board
State Resource Conservation Commission
State Solid Waste Management Board
State Transportation Board
State Water Resources Control Board
Trustees of the California State University and Colleges

The Director of the Task Force shall be Major General Frank J. Schober, Commanding General of State Military Forces; and

IT IS FURTHER ORDERED that the head of each such agency and department and each participating board and commission shall immediately designate a duly authorized representative to the Drought Emergency Task Force; and

IT IS FURTHER ORDERED that the duties of the Drought Emergency Task Force shall include, but not be limited to, the direction and coordination of state efforts to combat the effects of the drought, and to provide public information regarding the nature and extent of the drought and efforts to combat the effects thereof; and

IT IS FURTHER ORDERED that said agencies, departments, boards, and commissions make available to Major General Frank J. Schober such resources, facilities and personnel as he may request; and

Executive Order B-27-77, page 3 of 3

Executive Department
State of California

PAGE THREE

IT IS FURTHER ORDERED that all state agencies, departments, and participating boards and commissions shall communicate with me through Major General Frank J. Schober, Director of the Drought Emergency Task Force, with respect to all matters pertaining to the drought.

IN WITNESS WHEREOF, I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this fourth day of March, nineteen hundred and seventy-seven

Governor of California

ATTEST

March Fong Eu
Secretary of State

by Marjorie R. Kirschberger
Deputy Secretary of State

02/01/91

Executive Order W-3-91

G275
E9
W-3-91

EXECUTIVE DEPARTMENT
STATE OF CALIFORNIA

FILED
in the office of the Secretary of State
of the State of California
FEB 01 1991
MARCH FONG EU, Secretary of State
By Michele L. Williams
Deputy

EXECUTIVE ORDER NO. W-3-91

WHEREAS, most regions of the State of California have experienced conditions of drought for the previous four years, and some regions in Central and Southern California have experienced drought conditions for the past seven years; and

WHEREAS, California has received less than 25 percent of its normal rainfall for this water year, and there only remains two and one-half months in which significant rainfall can be anticipated; and

WHEREAS, reservoir storage throughout California is substantially depleted; with most reservoirs at or near an all-time low; with many reservoirs dropping to near their minimum pool levels; and some reservoirs holding less than they did in the 1976-77 drought; and

WHEREAS, the State Water Resources Control Board has held special hearings on the need to take specific steps to mitigate the effects of the current and possible future drought conditions; and

WHEREAS, the Emergency Services Act confers extraordinary powers on the Governor to provide leadership in responding to emergencies which are beyond the control of any individual city or county or which require a coordinated statewide response; and

WHEREAS, it is now necessary for all agencies of the State of California to undertake steps to mitigate the effects of the current drought, and to develop the information necessary to enable the Governor to coordinate and direct remedial actions at all levels of government within the state to combat existing or threatened drought-caused conditions of disaster or peril to persons or property should it become necessary to proclaim a state of emergency under the Emergency Services Act; and

WHEREAS, many cities, counties, and water purveyors in California have already taken significant actions to deal with the drought; those which do not already have drought emergency plans should be encouraged to plan now for future actions necessary to mitigate the effects of the drought, and all counties should be encouraged to appoint a drought coordinator, so that State and local agencies can make a coordinated response to any future drought emergency; and

WHEREAS, impacts of the drought can reach virtually all of California's population, affect it's natural resources and its economy, and mitigating the drought's impact will require the cooperation of all of our citizens, elected officials, and public agencies;

NOW THEREFORE, I, Pete Wilson, Governor of the State of California, by virtue of the power and authority vested in me by the Constitution and statutes of the State of California, do hereby issue the following orders and directives to become effective immediately:

IT IS ORDERED that The Director of Water Resources is hereby appointed as the Governor's Drought Administrator who shall be the Governor's representative with respect to all matters related to implementing this Executive Order, and any subsequent orders or directives with respect to the drought; and

Executive Order W-3-91, page 2 of 3

6905 P.2

PAGE 2

IT IS FURTHER ORDERED that the Drought Action Team is hereby established. The Governor's Drought Administrator shall serve as its Chair. The Action Team shall consist of the following persons, together with the directors or executive officers of such other agencies as may be appointed upon the recommendation of the Administrator, where he finds that their department or agency has statutory responsibilities, expertise, or resources which would significantly contribute to mitigation of the effects of the drought:

Secretary of the Resources Agency
Director of the Department of Food and Agriculture
Director of the Office of Emergency Services
Director of the Department of Finance
Director of the Department of Fish and Game
Director of the Department of Forestry and Fire Protection
Director of the Department of Health Services
Director of the Office of Planning and Research
Adjutant General of the Military Department

The Governor's Drought Administrator shall also invite the participation of any independent boards and commissions and federal agencies which have jurisdiction, expertise and resources which would significantly contribute to the mitigation of the effects of the drought, including, but not limited to the following:

State Water Resources Control Board
Public Utilities Commission
United States Department of Agriculture
United States Department of the Interior
United States Army Corps of Engineers
Federal Emergency Management Agency

IT IS FURTHER ORDERED, that the general duties of the Drought Action Team include, but are not limited to, directing and coordinating state efforts to combat the effects of the drought, encouraging the preparation and implementation of local drought emergency plans, providing liaison and coordination between state and local efforts, and providing the Executive Department of the State of California with periodic reports on the status of the drought, together with recommendations for timely actions to remedy the effects of the drought. Specific duties of the Action Team shall include, but are not limited to, the following:

* The Action Team shall report regularly to the Governor on water supply conditions in California and the status of state and local efforts to combat the drought's effects. The Action Team shall recommend any additional measures which it deems necessary to combat the drought and protect the health, safety, and property of the people, while providing maximum feasible protection to the important environmental resources of the State. The first report shall emphasize water supply conditions and shall be made no later than February 15, 1991.

* The reports shall contain any information the Action Team finds to be of assistance to the Governor in determining whether and when to proclaim a state of emergency due to drought conditions and shall include an assessment of equitable issues and a rational framework for "sharing the pain" if extraordinary measures are recommended.

* The Action Team shall review and report on the availability and effectiveness of state and federal financial assistance programs for the relief of critical domestic water supply shortages, drought-induced water shortages which threaten the viability of environmental resources, including significant fish and wildlife populations, drought-induced adverse impacts to the economy, and any other adverse effects of the drought. The Action Team shall also recommend state and federal legislation, as appropriate, to provide emergency financial assistance.

Executive Order W-3-91, page 3 of 3

PAGE 3

IT IS FURTHER ORDERED, that the Department of Water Resources and the Office of Emergency Services shall provide staff to assist the Action Team in carrying out its responsibilities. The Governor's Drought Administrator may also call upon other departments for staff as needed; and

IT IS FURTHER ORDERED, that the Department of Water Resources shall do the following:

* The Department shall provide increased technical assistance and coordination to local water supply agencies on the development and implementation of water conservation measures.

* The Department shall develop a clearinghouse for facilitating water marketing transactions between willing sellers and buyers of water, consistent with the need to protect fish and wildlife resources.

* The Department shall review the effectiveness of water conservation measures ordered for all state agencies and departments pursuant to Executive Order D-85-90, and shall recommend any further actions necessary to effect the water savings directed in that Executive Order, together with such additional water savings as the Department believes to be reasonably attainable, in view of the severity of regional water shortages.

* The Department shall expand the Drought Center, which has been operating since 1986, as necessary to provide a focal point for drought activities, including providing information and assistance; and

IT IS FURTHER ORDERED, that the Department of Health Services shall evaluate and report to the Governor's Drought Administrator on the feasibility of temporary revisions of applicable water quality standards to make additional supplies of water available for beneficial uses, consistent with the protection of public health, including, but not limited to, expanded use of gray water, use of available ground water, and expanded use of reclaimed water; and

IT IS FURTHER ORDERED, that the State Water Resources Control Board is requested to hold further hearings on the drought, as appropriate, and coordinate its hearings with the Governor's Drought Administrator and the Drought Action Team; and

IT IS FURTHER ORDERED, that all state agencies and departments shall fully cooperate with the Governor's Drought Administrator, and communicate to the Executive Department of the State of California through the Administrator with respect to all matters pertaining to the drought and the actions to be taken pursuant to this Executive Order and all future orders and directives that may be issued to mitigate the effects of the drought.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 1st day of February 1991.

Pete Wilson

Governor of California

ATTEST:

March Fong Eu

Secretary of State

06/04/2008

Executive Order S-06-08

WHEREAS *Statewide rainfall has been below normal in 2007 and 2008, with many Southern California communities receiving only 20 percent of normal rainfall in 2007, and Northern California this year experiencing the driest spring on record with most communities receiving less than 20 percent of normal rainfall from March through May; and*

WHEREAS *California is experiencing critically dry water conditions in the Sacramento and San Joaquin River basins and the statewide runoff forecast for 2008 is estimated to be 41 percent below average; and*

WHEREAS *water storage in many of the state's major reservoirs is far below normal including Lake Oroville, which supplies the State Water Project, at 50 percent of capacity, Lake Shasta at 61 percent of capacity and Folsom Lake at 63 percent of capacity; and*

WHEREAS *the Colorado River Basin has just experienced a record eight-year drought resulting in current reservoir storage throughout the river system reduced to just over 50 percent of total storage capacity; and*

WHEREAS *climate change will increasingly impact California's hydrology and is expected to reduce snowpack, alter the timing of runoff and increase the intensity and frequency of droughts in the western United States; and*

WHEREAS *diversions from the Sacramento-San Joaquin River Delta for the State Water Project (SWP) and federal Central Valley Project (CVP) are being greatly restricted due to various factors including federal court actions to protect fish species, resulting in estimated SWP deliveries of only 35 percent, and CVP deliveries of only 40 percent, of local agencies' requested amounts for 2008; and*

WHEREAS *dry conditions have created a situation of extreme fire danger in California, and these conditions resulted in devastating fires last year, resulting in proclamations of emergency for the counties of El Dorado, Los Angeles, Orange, Ventura, Santa Barbara, Riverside, San Bernardino, Santa Clara, Santa Cruz and San Diego, with wildfires there causing millions of dollars in damages; and*

WHEREAS *on May 9, 2008, I signed an Executive Order directing various agencies and departments within my administration to respond to these dry conditions and prepare for another potentially severe wildfire season; and*

WHEREAS *the current drought conditions are harming urban and rural economies, and the state's overall economic prosperity; and*

WHEREAS *some communities are restricting new development and mandating water conservation and rationing, and some farmers have idled permanent crops and are not planting seasonal crops this year, because of unreliable or uncertain water supplies; and*

WHEREAS *recent supply reductions have jeopardized agricultural production in the San Joaquin Valley; and*

WHEREAS *it is not possible to predict the duration of present drought conditions; and*

WHEREAS *while communities throughout the state have worked to significantly improve their drought preparedness, the readiness to cope with current and future drought conditions varies widely; and*

WHEREAS *immediate water conservation measures are needed this year to address current conditions and prepare for a dry 2009; and*

WHEREAS *the State of California is committed to enhancing drought response and drought preparedness and to protecting the state's economy and its environment*

NOW, THEREFORE, I, ARNOLD SCHWARZENEGGER, *Governor of the State of California, do hereby proclaim a condition of statewide drought, and in accordance with the authority vested in me by the Constitution and statutes of the State of California, do hereby issue the following orders to become effective immediately*

IT IS HEREBY ORDERED *that the Department of Water Resources (DWR) shall take immediate action to address the serious drought conditions and water delivery limitations that currently exist in California, and that are anticipated in the future, by taking the following actions:*

1. *Expedite existing grant programs for local water districts and agencies for new or ongoing water conservation and water use reduction programs and projects that are capable of timely implementation to ease drought conditions in 2008 or 2009.*
2. *Facilitate water transfers in 2008 to timely respond to potential emergency water shortages and water quality degradation, and prepare to operate a dry year water purchasing program in 2009.*
3. *In cooperation with local water agencies and other water-related organizations, conduct an aggressive water conservation and outreach campaign.*
4. *Immediately convene the Climate Variability Advisory Committee to prioritize and expedite drought-related climate research that will assist in responding to current drought conditions and help prepare for a potentially dry 2009.*
5. *Provide technical assistance for drought response to local water agencies and districts for improving landscape and agricultural irrigation efficiencies, leak detection and other measures as appropriate.*
6. *Review the water shortage contingency elements of Urban Water Management Plans and work cooperatively with water suppliers to implement improvements.*
7. *Coordinate and implement State Water Project operations and water exchanges to alleviate critical impacts to San Joaquin Valley agriculture.*
8. *Implement additional actions to facilitate drought response, preparedness and promote water conservation in 2008 and 2009, and which will contribute to achieving long term reductions in water use.*

IT IS FURTHER ORDERED *that DWR and the Department of Public Health (DPH) prioritize processing of loan and grant contracts for water suppliers and public water systems demonstrating drought-related hardships.*

IT IS FURTHER ORDERED *that DWR and DPH coordinate with the State Office of Emergency Services and local offices of emergency services to identify public water systems at risk of experiencing health and safety impacts due to drought conditions and water delivery limitations, and to mitigate such impacts.*

IT IS FURTHER ORDERED *that DWR and DPH work with local water districts to evaluate system interconnections among the state's large water purveyors, review the status or availability of mutual aid agreements among those large water purveyors, and work with the parties to those mutual aid agreements to correct any deficiencies that restrict the movement of water in an emergency situation*

IT IS FURTHER ORDERED *that DWR coordinate with the California Public Utilities Commission to identify investor-owned water utility systems at risk of experiencing health and safety impacts due to drought conditions and water delivery limitations, and to mitigate such impacts.*

IT IS FURTHER ORDERED *that DWR work with the Department of Food and Agriculture (CDFA), the United States*

Department of Agriculture and the United States Bureau of Reclamation to identify potential federal funding for local water agencies and farmers to facilitate the rapid installation of best available irrigation management and conservation systems.

