Report to the Legislature on the 2012-2016 Drought

As Required by Chapter 340 of 2016

March 2021

State of California | California Natural Resources Agency

Cover: Cracked earth as the result of drought conditions.

Acknowledgement: This document was made possible by the support of the California Department of Water Resources.

Message from the Secretary

California's last severe drought tested all aspects of how we manage water. Five consecutive dry years from 2012 to 2016 took their toll on many communities, our agricultural economy, and our state's remarkable natural environment.

Individual Californians and our leaders rose to the challenge. Across the state, communities reduced their water usage by an average of 25 percent. State agencies triaged emergency assistance to rural communities where wells ran dry. Governor Brown and legislators secured $7 billion in water resilience investments and together enacted landmark water management laws. Several years later, we continue to work with regions to advance a generation-long endeavor to sustain groundwater aquifers, to diversify water supplies, and to restore river health.

While Californians can take pride in this response, we must strengthen our drought preparation and response moving forward. In 2016, the Legislature wisely directed our agency to assess State government actions during the recent drought and suggest ways to better endure future dry years. This report provides that assessment, establishing a detailed record of actions taken and highlighting where we need to build our resilience.

As we navigate a global pandemic and the return of dry conditions, this report is timely and helpful. The availability of water is central to our work to protect residents, combat inequity, and drive California's economic recovery. Likewise, protecting fish, wildlife, and habitat remains a bedrock commitment of State water policy. Stronger drought preparation and response helps us achieve these critical priorities.

Experience is a great teacher. By heeding lessons from the 2012–2016 drought, we will better protect communities, ecosystems, and our economy during drought and help our state thrive in a changing climate.

Wade Crowfoot, Secretary
California Natural Resources Agency

STATE OF CALIFORNIA
Gavin Newsom, *Governor*

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Acronyms and Abbreviations

AB	*Assembly Bill*
ACWA	*Association of California Water Agencies*
AWMP	*agricultural water management plan*
CAL FIRE	*California Department of Forestry and Fire Protection*
Cal OES	*Governor's Office of Emergency Services*
CASGEM	*California Statewide Groundwater Elevation Monitoring program*
CDFA	*California Department of Food and Agriculture*
CDFW	*California Department of Fish and Wildlife*
CEQA	*California Environmental Quality Act*
CPUC	*California Public Utilities Commission*
CSD	*California Department of Community Services and Development*
CVP	*Central Valley Project*
Delta	*Sacramento-San Joaquin Delta*
DWR	*California Department of Water Resources*
HAB	*harmful algal bloom*
InSAR	*interferometric synthetic aperture radar*
IT	*information technology*
MWD	*Metropolitan Water District of Southern California*
MWELO	*Model Water Efficient Landscape Ordinance*
NASA	*National Aeronautics and Space Administration*
NMFS	*National Marine Fisheries Service*
NOAA	*National Oceanic and Atmospheric Administration*
Reclamation	*U.S. Bureau of Reclamation*
RTDOT	*Real-Time Drought Operations Management Team*
SB	*Senate Bill*
SGMA	*Sustainable Groundwater Management Act of 2014*
SWEEP	*State Water Efficiency and Enhancement Program*
SWP	*State Water Project*
UC	*University of California*
USDA	*U.S. Department of Agriculture*
USFS	*U.S. Forest Service*
USFWS	*U.S. Fish and Wildlife Service*
Water Board	*State Water Resources Control Board*

Executive Summary

California's drought between Water Years 2012 and 2016 was one of the most severe in state history. A string of five dry winters left some rural communities without water, interrupted surface water deliveries to some farmers in the Sacramento and San Joaquin valleys for two consecutive years, disrupted thousands of farming jobs, pushed some fish populations toward extinction, and created conditions that fueled some of the most catastrophic wildfires in state history.

The State response included actions not taken since the short but intense drought of 1976–1977. For example, water right administrators curtailed thousands of diversions on the mainstem Sacramento and San Joaquin rivers in order to protect fish and wildlife and senior water right holders.

Distinctive features of this drought included an unprecedented State response to drinking water problems associated with small water systems and private wells, mandatory state-imposed urban water use reduction, recognition of the cumulative impacts of vast land subsidence in the San Joaquin Valley, massive tree mortality in the central and southern Sierra Nevada, and greatly increased wildfire activity and harmful algal blooms.

The 2012–2016 drought was the latest of five severe droughts to grip the state in the last 120 years. It unfolded in a context of record statewide temperatures, which exacerbated the impacts of water shortage, setting new markers for extreme conditions. The Sierra Nevada snowpack in 2015, for example, was the lowest on record. Based on statewide precipitation, 2012–2015 were the four driest consecutive years on record. The single year 2014 was the third driest on record.

The drought revealed some strengths in the State's largely decentralized systems for managing water. Large urban water districts that had previously invested to diversify their supply sources and build new storage handled the drought without major disruption, and Californians responded heartily to the Governor's call for a reduction in water use of at least 25 percent.

But 2012–2016 showed serious problems, too. Water deliveries by the State's two largest water projects fell to unprecedentedly low levels. Growers turned to groundwater to make up the difference, and heavy pumping triggered record declines in groundwater levels. This accelerated land subsidence in parts of the San Joaquin Valley that in turn continued to damage water supply and flood risk management infrastructure.

Groundwater pumping by growers also contributed to the stranding of hundreds of wells used by individual families and small water systems. Faucets ran dry for some residents in rural communities, and at the drought's peak, the State was spending about half a million dollars a month for bulk and bottled water in these communities. Farmers fallowed an estimated 500,000 acres of farmland, and the State delivered more than two million boxes of food to community food banks in counties with the highest drought-related unemployment due to agricultural job losses.

The impact of record warm temperatures on marine and freshwater fisheries cannot be overstated. The combination of elevated temperatures and low precipitation harmed cold-water fisheries in many areas and also challenged water project operations to protect the fisheries. Wildlife managers conducted hundreds of separate rescues of stranded, native fish. A record number of young hatchery salmon were trucked directly to the ocean to avoid

hazardous stream conditions. On the upper Sacramento River below Shasta Dam, 95 percent of winter-run Chinook salmon production was lost in both 2014 and 2015 due to elevated temperatures. Wildlife managers imposed a record number of closures of commercial and recreational fisheries.

State leaders enacted several major legislative and regulatory changes during or after the 2012–2016 drought. These changes:

- require local agencies to bring overdrafted groundwater basins into sustainable conditions by 2042;
- establish new standards for indoor, outdoor, and industrial use of water;
- fund solutions for disadvantaged communities lacking access to safe drinking water;
- increase the frequency of water use reporting;
- give the State authority to order failing public water systems to consolidate with better-run systems; and
- tighten landscape efficiency standards for new developments.

Implementation of these laws and regulations is underway and should help California cope with extended dry conditions in the future. But there is still more to do. Recent experience makes clear that effective response depends heavily on capacity built before drought deepens. That includes reducing the drought vulnerability of water users and ecosystems, making key policy decisions in advance, improving hydroclimate forecasting to provide longer lead times for decision-making, having at hand the information necessary to make well-informed decisions, and creating the capacity to communicate effectively across governments and to the public about a rapidly changing situation.

The recommendations for State action in this report include providing longer lead times for State financial assistance to local agencies, dedicating staff to ongoing drought preparedness and response work, better accounting for wildlife needs before and during drought, improving the quality and timeliness of forecasting and data, and restoring forest health in upper watersheds. Some recommendations for State action in this report are narrow, others are broad, but all fit within the Newsom Administration's effort to address long-standing water problems and strengthen California's ability to cope with a changing climate.

Chapter 340 of 2016

SEC. 51.

(a) On or before January 1, 2020, the Natural Resources Agency shall submit to the relevant fiscal and policy committees of the Legislature and to the Legislative Analyst's Office a report summarizing lessons learned from the state's response to the drought. The report shall compile information from the various state entities responsible for drought response activities, including, but not limited to, the State Water Resources Control Board, the Department of Water Resources, the Department of Fish and Wildlife, the Department of Forestry and Fire Protection, and the Office of Emergency Services.

(b) The report shall discuss the state's drought response efforts for at least all of the following categories:

(1) Drinking water.

(2) Water rights.

(3) Water supply, including groundwater and operations of the State Water Project and the federal Central Valley Project.

(4) Water quality.

(5) Fish and wildlife.

(6) Water conservation.

(7) Fire protection.

(8) Emergency human assistance.

(c) The report shall include a discussion of, and data related to, all of the following for each of the categories included in the report pursuant to subdivision (b):

(1) Major drought response activities undertaken.

(2) Major challenges encountered.

(3) Efforts in which the state achieved notable successes.

(4) Efforts in which the state needs to make improvements.

(5) Recommendations for improving the state's response in the future, including potential changes to state policy and additional data the state should collect.

1 Overview

1.1 STATE ACTIONS

The 2012–2016 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 for drought impacts was issued, and it set a record for the number of executive orders and emergency proclamations issued through its duration. Notable impacts included first-ever zero water allocations to some Central Valley Project water contractors, record declines in groundwater levels, high fish mortality in some waterways, and rural areas with concentrations of private residential wells going dry. Satellite imagery highlighted for the first time the broad scope of damaging land subsidence occurring throughout the San Joaquin Valley in response to drought-induced groundwater extraction; subsidence rates matched the prior historical record for the San Joaquin Valley. The state experienced massive tree mortality in the central and southern Sierra and then-record levels of wildfire costs (subsequently surpassed by the catastrophic wildfires of 2017 and 2018).

The drought stands out for the large number of institutional response actions taken at the State level (Table 1.1). The initial action was a May 2013 directive by the Governor, Executive Order B-21-13, to expedite the review and processing of water transfers, a response employed in prior droughts. When the fall and early winter of 2013 stayed dry, the Governor formed a State interagency Drought Task Force in December 2013. Through the Drought Task Force, top leaders across State departments convened weekly to coordinate drought response. A January 2014 proclamation of statewide emergency based on continuing dry conditions soon followed. 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. It kept in place specified emergency response measures 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 it directed continuing response to lingering drought impacts. The order also directed that State agencies increase efforts to build drought resilience, including modernizing infrastructure for water supply reliability and improving monitoring of native fish and wildlife populations.

As authorized by Government Code Section 8571, the Governor's January 2014 proclamation suspended the California Environmental Quality Act (CEQA), and the regulations adopted pursuant to it, to the extent that CEQA otherwise would have applied to specified actions necessary to mitigate the effects of the drought. Subsequent executive orders extended the waiver of CEQA. Actions taken by State agencies under the provisions of the waiver included construction of an emergency drought

Table 1.1: Selected State Institutional Actions in 2012–16 Drought

Date	Action
May 2013	Executive Order B-21-13, expediting water transfers
December 2013	Formation of Governor's 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, making 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

barrier in the Sacramento-San Joaquin Delta, streamlining of general waste discharge requirements for recycled water, construction of fish habitat projects to minimize drought effects on State-listed endangered fishes, and temporary changes to water right permits for the State Water Project, Central Valley Project, and water districts in San Luis Obispo, El Dorado, Siskiyou, and Sonoma counties, and elsewhere.

A major legislative response action during the drought was provision of emergency funding through 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) 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 (SB) 88 (Chapter 27, Statutes of 2015) amended the Health and Safety Code to give the State Water Resources Control Board (Water Board) authority to require consolidation of water systems consistently failing to provide an adequate supply of safe drinking water, and it amended the Water Code to provide for more thorough measurement and reporting of diversions to the Water Board. Both provisions stemmed from resource management issues exacerbated by drought conditions—the lack of technical, managerial, and financial capacity at some small water systems and a lack of accurate data on diversions for the Water Board to use in administering water rights in times of shortage. Extended dry conditions also set the stage for public, stakeholder, and legislative support for enactment of the Sustainable Groundwater Management Act (SGMA) in 2014 and a package of bills known as the "Conservation As A Way of Life" laws, which call for creation of new urban efficiency standards for indoor and outdoor water use that take into account regional variations.

1.2 HYDROLOGICAL CONTEXT

The five-year drought of 2012–2016 followed shortly after California's three-year drought of 2007–2009. Water year 2017, the second wettest on record in terms of statewide precipitation, ended the 2012–2016 drought. Only two years in the decade prior to Water Year 2017 were not dry, prompting speculation about a long-term regime shift toward drier conditions. However, it is not possible to determine if this was a statistically significant change or simply the expression of California's natural climate variability.

Table 1.2: 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 1.3: Driest Water Years, Based on Statewide Precipitation

Years	Total Statewide Precipitation, inches
1924	10.7
1977	11.9
2014	13.1
1987	15.0
1931	15.1
2007	15.3
1994	15.7
1929	16.3
1990	16.5
1934	16.6
1976	16.8

Data credit: Western Regional Climate Center

The drought of 2007–2009 was still a recent memory when the 2012–2016 drought began. A slightly wetter than average Water Year 2010 had been followed by a wet 2011 (the first significantly wet water year since 2006), which had allowed for recovery of soil moisture and reservoir storage. The warm conditions associated with the 2007–2009 drought had continued and intensified. The Colorado River Basin returned to dry conditions in Water Year 2012.

The 2012–2016 drought was notable for its hydrologic severity, requiring response actions not necessary since the 1976–1977 drought. Continuing an observed 21st century trend, 2012–2016 occurred in a setting of record warm statewide temperatures; 2015 and 2014 were, respectively, the warmest and second-warmest calendar years of record in terms of statewide average 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).

The period from 2012 to 2015 set a record for the driest four consecutive water years based on statewide precipitation (Table 1.2). Water year 2014 was the single driest year of the drought, and it ranked as the state's third driest single water year of record (Table 1.3). Figures 1.1, 1.2, and 1.3 show plots of the Department of Water Resources' (DWR's) Northern Sierra 8-station, San Joaquin 5-station, and Tulare Basin 6-station precipitation indices 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 1.4 illustrates the impact of drought on runoff at key forecast points for the Central Valley rivers.