IT IS FURTHER ORDERED *that the CDFA work with county Agricultural Commissioners and others as necessary to identify and gather data on crop losses and other adverse economic impacts caused by the drought and, when necessary, transmit that information to the appropriate federal and state agencies.*

IT IS FURTHER STRONGLY ENCOURAGED *that local water agencies and districts work cooperatively on the regional and state level to take aggressive, immediate action to reduce water consumption locally and regionally for the remainder of 2008 and prepare for potential worsening water conditions in 2009.*

This Order is not intended to, and does not, create any rights or benefits, substantive or procedural, enforceable at law or in equity, against the State of California, its agencies, departments, entities, officers, employees, or any other person.

I FURTHER DIRECT *that as soon as hereafter possible, this Executive Order be filed in the Office of the Secretary of State and that widespread publicity and notice be given to this Executive Order.*

IN WITNESS WHEREOF *I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 4th day of June 2008.*

ARNOLD SCHWARZENEGGER, *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

06/12/2008

Emergency Proclamation Central Valley

STATE OF EMERGENCY – CENTRAL VALLEY REGION

PROCLAMATION
by the Governor of the State of California

WHEREAS *on June 4, 2008, I issued an Executive Order proclaiming a statewide drought; and*

WHEREAS *in my June 4 Executive Order, I called on all Californians to conserve water, and I directed state agencies and departments to take immediate action to address the serious drought conditions and water delivery reductions that exist in California; and*

WHEREAS *in issuing my June 4 Executive Order, I said that I would proclaim a state of emergency in any county where emergency conditions exist due to the drought, in an effort to protect the people and property of California, including the businesses, workers and communities that depend on water deliveries for their livelihood and survival; and*

WHEREAS *since issuing my June 4 Executive Order, I have determined that emergency conditions exist in Central Valley counties caused by the continuing drought conditions in California and the reductions in water deliveries; and*

WHEREAS *statewide rainfall has been below normal in 2007 and 2008, with many Southern California communities receiving only 20 percent of normal rainfall in 2007, and Northern California this year experiencing the driest spring on record with most communities receiving less than 20 percent of normal rainfall from March through May; and*

WHEREAS *California is experiencing critically dry water conditions in the Sacramento and San Joaquin River basins and the statewide runoff forecast for 2008 is estimated to be 41 percent below average; and*

WHEREAS *water storage in many of the reservoirs serving the Central Valley are far below normal including San Luis reservoir which is at 53 percent of capacity, Lake Shasta at 61 percent of capacity and Lake Oroville at just 50 percent of capacity; and*

WHEREAS *diversions from the Sacramento-San Joaquin River Delta for the State Water Project (SWP) and federal Central Valley Project (CVP) are being greatly restricted due to various factors including federal court actions to protect fish species, resulting in estimated SWP deliveries of only 35 percent, and CVP deliveries of only 40 percent, of local agencies' requested amounts for 2008; and*

WHEREAS *the United States Bureau of Reclamation (USBR) recently announced an unexpected reduction in its water supply allocations to Central Valley Project (CVP) contractors within the San Luis Delta Mendota Water Agency Service Area from 45 percent to 40 percent; and*

WHEREAS *this unanticipated reduction will result in crop loss, increased unemployment and other direct and indirect economic impacts to Central Valley counties; and*

WHEREAS *water rationing has been ordered by the City of Long Beach, the City of Roseville, and the East Bay Municipal Utility District, which serves 1.3 million people in Alameda and Contra Costa counties; and*

WHEREAS *on June 10, 2008, the Metropolitan Water District of Southern California, which supplies water for 26 cities and water agencies serving 18 million people in six southern California counties, declared a water supply alert in an effort to sustain their water reserves; and*

WHEREAS *some communities are also restricting new residential and commercial development because of unreliable or uncertain water supplies, and this is causing harm to the economy; and*

WHEREAS *dry conditions have created a situation of extreme fire danger in California, and these conditions resulted in devastating fires last year, with wildfires causing millions of dollars in damages; and*

WHEREAS *San Joaquin Valley agriculture constitutes a $20 billion industry, and serves as an essential part of California's economy; and*

WHEREAS *the lack of water will cause devastating harm to the communities that rely on this important industry, as growers lack sufficient water to finish the growing season, are forced to abandon planted crops, and are forced to dismiss workers; and*

WHEREAS *the lack of water is causing agricultural workers in the Central Valley to lose their jobs, resulting in a loss of livelihood, an inability to provide for their families, and increased negative social and economic impacts on the communities that depend on them; and*

WHEREAS *San Joaquin Valley agricultural production and processing industries account for almost 40 percent of regional employment, and every dollar produced on the farm generates more than three dollars in the local and regional economies, and the loss of these dollars is devastating communities; and*

WHEREAS *almost 20 percent of San Joaquin Valley residents already live in poverty, and it consistently ranks as the top region in the nation in foreclosures; and*

WHEREAS *as workers lose their jobs because of the lack of water, they often move their families away from the communities, resulting in further harm to local economies, lower enrollments in local schools and reduced funding for schools; and*

WHEREAS *the city of Fresno received only 54 percent of normal rainfall in 2007 and 76 percent of normal in 2008, and had its fourth driest spring on record; and*

WHEREAS *on June 11, 2008, the Fresno County Board of Supervisors passed a resolution declaring a local state of emergency due to the severe drought conditions, stating among other things that the lack of water has resulted in water rationing by Fresno County water districts; that these reductions are causing abandonment of current planted seasonal crops and permanent crops; that the cumulative crop reductions will result in job losses in Fresno County communities; that the loss of revenue has negatively impacted Fresno County businesses and Fresno County government tax revenue; and that there will be a substantial negative economic impact to the community; and*

WHEREAS *the Fresno County Board of Supervisors also requested that I declare a state of emergency due to the drought conditions; and*

WHEREAS *the Central Valley cities of Bakersfield, Modesto, Stockton, and Sacramento experienced their driest spring on*

record in 2008, and additional Central Valley counties are experiencing similar emergency conditions caused by drought and lack of water deliveries; and

WHEREAS *to date, almost $65 million in losses have been reported by 19 counties due to reduced rangeland grasses that are used to graze livestock, and those reductions have been caused by drought; and*

WHEREAS *statewide and local conditions collectively have led to the rationing of water by affected water districts to their member farmers and these further reductions are resulting in abandonment of current planted seasonal crops and permanent crops; and*

WHEREAS *the crop losses will cause increased food prices, which will negatively impact families and economies throughout California and beyond our borders; and*

WHEREAS *the lack of water deliveries has forced local communities to draw water from their emergency water reserves, putting communities at risk of further catastrophe if emergency reserves are depleted or cut off; and*

WHEREAS *the circumstances of the severe drought conditions, by reason of their magnitude, are beyond the control of the services, personnel, equipment and facilities of any single county, city and county, or city and require the combined forces of a mutual aid region or regions to combat; and*

WHEREAS *under the provisions of section 8558(b) of the California Government Code, I find that conditions of extreme peril to the safety of persons and property exist within the counties of Sacramento, San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulare and Kern, caused by the current and continuing severe drought conditions.*

NOW, THEREFORE, I, ARNOLD SCHWARZENEGGER, *Governor of the State of California, in accordance with the authority vested in me by the California Constitution and the California Emergency Services Act, and in particular, section 8625 of the California Government Code,* **HEREBY PROCLAIM A STATE OF EMERGENCY** *to exist within the counties of Sacramento, San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulare and Kern.*

IT IS HEREBY ORDERED *that all agencies of the state government utilize and employ state personnel, equipment and facilities for the performance of any and all activities consistent with the direction of my Office of Emergency Services (OES) and the State Emergency Plan, and that OES provide local government assistance under the authority of the California Disaster Assistance Act, and that the emergency exemptions in sections 21080(b)(3) and 21172 of the Public Resources Code shall apply to all activities and projects ordered and directed under this proclamation, to the fullest extent allowed by law.*

I FURTHER DIRECT THAT:

OES shall provide assistance under the authority of the California Disaster Assistance Act, by assisting public water agencies with drilling of groundwater wells or the improvement of existing wells and water delivery systems for human consumption, sanitation, and emergency protective measures, such as fire fighting.

The Department of Water Resources (DWR) shall transfer groundwater of appropriate quality through the use of the California Aqueduct to benefit farmers in the San Joaquin Valley.

DWR and the State Water Resources Control Board (SWRCB) shall expedite the processing of water transfer requests.

DWR, in cooperation with USBR, shall make operational changes to State Water Project facilities, including the San Luis Reservoir and Southern California reservoirs, that will permit additional water deliveries to the San Joaquin Valley.

DWR shall prepare and file necessary water right urgency change petitions to facilitate surface water transfers and the use of joint point of diversion by the SWP and Central Valley Project.

SWRCB shall expedite the processing and consideration of water rights urgency change petitions filed by DWR and other water agencies to facilitate water transfers to the San Joaquin Valley.

I FURTHER DIRECT *that as soon as hereafter possible, this proclamation be filed in the Office of the Secretary of State and that widespread publicity and notice be given of this proclamation.*

IN WITNESS WHEREOF *I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 12th day of June, 2008.*

ARNOLD SCHWARZENEGGER, *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

2/27/2009

Emergency Proclamation Water Shortage

STATE OF EMERGENCY – WATER SHORTAGE

PROCLAMATION
by the Governor of the State of California

WHEREAS *the State of California is now in its third consecutive year of drought; and*

WHEREAS *in each year of the current drought, annual rainfall and the water content in the Sierra snowpack have been significantly below the amounts needed to fill California's reservoir system; and*

WHEREAS *the rainfall and snowpack deficits in each year of the current drought have put California further and further behind in meeting its essential water needs; and*

WHEREAS *statewide, 2008 was the driest spring and summer on record, with rainfall 76 percent below average; and*

WHEREAS *the Sacramento and San Joaquin River systems, which provide much of the state's reservoir inflow, were classified as Critically Dry for the 2008 water year; and*

WHEREAS *in the second year of this continuous drought, on June 4, 2008, I issued an Executive Order proclaiming a statewide drought, and I ordered my administration to begin taking action to address the water shortage; and*

WHEREAS *because emergency conditions existed in the Central Valley in the second year of the drought, I issued an Emergency Proclamation on June 12, 2008, finding that conditions of extreme peril to the safety of persons and property existed in the counties of Sacramento, San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulare, and Kern caused by severe drought conditions, and I ordered my administration to take emergency action to assist the Central Valley; and*

WHEREAS *the drought conditions and water delivery limitations identified in my prior Executive Order and Emergency Proclamation still exist, and have become worse in this third year of drought, creating emergency conditions not just in the Central Valley, but throughout the State of California, as the adverse environmental, economic, and social impacts of the drought cause widespread harm to people, businesses, property, communities, wildlife and recreation; and*

WHEREAS *despite the recent rain and snow, the three year cumulative water deficit is so large there is only a 15 percent chance that California will replenish its water supply this year; and*

WHEREAS *in the time since the state's last major drought in 1991, California added 9 million new residents, experienced a significant increase in the planting of permanent, high-value crops not subject to fallowing, and was subjected to new biological opinions that reduced the flexibility of water operations throughout the year; and*

WHEREAS *because there is no way to know when the drought will end, further urgent action is needed to address the water shortage and protect the people and property in California; and*

WHEREAS *rainfall levels statewide for the 2008–2009 water year are 24 percent below average as of the February 1, 2009 measurement; and*

WHEREAS *the second snow pack survey of the 2009 winter season indicated that snow pack water content is 39 percent below normal; and*

WHEREAS *as of February 23, 2009, storage in the state's reservoir system is at a historic low, with Lake Oroville 70 percent below capacity, Shasta Lake 66 percent below capacity, Folsom Lake 72 percent below capacity, and San Luis Reservoir 64 percent below capacity; and*

WHEREAS *low water levels in the state's reservoir system have significantly reduced the ability to generate hydropower, including a 62 percent reduction in hydropower generation at Lake Oroville from October 1, 2008 to January 31, 2009; and*

WHEREAS *a biological opinion issued by the United States Fish and Wildlife Service on December 15, 2008, imposed a 30 percent restriction on water deliveries from the State Water Project and the Central Valley Project to protect Delta Smelt; and*

WHEREAS *State Water Project water allocations have now been reduced to 15 percent of requested deliveries, matching 1991 as the lowest water allocation year in State Water Project history, and Central Valley Project water allocations for agricultural users have now been reduced to zero; and*

WHEREAS *the lack of water has forced California farmers to abandon or leave unplanted more than 100,000 acres of agricultural land; and*

WHEREAS *California farmers provide nearly half of the fresh fruits, nuts and vegetables consumed by Americans, and the crop losses caused by the drought will increase food prices, which will further adversely impact families and economies throughout California and beyond our borders; and*

WHEREAS *agricultural revenue losses exceed $300 million to date and could exceed $2 billion in the coming season, with a total economic loss of nearly $3 billion in 2009; and*

WHEREAS *it is expected that State Water Project and Central Valley Project water delivery reductions will cause more than 80,000 lost jobs; and*

WHEREAS *the income and job losses will adversely impact entire communities and diverse sectors of the economy supported by those jobs and income, including the housing market and commercial business; and*

WHEREAS *these conditions are causing a loss of livelihood for many thousands of people, an inability to provide for families, and increased harm to the communities that depend on them; and*

WHEREAS *this loss of income and jobs will increase the number of defaults, foreclosures and bankruptcies, and will cause a loss of businesses and property at a time when Californians are already struggling with a nationwide and worldwide economic downturn; and*

WHEREAS *the Central Valley town of Mendota, as one example, already reports an unemployment rate of more than 40 percent and lines of a thousand or more for food distribution; and*

WHEREAS *when jobs, property and businesses are lost, some families will move away from their communities, causing further harm to local economies, lower enrollments in local schools and reduced funding for schools; and*

WHEREAS *at least 18 local water agencies throughout the state have already implemented mandatory water conservation measures, and 57 agencies have implemented other water conservation programs or restrictions on water deliveries, with many agencies considering additional rationing and water supply reductions in 2009; and*

WHEREAS *the lack of water has forced local communities to draw water from their emergency water reserves, putting communities at risk of further catastrophe if emergency reserves are depleted or cut off; and*

WHEREAS *the state recently endured one of its worst wildfire seasons in history and the continuing drought conditions increase the risk of devastating fires and reduced water supplies for fire suppression; and*

WHEREAS *on February 26, 2009, the United States Department of Agriculture and the United States Department of Interior created a Federal Drought Action Team to assist California to minimize the social, economic, and environmental impacts of the current drought; and*

WHEREAS *the circumstances of the severe drought conditions, by reason of their magnitude, are beyond the control of the services, personnel, equipment and facilities of any single county, city and county, or city and require the combined forces of a mutual aid region or regions to combat; and*

WHEREAS *under the provisions of section 8558(b) of the California Government Code, I find that conditions of extreme peril to the safety of persons and property exist in California caused by the current and continuing severe drought conditions and water delivery restrictions.*

NOW, THEREFORE, I, ARNOLD SCHWARZENEGGER, *Governor of the State of California, in accordance with the authority vested in me by the California Constitution and the California Emergency Services Act, and in particular California Government Code sections 8625 and 8571,* **HEREBY PROCLAIM A STATE OF EMERGENCY** *to exist in California.*

IT IS HEREBY ORDERED *that all agencies of the state government utilize and employ state personnel, equipment and facilities for the performance of any and all activities consistent with the direction of the California Emergency Management Agency (CalEMA) and the State Emergency Plan.*

I FURTHER DIRECT THAT:

1. *The California Department of Water Resources (DWR) shall, in partnership with other appropriate agencies, launch a statewide water conservation campaign calling for all Californians to immediately decrease their water use.*
2. *DWR shall implement the relevant mitigation measures identified in the Environmental Water Account Environmental Impact Report, Environmental Impact Statement, Supplement, and Addendums for the water transfers made through the 2009 Drought Water Bank. In addition, the California Air Resources Board shall, in cooperation with DWR and other agencies, expedite permitting and development of mitigation measures related to air quality impacts which may result from groundwater substitution transfers.*
3. *DWR and the State Water Resources Control Board (SWRCB) shall expedite the processing of water transfers and related efforts by water users and suppliers that cannot participate in the 2009 Drought Water Bank, provided the water users and suppliers can demonstrate that the transfer will not injure other legal users of water or cause unreasonable effects on fish and wildlife.*
4. *The SWRCB shall expedite the processing and consideration of the request by DWR for approval of the consolidation of the places of use and points of diversion for the State Water Project and federal Central Valley Project to allow flexibility among the projects and to facilitate water transfers and exchanges.*

5. *DWR shall implement short-term efforts to protect water quality or water supply, such as the installation of temporary barriers in the Delta or temporary water supply connections.*
6. *The SWRCB shall expedite the processing and consideration of requests by DWR to address water quality standards in the Delta to help preserve cold water pools in upstream reservoirs for salmon preservation and water supply.*
7. *To the extent allowed by applicable law, state agencies within my administration shall prioritize and streamline permitting and regulatory compliance actions for desalination, water conservation and recycling projects that provide drought relief.*
8. *The Department of General Services shall, in cooperation with other state agencies, immediately implement a water use reduction plan for all state agencies and facilities. The plan shall include immediate water conservation actions and retrofit programs for state facilities. A moratorium shall be placed on all new landscaping projects at state facilities and on state highways and roads except for those that use water efficient irrigation, drought tolerant plants or non-irrigated erosion control.*
9. *As a condition to receiving state drought financial assistance or water transfers provided in response to this emergency, urban water suppliers in the state shall be required to implement a water shortage contingency analysis, as required by California Water Code section 10632. DWR shall offer workshops and technical assistance to any agency that has not yet prepared or implemented the water shortage contingency analysis required by California law.*
10. *DWR shall offer technical assistance to agricultural water suppliers and agricultural water users, including information on managing water supplies to minimize economic impacts, implementing efficient water management practices, and using technology such as the California Irrigation Management Information System (CIMIS) to get the greatest benefit from available water supplies.*
11. *The Department of Public Health shall evaluate the adequacy of emergency interconnections among the state's public water systems, and provide technical assistance and continued financial assistance from existing resources to improve or add interconnections.*
12. *DWR shall continue to monitor the state's groundwater conditions, and shall collect groundwater-level data and other relevant information from water agencies, counties, and cities. It is requested that water agencies, counties and cities cooperate with DWR by providing the information needed to comply with this Proclamation.*
13. *DWR and the Department of Food and Agriculture shall recommend, within 30 days from the date of this Proclamation, measures to reduce the economic impacts of the drought, including but not limited to, water transfers, through-Delta emergency transfers, water conservation measures, efficient irrigation practices, and improvements to CIMIS.*
14. *The Department of Boating and Waterways shall recommend, within 30 days from the date of this Proclamation, and in cooperation with the Department of Parks and Recreation, measures to reduce the impacts of the drought conditions to water-based recreation, including but not limited to, the relocation or extension of boat ramps and assistance to marina owners.*

15. *The Labor and Workforce Development Agency shall recommend, within 30 days from the date of this Proclamation, measures to address the impact of the drought conditions on California's labor market, including but not limited to, identifying impacted areas, providing one-stop service, assisting employers and workers facing layoffs, and providing job training and financial assistance.*
16. *DWR and the Department of Food and Agriculture shall be the lead agencies in working with the Federal Drought Action Team to coordinate federal and state drought response activities.*
17. *The emergency exemptions in Public Resources Code sections 21080(b)(3), 21080(b)(4) and 21172, and in California Code of Regulations, title 14, section 15269(c), shall apply to all actions or efforts consistent with this Proclamation that are taken to mitigate or respond to this emergency. In addition, Water Code section 13247 is suspended to allow expedited responses to this emergency that are consistent with this Proclamation. The Secretary for the California Environmental Protection Agency and the Secretary for the California Natural Resources Agency shall determine which efforts fall within these exemptions and suspension, ensuring that these exemptions and suspension serve the purposes of this Proclamation while protecting the public and the environment. The Secretaries shall maintain on their web sites a list of the actions taken in reliance on these exemptions and suspension.*
18. *By March 30, 2009, DWR shall provide me with an updated report on the state's drought conditions and water availability. If the emergency conditions have not been sufficiently mitigated, I will consider issuing additional orders, which may include orders pertaining to the following:*
    - *(a) institution of mandatory water rationing and mandatory reductions in water use;*
    - *(b) reoperation of major reservoirs in the state to minimize impacts of the drought;*
    - *(c) additional regulatory relief or permit streamlining as allowed under the Emergency Services Act; and*
    - *(d) other actions necessary to prevent, remedy or mitigate the effects of the extreme drought conditions.*

I FURTHER REQUEST THAT:

19. *All urban water users immediately increase their water conservation activities in an effort to reduce their individual water use by 20 percent.*
20. *All agricultural water suppliers and agricultural water users continue to implement, and seek additional opportunities to immediately implement, appropriate efficient water management practices in order to minimize economic impacts to agriculture and make the best use of available water supplies.*
21. *Federal and local agencies also implement water use reduction plans for facilities within their control, including immediate water conservation efforts.*

I FURTHER DIRECT *that as soon as hereafter possible, this proclamation be filed in the Office of the Secretary of State and that widespread publicity and notice be given of this proclamation.*

IN WITNESS WHEREOF *I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 27th day of February, 2009.*

ARNOLD SCHWARZENEGGER, *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

06/19/2009

Executive Order S-11-09

WHEREAS *on June 4, 2008, I issued an Executive Order proclaiming a statewide drought, and I ordered my administration to take immediate action to address the water shortage; and*

WHEREAS *on June 12, 2008, I proclaimed a state of emergency for nine Central Valley counties because the drought had caused conditions of extreme peril to the safety of persons and property; and*

WHEREAS *on February 27, 2009, I proclaimed a state of emergency for the entire state as the severe drought conditions continued and the impacts were well beyond the Central Valley; and*

WHEREAS *the February 27, 2009 state of emergency proclamation provided specific orders and directions to my Department of Water Resources, State Water Resources Control Board, Department of General Services, Department of Public Health, California Department of Food and Agriculture, and Labor and Workforce Development Agency to reduce and mitigate the human, environmental, and economic impact of the drought; and*

WHEREAS *I have supported state and local water managers' efforts to increase the availability of water, directed efforts to better integrate regional water management practices to balance water demand with water supply, directed expedited water transfers, ordered increased job training, and substantially increased statewide water conservation; and*

WHEREAS *I have requested and we have received United States Department of Agriculture disaster designations for 21 counties for drought; and*

WHEREAS *the drought conditions have exacerbated unemployment and the local emergency food banks are struggling to meet the demands of hungry families.*

NOW, THEREFORE, I, ARNOLD SCHWARZENEGGER, *Governor of the State of California, in accordance with the authority vested in me by the state Constitution and statutes, activate the California Disaster Assistance Act to provide temporary supplemental assistance to the local governments and non-profit organizations that provide food and other aid to those who are impacted by the drought statewide.*

IT IS HEREBY ORDERED *that my California Emergency Management Agency, Department of Social Services, Labor and Workforce Development Agency, and California Department of Food and Agricultural develop a comprehensive strategy by July 15, 2009, to provide adequate nutrition for those individuals who are temporarily unable to afford food as a result of the drought conditions.*

IT IS FURTHER ORDERED THAT *the provisions of California Unemployment Insurance Code section 1253 imposing a one-week waiting period for unemployment insurance applicants are suspended as to all applicants who are unemployed as a specific result of the drought conditions, who apply for unemployment insurance benefits during the time period beginning June 19, 2009, and ending on the close of business on November 1, 2009, and who are otherwise eligible for unemployment insurance benefits in California.*

I FURTHER DIRECT *that as soon as hereafter possible, this Order be filed in the Office of the Secretary of State and that widespread publicity and notice be given this Order.*

IN WITNESS WHEREOF *I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 19th Day of June 2009.*

ARNOLD SCHWARZENEGGER, *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

State of Emergency Fresno County

PROCLAMATION BY THE GOVERNOR OF THE STATE OF CALIFORNIA

WHEREAS *on June 4, 2008, I issued an Executive Order proclaiming a statewide drought, and I ordered my administration to begin taking action to address the water shortage; and*

WHEREAS *on June 12, 2008, I proclaimed a state of emergency for nine Central Valley counties because the current and continuing severe drought had caused conditions of extreme peril to the safety of persons and property; and*

WHEREAS *on February 27, 2009, I proclaimed a state of emergency for the entire state as the severe drought conditions continued and the impacts were well beyond the Central Valley; and*

WHEREAS *on June 19, 2009, I issued an Executive Order that suspended the one-week waiting period for unemployment insurance applications and ordered the development of a comprehensive strategy to provide adequate nutrition for those individuals who are temporarily unable to afford food as a result of the severe drought conditions; and*

WHEREAS *severe drought conditions continue and over 28,000 people in Fresno County require emergency food assistance; and*

WHEREAS *local emergency food assistance organizations serving the Fresno County area cannot keep up with the demand for food; and*

WHEREAS *the circumstances of these continuing severe drought conditions, by reason of their magnitude, are or are likely to be beyond the control of the services, personnel, equipment, and facilities of any single county, city and county, or city and require the combined forces of a mutual aid region or regions to combat; and*

WHEREAS *under the provisions of section 8558(b) of the California Government Code, I find that conditions of extreme peril to the safety of persons and property continue to exist in Fresno County, caused by the current and continuing severe drought conditions.*

NOW, THEREFORE, I, ARNOLD SCHWARZENEGGER, *Governor of the State of California, in accordance with the authority vested in me by the state Constitution and statutes, including the California Emergency Services Act, and in particular, section 8625 of the California Government Code,* **HEREBY PROCLAIM A STATE OF EMERGENCY** *to exist within Fresno County.*

IT IS HEREBY ORDERED *that all agencies of the state government utilize and employ state personnel, equipment and facilities for the performance of any and all activities consistent with the direction of the California Emergency Management Agency (CalEMA) and the State Emergency Plan, and that CalEMA provide local government assistance under the authority of the California Disaster Assistance Act.*

I FURTHER DIRECT *that as soon as hereafter possible, this proclamation be filed in the Office of the Secretary of State and that widespread publicity and notice be given of this proclamation.*

IN WITNESS WHEREOF *I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 21st Day of July 2009.*

ARNOLD SCHWARZENEGGER, *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

05/20/2013

Executive Order B-21-13

WHEREAS *much of California experienced record dry conditions in January through March 2013, registering historic lows on the Northern Sierra and the San Joaquin precipitation indices; and*

WHEREAS *record dry and warm conditions resulted in a snowpack substantially below average, with estimated May water content in the statewide snowpack being only 17 percent of average and with the spring snowmelt season now being well underway; and*

WHEREAS *the water year began with adequate rainfall, but restrictions to protect Delta smelt prevented pumping water from the Delta to store in the San Luis Reservoir have resulted in substantial losses to the State Water Project and to the Central Valley Project; and*

WHEREAS *only 35 percent of State Water Project contractors' and 20 percent of south-of-Delta Central Valley Project agricultural contractors' requested amounts have been allocated because of these conditions; and*

WHEREAS *reductions in surface water deliveries will likely force San Joaquin Valley agricultural water users to extract additional groundwater from already overused basins, potentially resulting in additional land subsidence; and*

WHEREAS *the supply reductions will jeopardize agricultural production in parts of the San Joaquin Valley; and*

WHEREAS *the supply reductions will also impact millions of municipal and industrial water users across California; and*

WHEREAS *the Legislature has, in Water Code section 109, declared that the State's established policy is to facilitate the voluntary transfer of water and water rights, and has directed the Department of Water Resources and State Water Resources Control Board to encourage voluntary transfers.*

NOW, THEREFORE, I, EDMUND G. BROWN JR., *Governor of the State of California, do hereby issue this Order to become effective immediately.*

IT IS HEREBY ORDERED *that the Department of Water Resources (DWR) and the State Water Resources Control Board (SWRCB) take immediate action to address the dry conditions and water delivery limitations, by doing the following:*

1. *Expedite processing of one-year water transfers for 2013 and assist water transfer proponents and suppliers as necessary, provided that the transfers will not harm other legal users of water and will not unreasonably affect fish, wildlife, or other in-stream beneficial uses.*
2. *The SWRCB shall expedite review and processing of water transfer petitions in accordance with applicable provisions of the Water Code.*
3. *The DWR shall expedite and facilitate water transfer proposals in accordance with applicable provisions of the Water Code.*
4. *The DWR shall coordinate State Water Project operations, in cooperation with Central Valley Project operations, to alleviate critical impacts to San Joaquin Valley agriculture.*
5. *The DWR shall continue to analyze trends in groundwater levels in the San Joaquin Valley, together with impacts of groundwater extraction on land subsidence.*

6. *The DWR and the SWRCB shall make all efforts to coordinate with relevant federal agencies, water districts, and water agencies to expedite the review and approval of water transfers in California.*

This order is not intended to, and does not, create any rights or benefits, substantive or procedural, enforceable at law or in equity, against the State of California, its agencies, departments, entities, officers, employees, or any other person.