The 2012–2016 drought began with a dry 2012, but initial impacts 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 the Water Board 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. In some parts of Northern California, more than 50 consecutive days passed with no

Figure 1.1: Northern Sierra 8-Station Precipitation Index for Selected Years

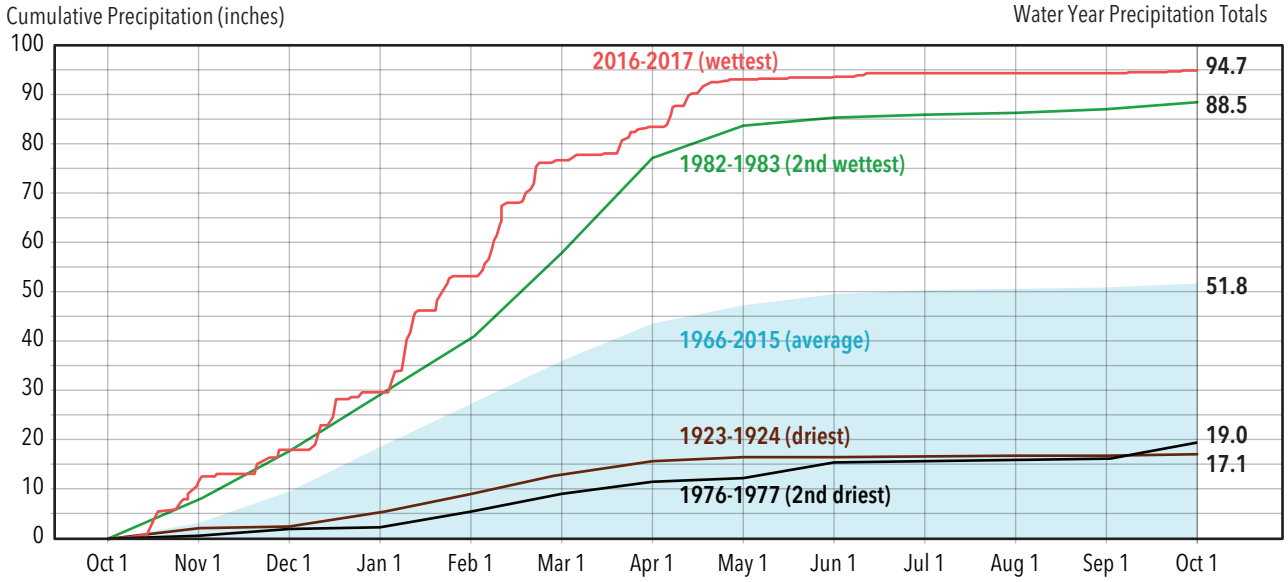


Figure 1.2: Southern Sierra 5-Station Precipitation Index for Selected Years

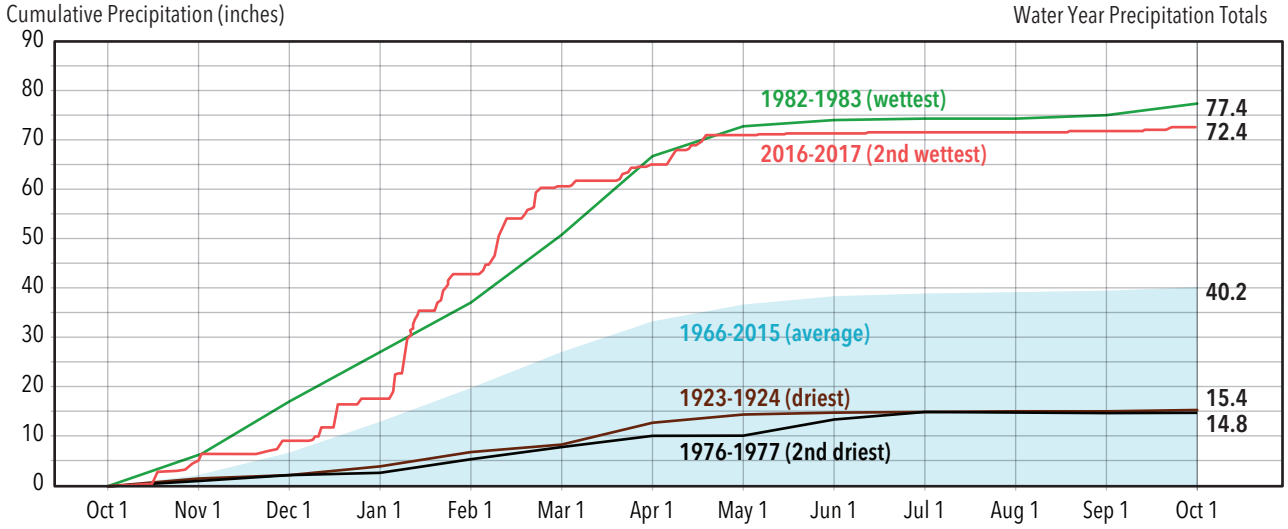


Figure 1.3: Tulare Basin 6-Station Precipitation Index for Selected Years

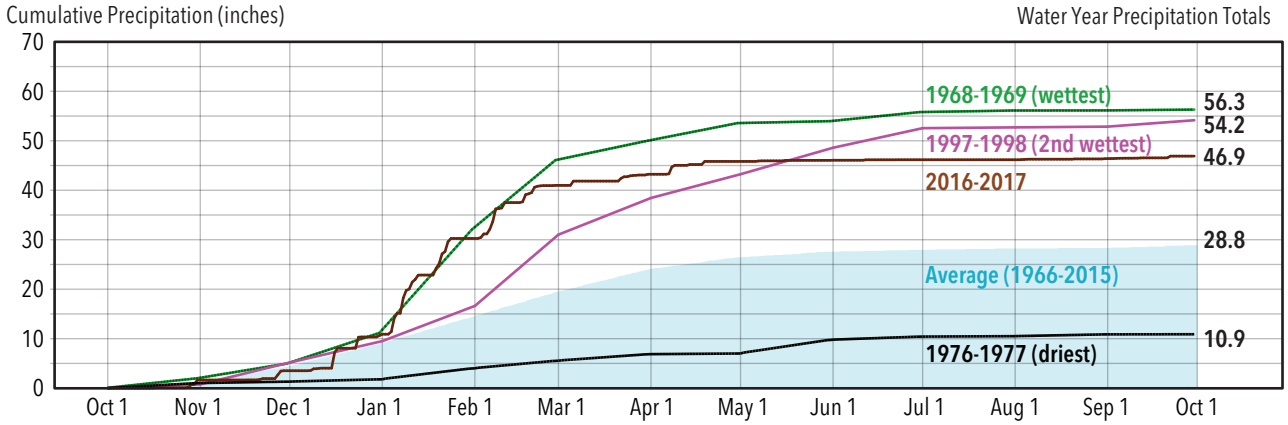
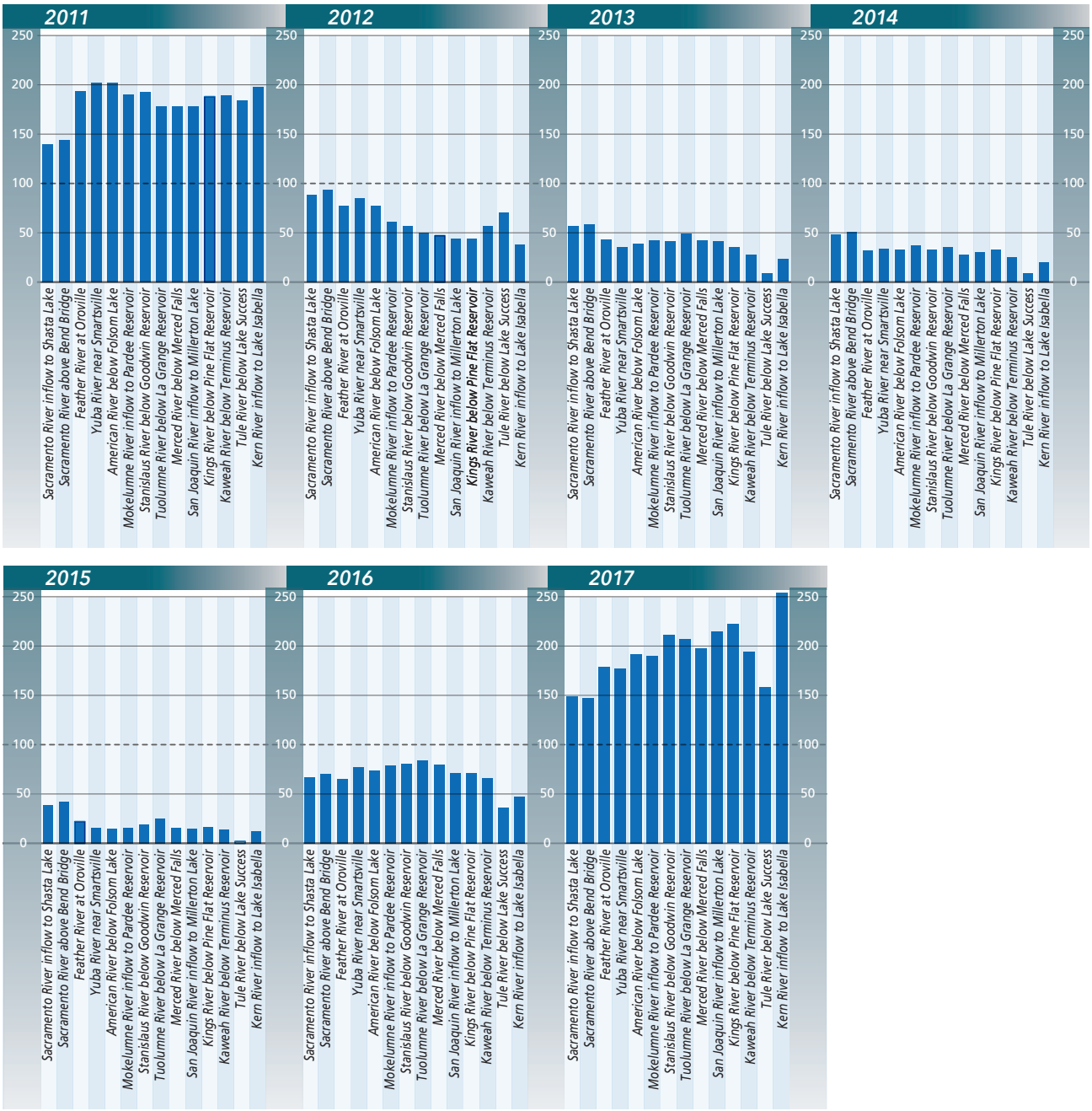


Figure 1.4: Water Year 2011–2017 April–July Runoff at Forecast Points on Major Central Valley Rivers, as Percent of Average



measurable precipitation—at a time when the year's maximum monthly precipitation totals typically should have been registered. The record dry December 2013, combined with the previous record dry January–May 2013, resulted in 2013 being the then-driest year of record for many communities, including San Francisco, Sacramento, and Los Angeles.

In December 2013, the Governor formed a State interagency Drought Task Force to coordinate assessment of dry conditions and recommend State actions. Sustained dry conditions 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. Water Years 2014 and 2015 were the driest years of this drought. 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. Storms returned in the very wet Water Year 2017, and Executive Order B-40-17 in April 2017 ended the proclamation of statewide emergency.

1.2.1 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 2012–2016 droughts—the only statewide emergency declarations due to drought in state history. 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.

1.2.2 The 2012–2016 Drought in the Context of California's Most Significant Historical Droughts

The five-year 2012–2016 drought was only the most recent of California's significant droughts of statewide spatial scale in the past century. The 1929–1934 drought featured severe drought conditions over much of the western United States, including the Great Plains region affected by the Dust Bowl drought. 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 profoundly test current water management.

The 1976–1977 drought came after a long period of relative quiescence with respect to water shortages, following several decades of relatively wetter conditions statewide. (Regional droughts did occur, such as the 1959–1961 drought in Southern California.) The 1976–1977 drought caught many water users by surprise. Its effects were severe and widespread, given the relative short duration. The drought began with a very dry 1976 that provided the antecedent conditions to make 1977 the driest year of statewide runoff, a ranking that lasts today. Many California water conservation efforts date to this drought, when local water suppliers unprepared for major reductions rapidly implemented conservation programs to cope.

The 1987–1992 drought was 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 that 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 during the 1987–1992 drought resulted in enactment of numerous Water Code provisions relating to water

conservation and water transfers and signaled the beginning of widespread development of voluntary water transfer arrangements.

The three-year drought of 2007–2009 was most notable for its markedly different institutional conditions as compared to the state's earlier droughts. Surplus Colorado River water was no longer available to California to help mitigate shortages in intrastate water supplies. New restrictions on Central Valley Project (CVP) and State Water Project (SWP) diversions from the Sacramento-San Joaquin Delta (Delta) to protect fish species listed as endangered or threatened exacerbated the impacts of hydrologic drought and served as a trigger for the statewide drought emergency proclamation.

The California of the 2012–2016 drought was not the California of the 1987–1992 drought, nor of the drought of the 1920s–1930s, nor of the so-called Great Drought of 1872. The state's human population had increased to roughly 40 million people, and human development had greatly altered river systems and landscapes. Many farmers had shifted from lower-value field crops, which gave farmers the flexibility to not irrigate in dry years, to longer-lived tree and vine crops that required water regardless of drought. Myriad non-native plant and animal species had been introduced and thrived, often out-competing native species and altering the way ecosystems functioned, from estuaries to grasslands. The climate had warmed. Snowpacks had been diminishing, and precipitation patterns had been changing. New climate-driven risks had been emerging, notably record-breaking heat waves and catastrophic wildfire coupled with drought.

Comparing the five-year 2012–2016 drought with the six-year 1987–1992 drought is instructive. Water suppliers typically made full deliveries to their customers in the 1987–1992 event until the fifth or sixth year of the drought, when large cutbacks occurred. Frequently, the full deliveries came at the expense of environmental conditions and reservoir storage. Many of the state's larger reservoirs ended 1991 (the drought's driest year) with low carryover storage. Surplus Colorado River water was available to Southern California, providing an offset to reductions in SWP deliveries. The 1987–1992 drought's impact on groundwater supplies was difficult to discern for lack of data. The drought occurred just as the World Wide Web was being rolled out; the rapid availability of data and information about impacts that we take for granted today was largely nonexistent. Presaging today's linkage of drought and catastrophic wildfire, the 1991 Oakland Hills fire, the then-largest dollar-loss fire event in United States history, demonstrated the risk of major wildfire damage in densely populated urban areas located in a wildland-urban interface.

The wildfire season lasted virtually year-round in 2012–2016. Dead vegetation from the drought years contributed to catastrophic wildfires of unprecedented scale following the drought's ending, which heightened the risk for damage or destruction of urban water supply infrastructure. Extensive data and information about water supply conditions and impacts were available in real time during the 2012–2016 drought. SWP and CVP contractors experienced unprecedented reductions, including two years of zero deliveries for CVP agricultural contractors. The Colorado River Basin had been in long-term drought conditions, and surplus supplies from that source were not available. Large-scale tree mortality in mountain forests had been observed in prior droughts; urban tree mortality also marked the 2012–2016 drought. Record warm statewide temperatures resulted in reduced water storage in mountain snowpack, threatened the survival of salmon and steelhead populations, increased the occurrence of harmful algal blooms, and contributed to heightened wildfire risk.