I FURTHER DIRECT *that as soon as hereafter possible, this Executive Order be filed in the Office of the Secretary of State and that widespread publicity and notice be given to this Executive Order.*

IN WITNESS WHEREOF *I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 20th day of May 2013.*

EDMUND G. BROWN JR., *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

01/17/2014

A Proclamation of a State of Emergency

WHEREAS *the State of California is experiencing record dry conditions, with 2014 projected to become the driest year on record; and*

WHEREAS *the state's water supplies have dipped to alarming levels, indicated by: snowpack in California's mountains is approximately 20 percent of the normal average for this date; California's largest water reservoirs have very low water levels for this time of year; California's major river systems, including the Sacramento and San Joaquin rivers, have significantly reduced surface water flows; and groundwater levels throughout the state have dropped significantly; and*

WHEREAS *dry conditions and lack of precipitation present urgent problems: drinking water supplies are at risk in many California communities; fewer crops can be cultivated and farmers' long-term investments are put at risk; low-income communities heavily dependent on agricultural employment will suffer heightened unemployment and economic hardship; animals and plants that rely on California's rivers, including many species in danger of extinction, will be threatened; and the risk of wildfires across the state is greatly increased; and*

WHEREAS *extremely dry conditions have persisted since 2012 and may continue beyond this year and more regularly into the future, based on scientific projections regarding the impact of climate change on California's snowpack; and*

WHEREAS *the magnitude of the severe drought conditions presents threats beyond the control of the services, personnel, equipment and facilities of any single local government and require the combined forces of a mutual aid region or regions to combat; and*

WHEREAS *under the provisions of section 8558(b) of the California Government Code, I find that conditions of extreme peril to the safety of persons and property exist in California due to water shortage and drought conditions with which local authority is unable to cope.*

NOW, THEREFORE, I, EDMUND G. BROWN JR., *Governor of the State of California, in accordance with the authority vested in me by the state Constitution and statutes, including the California Emergency Services Act, and in particular, section 8625 of the California Government Code* **HEREBY PROCLAIM A STATE OF EMERGENCY** *to exist in the State of California due to current drought conditions.*

IT IS HEREBY ORDERED THAT:

1. *State agencies, led by the Department of Water Resources, will execute a statewide water conservation campaign to make all Californians aware of the drought and encourage personal actions to reduce water usage. This campaign will be built on the existing Save Our Water campaign (www.saveourh20.org) and will coordinate with local water agencies. This campaign will call on Californians to reduce their water usage by 20 percent.*

2. *Local urban water suppliers and municipalities are called upon to implement their local water shortage contingency plans immediately in order to avoid or forestall outright restrictions that could become necessary later in the drought season. Local water agencies should also update their legally required urban and agricultural water management plans, which help plan for extended drought conditions. The Department of Water Resources will make the status of these updates publicly available.*
3. *State agencies, led by the Department of General Services, will immediately implement water use reduction plans for all state facilities. These plans will include immediate water conservation actions, and a moratorium will be placed on new, non-essential landscaping projects at state facilities and on state highways and roads.*
4. *The Department of Water Resources and the State Water Resources Control Board (Water Board) will expedite the processing of water transfers, as called for in Executive Order B-21-13. Voluntary water transfers from one water right holder to another enables water to flow where it is needed most.*
5. *The Water Board will immediately consider petitions requesting consolidation of the places of use of the State Water Project and Federal Central Valley Project, which would streamline water transfers and exchanges between water users within the areas of these two major water projects.*
6. *The Department of Water Resources and the Water Board will accelerate funding for water supply enhancement projects that can break ground this year and will explore if any existing unspent funds can be repurposed to enable near-term water conservation projects.*
7. *The Water Board will put water right holders throughout the state on notice that they may be directed to cease or reduce water diversions based on water shortages.*
8. *The Water Board will consider modifying requirements for reservoir releases or diversion limitations, where existing requirements were established to implement a water quality control plan. These changes would enable water to be conserved upstream later in the year to protect cold water pools for salmon and steelhead, maintain water supply, and improve water quality.*
9. *The Department of Water Resources and the Water Board will take actions necessary to make water immediately available, and, for purposes of carrying out directives 5 and 8, Water Code section 13247 and Division 13 (commencing with section 21000) of the Public Resources Code and regulations adopted pursuant to that Division are suspended on the basis that strict compliance with them will prevent, hinder, or delay the mitigation of the effects of the emergency. Department of Water Resources and the Water Board shall maintain on their websites a list of the activities or approvals for which these provisions are suspended.*

10. *The state's Drinking Water Program will work with local agencies to identify communities that may run out of drinking water, and will provide technical and financial assistance to help these communities address drinking water shortages. It will also identify emergency interconnections that exist among the state's public water systems that can help these threatened communities.*
11. *The Department of Water Resources will evaluate changing groundwater levels, land subsidence, and agricultural land fallowing as the drought persists and will provide a public update by April 30 that identifies groundwater basins with water shortages and details gaps in groundwater monitoring.*
12. *The Department of Water Resources will work with counties to help ensure that well drillers submit required groundwater well logs for newly constructed and deepened wells in a timely manner and the Office of Emergency Services will work with local authorities to enable early notice of areas experiencing problems with residential groundwater sources.*
13. *The California Department of Food and Agriculture will launch a one-stop website (www.cdfa.ca.gov/drought) that provides timely updates on the drought and connects farmers to state and federal programs that they can access during the drought.*
14. *The Department of Fish and Wildlife will evaluate and manage the changing impacts of drought on threatened and endangered species and species of special concern, and develop contingency plans for state Wildlife Areas and Ecological Reserves to manage reduced water resources in the public interest.*
15. *The Department of Fish and Wildlife will work with the Fish and Game Commission, using the best available science, to determine whether restricting fishing in certain areas will become necessary and prudent as drought conditions persist.*
16. *The Department of Water Resources will take necessary actions to protect water quality and water supply in the Delta, including installation of temporary barriers or temporary water supply connections as needed, and will coordinate with the Department of Fish and Wildlife to minimize impacts to affected aquatic species.*
17. *The Department of Water Resources will refine its seasonal climate forecasting and drought prediction by advancing new methodologies piloted in 2013.*
18. *The California Department of Forestry and Fire Protection will hire additional seasonal firefighters to suppress wildfires and take other needed actions to protect public safety during this time of elevated fire risk.*
19. *The state's Drought Task Force will immediately develop a plan that can be executed as needed to provide emergency food supplies, financial assistance, and unemployment services in communities that suffer high levels of unemployment from the drought.*
20. *The Drought Task Force will monitor drought impacts on a daily basis and will advise me of subsequent actions that should be taken if drought conditions worsen.*

I FURTHER DIRECT *that as soon as hereafter possible, this Proclamation be filed in the Office of the Secretary of State and that widespread publicity and notice be given of this Proclamation.*

IN WITNESS WHEREOF *I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 17th day of January, 2014.*

EDMUND G. BROWN JR., *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

04/25/2014

A Proclamation of a Continued State of Emergency

WHEREAS *on January 17, 2014, I proclaimed a State of Emergency to exist in the State of California due to severe drought conditions; and*

WHEREAS *state government has taken expedited actions as directed in that Proclamation to minimize harm from the drought; and*

WHEREAS *California's water supplies continue to be severely depleted despite a limited amount of rain and snowfall since January, with very limited snowpack in the Sierra Nevada mountains, decreased water levels in California's reservoirs, and reduced flows in the state's rivers; and*

WHEREAS *drought conditions have persisted for the last three years and the duration of this drought is unknown; and*

WHEREAS *the severe drought conditions continue to present urgent challenges: water shortages in communities across the state, greatly increased wildfire activity, diminished water for agricultural production, degraded habitat for many fish and wildlife species, threat of saltwater contamination of large fresh water supplies conveyed through the Sacramento-San Joaquin Bay Delta, and additional water scarcity if drought conditions continue into 2015; and*

WHEREAS *additional expedited actions are needed to reduce the harmful impacts from the drought as the state heads into several months of typically dry conditions; and*

WHEREAS *the magnitude of the severe drought conditions continues to present threats beyond the control of the services, personnel, equipment, and facilities of any single local government and require the combined forces of a mutual aid region or regions to combat; and*

WHEREAS *under the provisions of section 8558(b) of the Government Code, I find that conditions of extreme peril to the safety of persons and property continue to exist in California due to water shortage and drought conditions with which local authority is unable to cope; and*

WHEREAS *under the provisions of section 8571 of the Government Code, I find that strict compliance with the various statutes and regulations specified in this proclamation would prevent, hinder, or delay the mitigation of the effects of the drought.*

NOW, THEREFORE, I, EDMUND G. BROWN JR., *Governor of the State of California, in accordance with the authority vested in me by the Constitution and statutes of the State of California, including the Emergency Services Act and in particular Government Code section 8567, do hereby issue this Executive Order, effective immediately, to mitigate the effects of the drought conditions upon the people and property within the State of California.*

IT IS HEREBY ORDERED THAT:

1. *The orders and provisions contained in Proclamation No. 1-17-2014, dated January 17, 2014, remain in full force and effect except as modified herein.*

2. *The Department of Water Resources and the State Water Resources Control Board (Water Board) will immediately and expeditiously process requests to move water to areas of need, including requests involving voluntary water transfers, forbearance agreements, water exchanges, or other means. If necessary, the Department will request that the Water Board consider changes to water right permits to enable such voluntary movements of water.*

3. *Recognizing the tremendous importance of conserving water during this drought, all California residents should refrain from wasting water:*

   a. Avoid using water to clean sidewalks, driveways, parking lots and other hardscapes.

   b. Turn off fountains and other decorative water features unless recycled or grey water is available.

   c. Limit vehicle washing at home by patronizing local carwashes that use recycled water.

   d. Limit outdoor watering of lawns and landscaping to no more than two times a week.

   Recreational facilities, such as city parks and golf courses, and large institutional complexes, such as schools, business parks and campuses, should immediately implement water reduction plans to reduce the use of potable water for outdoor irrigation.

   Commercial establishments such as hotel and restaurants should take steps to reduce water usage and increase public awareness of the drought through measures such as offering drinking water only upon request and providing customers with options to avoid daily washing of towels or sheets.

   Professional sports facilities, such as basketball arenas, football, soccer, and baseball stadiums, and hockey rinks should reduce water usage and increase public awareness of the drought by reducing the use of potable water for outdoor irrigation and encouraging conservation by spectators.

   The Water Board shall direct urban water suppliers that are not already implementing drought response plans to limit outdoor irrigation and other wasteful water practices such as those identified in this Executive Order. The Water Board will request by June 15 an update from urban water agencies on their actions to reduce water usage and the effectiveness of these efforts. The Water Board is directed to adopt emergency regulations as it deems necessary, pursuant to Water Code section 1058.5, to implement this directive.

   Californians can learn more about conserving water from the Save Our Water campaign (SaveOurH2O.org).