California's most significant historical droughts share some common themes and lessons. Historically, there have been important gaps in information or tools uniquely associated with drought: the ability to characterize statewide groundwater conditions, to predict whether the next months will be wet or dry (seasonal forecasting), and

to improve resilience of small water systems and communities that do not have multiple water sources or are geographically isolated. Although progress has been made on obtaining groundwater level data and on focusing on small water system improvements, much work remains to be done on improving seasonal forecasting to support drought response. Additional data gaps have emerged as California's population and water use have grown. During the 2012–2016 drought, lack of sufficient data on water diversion volumes and water use, places of use, reservoir temperatures, and water supply in disadvantaged communities created inefficiencies or prevented rapid responses to critical health and human safety and environmental needs. Lack of data on instream flow requirements for native species has made protection of endangered and sensitive species more difficult during times of shortage.

Impacts experienced in California's most significant droughts (Table 1.4) can be summarized by category (health and safety, economic, or environmental) and broken out for managed and unmanaged systems. Some impacts can be associated with both managed and unmanaged systems; for example, impacts to anadromous fish species can occur either in free-flowing streams or in rivers controlled by major reservoirs. The distinction between managed and unmanaged systems is important in that it points out where response tools based only on water management actions can and cannot be used.

California's most serious droughts highlight a lack of drought resilience in some geographic areas. In some cases, the same water suppliers have been provided State emergency assistance in multiple events. Climate change heightens the need for local investment in drought resilience and creation of contingency plans for both communities and natural systems.

Table 1.4: 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 (e.g., Salmonids)		x	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 (e.g., Salmonids, Wildlife Refuges)		x	x
Land Subsidence		x	x

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.

2

State Drought Response Actions

The State response in the 2012–2016 drought related primarily to drinking water, water rights, water supply, water quality, fish and wildlife, water conservation, fire protection, emergency human assistance, and agriculture, as described in the following sections. In many cases, State actions involved redirecting existing programs and capabilities to support drought response. Effective drought response depends heavily on capabilities put in place prior to drought, and on being prepared to use those capabilities to mitigate drought impacts.

Recommendations for improving response in future droughts are discussed in the sections below, and a summary table is provided as an appendix.

2.1 DRINKING WATER

Major drought response activities undertaken

Most of the state's urban water suppliers successfully met their customers' needs during the five-year drought. Historically, the state's largest urban suppliers have performed well in multiyear droughts because they have the technical, managerial, and financial resources necessary for ensuring water supply reliability. State financial assistance has been available to large systems over multiple decades for integrated regional water management projects and other infrastructure projects helping with water supply reliability, and for Safe Drinking Water Act compliance. A framework for water shortage planning was provided in the Urban Water Management Planning Act (initially adopted in 1983). The water shortage "stress test" process that the Water Board required larger suppliers to perform in 2016 found that of the 379 larger water systems responding, only 36 suppliers identified a need for some level of mandated water use reduction over the next three years, assuming continuation of very dry hydrologic conditions.

Drinking water shortages were primarily experienced in rural areas, and among small public water systems and homes dependent on private wells, including on tribal lands. Although most of the small system/private household water shortages were related to dry wells, some shortages were associated with creek and spring diversions, especially in the northernmost part of the state. Some of the affected areas had struggled in previous droughts because of vulnerable sources of supply (such as fractured rock groundwater), including parts of Mendocino and Lake counties on the North Coast and Sierra foothill counties such as Tuolumne and Mariposa. However, drought exacerbates a chronic problem experienced by some small systems on fractured rock groundwater whose wells go dry every summer in all but wet years. Geographically, these highly vulnerable systems span the state from the Sierra Nevada and Bay Area foothills to Southern California.

A new type of shortage emerged in the southern San Joaquin Valley where heavy groundwater pumping, largely for irrigation, exacerbated preexisting drinking water quality problems experienced by disadvantaged communities and caused private residential wells to go dry. A 2011 DWR grant to Tulare County for a Tulare Lake Basin disadvantaged community water study had been a catalyst for identifying drinking water problems in the study area (352 communities) and for bringing together communities with nongovernmental 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 contributed to a concentration of impacts that resulted in a first-ever major State assistance effort to provide permanent water supplies to private well owners by connecting them to public water systems.

Executive Order B-26-14 had authorized the California Office of Emergency Services (Cal OES) to use California Disaster Assistance Act funds to provide temporary emergency drinking water (bottled water or temporary tanks) to residents without water. The Water Board and the Department of Public Health (which had previously administered the Safe Drinking Water Act) also approved more than $52 million in funding for 413 interim and emergency drinking water projects. Cal OES worked with county offices of emergency services to provide an unprecedented level of response in terms of distribution of bottled water, installation of temporary tanks at private residences, bulk water haulage to fill the tanks, and provision of shower trailers. Most of the assistance was focused on the San Joaquin Valley and much of it on unincorporated communities in Tulare County. Traditionally, provision of temporary emergency drinking water is a short-term response action associated with immediate disasters such earthquakes or wildfires. In contrast, the drought response entailed providing emergency water to affected households for as long as three years in some cases. During the peak of the drought emergency, Cal OES' costs for provision of emergency bottled and bulk water were averaging about half a million dollars a month. These activities continued after the drought ended because groundwater levels had not recovered.

For the first time, State assistance was authorized for residents with dry private wells, specifically for development of permanent water supplies, such as connection to a public water system. Executive Order B-36-15 in November 2015 authorized the Water Board to use up to $5 million of emergency drought funding to assist drinking water systems serving fewer than 15 connections (those too small to fall under State regulatory jurisdiction) and private well owners. This funding enabled projects such as drilling of new wells; construction of pipelines, storage tanks, and pumps; and installation of residential laterals. DWR, Cal OES, and the Water Board used the drought emergency funds in partnership with the U.S. Department of Agriculture (USDA) and involved counties to plan, design, and construct connection projects for communities in Fresno, Tulare, Tuolumne, and Santa Barbara counties. It is unusual for the State to take over the development of a local water system. These projects resulted in the connection of more than 1,000 residences to public water systems, more than 750 of them in East Porterville. Costs for the East Porterville connections alone exceeded $48 million.

The Water Board oversees approximately 7,500 public water systems in California, about 92 percent of which serve fewer than 1,000 connections. During the drought, the Water Board tracked systems that were at risk of near-term shortages and helped vulnerable systems find options for water supplies and apply for drought emergency funding. As shown in Figure 2.1, the Water Board provided drought emergency funding to more than 180 mostly small systems for projects such as

Figure 2.1: State Water Resources Control Board Drought Assistance for Public Water Systems

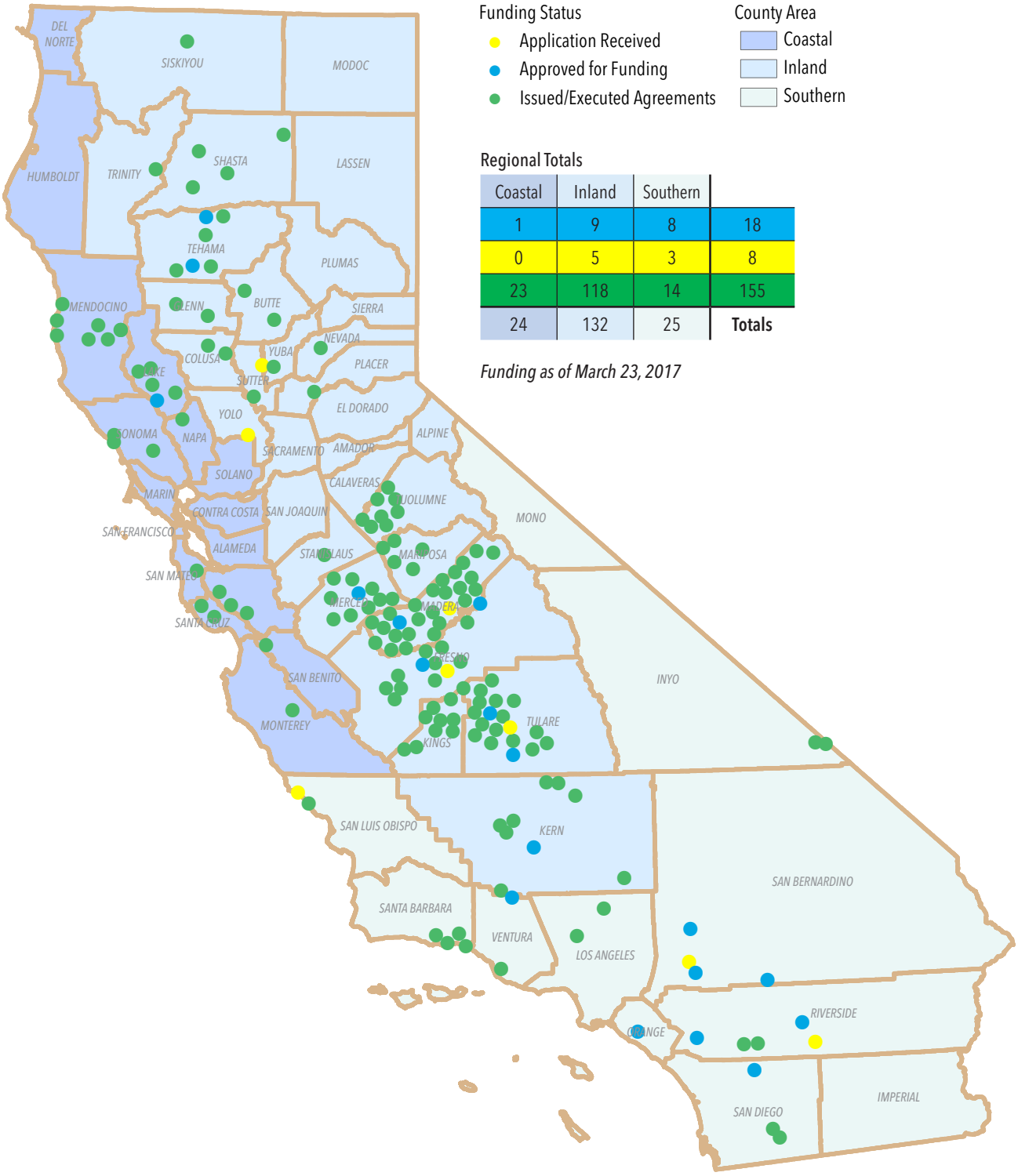


Figure credit: State Water Resources Control Board

interconnecting with another system or drilling new or deeper wells. The Water Board imposed moratoriums on new connections for systems with precarious supplies, sometimes in concert with water diversion curtailment notices. Legislation enacted in 2015 provided the Water Board with new authority to require that systems consistently failing to provide adequate supplies of safe drinking water consolidate with other systems. Additionally, more than 100 water systems have voluntarily consolidated since 2016.

Major challenges encountered

Drought exacerbates other vulnerabilities experienced by smaller public water systems and private well owners, especially those in rural areas. These water users may face impacts stemming from legacy land use planning decisions, vulnerable sources of supply, groundwater water quality impairment, and, for public water systems regulated by the federal Safe Drinking Water Act, lack of technical, managerial, or financial capacity to operate their systems. Such circumstances cannot be overcome rapidly under normal hydrologic conditions and they become a substantial complication if drought emergency response is necessary. Some small water systems in rural area have demonstrated chronic vulnerability to drought and have repeatedly received State emergency drought assistance. Small systems fundamentally lack the rate-payer base to be able to afford major investments in improving their drought resiliency.

Responding to small water system drought problems is generally staff-intensive and time-consuming. Often state agencies must bring together multiple local jurisdictions (counties, cities, special districts) to attempt to quickly solve a multijurisdictional problem that has not been addressed precisely because the problem is institutionally complex or because there is local disagreement on a solution and competition for limited water resources. Rural counties and small special districts often have limited staff resources and can be overwhelmed by multiple drought response needs. Counties have primary responsibility for responding to dry private wells, but they may not have good information about the extent of impacted areas or be prepared to respond to widespread problems.

If local jurisdictions are unable, the State can provide

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.

emergency drinking water supplies (bulk/bottled water) quickly under the authority of the California Emergency Services Act. But it is substantially more complicated to put in place a temporary fix that can transition to a permanent solution, especially for disadvantaged communities with minimal resources. The California Emergency Services Act was not designed to be a tool for providing long-term water supplies to drought-vulnerable areas. Developing a permanent solution can entail putting together a financial assistance package from multiple State and federal programs with different authorities and requirements, an effort that normally entails substantial lead time and does not fit well within the context of an urgent situation. In addition, the cost of contracting and drilling wells increased substantially during the drought emergency, resulting in greater costs to the State.

Notable State successes

The Water Board, DWR, Cal OES, and USDA Rural Development worked closely together to coordinate assistance to affected public water systems and private well owners, typically identifying which agency would be the lead for working with a system and putting together a financial assistance package from various funding sources, based on the eligibility requirements of available programs. The agencies coordinated with Indian Health Services, the Bureau of Indian Affairs, and the U.S. Army Corps of Engineers regarding their response to drinking water shortages on tribal lands.

Partnering with organizations and community groups specializing in delivering services or providing technical assistance to small water systems and disadvantaged communities was an integral part of State drought response actions. DWR partnered with the California Rural Water Association and the Water Board with the Rural Community Assistance Corporation to provide statewide technical assistance to small systems. Emergency drinking water projects for disadvantaged communities often involved the assistance of partners such as Self-Help Enterprises.

The State response to dry private wells was unprecedented and required addressing many new issues. For example, initial guidelines for the emergency water tank program restricted placement of the tanks at rental properties because rental properties are a private business. In Tulare County, where most of the tanks were installed, the county developed a process with landlords that would satisfy State requirements and allow Cal OES to approve tanks at rentals. In East Porterville, connecting residents in the unincorporated area under county jurisdiction to the City of Porterville's system required not only encouraging disadvantaged community residents who were often wary of government agencies to agree to sign up, but also resolving long-standing institutional issues between city and county jurisdictions. These activities were staff-intensive and substantially lengthened the time needed to carry out solutions.

The 2015 legislation giving the Water Board new authority to require certain water systems to consolidate with others is an important tool for addressing small systems that are chronically unable to meet drinking water regulatory requirements, and for helping connect areas with dry private wells to public systems. More than 100 water systems have voluntarily consolidated since 2016.

Efforts where improvement is needed

As reports of dry private wells in Tulare County escalated early in the drought, the State Office of Planning and Research began working with the county to informally track the number of reported incidents, later expanding that effort to other counties, particularly in the San Joaquin Valley. DWR was subsequently tasked with maintaining a web-based reporting system for household water shortages (for example, dry private wells). (As a rough estimate from DWR well completion reports, there are approximately one million private residential wells in California.) County participation was voluntary and relied upon voluntary reporting by residents. Through January 2019, more than 2,600 reports were received (most in 2014 and 2015); more than half were received from Tulare County, reflecting

extensive outreach conducted by State and local agencies and nongovernmental organizations related to East Porterville water shortage issues. While useful in beginning a dialog with counties about the extent of household water shortage problems, there are serious limitations with the data received. Counties are responsible for regulating water systems serving fewer than 15 connections and rarely collect data from homes served by private residential wells. Residents seldom report dry private well issues to counties. Data received by DWR suggest that there were minimal dry wells in areas historically known for widespread dry wells during drought and which were known to have had them in 2012–2016. The reported data substantially undercount the expected number of dry private wells on a statewide basis. Although a tracking mechanism was successfully established, its limited utilization demonstrates the difficulties of obtaining household water shortage data. The existing system, dependent upon voluntary reporting, is better suited for response to an immediate, local catastrophic event such as wildfire. In alluvial groundwater basins, water level data and well logs (where available) can provide at least a general idea of shortage risks to private well owners, but other approaches would need to be developed for fractured rock groundwater areas.

Recommendations for improving State response

Improving the resilience of small water systems is a challenge that extends far beyond the scope of drought preparedness and response. Legislation enacted in 2019 (SB 200) authorized a new Water Board program funded at $130 million annually for 10 years to assist water systems serving disadvantaged communities to provide safe drinking water. Over time, implementation of this program together with the Water Board's mandatory consolidation authority for the small percentage of chronically noncompliant systems should reduce the number of small water systems with high drought vulnerability.

As required by Assembly Bill (AB) 1668, DWR has, in consultation with the Water Board and others, developed a list of small water suppliers that may be at risk of drought and water shortage. State agencies should consider, as appropriate, actions such as connection moratoriums, system consolidation, and targeted technical or financial assistance to lessen the vulnerability of these systems to future droughts. At-risk systems often need to establish a drought factor of safety by increasing their available water supplies, an action that typically entails a lead time of several years.

Longer lead times would benefit the provision of State financial assistance to local water agencies for urgent drought response infrastructure projects. Large and small local agencies frequently did not have well-developed projects ready for funding when DWR announced the availability of drought grants under its Integrated Regional Water Management Program or when the Water Board stepped in to respond to small systems facing critical drinking water shortages. In future droughts, longer lead time for potential financial assistance drought response actions could be achieved by announcing at the end of a second dry winter the intent to authorize financial assistance in the event of a third dry winter. Consideration also should be given for triggering immediate State financial assistance at the end of a second dry year for proactive measures to diagnose potential problems at small water systems, specifically leak detection inspections and well inspections.

A State drought emergency proclamation can speed response actions by reducing the time involved for contracting requirements or environmental permitting, but the time required to formulate a project, negotiate agreements among involved local jurisdictions, and obtain required local cost-sharing agreements may be considerable. Institutional arrangements can be especially challenging for small water system problems where multiple State and local entities may need to be involved in designing a solution and negotiating agreements on behalf of a system with limited technical, managerial, and

financial capacity. Provision of such assistance and oversight, therefore, should come as part of existing regulatory and financial assistance programs.

Drinking water systems receive a sanitary survey, or detailed inspection, every three years that includes an evaluation of the adequacy of the water system's source. Historically the focus has been on the water quality of the source, but this could be expanded to include evaluation of the source's resilience in the face of drought. An overwhelming number of small water system have a single source, generally a groundwater well, and do not maintain more than a day's worth of storage. Documenting and highlighting the water system at risk is a first step toward improvement.

Streamlined financial State assistance would help local agencies and small water systems in emergency funding situations, including drought. Consolidating appropriations among fewer State programs, so recipients only receive funding from one agency, for example, could minimize funding agreements and reporting structures.

Based on the effort to track voluntary reporting of household water shortages/dry private residential wells, DWR and the Water Board should consider whether other methods of obtaining household water shortage information at a statewide scale are feasible. Over the long-term, implementation of the SGMA in designated basins could provide information on shortage risks. Other approaches would be needed for fractured rock groundwater source areas.

Many of the rural small water systems that experience problems during droughts rely on fractured rock groundwater sources that are insufficient during dry hydrologic times. Often these communities date to land-use planning decisions in the mid-20th century or earlier that did not assess water availability. Legislation enacted in 2001 (SB 221 and SB 610) requires that local land use agencies approving new development projects of 500 units or more verify that water supplies are available to serve the proposed development. The resilience of developments approved under the 19-year-old legislation should be reviewed to gauge the effectiveness of the law as well as whether the 500-unit limit should be lowered, or other changes made, to prevent development without adequate water resources.

2.2 WATER RIGHTS

Major drought response activities undertaken

The intensive level of effort needed to administer the water right system on the state's major river systems was unprecedented since the 1976–1977 drought. The scale and magnitude of the 2012–2016 drought required curtailments of diversions under relatively senior water rights in the mainstem Sacramento-San Joaquin river systems to protect releases from upstream reservoirs such as Shasta and Oroville, with the level of necessary curtailments similar to that needed in 1976 and 1977. In 2014, the Water Board notified more than 9,000 holders of appropriative water rights of the lack of water availability under their priority of right. In the spring of 2015, the Water Board issued notices to all post-1914 appropriators in the Sacramento-San Joaquin watersheds and in the Delta, followed in June by similar notices to pre-1914 diverters with a priority date of 1903 or later (Figure 2.2). These notifications reflected the fact that almost all summer flow in the mainstem Sacramento-San Joaquin river systems was being sustained by reservoir storage releases to meet environmental regulatory objectives or deliveries to water contractors; there was minimal natural flow in the system.

In 2014 and 2015, the Water Board also adopted emergency regulations for selected streams where those regulations were necessary to protect salmonids, as discussed below. The regulations set minimum instream flows during specified periods where necessary for survival of the species and provided for curtailments as necessary to protect those flows.

The Water Board issued two kinds of notices:

- Curtailment notices authorized by a regulation or permit term, which amount to binding regulatory orders to curtail.
- Notices informing a water right holder of the apparent lack of sufficient water to support diversions under their priority. These notices warn diverters that if they do not curtail diversions, they may be subject to enforcement for unauthorized diversion. The notices do not amount to a binding determination that insufficient water is available.

Diverters filed litigation challenging both kinds of notices. In Stanford Vina Ranch Irrigation Company v. State of California, et al. (June 18, 2020, No. C085762) the Court of Appeal upheld curtailment authorized by regulation. In California Water Curtailment Cases (H047270, app. pending), diverters are challenging notices warning of the potential for enforcement if they divert when there is insufficient water available to support their diversions.

More than 950 inspections were conducted related to the 2014 notices, and more than 2,200 water right compliance inspections were conducted during the drought. DWR provided staff to the Water Board to assist with the large number of compliance inspections, an action last taken in the 1976–1977 drought. In general, the inspectors, who by law must notify landowners and get prior permission for on-site inspections, found good compliance with permits and curtailments. In addition, the presence of inspection staff helped promote and encourage compliance with the curtailments.

In 2015, riparian water rights claimants in the Delta negotiated a voluntary diversion reduction program with the Water Board's Delta Watermaster. The intent of the voluntary program was to provide regulatory certainty for participating diverters, given the very dry hydrology. Riparian diverters participating in the program who voluntarily reduced their diversions by 25 percent during the summer growing season would not be subject to curtailment enforcement by the Watermaster. An estimated 180,000 acres participated in the program. It has long been observed that measuring consumptive water use within the Delta is technically difficult due to the area's complex hydrological setting, but such estimates are critical for administering water rights and planning CVP and SWP exports. The Watermaster organized a study that began in 2015 to compare methods of estimating Delta crop evapotranspiration. One finding of the study was that in the right setting, satellite-based remote sensing methods can provide a cost-effective method for standardization and consistency across measurements.

Numerous other actions were taken within and outside of the major Central Valley watersheds. These included adoption of emergency regulations for enhanced conservation measures to protect instream flows for targeted fish habitats and informational orders to obtain data on water use.

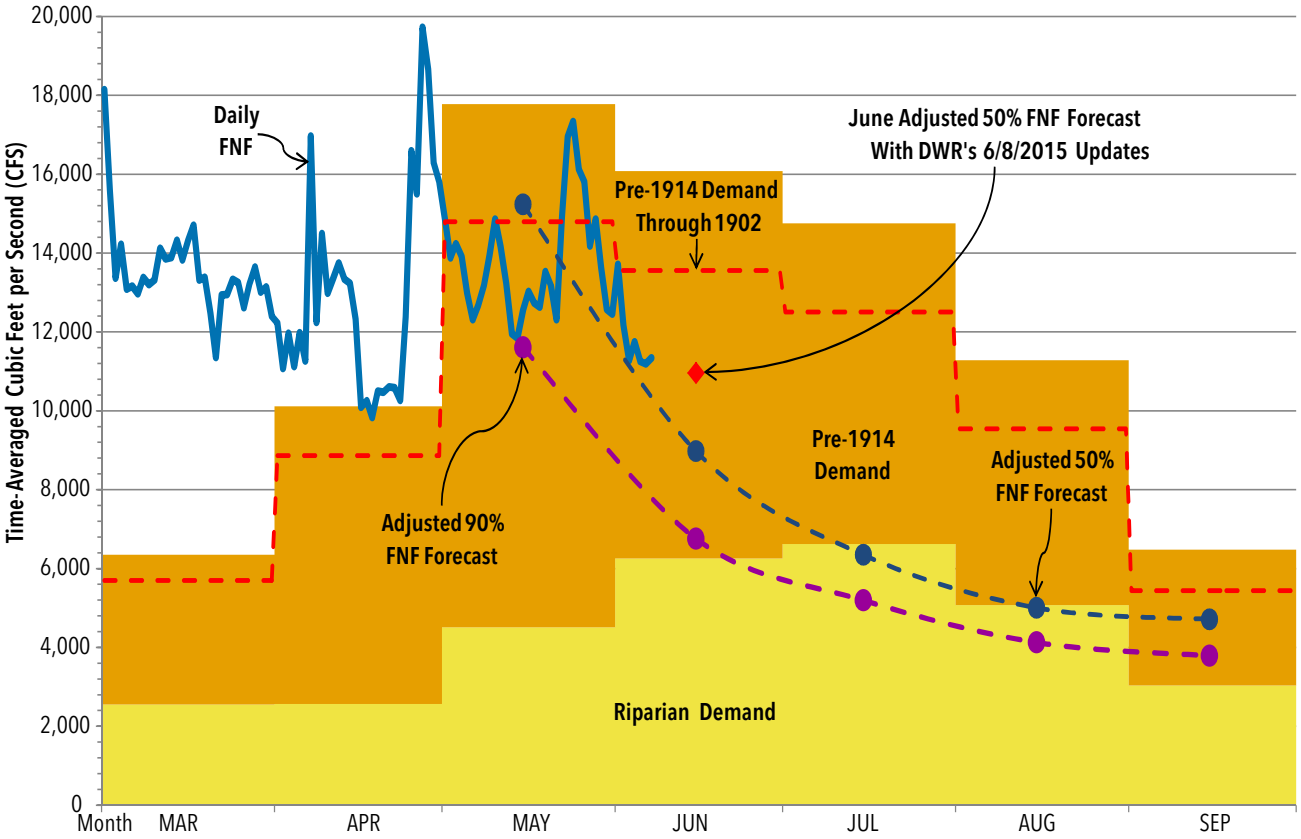
The Water Board adopted emergency regulations allowing for curtailment when stream flows fell too low for migrating fish in the Sacramento River tributaries of Mill, Deer, and Antelope creeks. These regulations complemented an initiative by the National Marine Fisheries Service (NMFS) and the California Department of Fish and Wildlife (CDFW) to encourage voluntary agreements among water users to coordinate diversions or share water. Separate emergency regulations for the watersheds of four Russian River tributaries restricted certain uses of water to reduce the amount of water diverted, leaving behind more water instream to protect Coho salmon and steelhead. Under the Russian River emergency regulations, the Water Board also collected information on surface and groundwater diverted from the watersheds by landowners and water suppliers. This information was needed to estimate total water demand for the watersheds and, if curtailment had been necessary, to determine water right priorities.

As directed by executive orders beginning in 2015, the Water Board developed a program to prioritize issuance of temporary water rights permits to allow agencies to take advantage of opportunistic high flow conditions for

groundwater recharge. Relatively few local agencies submitted applications for such permits. Where implemented, these permits were used to store tens of thousands of acre-feet of surface water underground during the wet years following the drought. The Yolo County Flood Control and Water Conservation District has obtained temporary underground storage permits each year for the past five years, and it has diverted over 21,000 acre-feet to underground storage since 2016, which was consumptively used for irrigation later each summer.

In some streams, major water right holders found it increasingly difficult to meet the environmental flow conditions in their water rights. To improve environmental conditions, enable transfers, and allow new, temporary

Figure 2.2: 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 credit: State Water Resources Control Board

diversions, the Water Board put significant effort into quickly processing temporary water right actions, including temporary urgency change petitions and water quality certifications for Federal Energy Regulatory Commission license amendments. These actions helped preserve diminishing reservoir storage and were often processed in a matter of days or even hours. However, these actions were not without controversy, largely due to the effects of lower flows for environmental habitat and fish species. The temporary urgency change petitions had both positive and negative impacts on sensitive anadromous species in Butte Creek. The changes in Butte Creek allowed for cold water holding areas for adult fish during the summer. In the Yuba River, changes resulted in lower flows that in turn resulted in temperature and flow impacts that affected steelhead juvenile fry and eggs.

Major challenges encountered

The drought highlighted the huge need for better information about many aspects of water management. This includes better understanding of the timing and volume of streamflows needed to protect fish, wildlife, and habitat. It also includes measuring and monitoring streamflow and diversions in near real time to support water rights administration and enforcement of curtailments. Although most large river systems with major water infrastructure are relatively well monitored in terms of streamflow, the same is not true for smaller tributary streams that may be ecologically important but have no water control structures other than irrigation diversions. Currently, diversions of 10,000 acre-feet or more annually are required to provide near real-time telemetered diversion data. Additionally, continuously monitored temperature data are lacking in many waterways important for listed salmonid species.

In the Bay-Delta watershed, pre-1960 appropriators and riparian diverters are not subject to a regulation, order, or permit condition requiring them to curtail diversions to meet water quality objectives. That reality, combined with outdated and infrequent water use reporting (prior to the drought, water users reported their use every three years), means that it is difficult to calculate when there are insufficient flows available for those pre-1960 appropriative and riparian diverters and to prevent those diverters from using water that may not be available to them legally. Data made available under the 2015 legislation, SB 88, will help inform water availability analyses and curtailments in the future, but only a year after the water use. The lack of any regulatory requirement that these diverters not divert flows needed to meet water quality objectives and the lack of real-time water use information make demand and availability for pre-1960 and riparian rights difficult to forecast or determine.