4. *Homeowners Associations (commonly known as HOAs) have reportedly fined or threatened to fine homeowners who comply with water conservation measures adopted by a public agency or private water company. To prevent this practice, pursuant to Government Code section 8567, I order that any provision of the governing document, architectural or landscaping guidelines, or policies of a common interest development will be void and unenforceable to the extent it has the effect of prohibiting compliance with the water-saving measures contained in this directive, or any conservation measure adopted by a public agency or private water company, any provision of Division 4, Part 5 (commencing with section 4000) of the Civil Code notwithstanding.*

5. *All state agencies that distribute funding for projects that impact water resources, including groundwater resources, will require recipients of future financial assistance to have appropriate conservation and efficiency programs in place.*

6. *The Department of Fish and Wildlife will immediately implement monitoring of winter-run Chinook salmon in the Sacramento River and its tributaries, as well as several runs of salmon and species of smelt in the Delta as described in the April 8, 2014 Drought Operations Plan.*

7. *The Department of Fish and Wildlife will implement projects that respond to drought conditions through habitat restoration and through water infrastructure projects on property owned or managed by the Department of Fish and Wildlife or the Department of Water Resources for the benefit of fish and wildlife impacted by the drought.*
8. *The Department of Fish and Wildlife will work with other state and federal agencies and with landowners in priority watersheds to protect threatened and endangered species and species of special concern and maximize the beneficial uses of scarce water supplies, including employment of voluntary agreements to secure instream flows, relocation of members of those species, or through other measures.*
9. *The Department of Water Resources will expedite the consideration and, where appropriate, the implementation, of pump-back delivery of water through the State Water Project on behalf of water districts.*
10. *The Water Board will adopt statewide general waste discharge requirements to facilitate the use of treated wastewater that meets standards set by the Department of Public Health, in order to reduce demand on potable water supplies.*
11. *The Department of Water Resources will conduct intensive outreach and provide technical assistance to local agencies in order to increase groundwater monitoring in areas where the drought has significant impacts, and develop updated contour maps where new data becomes available in order to more accurately capture changing groundwater levels. The Department will provide a public update by November 30 that identifies groundwater basins with water shortages, details remaining gaps in groundwater monitoring, and updates its monitoring of land subsidence and agricultural land fallowing.*
12. *The California Department of Public Health, the Office of Emergency Services, and the Office of Planning and Research will assist local agencies that the Department of Public Health has identified as vulnerable to acute drinking water shortages in implementing solutions to those water shortages.*
13. *The Department of Water Resources and the Water Board, in coordination with other state agencies, will provide appropriate assistance to public agencies or private water companies in establishing temporary water supply connections to mitigate effects of the drought.*
14. *For the protection of health, safety, and the environment, CAL FIRE, the Office of Emergency Services, the Department of Water Resources, and the Department of Public Health, where appropriate, may enter into contracts and arrangements for the procurement of materials, goods, and services necessary to quickly mitigate the effects of the drought.*
15. *Pursuant to the drought legislation I signed into law on March 1, 2014, by July 1, 2014, the California Department of Food and Agriculture, in consultation with the Department of Water Resources and Water Board, will establish and implement a program to provide financial incentives to agricultural operations to invest in water irrigation treatment and distribution systems that reduce water and energy use, augment supply, and increase water and energy efficiency in agricultural applications.*

16. *To assist landowners meet their responsibilities for removing dead, dying and diseased trees and to help landowners clear other trees and plants close to structures that increase fire danger, certain noticing requirements are suspended for these activities. Specifically, the requirement that any person who conducts timber operations pursuant to the exemptions in Title 14, California Code of Regulations sections 1038 (b) and (c) submit notices to CAL FIRE under the provisions of Title 14, California Code of Regulations, section 1038.2 is hereby suspended. Timber operations pursuant to sections 1038 (b) and (c) may immediately commence operations upon submission of the required notice to CAL FIRE and without a copy of the Director's notice of acceptance at the operating site. All other provisions of these regulations will remain in effect.*
17. *The Water Board will adopt and implement emergency regulations pursuant to Water Code section 1058.5, as it deems necessary to prevent the waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water, to promote water recycling or water conservation, and to require curtailment of diversions when water is not available under the diverter's priority of right.*
18. *In order to ensure that equipment and services necessary for drought response can be procured quickly, the provisions of the Government Code and the Public Contract Code applicable to state contracts, including, but not limited to, advertising and competitive bidding requirements, are hereby suspended for directives 7 and 14. Approval by the Department of Finance is required prior to the execution of any contract entered into pursuant to these directives.*
19. *For several actions called for in this proclamation, environmental review required by the California Environmental Quality Act is suspended to allow these actions to take place as quickly as possible. Specifically, for actions taken by state agencies pursuant to directives 2, 3, 6–10, 13, 15, and 17, for all actions taken pursuant to directive 12 when the Office of Planning and Research concurs that local action is required, and for all necessary permits needed to implement these respective actions, Division 13 (commencing with section 21000) of the Public Resources Code and regulations adopted pursuant to that Division are hereby suspended. The entities implementing these directives will maintain on their websites a list of the activities or approvals for which these provisions are suspended. This suspension and that provided in paragraph 9 of the January 17, 2014 Proclamation will expire on December 31, 2014, except that actions started prior to that date shall not be subject to Division 13 for the time required to complete them.*
20. *For several actions called for in this proclamation, certain regulatory requirements of the Water Code are suspended to allow these actions to take place as quickly as possible. Specifically, for actions taken pursuant to directive 2, section 13247 of the Water Code is suspended. The 30-day comment period provided in section 1726(f) of the Water Code is also suspended for actions taken pursuant to directive 2, but the Water Board will provide for a 15-day comment period. For actions taken by state agencies pursuant to directives 6 and 7, Chapter 3 of Part 3 (commencing with section 85225) of the Water Code is suspended. The entities implementing these directives will maintain on their websites a list of the activities or approvals for which these provisions are suspended.*

I FURTHER DIRECT *that as soon as hereafter possible, this Proclamation shall be filed in the Office of the Secretary of State and that widespread publicity and notice be given to this Proclamation.*

IN WITNESS WHEREOF *I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 25th day of April, 2014*

EDMUND G. BROWN JR., *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

09/18/2014

Executive Order B-26-14

WHEREAS *on January 17, 2014, I proclaimed a State of Emergency to exist throughout the State of California due to severe drought conditions; and*

WHEREAS *on April 25, 2014, I proclaimed a Continued State of Emergency to exist throughout the State of California due to the ongoing drought; and*

WHEREAS *drought conditions have persisted for the last three years and the duration of this drought is unknown; and*

WHEREAS *many residents across the state who rely on domestic wells or very small water systems now live in homes that can no longer provide water for drinking or sanitation purposes due to declining groundwater supplies resulting from the drought; and*

WHEREAS *the shortage of water for drinking and sanitation purposes that many residents now face constitutes a threat to human health and safety; and*

WHEREAS *additional expedited actions are needed to reduce the harmful impacts from these water shortages and other impacts of the drought; and*

WHEREAS *the magnitude of the severe drought conditions continues to present threats beyond the control of the services, personnel, equipment, and facilities of any single local government and require the combined forces of a mutual aid region or regions to combat; and*

WHEREAS *under the provisions of section 8571 of the California Government Code, I find that strict compliance with various statutes and regulations specified in this order would prevent, hinder, or delay the mitigation of the effects of the drought.*

NOW, THEREFORE, I, EDMUND G. BROWN JR., *Governor of the State of California, in accordance with the authority vested in me by the Constitution and statutes of the State of California, in particular Government Code sections 8567 and 8571 of the California Government Code, do hereby issue this Executive Order, effective immediately.*

IT IS HEREBY ORDERED THAT:

1. *The Office of Emergency Services shall provide local government assistance as it deems appropriate for the purposes of providing temporary water supplies to households without water for drinking and/or sanitation purposes under the authority of the California Disaster Assistance Act, California Government Code section 8680 et seq. and California Code of Regulations, Title 19, section 2900 et seq.*
2. *The provisions of the Government Code and Public Contract Code applicable to state contracts and procurement, including but not limited to, advertising and competitive bidding requirements, are hereby waived for the sole purpose of allowing state agencies and departments to purchase water for the protection of health, safety, and the environment.*

3. *The provisions of California Penal Code section 396 prohibiting price gouging in times of emergency are hereby reinstated as of the date of this Order. The 30-day time period limitation under subsection (b) is hereby waived. For the purposes of calculating the price differential, the price of goods or services shall be compared to the price in effect as of the date of this Order.*
4. *The State Water Resources Control Board, the Department of Water Resources, the Office of Emergency Services, and the Office of Planning and Research will assist local agencies with the identification of acute drinking water shortages in domestic water supplies, and will work with local agencies in implementing solutions to those water shortages. For any actions the listed state agencies take pursuant to this directive, for any actions taken by a local agency where the Office of Planning and Research concurs that local action is required, and for any necessary permits to carry out those actions, Division 13 (commencing with section 21000) of the Public Resources Code and regulations adopted pursuant to that Division are hereby suspended. This suspension will expire on December 31, 2014, except that actions started prior to that date shall not be subject to Division 13 for the time required to complete them.*

This Executive Order is not intended to, and does not, create any rights or benefits, substantive or procedural, enforceable at law or in equity, against the State of California, its agencies, departments, entities, officers, employees, or any other person.

I FURTHER DIRECT *that as soon as hereafter possible, this Order be filed in the Office of the Secretary of State and that widespread publicity and notice be given to this Order.*

IN WITNESS WHEREOF *I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 18th day of September 2014.*

EDMUND G. BROWN JR., *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

12/22/2014

Executive Order B-28-14

WHEREAS *on January 17, 2014, I proclaimed a State of Emergency to exist throughout the State of California due to severe drought conditions; and*

WHEREAS *on April 25, 2014, I proclaimed a Continued State of Emergency to exist throughout the State of California due to the ongoing drought; and*

WHEREAS *the rainfall the State has recently experienced, while significant, is insufficient to end the historic drought that continues to impact the State, and it is unknown how much rain will fall over the next few months; and*

WHEREAS *additional expedited actions are needed to reduce the harmful impacts from water shortages and other impacts of the drought; and*

WHEREAS *the magnitude of the severe drought conditions continues to present threats beyond the control of the services, personnel, equipment, and facilities of any single local government and require the combined forces of a mutual aid region or regions to combat; and*

WHEREAS *under the provisions of section 8571 of the California Government Code, I find that strict compliance with various statutes and regulations specified in this order would prevent, hinder, or delay the mitigation of the effects of the drought.*

NOW, THEREFORE, I, EDMUND G. BROWN JR., *Governor of the State of California, in accordance with the authority vested in me by the Constitution and statutes of the State of California, in particular Government Code sections 8567 and 8571 of the California Government Code, do hereby issue this Executive Order, effective immediately.*

IT IS HEREBY ORDERED THAT:

The waiver of the California Environmental Quality Act and Water Code section 13247 in paragraph 9 of the January 17, 2014 Proclamation, and paragraph 19 of the April 25, 2014 Proclamation, is extended through May 31, 2016. This waiver shall also apply to the adoption of water reclamation requirements by the State Water Board that serve the purpose of paragraph 10 of the April 25, 2014 Proclamation. Drought relief actions taken pursuant to these paragraphs that are started prior to May 31, 2016, but not completed, shall not be subject to Division 13 (commencing with section 21000) of the Public Resources Code or Water Code section 13247 for the time required to complete them.

This Executive Order is not intended to, and does not, create any rights or benefits, substantive or procedural, enforceable at law or in equity, against the State of California, its agencies, departments, entities, officers, employees, or any other person.

I FURTHER DIRECT *that as soon as hereafter possible, this Order be filed in the Office of the Secretary of State and that widespread publicity and notice be given to this Order.*

IN WITNESS WHEREOF *I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 22nd day of December 2014.*

EDMUND G. BROWN JR., *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

04/01/2015

Executive Order B-29-15

WHEREAS *on January 17, 2014, I proclaimed a State of Emergency to exist throughout the State of California due to severe drought conditions; and*

WHEREAS *on April 25, 2014, I proclaimed a Continued State of Emergency to exist throughout the State of California due to the ongoing drought; and*

WHEREAS *California's water supplies continue to be severely depleted despite a limited amount of rain and snowfall this winter, with record low snowpack in the Sierra Nevada mountains, decreased water levels in most of California's reservoirs, reduced flows in the state's rivers and shrinking supplies in underground water basins; and*

WHEREAS *the severe drought conditions continue to present urgent challenges including: drinking water shortages in communities across the state, diminished water for agricultural production, degraded habitat for many fish and wildlife species, increased wildfire risk, and the threat of saltwater contamination to fresh water supplies in the Sacramento-San Joaquin Bay Delta; and*

WHEREAS *a distinct possibility exists that the current drought will stretch into a fifth straight year in 2016 and beyond; and*

WHEREAS *new expedited actions are needed to reduce the harmful impacts from water shortages and other impacts of the drought; and*

WHEREAS *the magnitude of the severe drought conditions continues to present threats beyond the control of the services, personnel, equipment, and facilities of any single local government and require the combined forces of a mutual aid region or regions to combat; and*

WHEREAS *under the provisions of section 8558(b) of the Government Code, I find that conditions of extreme peril to the safety of persons and property continue to exist in California due to water shortage and drought conditions with which local authority is unable to cope; and*

WHEREAS *under the provisions of section 8571 of the California Government Code, I find that strict compliance with various statutes and regulations specified in this order would prevent, hinder, or delay the mitigation of the effects of the drought.*

NOW, THEREFORE, I, EDMUND G. BROWN JR., *Governor of the State of California, in accordance with the authority vested in me by the Constitution and statutes of the State of California, in particular Government Code sections 8567 and 8571 of the California Government Code, do hereby issue this Executive Order, effective immediately.*

IT IS HEREBY ORDERED THAT:

1. *The orders and provisions contained in my January 17, 2014 Proclamation, my April 25, 2014 Proclamation, and Executive Orders B-26-14 and B-28-14 remain in full force and effect except as modified herein.*

SAVE WATER

2. *The State Water Resources Control Board (Water Board) shall impose restrictions to achieve a statewide 25%*

reduction in potable urban water usage through February 28, 2016. These restrictions will require water suppliers to California's cities and towns to reduce usage as compared to the amount used in 2013. These restrictions should consider the relative per capita water usage of each water suppliers' service area, and require that those areas with high per capita use achieve proportionally greater reductions than those with low use. The California Public Utilities Commission is requested to take similar action with respect to investor-owned utilities providing water services.

3. *The Department of Water Resources (the Department) shall lead a statewide initiative, in partnership with local agencies, to collectively replace 50 million square feet of lawns and ornamental turf with drought tolerant landscapes. The Department shall provide funding to allow for lawn replacement programs in underserved communities, which will complement local programs already underway across the state.*
4. *The California Energy Commission, jointly with the Department and the Water Board, shall implement a time-limited statewide appliance rebate program to provide monetary incentives for the replacement of inefficient household devices.*
5. *The Water Board shall impose restrictions to require that commercial, industrial, and institutional properties, such as campuses, golf courses, and cemeteries, immediately implement water efficiency measures to reduce potable water usage in an amount consistent with the reduction targets mandated by Directive 2 of this Executive Order.*
6. *The Water Board shall prohibit irrigation with potable water of ornamental turf on public street medians.*
7. *The Water Board shall prohibit irrigation with potable water outside of newly constructed homes and buildings that is not delivered by drip or microspray systems.*
8. *The Water Board shall direct urban water suppliers to develop rate structures and other pricing mechanisms, including but not limited to surcharges, fees, and penalties, to maximize water conservation consistent with statewide water restrictions. The Water Board is directed to adopt emergency regulations, as it deems necessary, pursuant to Water Code section 1058.5 to implement this directive. The Water Board is further directed to work with state agencies and water suppliers to identify mechanisms that would encourage and facilitate the adoption of rate structures and other pricing mechanisms that promote water conservation. The California Public Utilities Commission is requested to take similar action with respect to investor-owned utilities providing water services.*

INCREASE ENFORCEMENT AGAINST WATER WASTE

9. *The Water Board shall require urban water suppliers to provide monthly information on water usage, conservation, and enforcement on a permanent basis.*
10. *The Water Board shall require frequent reporting of water diversion and use by water right holders, conduct inspections to determine whether illegal diversions or wasteful and unreasonable use of water are occurring, and bring enforcement actions against illegal diverters and those engaging in the wasteful and unreasonable use of water. Pursuant to Government Code sections 8570 and 8627, the Water Board is granted authority to inspect property or diversion facilities to ascertain compliance with water rights laws and regulations where there is cause to believe such laws and regulations have been violated. When access is not granted by a property owner, the Water Board may obtain an inspection warrant pursuant to the procedures set 1 forth in Title 13 (commencing with section 1822.50) of Part 3 of the Code of Civil Procedure for the purposes of conducting an inspection pursuant to this directive.*
11. *The Department shall update the State Model Water Efficient Landscape Ordinance through expedited regulation. This updated Ordinance shall increase water efficiency standards for new and existing landscapes through more efficient irrigation systems, greywater usage,*

onsite storm water capture, and by limiting the portion of landscapes that can be covered in turf. It will also require reporting on the implementation and enforcement of local ordinances, with required reports due by December 31, 2015. The Department shall provide information on local compliance to the Water Board, which shall consider adopting regulations or taking appropriate enforcement actions to promote compliance. The Department shall provide technical assistance and give priority in grant funding to public agencies for actions necessary to comply with local ordinances.

12. *Agricultural water suppliers that supply water to more than 25,000 acres shall include in their required 2015 Agricultural Water Management Plans a detailed drought management plan that describes the actions and measures the supplier will take to manage water demand during drought. The Department shall require those plans to include quantification of water supplies and demands for 2013, 2014, and 2015 to the extent data is available. The Department will provide technical assistance to water suppliers in preparing the plans.*
13. *Agricultural water suppliers that supply water to 10,000 to 25,000 acres of irrigated lands shall develop Agricultural Water Management Plans and submit the plans to the Department by July 1, 2016. These plans shall include a detailed drought management plan and quantification of water supplies and demands in 2013, 2014, and 2015, to the extent that data is available. The Department shall give priority in grant funding to agricultural water suppliers that supply water to 10,000 to 25,000 acres of land for development and implementation of Agricultural Water Management Plans.*
14. *The Department shall report to Water Board on the status of the Agricultural Water Management Plan submittals within one month of receipt of those reports.*
15. *Local water agencies in high and medium priority groundwater basins shall immediately implement all requirements of the California Statewide Groundwater Elevation Monitoring Program pursuant to Water Code section 10933. The Department shall refer noncompliant local water agencies within high and medium priority groundwater basins to the Water Board by December 31, 2015, which shall consider adopting regulations or taking appropriate enforcement to promote compliance.*
16. *The California Energy Commission shall adopt emergency regulations establishing standards that improve the efficiency of water appliances, including toilets, urinals, and faucets available for sale and installation in new and existing buildings.*

INVEST IN NEW TECHNOLOGIES

17. *The California Energy Commission, jointly with the Department and the Water Board, shall implement a Water Energy Technology (WET) program to deploy innovative water management technologies for businesses, residents, industries, and agriculture. This program will achieve water and energy savings and greenhouse gas reductions by accelerating use of cutting-edge technologies such as renewable energy-powered desalination, integrated onsite reuse systems, water-use monitoring software, irrigation system timing and precision technology, and on-farm precision technology.*

STREAMLINE GOVERNMENT RESPONSE

18. *The Office of Emergency Services and the Department of Housing and Community Development shall work jointly with counties to provide temporary assistance for persons moving from housing units due to a lack of potable water who are served by a private well or water utility with less than 15 connections, and where all reasonable attempts to find a potable water source have been exhausted.*
19. *State permitting agencies shall prioritize review and approval of water infrastructure projects and programs that increase local water supplies, including water recycling facilities, reservoir improvement projects, surface water treatment plants, desalination plants, stormwater capture, and greywater systems. Agencies*

shall report to the Governor's Office on applications that have been pending for longer than 90 days.

20. *The Department shall take actions required to plan and, if necessary, implement Emergency Drought Salinity Barriers in coordination and consultation with the Water Board and the Department of Fish and Wildlife at locations within the Sacramento-San Joaquin delta estuary. These barriers will be designed to conserve water for use later in the year to meet state and federal Endangered Species Act requirements, preserve to the extent possible water quality in the Delta, and retain water supply for essential human health and safety uses in 2015 and in the future.*
21. *The Water Board and the Department of Fish and Wildlife shall immediately consider any necessary regulatory approvals for the purpose of installation of the Emergency Drought Salinity Barriers.*
22. *The Department shall immediately consider voluntary crop idling water transfer and water exchange proposals of one year or less in duration that are initiated by local public agencies and approved in 2015 by the Department subject to the criteria set forth in Water Code section 1810.*
23. *The Water Board will prioritize new and amended safe drinking water permits that enhance water supply and reliability for community water systems facing water shortages or that expand service connections to include existing residences facing water shortages. As the Department of Public Health's drinking water program was transferred to the Water Board, any reference to the Department of Public Health in any prior Proclamation or Executive Order listed in Paragraph 1 is deemed to refer to the Water Board.*
24. *The California Department of Forestry and Fire Protection shall launch a public information campaign to educate the public on actions they can take to help to prevent wildfires including the proper treatment of dead and dying trees. Pursuant to Government Code section 8645, $1.2 million from the State Responsibility Area Fire Prevention Fund (Fund 3063) shall be allocated to the California Department of Forestry and Fire Protection to carry out this directive.*
25. *The Energy Commission shall expedite the processing of all applications or petitions for amendments to power plant certifications issued by the Energy Commission for the purpose of securing alternate water supply necessary for continued power plant operation. Title 20, section 1769 of the California Code of Regulations is hereby waived for any such petition, and the Energy Commission is authorized to create and implement an alternative process to consider such petitions. This process may delegate amendment approval authority, as appropriate, to the Energy Commission Executive Director. The Energy Commission shall give timely notice to all relevant local, regional, and state agencies of any petition subject to this directive, and shall post on its website any such petition.*
26. *For purposes of carrying out directives 2–9, 11, 16–17, 20–23, and 25, Division 13 (commencing with section 21000) of the Public Resources Code and regulations adopted pursuant to that Division are hereby suspended. This suspension applies to any actions taken by state agencies, and for actions taken by local agencies where the state agency with primary responsibility for implementing the directive concurs that local action is required, as well as for any necessary permits or approvals required to complete these actions. This suspension, and those specified in paragraph 9 of the January 17, 2014 Proclamation, paragraph 19 of the April 25, 2014 proclamation, and paragraph 4 of Executive Order B-26-14, shall remain in effect until May 31, 2016. Drought relief actions taken pursuant to these paragraphs that are started prior to May 31, 2016, but not completed, shall not be subject to Division 13 (commencing with section 21000) of the Public Resources Code for the time required to complete them.*
27. *For purposes of carrying out directives 20 and 21, section 13247 and Chapter 3 of Part 3 (commencing with section 85225) of the Water Code are suspended.*

28. *For actions called for in this proclamation in directive 20, the Department shall exercise any authority vested in the Central Valley Flood Protection Board, as codified in Water Code section 8521, et seq., that is necessary to enable these urgent actions to be taken more quickly than otherwise possible. The Director of the Department of Water Resources is specifically authorized, on behalf of the State of California, to request that the Secretary of the Army, on the recommendation of the Chief of Engineers of the Army Corps of Engineers, grant any permission required pursuant to section 14 of the Rivers and Harbors Act of 1899 and codified in section 48 of title 33 of the United States Code.*
29. *The Department is directed to enter into agreements with landowners for the purposes of planning and installation of the Emergency Drought Barriers in 2015 to the extent necessary to accommodate access to barrier locations, land-side and water-side construction, and materials staging in proximity to barrier locations. Where the Department is unable to reach an agreement with landowners, the Department may exercise the full authority of Government Code section 8572.*
30. *For purposes of this Executive Order, chapter 3.5 (commencing with section 11340) of part 1 of division 3 of the Government Code and chapter 5 (commencing with section 25400) of division 15 of the Public Resources Code are suspended for the development and adoption of regulations or guidelines needed to carry out the provisions in this Order. Any entity issuing regulations or guidelines pursuant to this directive shall conduct a public meeting on the regulations and guidelines prior to adopting them.*
31. *In order to ensure that equipment and services necessary for drought response can be procured quickly, the provisions of the Government Code and the Public Contract Code applicable to state contracts, including, but not limited to, advertising and competitive bidding requirements, are hereby suspended for directives 17, 20, and 24. Approval by the Department of Finance is required prior to the execution of any contract entered into pursuant to these directives.*

This Executive Order is not intended to, and does not, create any rights or benefits, substantive or procedural, enforceable at law or in equity, against the State of California, its agencies, departments, entities, officers, employees, or any other person.

I FURTHER DIRECT *that as soon as hereafter possible, this Order be filed in the Office of the Secretary of State and that widespread publicity and notice be given to this Order.*

IN WITNESS WHEREOF *I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 1st day of April 2015.*

EDMUND G. BROWN JR., *Governor of California*

ATTEST:

ALEX PADILLA, *Secretary of State*

10/30/2015

A Proclamation of a State of Emergency

WHEREAS *the State of California is experiencing record drought conditions, which have persisted for the last four years; and*

WHEREAS *on January 17, 2014, I proclaimed a State of Emergency to exist throughout the State of California due to severe drought conditions; and*

WHEREAS *a lack of precipitation over the last four years has made trees in many regions of California susceptible to epidemic infestations of native bark beetles, which are constrained under normal circumstances by the defense mechanisms of healthy trees; and*

WHEREAS *these drought conditions and resulting bark beetle infestations across broad areas have caused vast tree mortality in several regions of the state, with the United States Forest Service estimating that over 22 million trees are dead and that tens of millions more are likely to die by the end of this year; and*

WHEREAS *recent scientific measurements suggest that the scale of this tree die-off is unprecedented in modern history; and*

WHEREAS *this die-off is of such scale that it worsens wildfire risk across large regions of the State, presents life safety risks from falling trees to Californians living in impacted rural, forested communities, and worsens the threat of erosion across watersheds; and*

WHEREAS *such wildfires will release thousands of tons of greenhouse gas emissions and other harmful air pollutants; and*

WHEREAS *the circumstances of the tree die-off, by reason of its magnitude, is or is likely to be beyond the control of the services, personnel, equipment and facilities of any single county, city and county, or city and require the combined forces of a mutual aid region or regions to combat; and*

WHEREAS *under the provisions of section 8558(b) of the California Government Code, I find that conditions of extreme peril to the safety of persons and property exist within the State of California due to these events; and*

WHEREAS *under the provisions of section 8571 of the California Government Code, I find that strict compliance with various statutes and regulations specified in this order would prevent, hinder, or delay the mitigation of the effects of the drought.*

NOW, THEREFORE, I, EDMUND G. BROWN JR., *Governor of the State of California, in accordance with the authority vested in me by the State Constitution and statutes, including the California Emergency Services Act, and in particular, section 8625 of the California Government Code,* **HEREBY PROCLAIM A STATE OF EMERGENCY** *to exist within the State of California.*

IT IS HEREBY ORDERED THAT:

1. *The Department of Forestry and Fire Protection, the California Natural Resources Agency, the California Department of Transportation, and the California Energy Commission shall immediately identify areas of the State that represent high hazard zones for wildfire and falling trees using best available science and geospatial data.*
2. *State agencies, utilities, and local governments to the extent required by their existing responsibilities to protect the public health and safety, shall undertake efforts to remove dead or dying trees in these high hazard zones that threaten power lines, roads and other evacuation corridors, critical community infrastructure, and other existing structures. Incidental vegetation such as shrubs that restrict access for safe and efficient removal of the dead and dying trees also may be removed. The Department of Forestry and Fire Protection shall issue emergency guidelines setting forth the relevant criteria, and the California Conservation Corps shall assist government entities in implementing this directive to the extent feasible.*
3. *The Department of Forestry and Fire Protection shall identify potential storage locations for removed trees across impacted areas in partnership with federal agencies and local jurisdictions.*
4. *The California Department of Transportation shall formally request immediate assistance through the Federal Highway Administration's Emergency Relief Program, Title 23, United States Code section 125, in order to obtain federal assistance for removal of dead and dying trees that are adjacent to highways.*
5. *The Department of General Services will identify state facilities, and the California Department of Transportation shall identify highway and road corridors, where woodchips produced from dead trees can be used as mulch.*
6. *The Governor's Office of Emergency Services and the Department of Forestry and Fire Protection shall work with impacted counties to distribute portable equipment across high hazard zones so that isolated communities can remove and process wood waste locally where appropriate.*
7. *The California Air Resources Board and the California Department of Forestry and Fire Protection shall work together and with federal land managers and the United States Environmental Protection Agency to expand the practice of prescribed burns, which reduce fire risk and avoid significant pollution from major wildfires, and increase the number of allowable days on a temporary basis to burn tree waste that has been removed in high hazard areas.*
8. *The California Public Utilities Commission shall utilize its authority to extend contracts on existing forest bioenergy facilities receiving feedstock from high hazard zones.*
9. *The California Public Utilities Commission shall take expedited action to ensure that contracts for new forest bioenergy facilities that receive feedstock from high hazard zones can be executed within six months, including initiation of a targeted renewable auction mechanism and consideration of adjustments to the BioMat Program defined pursuant to Public Utilities Code section 399.20. No later than six months after the BioMat program begins, the California Public Utilities Commission shall evaluate the need for revisions to the program to facilitate contracts for forest bioenergy facilities.*
10. *The California Public Utilities Commission shall prioritize facilitation of interconnection agreements for forest bioenergy facilities in high hazard zones, and shall order the use of expedited mediation or other alternative dispute resolution processes when conflicts delay development of projects.*

11. *The California Energy Commission shall prioritize grant funding from the Electric Program Investment Charge for woody biomass-to-energy technology development and deployment, consistent with direction from the California Public Utilities Commission.*
12. *The California Department of Forestry and Fire Protection, the California Energy Commission, and other appropriate agencies shall work with land managers to estimate biomass feedstock availability, storage locations, and volumes that may be available for use as bioenergy feedstock at existing and new facilities.*
13. *The California Department of Forestry and Fire Protection and the California Energy Commission shall work with bioenergy facilities that accept forest biomass from high hazards zones to identify potential funds to help offset higher feedstock costs.*
14. *The California Department of Resources Recycling and Recovery and the California Department of Forestry and Fire Protection will work with affected counties and existing wood product markets to determine the feasibility for expanded wood product markets in California.*
15. *For purposes of carrying out directives 1, 2, and 5 through 8, Division 13 (commencing with section 21000) of the Public Resources Code and regulations adopted pursuant to that Division are hereby suspended. This suspension applies to any actions taken by state agencies, and for actions taken by local agencies where the state agency with primary responsibility for implementing the directive concurs that local action is required, as well as for any necessary permits or approvals required to complete these actions.*
16. *In order to ensure that equipment and services necessary for emergency response can be procured quickly, the provisions of the Government Code and the Public Contract Code applicable to state contracts, including, but not limited to, advertising and competitive bidding requirements, are hereby suspended as necessary to carry out this Proclamation. Approval by the Department of Finance is required prior to the execution of any contract entered into pursuant to these directives.*
17. *For purposes of this Proclamation, Chapter 3.5 (commencing with section 11340) of Part 1 of Division 3 of the Government Code is suspended for the development and adoption of regulations or guidelines needed to carry out the provisions in this Order. Any entity issuing regulations or guidelines pursuant to this directive shall conduct a public meeting on the regulations and guidelines prior to adopting them.*
18. *The Office of Emergency Services shall provide local government assistance as appropriate under the authority of the California Disaster Assistance Act, California Government Code section 8680 et seq. and California Code of Regulations, title 19, section 2900 et seq.*
19. *State agencies shall actively monitor tree removal efforts directed by this Proclamation to assess their effectiveness in protecting forest health and strengthening forest resilience.*

This Proclamation is not intended to, and does not, create any rights or benefits, substantive or procedural, enforceable at law or in equity, against the State of California, its agencies, departments, entities, officers, employees, or any other person.

I FURTHER DIRECT *that as soon as hereafter possible, this proclamation be filed in the Office of the Secretary of State and that widespread publicity and notice be given of this proclamation.*

IN WITNESS WHEREOF *I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 30th day of October 2015.*

EDMUND G. BROWN JR., *Governor of California*

ATTEST:

ALEX PADILLA, *Secretary of State*

11/13/2015

Executive Order B-36-15

WHEREAS *on January 17, 2014, I proclaimed a State of Emergency throughout the State of California due to severe drought conditions, which persist after four years; and*

WHEREAS *California is experiencing a range of extreme weather events such that the state must simultaneously prepare for a fifth year of drought and the possibility of major winter storms driven by the warming trend in the Pacific Ocean known as El Niño; and*

WHEREAS *the ongoing drought continues to affect water supplies, agriculture, businesses, and communities, and is further stressing California's fish and wildlife; and*

WHEREAS *wildfires have damaged critical infrastructure, including power plants, and hundreds of thousands of acres are and continue to be vulnerable to debris and mudslides due to scarring from significant wildfires in recent years; and*

WHEREAS *the magnitude of the severe drought conditions and wildfires continues to present threats beyond the control of the services, personnel, equipment, and facilities of any single local government and require the combined forces of a mutual aid region or regions to combat; and*

WHEREAS *under the provisions of section 8558(b) of the Government Code, I find that conditions of extreme peril to the safety of persons and property continue to exist in California due to water shortage, drought conditions, and wildfires; and*

WHEREAS *under the provisions of section 8571 of the Government Code, I find that strict compliance with various statutes and regulations specified in this order would prevent, hinder, or delay the mitigation of the effects of the drought and wildfires.*

NOW, THEREFORE, I, EDMUND G. BROWN JR., *Governor of the State of California, in accordance with the authority vested in me by the Constitution and statutes of the State of California, in particular sections 8567 and 8571 of the Government Code, do hereby issue this Executive Order, effective immediately.*

IT IS HEREBY ORDERED THAT:

1. *The orders and provisions contained in my January 17, 2014 Proclamation, my April 25, 2014 Proclamation, and Executive Orders B-26-14, B-28-14, and B-29-15 remain in full force and effect except as modified herein.*
2. *To demonstrate the feasibility of projects that can use available high water flows to recharge local groundwater while minimizing flooding risks, the State Water Resources Control Board and California Regional Water Quality Control Boards shall prioritize temporary water right permits, water quality certifications, waste discharge requirements, and conditional waivers of waste discharge requirements to accelerate approvals for projects that enhance the ability of a local or state agency to capture high precipitation events this winter and spring for local*

storage or recharge, consistent with water rights priorities and protections for fish and wildlife.

3. *If drought conditions persist through January 2016, the Water Board shall extend until October 31, 2016, restrictions to achieve a statewide reduction in urban potable water usage. The Water Board shall consider modifying its existing restrictions to address uses of potable and non-potable water, as well as to incorporate insights gained from existing restrictions. The California Public Utilities Commission is requested to take similar action with respect to investor-owned utilities providing water services.*
4. *Of the $15 million appropriated in Item 3940-101-0679 of the Budget Act of 2015, the State Water Resources Control Board shall use up to $5 million for permanent solutions that provide safer, cleaner, and more reliable drinking water to households served by water systems serving less than 15 drinking water connections or households served by domestic wells or other individual water supplies. The Water Board shall prioritize funds to public agencies and other entities eligible for funding under Water Code section 13442, but the Water Board may provide direct assistance to well owners without water for alternative safe drinking water supplies, if an entity eligible under Water Code section 13442 is unable or unwilling to provide assistance.*
5. *The Energy Commission shall expedite the processing of all applications or petitions for amendments to power plant certifications issued by the Energy Commission for the purpose of remediating any wildfire damage and to restore power plant operation by authorizing emergency construction activities including demolition, alteration, replacement, repair or reconstruction necessary for power plant operation. Title 20, section 1769 of the California Code of Regulations is hereby waived for any such petition, and the Executive Director of the Energy Commission shall approve such petitions as he deems necessary. The Energy Commission shall give timely notice to all relevant local, regional, and state agencies of any petition subject to this directive, and shall post on its website any such petition.*
6. *For purposes of carrying out directives in this Executive Order, Division 13 (commencing with section 21000) of the Public Resources Code and regulations adopted pursuant to that Division are hereby suspended. This suspension applies to any actions taken by state agencies, and for actions taken by local agencies where the state agency with primary responsibility for implementing the directive concurs that local action is required, as well as for any necessary permits or approvals required to complete these actions. This suspension, and those specified in paragraph 26 of Executive Order B-29-15 and any similar suspension specified in any of the orders listed in Paragraph 1 shall remain in effect until the drought state of emergency, or wildfire state of emergency with respect to directive 16, is terminated.*
7. *For purposes of carrying out directive 5, Chapter 3.5 (commencing with section 11340) of Part 1 of Division 3 of the Government Code is suspended for the development and adoption of regulations or guidelines needed to carry out the provisions in this Order.*

This Executive Order is not intended to, and does not, create any rights or benefits, substantive or procedural, enforceable at law or in equity, against the State of California, its agencies, departments, entities, officers, employees, or any other person.

I FURTHER DIRECT *that as soon as hereafter possible, this order be filed in the Office of the Secretary of State and that widespread publicity and notice be given of this order.*

IN WITNESS WHEREOF *I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 13th day of November 2015.*

EDMUND G. BROWN JR., *Governor of California*

ATTEST:

ALEX PADILLA, *Secretary of State*

05/09/2016

Executive Order B-37-16 Making Conservation a California Way of Life

WHEREAS *California has suffered through a severe multi-year drought that has threatened the water supplies of communities and residents, devastated agricultural production in many areas, and harmed fish, animals and their environmental habitats; and*

WHEREAS *Californians responded to the drought by conserving water at unprecedented levels, reducing water use in communities by 23.9% between June 2015 and March 2016 and saving enough water during this period to provide 6.5 million Californians with water for one year; and*

WHEREAS *severe drought conditions persist in many areas of the state despite recent winter precipitation, with limited drinking water supplies in some communities, diminished water for agricultural production and environmental habitat, and severely depleted groundwater basins; and*

WHEREAS *drought conditions may persist in some parts of the state into 2017 and beyond, as warmer winter temperatures driven by climate change reduce water supply held in mountain snowpack and result in drier soil conditions; and*

WHEREAS *these ongoing drought conditions and our changing climate require California to move beyond temporary emergency drought measures and adopt permanent changes to use water more wisely and to prepare for more frequent and persistent periods of limited water supply; and*

WHEREAS *increasing long-term water conservation among Californians, improving water use efficiency within the state's communities and agricultural production, and strengthening local and regional drought planning are critical to California's resilience to drought and climate change; and*

WHEREAS *these activities are prioritized in the California Water Action Plan, which calls for concrete, measurable actions that "Make Conservation a California Way of Life" and "Manage and Prepare for Dry Periods" in order to improve use of water in our state.*

NOW, THEREFORE, I, EDMUND G. BROWN JR., *Governor of the State of California, in accordance with the authority vested in me by the Constitution and statutes of the State of California, in particular California Government Code sections 8567 and 8571, do hereby issue this Executive Order, effective immediately.*

IT IS HEREBY ORDERED THAT:

The orders and provisions contained in my January 17, 2014 Emergency Proclamation, my April 25, 2014 Emergency Proclamation, Executive Orders B-26-14, B-28-14, B-29-15, and B-36-15 remain in full force and in effect except as modified herein.

State agencies shall update temporary emergency water restrictions and transition to permanent, long-term improvements in water use by taking the following actions.