Finally, another factor that makes coordination and management challenging is that water right information is not within easy reach of the public; many records exist only on paper. Digitization of water rights data in an easy-to-use format would build understanding and transparency.

Notable State successes

Collaboration among State agencies was critical for curtailment inspections, data sharing, and fish and wildlife preservation efforts. The innovative effort by the Delta Watermaster to bring together operational agencies and researchers to review different methodologies for estimating consumptive water use in the Delta highlighted water measurement and water use estimation challenges and pointed out opportunities for incorporating increased remote sensing technologies in estimating water use.

In general, the State was able to manage the process of rapidly changing conditions within California's watersheds relatively well. Though staff-intensive and time-intensive, temporary urgency change petitions were processed quickly and allowed State and federal management of critical water infrastructure to balance water supply and environmental needs. The emergency suspension of CEQA allowed rapid adoption and consideration of important management decisions. Emergency CEQA suspension was also important in other Water Board regulatory actions, including rapid permitting of underground storage projects and the development of the instream flow regulations identified above.

Efforts where improvement is needed

A common theme experienced during the drought was the need for better information to manage risk, including temperature and precipitation forecasting with longer lead times. Temperature planning problems at Shasta Dam led to a herculean effort by regulatory and water supply agencies to modify previously agreed-upon flow requirements in the midst of the summer delivery season. Temporary changes to flow requirements below Shasta and elsewhere were necessary under the circumstances, but the net effect of these changes was a substantial relaxation of environmental requirements, putting even more strain on fish and wildlife. It is estimated that 95 percent of the Sacramento River winter-run Chinook production was lost in both 2014 and 2015 due to elevated temperatures below Shasta Dam. A third year of elevated temperatures likely would have jeopardized the viability of the population. The temperature issues observed during the drought highlighted the need for careful consideration of reservoir carryover during the first dry year of a drought but also provided recognition that holding additional water in storage can have ramifications for water users.

Recommendations for improving State response

The State should address temperature management in ecologically important streams prior to the next drought.

Robust and high-quality water data and transparency are crucial to managing shortages. Shared data will help agencies make decisions and help the public understand how those decisions are made.

Water rights information should be made easily available to the public by rebuilding the State's water rights database to include digital place of use, diversion, and case history information.

Water Board staff should improve the quality and timeliness of its water demand data and make that information readily available. Improved water use data–in particular, better temporal resolution and data quality assurance–are needed to support shortage analyses for water rights administration. This should involve developing a robust data analytics strategy and process for ensuring diversion data are accurate and useful. The requirement in SB 88 for actual measurement of diversions is a key part of this, as are opportunities to use satellite-based remote sensing applications to estimate evapotranspiration.

The Water Board should consider modifying the current requirement in its regulations that diverters of 10,000 acre-feet or more annually provide near real-time telemetered diversion data to apply to diverters of 500 acre-feet or more annually.

The Water Board should seek opportunities to streamline water rights enforcement processes for protection of senior water right holders. Earlier notices of likely unavailability of water under the diverter's priority, combined with adoption of regulations setting curtailment requirements, could have helped protect senior right holders and environmental resources later in the 2014 and 2015 growing seasons when water use, temperature, and flow were most critical.

Longer lead times are needed for effectively administering curtailments on the state's major river systems, and for supporting water rights holders' decisions to trigger temporary transfers or secure alternative supply sources.

Dedicated State staff are needed to support ongoing drought planning and preparedness work, and these resources could be used during droughts to form the core of a larger drought response team.

The Water Board should continue long-term planning efforts, including efforts to develop and implement instream flow objectives for the reasonable protection of beneficial uses, including fish and wildlife, and include drought provisions in these planning processes to the extent possible.

2.3 WATER SUPPLY

Major drought response activities undertaken

Most California surface water sources were affected by drought conditions, except for imported Colorado River supplies. Historically, the Colorado River has been a highly reliable supply for the state, even in dry conditions, thanks to its substantial reservoir storage capacity. That remained true in the 2012–2016 drought. More recently, long-term drought has increased shortage risk on the system, triggering modifications to existing management guidelines as total reservoir system storage continues to fluctuate around the half-full mark. In May 2019, the seven states that depend on the Colorado River adopted drought contingency plans to help address sustained dry conditions.

In the 2012–2016 drought, the Santa Barbara area was one of a few larger urban areas at significant risk of drinking water shortages. Declining levels in Lake Cachuma, owned by the U.S. Bureau of Reclamation (Reclamation), resulted in local agency installation of a barge-mounted temporary emergency pumping plant and more than 3,000 feet of temporary pipeline. Emergency pumping began in August 2015 and continued until February 2017; the reservoir had dropped to 7 percent of capacity by early Water Year 2016. DWR and the Water Board provided $3 million in drought assistance for the emergency pumping operation. Subsequently, DWR provided a $10 million grant toward improvement and 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 plant was used for less than a year and then mothballed until the 2012–2016 drought.

Looking out over Lake Cachuma at the intake tower that feeds water into the distribution system serving the greater Santa Barbara area. The temporary drought emergency pipeline in the lower foreground extends to a barge-mounted pumping plant in the reservoir.

Between June 2014 and December 2018, the Water Board approved $1.3 billion in drought funding, both grants and loans, to support 54 recycled water projects. The projects are expected to provide an additional 197,500 acre-feet of recycled water each year, increasing the state's recycled water supply by more than 27 percent.

As previously described in the drinking water section, other State emergency drought response actions related to water supplies were concentrated on smaller water systems and private well owners.

2.3.1 CVP and SWP

A defining feature of the 2012–2016 drought was the unprecedented reductions in CVP and SWP supplies (Table 2.1), most notably the zero allocations to CVP agricultural contractors in 2014 and 2015, and SWP allocations of 5 and 30 percent in 2014 and 2015, respectively. 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. However, the ability to arrange water transfers was constrained by the very dry hydrology of 2014 and 2015 and by uncertainty of the allocation amounts to the CVP and SWP water rights settlement contractors who often participate as sellers in transfers. (For instance, the SWP's Feather River water rights settlement contractors were cut by 50 percent in 2015.) DWR did not operate a drought water bank or dry year water purchasing program during 2012–2016 but did convey water for transfers initiated by local agencies. From 2012 to 2014, DWR conveyed 166,805 acre-feet of water made available through cropland idling or crop-shifting transfers; there

Table 2.1: CVP and SWP Allocations During the 2012–2016 Drought (Allocation in percent)

	SWP	CVP						
		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 a 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.

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 during that time for conveyance by the CVP.

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. Requirements to avoid potential impacts to Endangered Species Act-listed migratory and resident fish species were main drivers for considering potential barrier locations and the timing of installation. Installation of a 2014 barrier was planned and then deferred after above-average precipitation in the late spring.

One barrier ultimately was installed, at West False River in 2015. Construction started in May and removal began in September so that in-water work would be completed by mid-November, as required by environmental permits. Barrier installation and removal cost a total of $36 million. The barrier allowed for the conservation of about 100,000 acre-feet of water in reservoir storage. DWR prepared a detailed report on the barrier's efficacy (California Department of Water Resources 2019).

In January 2014, Reclamation and DWR submitted a temporary urgency change petition to the Water Board to seek a temporary modification to their water rights permits and licenses. Beginning on January 31, 2014, the Water Board issued a series of orders granting temporary modifications in response to drought conditions. The modifications allowed the projects to reduce Delta outflow and other flow-dependent water quality requirements and thus conserve upstream storage for later use. These modifications provided operational flexibility for managing the SWP and CVP under significantly drier hydrologic conditions than those anticipated when the Water Board adopted Water Right Decision 1641 in 1999, which required Reclamation and DWR to meet certain Delta water quality objectives. One element of the petition was forming a Real-Time Drought Operations Management Team (RTDOT), which included high-level representatives of DWR, Reclamation, the Water Board, CDFW, the U.S. Fish and Wildlife Service (USFWS), and NMFS. The RTDOT met at least weekly to coordinate CVP and SWP operations to

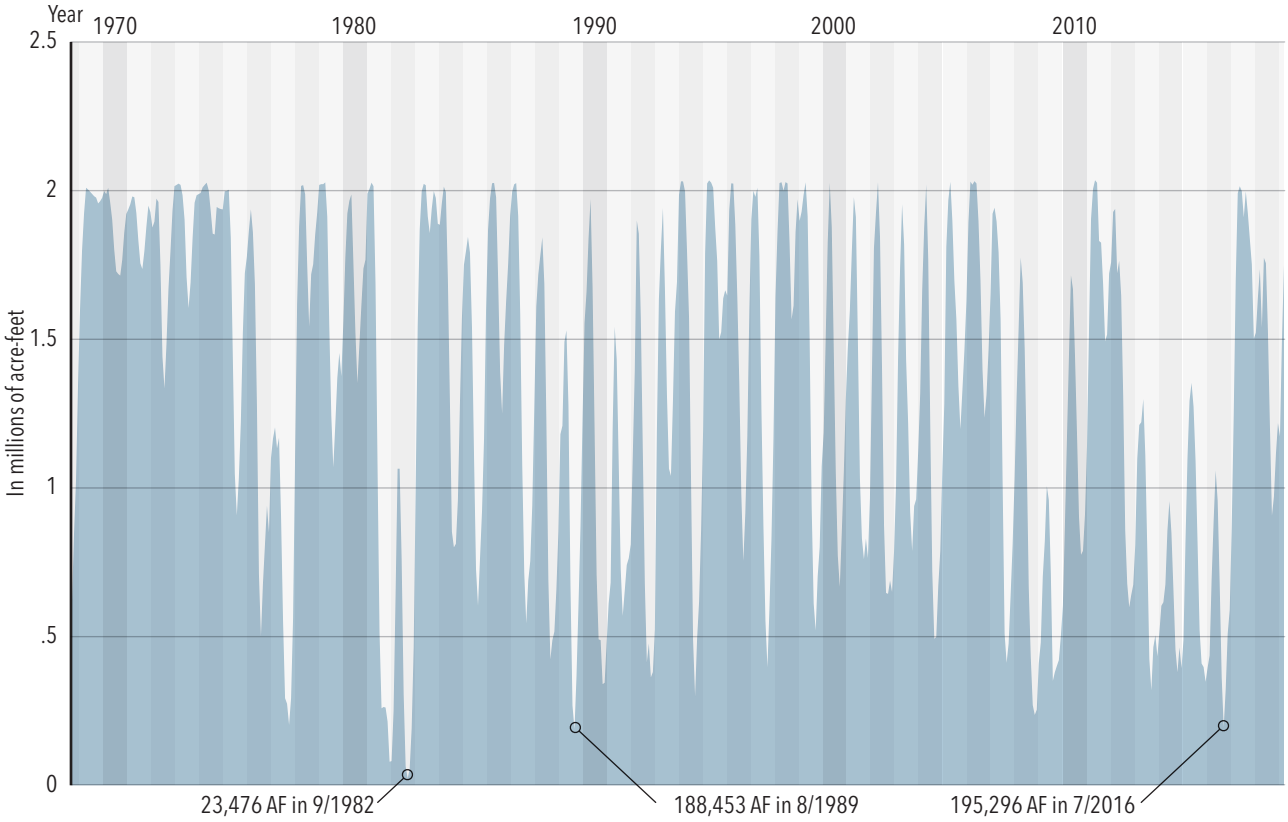
manage minimum health and safety water needs, Delta saltwater intrusion, cold water for salmonids, and actions to maintain minimum protections for endangered species and other fish and wildlife resources.

The 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 drought contingency plans for submission to the Water Board. 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 the following year was dry, particularly for preservation of a cold-water pool at Shasta Lake for Sacramento River salmonids.

Operating Shasta Dam to manage water temperatures for downstream Sacramento River salmonids was an ongoing challenge during the drought. Meager snowpack in Water Years 2014 and 2015 limited the volume of cold water entering the reservoir, and air temperatures warmed rivers and tributary streams. CDFW estimated that 95 percent of juvenile Sacramento River wild winter-run Chinook salmon were lost in 2014 and 2015 when Reclamation ran out of sufficiently cold water to release in the summer for temperature management, resulting in downstream river temperatures rising to more than 60 degrees. In Water Year 2015, overly optimistic temperature projections at Shasta Lake contributed to the water being

Figure 2.3: 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 dam's upstream face. 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.



warmer than expected because Reclamation failed to report or act on high temperatures immediately because the temperatures were different than what Reclamation had modeled. This delay in reporting actual temperatures triggered a May revision by NMFS of Reclamation's previously approved temperature plan that resulted in greatly reduced deliveries to CVP service contractors during the peak summer season. Reclamation borrowed water from the SWP's share of San Luis Reservoir, causing the reservoir to drop to near-record low levels (Figure 2.3), and solicited water loans and exchanges from other agencies to meet Delta salinity requirements and avoid shutting off deliveries to south-of-Delta water users.

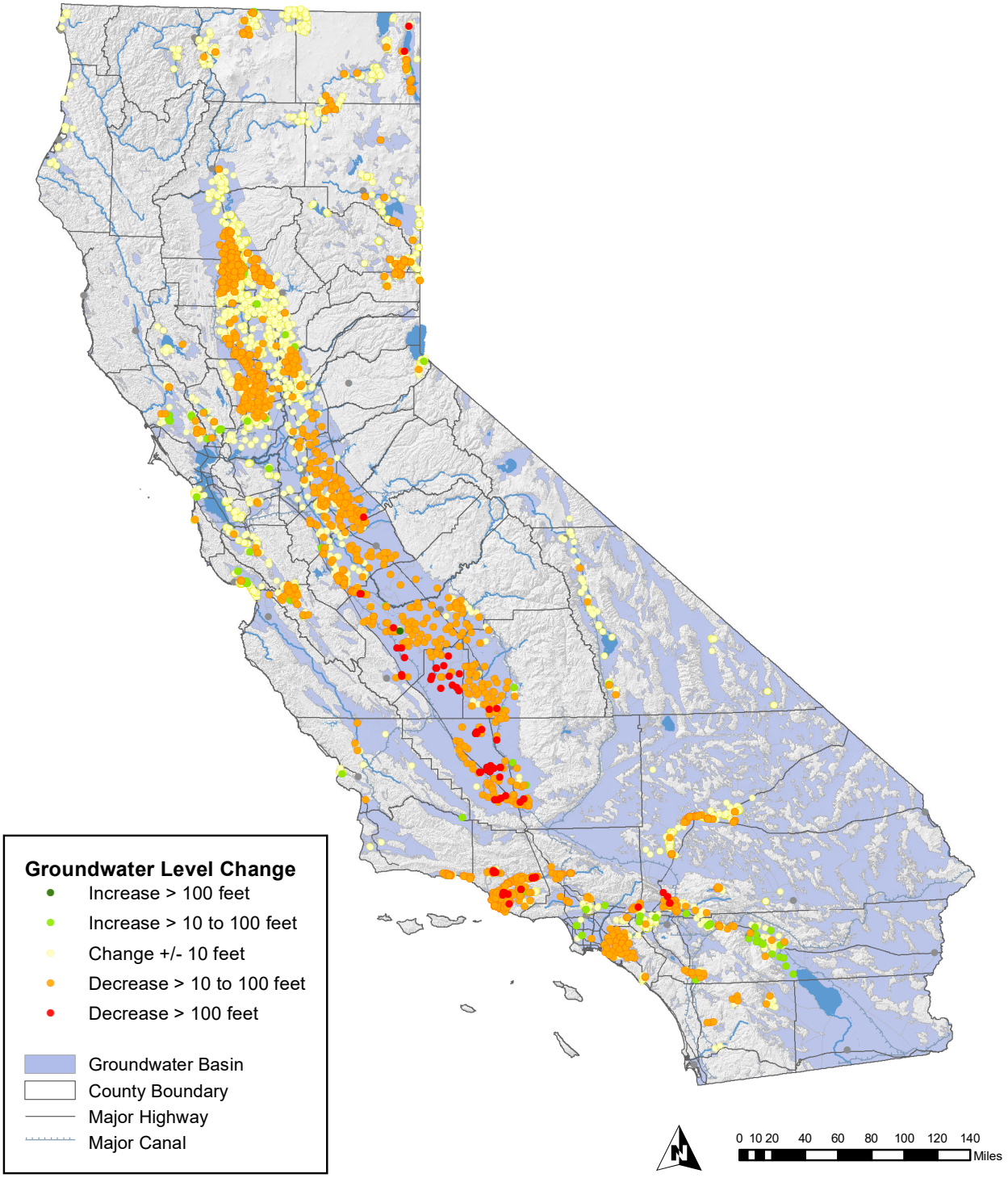
In an effort to preserve the remaining cold water in Shasta for juvenile winter-run Chinook salmon in the Sacramento River, Reclamation drew down Folsom Lake on the American River in the later summer and early fall of 2015 to meet regulatory requirements for Delta salinity. Based on projections showing that lake levels could drop below the elevation of the inlet supplying suburban Sacramento water agencies that rely heavily on lake water, Reclamation began construction of an emergency pumping barge in the summer of 2015. The City of Folsom and Folsom State Prison were of particular concern because they had no local groundwater supply sources and would have had to rely on imported groundwater supplies shared under a complicated arrangement with other Sacramento-area water agencies. El Dorado Irrigation District also installed a temporary emergency barge on the lake as a precaution to be able to supply the community of El Dorado Hills. Ultimately, emergency pumping operations were not necessary, although Folsom Lake reached a record low of 14 percent of capacity in November 2015. In Water Year 2016, near-normal precipitation for Northern California reduced the risk of stranding municipal intakes at the lake.

2.3.2 Groundwater

During the drought, many water users, urban and rural water suppliers, and farmers switched from relying primarily on surface water to groundwater. DWR has estimated that about 40 percent of California's urban and agricultural water is supported by groundwater in average water years, a figure that increases to about 60 percent in dry years. It is important to note that there were no State-imposed limitations on groundwater extraction during the drought. Provisions of the Sustainable Groundwater Management Act of 2014 (SGMA) that could result in local requirements to reduce extractions began taking effect in January 2020. Full implementation of the law should bring overdrafted groundwater basins into sustainable conditions over the next two decades. The SGMA allows groundwater sustainability plans to be flexible in how basins reach sustainability, including during drought. Basin managers, for example, could choose to pump more in drought years and bring the basin back into balance during wetter years. But even during drought periods, locally defined management actions will need to meet the sustainability criteria in their plans as well as consider long-term objectives.

Groundwater overdraft was a highly significant and difficult to reverse impact of the 2012–2016 drought. DWR's California Statewide Groundwater Elevation Monitoring program (CASGEM) made assessment of this impact possible with statewide groundwater level data. 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). A key report finding was that recent groundwater levels in many areas of the San Joaquin Valley had fallen more than 100 feet below previous historical levels. Groundwater depletion exacerbated or highlighted existing water quality issues in some basins. Degraded groundwater quality made it more difficult for communities and domestic well users to drill new wells or find alternative sources of water supply that did not require expensive pretreatment before it could be used. In other parts of the state, such as the northern San Francisco Bay, South Coast, and South Lahontan areas, groundwater levels were more

Figure 2.4: Cumulative Change in Statewide Groundwater Levels, 2012–2016 Drought



than 50 feet below previous historical lows. Figure 2.4 shows the drought's impacts on groundwater elevations throughout the state. 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.

2.3.3 Measuring Impacts of Water Shortages

Remote sensing technologies offer rapid-response capability for monitoring impacts during drought conditions. The benefit of satellite-based remote sensing applications is their ability to provide impact detection, for at least screening-level purposes, over large spatial areas and at reasonable cost. DWR piloted two successful examples.

Surface water shortages to agricultural water users spurred increased land fallowing, primarily in the San Joaquin Valley. In a pilot project supported by the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS), and the USDA, satellite imagery was used to prepare monthly updates of summer growing season land fallowing for DWR. This effort built upon work performed by the USDA's National Agricultural Statistics Service for its annual cropland data layer product. The pilot project's purpose was to make information available for near-term drought impact assessment. Figure 2.5 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).

Figure 2.5: Land Idling Based on Satellite Imagery, September Comparison of a Wet 2011 with a Dry 2015

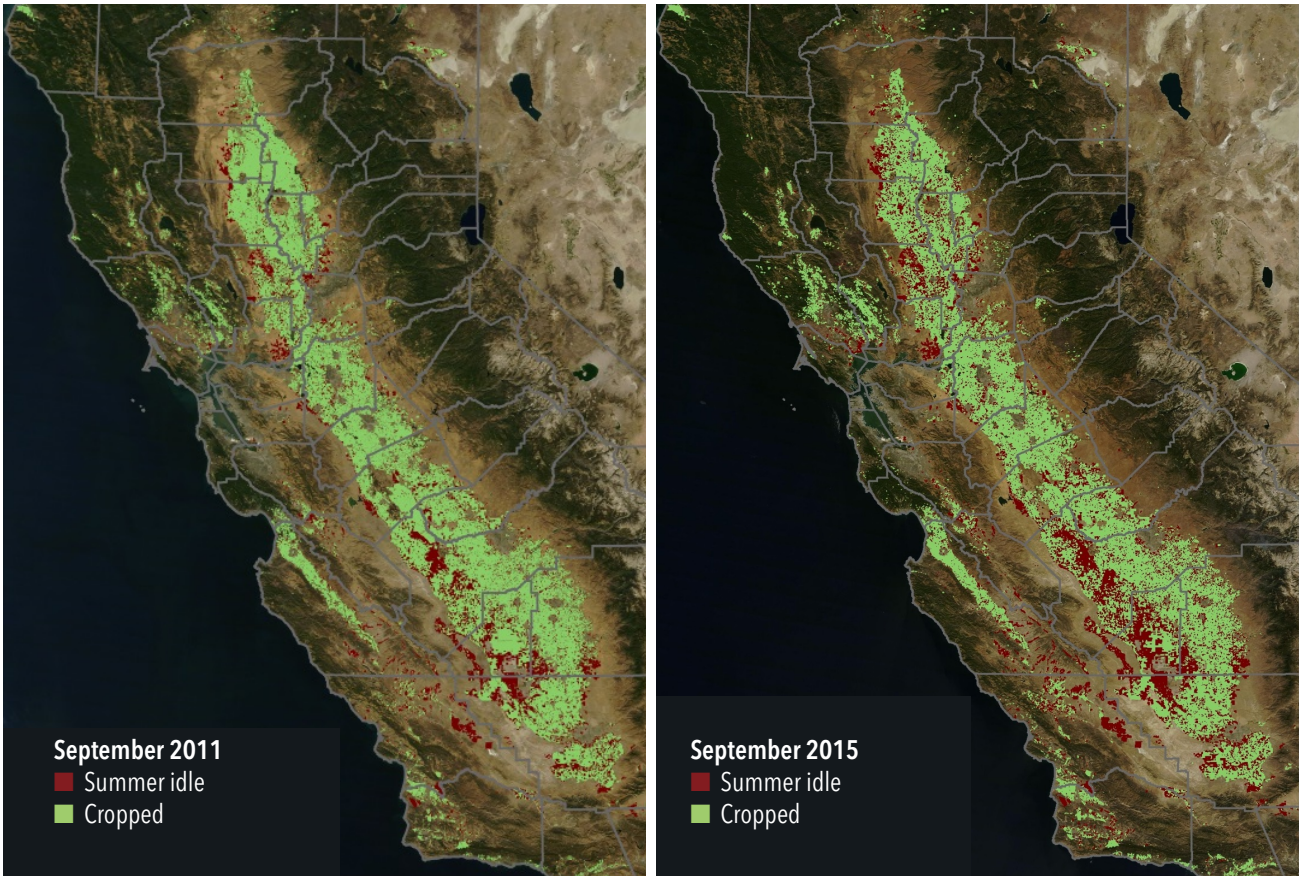


Figure credit: NASA

Figure 2.6: San Joaquin Valley Land Subsidence, May 2015–September 2016

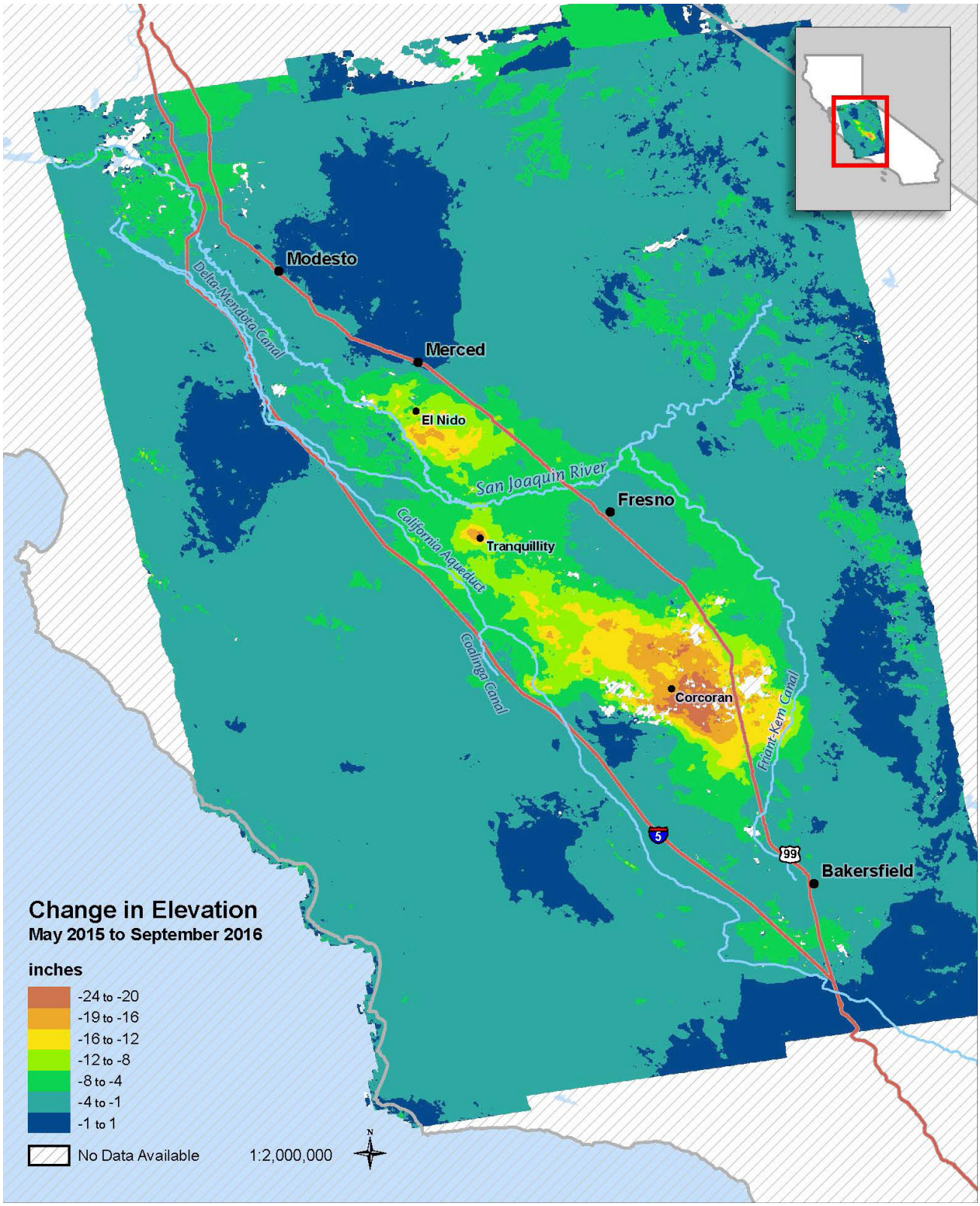
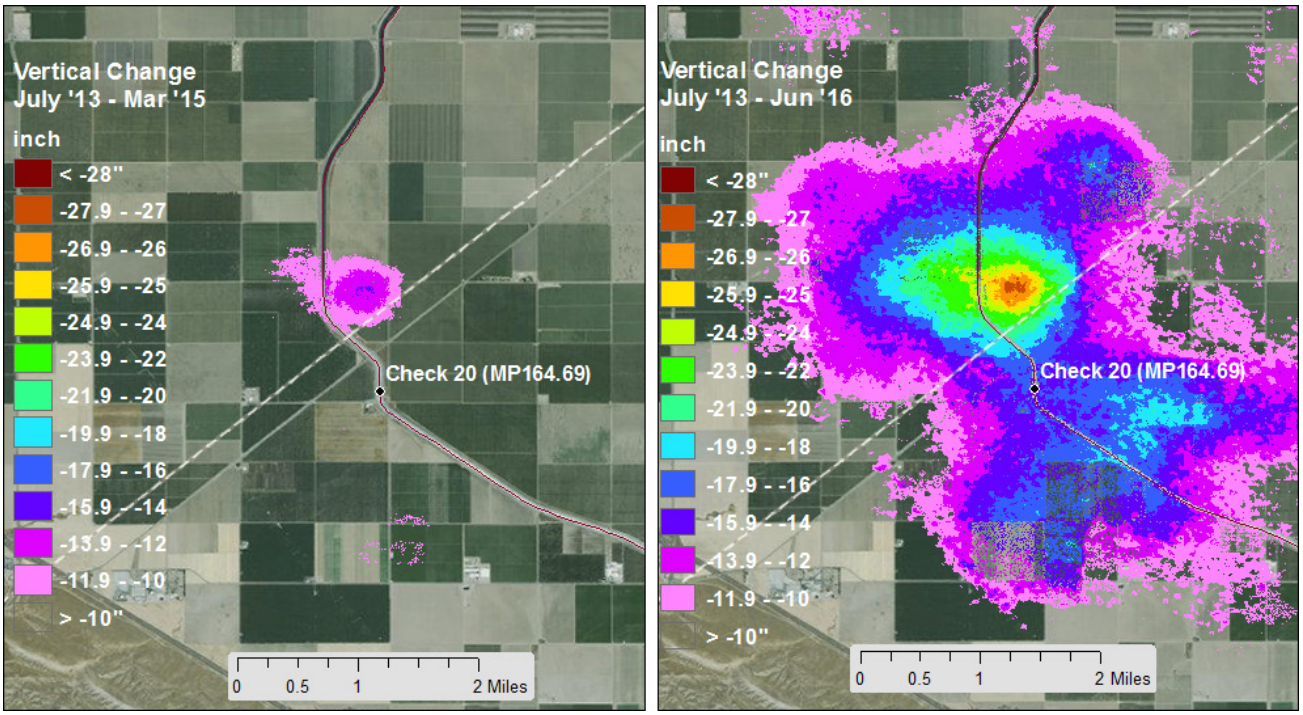


Figure credit: NASA JPL

Figure 2.7: 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

DWR contracted with NASA's Jet Propulsion Laboratory to provide regional-scale monitoring of land subsidence caused by groundwater extraction through use of satellite-based and aircraft-based interferometric synthetic aperture radar (InSAR). The driver for the monitoring was to assess subsidence risk to critical water infrastructure such as the SWP's California Aqueduct. The San Joaquin Valley was a geographic focus because of the region's long-term history of subsidence and extensive water infrastructure. Figure 2.6 shows a sample of the InSAR results. Observed annual San Joaquin Valley subsidence rates in some areas matched the record highs of approximately one 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 service contractors in 2014 and 2015. High-resolution, aircraft-based InSAR monitoring was able to detect the impacts of pumping on infrastructure, including the California Aqueduct (Figure 2.7).