USE WATER MORE WISELY

1. *The State Water Resources Control Board (Water Board) shall, as soon as practicable, adjust emergency water conservation regulations through the end of January 2017 in recognition of the differing water supply conditions across the state. To prepare for the possibility of another dry winter, the Water Board shall also develop, by January 2017, a proposal to achieve a mandatory reduction in potable urban water usage that builds off of the mandatory 25% reduction called for in Executive Order B-29-15 and lessons learned through 2016.*
2. *The Department of Water Resources (Department) shall work with the Water Board to develop new water use targets as part of a permanent framework for urban water agencies. These new water use targets shall build upon the existing state law requirements that the state achieve a 20% reduction in urban water usage by 2020. (Senate Bill No. 7 (7th Extraordinary Session, 2009–2010).) These water use targets shall be customized to the unique conditions of each water agency, shall generate more statewide water conservation than existing requirements, and shall be based on strengthened standards for:*
   a. *Indoor residential per capita water use;*
   b. *Outdoor irrigation, in a manner that incorporates landscape area, local climate, and new satellite imagery data;*
   c. *Commercial, industrial, and institutional water use; and*
   d. *Water lost through leaks.*

   The Department and Water Board shall consult with urban water suppliers, local governments, environmental groups, and other partners to develop these water use targets and shall publicly issue a proposed draft framework by January 10, 2017.
3. *The Department and the Water Board shall permanently require urban water suppliers to issue a monthly report on their water usage, amount of conservation achieved, and any enforcement efforts.*
4. *The Water Board shall permanently prohibit practices that waste potable water, such as:*
   - *Hosing off sidewalks, driveways and other hardscapes;*
   - *Washing automobiles with hoses not equipped with a shut-off nozzle;*
   - *Using non-recirculated water in a fountain or other decorative water feature;*
   - *Watering lawns in a manner that causes runoff, or within 48 hours after measurable precipitation; and*
   - *Irrigating ornamental turf on public street medians.*
5. *The Water Board and the Department shall direct actions to minimize water system leaks that waste large amounts of water. The Water Board, after funding projects to address health and safety, shall use loans from the Drinking Water State Revolving Fund to prioritize local projects that reduce leaks and other water system losses.*
6. *The Water Board and the Department shall direct urban and agricultural water suppliers to accelerate their data collection, improve water system management, and prioritize capital projects to reduce water waste. The California Public Utilities Commission shall order investor-owned water utilities to accelerate work to minimize leaks.*
7. *The California Energy Commission shall certify innovative water conservation and water loss detection and control technologies that also increase energy efficiency.*

STRENGTHEN LOCAL DROUGHT RESILIENCE

8. *The Department shall strengthen requirements for urban Water Shortage Contingency Plans, which urban water agencies are required to maintain. These updated requirements shall include adequate actions to respond to droughts lasting at least five years, as well as more frequent and severe periods of drought. While remaining customized according to local conditions, the updated requirements shall also create common statewide standards so that these plans can be quickly utilized during this and any future droughts.*

9. *The Department shall consult with urban water suppliers, local governments, environmental groups, and other partners to update requirements for Water Shortage Contingency Plans. The updated draft requirements shall be publicly released by January 10, 2017.*
10. *For areas not covered by a Water Shortage Contingency Plan, the Department shall work with counties to facilitate improved drought planning for small water suppliers and rural communities.*

IMPROVE AGRICULTURAL WATER USE EFFICIENCY AND DROUGHT PLANNING

11. *The Department shall work with the California Department of Food and Agriculture to update existing requirements for Agricultural Water Management Plans to ensure that these plans identify and quantify measures to increase water efficiency in their service area and to adequately plan for periods of limited water supply.*
12. *The Department shall permanently require the completion of Agricultural Water Management Plans by water suppliers with over 10,000 irrigated acres of land.*
13. *The Department, together with the California Department of Food and Agriculture, shall consult with agricultural water suppliers, local governments, agricultural producers, environmental groups, and other partners to update requirements for Agricultural Water Management Plans. The updated draft requirements shall be publicly released by January 10, 2017. The Department, Water Board and California Public Utilities Commission shall develop methods to ensure compliance with the provisions of this Executive Order, including technical and financial assistance, agency oversight, and, if necessary, enforcement action by the Water Board to address non-compliant water suppliers.*

This Executive Order is not intended to, and does not, create any rights or benefits, substantive or procedural, enforceable at law or in equity, against the State of California, its agencies, departments, entities, officers, employees, or any other person.

I FURTHER DIRECT *that as soon as hereafter possible, this order be filed in the Office of the Secretary of State and that widespread publicity and notice be given of this order.*

IN WITNESS WHEREOF *I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 9th day of May 2016.*

EDMUND G. BROWN JR., *Governor of California*

ATTEST:

ALEX PADILLA, *Secretary of State*

04/07/2017

Executive Order B-40-17

WHEREAS *California has endured a severe multi-year drought that has threatened the water supplies of communities and residents, devastated agricultural production in many areas, and harmed fish, animals and their environmental habitats; and*

WHEREAS *Californians responded to the drought by conserving water at unprecedented levels, reducing water use in communities by more than 22% between June 2015 and January 2017; and*

WHEREAS *the State Water Resources Control Board, the Department of Water Resources, the Department of Fish and Wildlife, the Office of Emergency Services, and many other state agencies worked cooperatively to manage and mitigate the effects of the drought on our communities, businesses, and the environment; and*

WHEREAS *the State provided 66,344,584 gallons of water to fill water tanks for communities suffering through drought-related water shortages, outages, or contamination, and provided emergency assistance to drill wells and connect communities to more robust water systems; and*

WHEREAS *the State took a number of important actions to preserve and protect fish and wildlife resources, including stream and species population monitoring, fish rescues and relocations, infrastructure improvements at trout and salmon hatcheries, and infrastructure to provide critical habitat for waterfowl and terrestrial animals; and*

WHEREAS *the State established a Statewide Water Efficiency and Enhancement Program for agricultural operations that provides financial assistance for the implementation of irrigation systems that save water; and*

WHEREAS *water content in California's mountain snowpack is 164 percent of the season average; and*

WHEREAS *Lake Oroville, the State Water Project's principal reservoir, is 101 percent of average, Lake Shasta, the federal Central Valley Project's largest reservoir, is at 110 percent of average, and the great majority of California's other major reservoirs are above normal storage levels; and*

WHEREAS *despite winter precipitation, the effects of the drought persist in areas of the Central Valley, including groundwater depletion and subsidence; and*

WHEREAS *our changing climate requires California to continue to adopt and adhere to permanent changes to use water more wisely and to prepare for more frequent and persistent periods of limited water supply; and*

WHEREAS *increasing long-term water conservation among Californians, improving water use efficiency within the State's communities and agricultural production, and strengthening local and regional drought planning are critical to California's resilience to drought and climate change.*

NOW, THEREFORE, I, EDMUND G. BROWN JR., *Governor of the State of California, in accordance with the authority vested in me by the Constitution and statutes of the State of California, do hereby* **TERMINATE THE JANUARY 17, 2014 DROUGHT STATE OF EMERGENCY** *for all counties in California except the Counties of Fresno, Kings, Tulare, and Tuolumne.*

I FURTHER ORDER THAT:

1. *The orders and provisions contained in my April 25, 2014 Emergency Proclamation, as well as Executive Orders B-26-14, B-28-14, B-29-15, and B-36-15 are rescinded.*
2. *The orders and provisions contained in Executive Order B-37-16, Making Water Conservation a California Way of Life, remain in full force and effect except as modified by this Executive Order.*
3. *As required by the State Emergency Plan and Government Code section 8607(f), the Office of Emergency Services, in coordination with other state agencies, shall produce an after-action report detailing the State's response to the drought and any lessons learned in carrying out that response.*

MAINTAINING CONSERVATION AS A WAY OF LIFE

4. *The State Water Resources Control Board (Water Board) shall continue development of permanent prohibitions on wasteful water use and requirements for reporting water use by urban water agencies, and to provide a bridge to those permanent requirements, shall maintain the existing emergency regulations until they expire as provided by the Water Code. Permanent restrictions shall prohibit wasteful practices such as:*
   - *Hosing off sidewalks, driveways and other hardscapes;*
   - *Washing automobiles with hoses not equipped with a shut-off nozzle;*
   - *Using non-recirculated water in a fountain or other decorative water feature;*
   - *Watering lawns in a manner that causes runoff, or within 48 hours after measurable precipitation; and*
   - *Irrigating ornamental turf on public street medians.*
5. *The Water Board shall rescind those portions of its existing emergency regulations that require a water supply stress test or mandatory conservation standard for urban water agencies.*
6. *The Department of Water Resources (Department) shall continue work with the Water Board to develop standards that urban water suppliers will use to set new urban water use efficiency targets as directed by Executive Order B-37-16. Upon enactment of legislation, the Water Board shall adopt urban water use efficiency standards that include indoor use, outdoor use, and leaks as well as performance measures for commercial, industrial, and institutional water use. The Department shall provide technical assistance and urban landscape area data to urban water suppliers for determining efficient outdoor use.*
7. *The Water Board and the Department shall continue to direct actions to minimize water system leaks that waste large amounts of water. The Water Board, after funding projects to address health and safety, shall use loans from the Drinking Water State Revolving Fund to prioritize local projects that reduce leaks and other water system losses.*
8. *The Water Board and the Department shall continue to take actions to direct urban and agricultural water suppliers to accelerate their data collection, improve water system management, and prioritize capital projects to reduce water waste. The California Public Utilities Commission is requested to work with investor-owned water utilities to accelerate work to minimize leaks.*

9. *The Water Board is further directed to work with state agencies and water suppliers to identify mechanisms that would encourage and facilitate the adoption of rate structures and other pricing mechanisms that promote water conservation.*

10. *All state agencies shall continue response activities that may be needed to manage the lingering drought impacts to people and wildlife. State agencies shall increase efforts at building drought resiliency for the future, including evaluating lessons learned from this current drought, completing efforts to modernize our infrastructure for drought and water supply reliability, and shall take actions to improve monitoring of native fish and wildlife populations using innovative science and technology.*

CONTINUED DROUGHT RESPONSE IN FRESNO, KINGS, TULARE, AND TUOLUMNE COUNTIES

11. *The Water Board will continue to prioritize new and amended safe drinking water permits that enhance water supply and reliability for community water systems facing water shortages or that expand service connections to include existing residences facing water shortages.*

12. *The Department and the Water Board will accelerate funding for local water supply enhancement projects and will continue to explore if any existing unspent funds can be repurposed to enable near-term water conservation projects.*

13. *The Water Board will continue to work with local agencies to identify communities that may run out of drinking water, and will provide technical and financial assistance to help these communities address drinking water shortages. It will also identify emergency interconnections that exist among the State's public water systems that can help these threatened communities. The Department, the Water Board, the Office of Emergency Services, and the Office of Planning and Research will work with local agencies in implementing solutions to those water shortages.*

14. *For actions taken in the Counties of Fresno, Kings, Tulare, and Tuolumne pursuant to directives 11–13, the provisions of the Government Code and the Public Contract Code applicable to state contracts, including, but not limited to, advertising and competitive bidding requirements, as well as Division 13 (commencing with section 21000) of the Public Resources Code and regulations adopted pursuant to that Division, are hereby suspended. These suspensions apply to any actions taken by state agencies, and for actions taken by local agencies where the state agency with primary responsibility for implementing the directive concurs that local action is required, as well as for any necessary permits or approvals required to complete these actions.*

15. *California Disaster Assistance Act Funding is authorized until June 30, 2017 to provide emergency water to individuals and households who are currently enrolled in the emergency water tank program.*

16. *State departments shall commence all drought remediation projects in Fresno, Kings, Tulare, and Tuolumne Counties within one year of the date of this Executive Order.*

This Executive Order is not intended to, and does not, create any rights or benefits, substantive or procedural, enforceable at law or in equity, against the State of California, its agencies, departments, entities, officers, employees, or any other person.

I FURTHER DIRECT *that as soon as hereafter possible, this Order be filed in the Office of the Secretary of State and that widespread publicity and notice be given of this Order.*

IN WITNESS WHEREOF *I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 7th day of April 2017.*

EDMUND G. BROWN JR., *Governor of California*

ATTEST:

ALEX PADILLA, *Secretary of State*

08/31/2017

Executive Order B-42-17

WHEREAS *on October 30, 2015, I proclaimed a State of Emergency to exist within the State of California due to the unprecedented tree mortality resulting from severe drought and bark beetle infestations across several regions of the State; and*

WHEREAS *the scope of the tree die-off has increased since my initial Proclamation, with the United States Forest Service most recently estimating that 102 million trees have died; and*

WHEREAS *this die-off is of such scale that it worsens wildfire risk across large regions of the State, presents risks from falling trees to Californians living in impacted rural, forested communities, and worsens the threat of erosion across watersheds; and*

WHEREAS *such wildfires will release thousands of tons of greenhouse gas emissions and other harmful air pollutants; and*

WHEREAS *the circumstances of the tree die-off, by reason of its magnitude, proved to be beyond the control of the services, personnel, equipment and facilities of any single county, city and county, or city and required the combined forces of a mutual aid region or regions to combat; and*

WHEREAS *the tree mortality crisis has increased the need for licensed professionals to remove dead trees that threaten life, property, and the environment; and*

WHEREAS *the licensure requirements of the Z'berg-Nejedly Forest Practice Act and the California Contractors License Law together have limited the available pool of licensed professionals to remove dead trees; and*

WHEREAS *the scope of the tree mortality crisis necessitates that the State mobilize all available resources to mitigate the impacts of the crisis.*

NOW, THEREFORE, I, EDMUND G. BROWN JR., *Governor of the State of California, in accordance with the authority vested in me by the Constitution and statutes of the State of California, in particular California Government Code sections 8567 and 8571, do hereby issue this Executive Order, effective immediately.*

IT IS HEREBY ORDERED THAT:

The orders and provisions contained in my October 30, 2015 Emergency Proclamation remain in full force and in effect except as modified herein.

I FURTHER ORDER THAT:

1. *Any individual who holds a timber operator license is hereby authorized to perform tree removal that would otherwise require a tree service contractor's license with the C-61/D-49 classification, where such removal is performed on dead or dying trees in high hazard zones. The provisions of the Business and Professions Code and the California Code of Regulations requiring licensure for this tree removal are hereby suspended as to individuals who hold a valid timber operator license.*

2. *Any individual who holds a tree service contractor's license with the C-61/D-49 classification is hereby authorized to perform timber operations that would otherwise require a timber operator license, where such operations are performed on dead or dying trees in high hazard zones. In order to perform such services, a tree service contractor must maintain the insurance coverage in the form and amount specified in Public Resources Code section 4572(c) prior to the conduct of timber operations, shall maintain the insurance coverage throughout the conduct of timber operations, and shall comply with all operational provisions of the Forest Practice Act and Rules applicable to the timber operations. The provisions of the Forest Practice Act and the applicable Rules requiring licensure for these timber operations are hereby suspended as to individuals who hold a valid tree service contractor's license.*

This Executive Order is not intended to, and does not, create any rights or benefits, substantive or procedural, enforceable at law or in equity, against the State of California, its agencies, departments, entities, officers, employees, or any other person.

I FURTHER DIRECT *that as soon as hereafter possible, this order be filed in the Office of the Secretary of State and that widespread publicity and notice be given of this order.*

IN WITNESS WHEREOF *I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 31st day of August, 2017.*

EDMUND G. BROWN JR., *Governor of California*

ATTEST:

ALEX PADILLA, *Secretary of State*

California Department of Water Resources
1416 Ninth Street, Sacramento, CA 95814
www.water.ca.gov/drought