Major challenges encountered

One of the most glaring examples of drought impact intensification due to climate change was the struggle to maintain cold-water habitat to support Endangered Species Act-listed salmonids. Nowhere were the challenges more obvious than the efforts to operate Shasta Dam and other CVP facilities to manage Sacramento River temperatures for salmon. It is physically difficult to maintain sufficiently cold summer river temperatures in water years with minimal snowpack runoff and record warm air temperatures throughout the summer months while also prioritizing early spring deliveries to contractors. A 2017 study by CalTrout and the University of California (UC), Davis, suggested that if present trends continue, 45 percent of California's salmon, steelhead, and trout are likely to be extinct in the next 50 years and 74 percent in the next 100 years.

Figure 2.8: Wells with Groundwater Level Data Available for 2007–2009 Drought

Determining how to manage anadromous fish populations in a significantly warming climate represents a long-term planning effort that goes beyond drought responses.

A significant problem with some projects, especially the CVP, was a failure to manage proactively. Instead of conserving supplies to achieve objectives, Reclamation waited until it was too late to avoid a violation before asking regulators for relaxation. An important lesson is to require advanced planning by reservoir operators, including but not limited to temperature management planning.

Notable State successes

The formation and implementation of RTDOT was a successful method of adaptively managing CVP and SWP operations in coordination with the Endangered Species Act and other Bay-Delta environmental regulatory requirements under challenging hydrologic conditions. In the future, improved planning for more extreme dry periods would ease real-time response coordination, provide more certainty for agencies and water users, and allow for better public participation in decision-making. Preparation of the CVP and SWP drought contingency plans was useful for providing some measure of certainty for project contractors during the water delivery year, although 2016 deliveries to CVP service contractors were threatened during the peak of the summer growing season by the problems with Shasta Dam temperature operations.

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 stranded by dropping reservoir levels.

CASGEM yielded notable improvement in situational awareness to support State drought response and to assess statewide groundwater conditions. The difference in availability of statewide groundwater level data between the (pre-CASGEM) 2007–2009 drought and the 2012–2016 event was striking; compare Figure 2.8 with Figure 2.4. Data for the Central Coast and Southern California were notably absent in 2007–2009. As local groundwater elevation data reporting shifts from CASGEM to local groundwater sustainability agencies created under SGMA, it is important to ensure that the full functionality of data previously provided through CASGEM is not impaired.

The InSAR remote sensing monitoring of land subsidence was extremely successful. It showed for the first time the extent of land subsidence over the entire San Joaquin Valley, identifying subsidence hotspots at critical water supply and flood control infrastructure, and even permitting the linkage of increased groundwater pumping for drought water transfers to the development of new subsidence hotspots. The success of InSAR monitoring for drought response purposes has led DWR to continue providing InSAR data as a technical resource to support local agency implementation of SGMA.

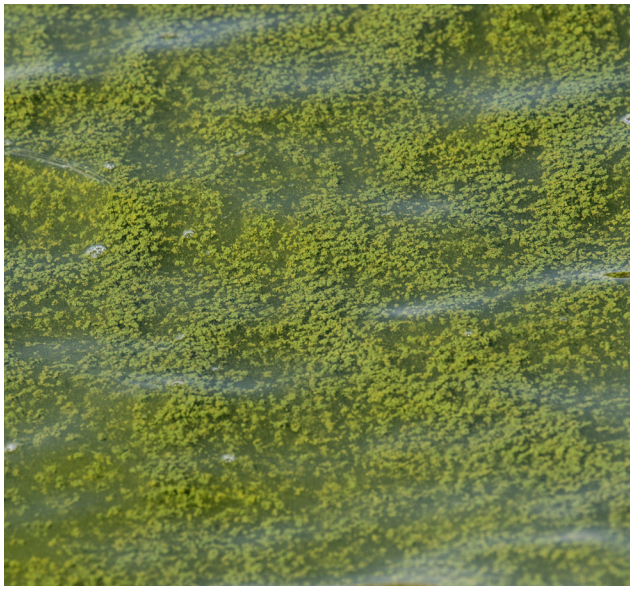
Recommendations for improving State response

Allowing Reclamation to draw down Folsom Lake to very low levels in 2015 to preserve the ability to make cold-water fishery releases from Shasta Lake was an operational

decision that increased potential risk for urban water users heavily dependent on diversions from Folsom Lake. Fishery needs were met to some degree, but the trade-offs carried high risks. An important lesson is to require advanced planning, including but not limited to temperature management planning. Reclamation should develop a more proactive temperature management plan early in the season, before delivery decisions are made. The Water Board requested that Reclamation provide a long-term protocol for temperature planning following the drought. That protocol called for early planning prior to initial water supply allocations and other measures. The Water Board should continue to pursue development of this protocol in collaboration with Reclamation and in consultation with other resource agencies.

DWR is presently making a limited investment with available funds in improving sub-seasonal to seasonal precipitation forecasting ability. This effort should be continued and expanded, and efforts should be made in the federal budget process to support needed research funding for NOAA. Innovations being developed by DWR can leverage federal research funding. Similarly, DWR should continue to support leading-edge remote sensing technologies for monitoring high-elevation snowpack to improve snowpack runoff forecasting.

Increased information technology (IT) investment is needed to enable State agencies to take advantage of available opportunities to use satellite-based remote sensing data to estimate evapotranspiration and water use. The ability of State agencies to implement remote sensing products developed by the research community has been hampered by IT limitations. For example, DWR has been unable to use applications that entail processing and storing large volumes of satellite data from NASA and university partners, such as the application for tracking agricultural land fallowing and the Spatial California Irrigation Management Information System water conservation technical assistance product.



Close-up of an August 2019 HAB at San Luis Reservoir.

DWR should develop a tool for communicating the status of drought and statewide water supplies that can be easily understood by a general audience. The national-scale U.S. Drought Monitor, a product developed by the University of Nebraska with federal financial support, was not designed to characterize water supply availability in a state as hydrologically complex as California. It can be misleading for people unfamiliar with its assumptions.

Prior to drought, water suppliers that have received State emergency assistance in multiple droughts should be a special focus for drought preparedness assistance or technical, managerial, and financial capacity review.

Regional water supply security in times of drought depends on a diversified portfolio of supply sources. These sources will vary by region, but water use efficiency, recycling, and stormwater capture all can play important roles in building drought resilience. State policies and investments should continue to encourage such projects.

2.4 WATER QUALITY

Major drought response activities undertaken

The drought's most visible water quality impact was harmful algal blooms (HABs), which were reported more

frequently during the 2012–2016 drought than during prior droughts. Reported freshwater bloom locations were widely distributed, ranging from the Klamath River in the north to Southern California lakes such as Lake Elsinore and the Salton Sea.

Increased reporting of HABS likely reflects multiple factors, including a high incidence of events due to low lake and reservoir levels combined with record temperatures during the drought years, as well as increasing awareness of the health impacts associated with HABs. Low flows and increased temperatures in rivers increased the occurrence and duration of harmful algal growth in flowing waters. Additionally, the mild winters increased the frequency of blooms in the winter, spring, and fall, seasons when blooms are usually less common.

The Water Board released its California HABs Portal in 2016 to centralize information on this subject, provide interactive maps of reported blooms, and improve coordination among the affected agencies and organizations. In addition, the Water Board has subsequently been participating in interagency collaborations on monitoring and outreach.

Recreational contact with HABs can have immediate potential health impacts that include dogs dying after swimming in affected waterbodies and people experiencing skin rashes and other symptoms. Reservoir and recreational facility operators and local health agencies frequently posted closure or warning notices at affected locations. DWR facilities with warnings or closures during the drought included San Luis Reservoir, Pyramid Lake, and Silverwood Lake.

Groundwater quality impacts associated with droughts are tied to the increased reliance on and extraction of groundwater. This increased pumping encourages and exacerbates seawater intrusion in coastal areas. In addition, increased salinity levels in surface waters and recycled water used for irrigation during drought periods can accelerate the accumulation of salinity within groundwater basins, especially in the southern San Joaquin Valley. Finally, increased groundwater extraction associated with droughts may act to enhance downward migration of certain contaminants, such as nitrate and uranium, in shallow groundwater into deeper groundwater supplies. Due to slow migration rates and longer response times, these water quality impacts are not as rapid and noticeable when compared with changes in surface water, but they are known threats to the groundwater resource.

Major challenges encountered

Prior to initiation of the Water Board's California HABs Portal in 2016, there was no centralized place with web support for affected agencies to report HABs, coordinate response, and obtain resources. In addition, guidelines for response and posting advisories for blooms were not uniform statewide until standardized guidelines were developed by a workgroup under the California Water Quality Monitoring Council and gained visibility. Therefore, understanding the effect of the drought on HABs was challenging, and there was no system to track HABs in the first years of the drought.

Notable State successes

The freshwater HABs program has increased its infrastructure and systems for tracking and responding to blooms. Since 2016, when formal reporting began, the number of partner entities that provide data to the HABs map has increased significantly. Legislation enacted in 2019 (AB 834) requires the Water Board to establish a freshwater and estuarine harmful algal bloom program to support monitoring and public posting of HABs at the state, regional watershed, and site-specific scales.

Efforts where improvement is needed

Average warmer temperatures are likely to make HABs more common and widespread. Sediment, fertilizer, and other nutrient-rich material in runoff to waterbodies exacerbate the problem.

Recommendations for improving State response

Allocation of dedicated staff and resources is needed to implement AB 834 and create an effective statewide

Figure 2.9: Adult Coho Salmon Returning to the Scott River Watershed, Siskiyou County, from 2007 to 2018 (Source: CDFW)

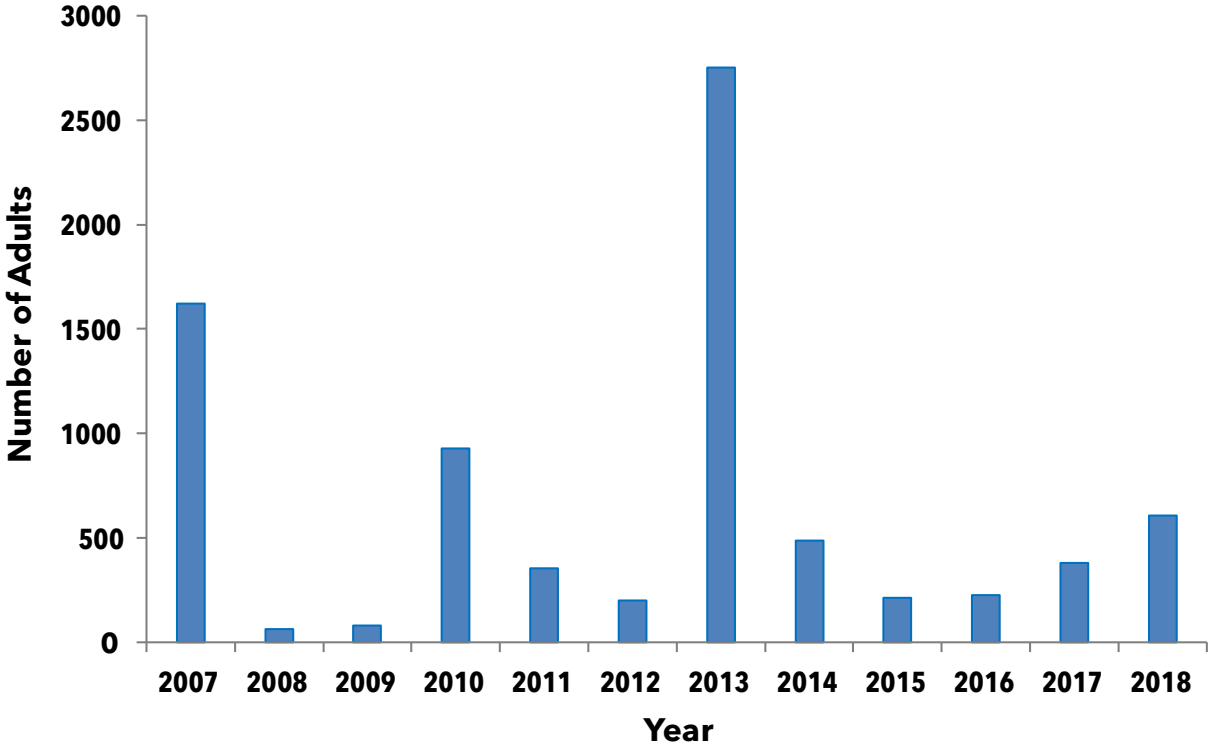
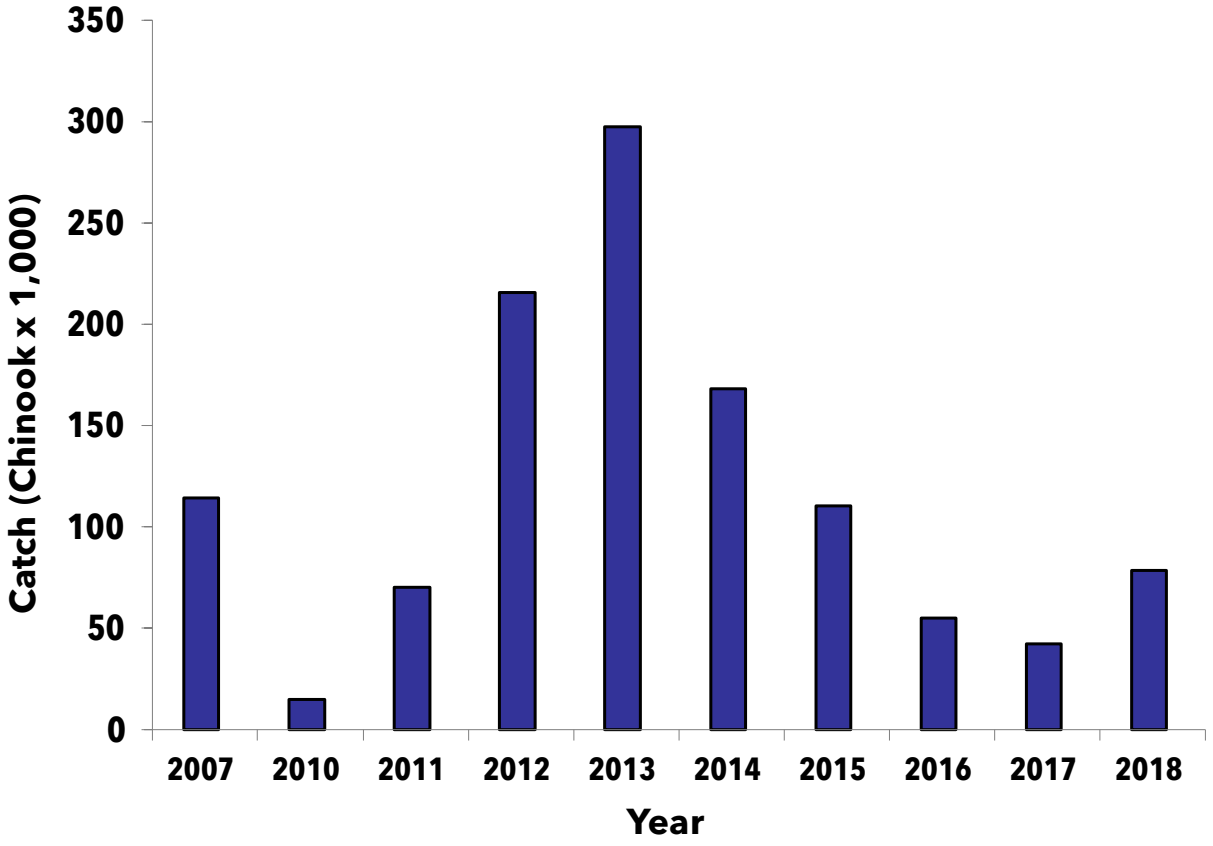


Figure 2.10: Commercial Chinook Salmon Landings in California (Source: CDFW)



system for monitoring, reporting, and tracking HABs. Statewide programs should focus on minimizing erosion, fertilizers, and other nutrient-rich nonpoint sources of pollution.

2.5 FISH AND WILDLIFE

Major drought response activities undertaken

The impact of record warm and dry conditions on both inland and marine fisheries throughout the state is difficult to overstate. Drought is an additional stressor for fish populations already experiencing long-term declines for multiple reasons that include loss of habitat, competition from introduced species, and water quality degradation. The 2012–2016 combination of record warmth and low flow compromised the ability of many species, including salmon and steelhead, to survive and reproduce. Climate-driven ocean conditions and ocean predation also affect anadromous fish species including Coho and Chinook salmon.

CDFW used drought emergency funds to conduct focused monitoring on drought stressors primarily related to anadromous fish species and their habitats in coastal watersheds and the Central Valley. Depending on the location, monitored parameters included flow, temperature, dissolved oxygen, or wetted channel area (stream fragmentation). The intent of the monitoring, covering 17 species or subspecies in 28 counties, was to provide better understanding of drought-related threats to vulnerable species and to help CDFW make resource management decisions.

Examples from this monitoring are shown in Table 2.2 and Figure 2.9. During the drought, survival for Sacramento River winter-run Chinook fry fell significantly, and fewer adult Coho returned to the Scott River. Salmon and steelhead require relatively cold fresh water for spawning, hatching, and rearing before migrating to the ocean to mature, with Coho salmon, for example, typically staying in fresh water for one to two years. The effects of river conditions during the drought are thus seen in salmon

Table 2.2: Sacramento River Winter-Run Chinook Salmon Egg-to-Fry Survival Rate at Red Bluff Diversion Dam from 2004 to 2016

Years	Egg-to-Fry Survival	Years	Egg-to-Fry Survival
2003	23.0%	2010	37.5%
2004	20.9%	2011	48.6%
2005	18.5%	2012	26.9%
2006	15.4%	2013	15.1%
2007	21.1%	2014	5.9%
2008	17.5%	2015	4.2%
2009	33.3%	2016	24.0%

Data credit: CDFW

populations three to five years later as adult salmon return from the ocean to spawn. Figure 2.10 shows California's commercial Chinook salmon ocean fishery harvest from 2007 to 2018, illustrating annual variability of the commercial fishery. (Commercial fisheries were closed in 2008 and 2009.)

Other drought-related fishery monitoring efforts included tracking the location of Delta smelt, a species state-listed as endangered and federally listed as threatened, to provide near real-time information to support operations at the CVP and SWP pumping plants in the South Delta. This program subsequently transitioned to an enhanced Delta smelt monitoring program carried out by USFWS to obtain a broader picture of Delta smelt abundance than that provided by CDFW's historical annual spring and fall surveys.

As described earlier, managing water project operations to try to control temperatures for salmon in the Sacramento River below Shasta Dam was perhaps the most challenging facet of CVP operations during the drought. Warm river temperatures led to fishery response actions such as trucking Chinook smolts to downstream release sites, rather than allowing them to make their way down the Sacramento River, to improve their chances of survival. This

action resulted in approximately 75 percent of 34 million fall-run Chinook smolts being trucked downstream of the Delta. This action was unprecedented, as normal hatchery operations truck approximately 10 million smolts during normal water-year operations.

A pool of anomalously warm water nicknamed "the Blob" dominated the northeastern Pacific Ocean in 2014–2016 which, together with warm conditions from El Niño, resulted in the northward migration of many species typically seen off the coast of Mexico. The marine heat wave disrupted ocean food chains through weakening of the upwelling process that brings cooler nutrient-rich water to the surface, ultimately reducing food availability for commercial fish stocks as well as for marine mammals. NMFS declared two California "unusual mortality events," pursuant to the Marine Mammal Protection Act, for sea lions in 2013–2017 and for Guadalupe fur seals in 2015–2018. Also associated with "the Blob" was a harmful algal bloom that stretched along the entire West Coast from Alaska through California and resulted in closure of recreational and commercial fisheries for sardines, anchovies, crabs, and clams in the affected areas.

CDFW took advantage of drought emergency funding to improve water supplies at some of its hatcheries and wildlife management areas, including rehabilitating existing wells, drilling new wells, repairing water conveyance facilities, and installing new pipelines. State wildlife areas with such projects included Honey Lake, Eel River, Mouth of Cottonwood Creek, Gray Lodge, Upper Butte Basin, Grizzly Island, Napa-Sonoma Marshes, Mendota, Carrizo Plain, and the Cosumnes River and Canebrake ecological reserves. Work at hatcheries included installation of water recirculation systems, chillers, and fish rescue units at locations such as the interim San Joaquin salmon facility and the Mount Shasta, Nimbus, American River, Merced River, Mojave River, and Fillmore hatcheries. Emergency drought funding was also used for implementing a pilot Central Valley steelhead monitoring plan.

Extensive efforts were made in larger managed streams (where dams and other structures regulate flows) to use flow requirements to control temperatures for Endangered Species Act-listed species. On Mill and Antelope creeks in the Sacramento Valley, which support self-sustaining populations of spring-run Chinook salmon, CDFW negotiated voluntary agreements with landowners or diverters to enable monitoring or fish rescue and relocation, forbearance of diversions, or provision of instream flows. These voluntary agreements were spurred by the Water Board's emergency regulations for the watersheds: water users could avoid curtailment if they could reach voluntary agreements with NMFS and CDFW to protect stream flows. Statewide, a limited number of local voluntary management agreements addressed low-flow conditions and species protection. On the Scott River, voluntary agreements allowed onstream diversions to continue as long as the diverter reduced or eliminated diversions during the base flow late summer-fall season to protect juvenile Coho salmon. These agreements helped preserve critical species resources but addressed a small portion of the state. In general, voluntary agreements are hampered by a lack of background data on water right uses and users, instream flow species needs, and staffing requirements.

CDFW carried out a variety of fish rescues during the drought. More than 850 separate rescues of native fishes were conducted, as well as rescues of at-risk native wildlife, including the western pond turtle and Amargosa vole, which inhabit isolated wetlands of the Mojave Desert. In some cases, rescued fish were brought into captivity until their habitat recovered. Many salmonid fish rescues involved capturing and relocating juveniles and adults in response to fish stranding or capturing individuals for captive rearing projects to preserve genetic diversity. For example, juvenile Coho salmon were collected from Redwood Creek in Marin County and raised in Warm Springs Hatchery, with adults subsequently released back into Redwood Creek to spawn. Rescues focused on the most threatened native fish, such as salmon and trout species, and inland freshwater species including species of

special concern, such as the unarmored three-spine stickleback and Sacramento perch. Although most of CDFW's drought response efforts were focused on aquatic species, response efforts also included rehabilitation of wildlife guzzlers, an Amargosa vole captive breeding and habitat restoration project, and a supplemental feeding experiment for San Joaquin Valley kangaroo rats.

During the drought, the California Fish and Game Commission imposed numerous closures of recreational fisheries to protect species populations. Fishery closures were implemented on the upper Sacramento River upstream of Redding, American River, and Merced River to protect vulnerable anadromous fish. The upper Sacramento River was eventually closed permanently to protect the endangered winter-run Chinook salmon. As drought severity peaked in early 2014, the commission required what were described at the time as unprecedented fishery closures on the North Coast, an area then experiencing especially dry hydrology. In 2016, the commission adopted emergency regulations authorizing CDFW to impose temporary closures.

Major challenges encountered

Obtaining near real-time data on streamflow and water temperature in smaller waterways that lack the instrumentation infrastructure of the state's major river systems is difficult. CDFW expended substantial staff resources during the drought manually collecting water quantity and quality data on streams important for salmonid and trout habitat.

CDFW's hatcheries experienced severe difficulties because of decreased water supply, inferior water quality, and increased threat of water pathogens connected to the prolonged drought.

The drought worsened the effects of illegal large-scale marijuana growing operations on remote public lands, especially federal lands in northwestern California, by drying up headwater fish and wildlife habitat and introducing large quantities of fertilizers and pesticides into sensitive upper watersheds.

The drought triggered the need at CDFW for additional support for field monitoring, fish rescues, human-wildlife conflicts, IT, and internal and external communications. CDFW had adequate funds for contracts, grants, and some infrastructure improvements, but funding to support field activities was lacking in many cases. Hiring and mobilizing staff posed a significant challenge. Eighteen limited-term staff were hired to aid in the drought response, but hundreds of permanent staff in the field and headquarters shifted responsibilities to address drought.

A lack of resources hobbled the department's ability to promptly communicate information internally and to partners, local government, and the public.

Notable State successes

The significant support funding made available through drought emergency funds allowed CDFW to carry out much-needed maintenance and upgrades at many hatchery and wildlife area facilities. Hatchery improvements such as additional water filtration, the use of ultraviolet light to kill pathogens, and installation of self-contained circular fish tanks enabled several State facilities to rear trout, steelhead, and salmon under abnormal conditions.

CDFW was able to implement water-use efficiency projects at wildlife areas, ecological reserves, and hatcheries that will conserve water and improve the function and resilience of the facilities.

There were an unprecedented number of recreational and commercial fishery closures at inland and coastal sites during the drought. The California Fish and Game Commission adopted emergency regulations allowing CDFW to temporarily close drought-affected fisheries. These measures were instrumental for resource protection in key areas.

The Water Board, State and federal law enforcement, and federal land management agencies partnered to investigate and respond to illegal marijuana grows on public lands. Partnerships also included operations on tribal lands, including requests from the Yurok Tule River tribes for large-scale eradication efforts on reservation lands.

CDFW teamed with the Water Board to identify a set of environmentally diverse watersheds for tracking drought impacts and responses. The Ventura, Shasta, Scott, and South Fork Eel rivers; Mark West Creek on the Russian River; and Mill Creek on the Sacramento River are now permanent reference points for both departments in evaluating watershed health.

In response to the drought, CDFW began a successful human-wildlife conflicts program that continues. It has led to interagency collaborations such as the "Keep Tahoe Bears Wild" project.

Hatchery improvements made to address the impacts of the drought have also allowed CDFW to bring into captivity the most-at-risk populations of some fish species, including Coho salmon, golden trout, McCloud River redband trout, Central Valley steelhead, and unarmored three-spine stickleback.

Efforts where improvement is needed

The lack of stream gauging data on waterways that provide important habitat for listed anadromous and inland trout fish species made it more difficult to plan for fish rescues and respond to stranding events. With the experience and data obtained during this drought, efforts should be made to identify stream reaches that would be at risk in future droughts due to high temperatures, low flows creating hydraulic discontinuity, or fish passage impediments such as culverts. These areas should be prioritized for attention in future droughts.

The extensive environmental monitoring effort made during this drought demonstrated that more IT support for ecological mapping, data management, and programming is needed, especially for field operations and related data collection. Dedicated IT resources would allow field personnel to concentrate on being in the field and support improved communications between CDFW and other agency partners and the public.

The 24-month, limited-term positions provided to CDFW and other agencies including the Water Board for drought response were insufficient to support drought response or to plan for or prepare for future droughts; the drought lasted well beyond two years. Permanent staffing is needed to support ongoing drought preparedness, with those resources shifting to drought response when dry conditions occur.

A CDFW drought communications center should be established to improve internal coordination and information sharing and to prepare notices and news releases for the public.

Recommendations for improving State response

Allocate additional staff resources for drought preparedness, environmental resilience actions, IT support, and communications.

Better account for species needs (including temperature) when making supply allocations at the start of a dry year.

Develop instream flow science and data and make that data available to the public so that local groups can better plan for and manage their own watersheds.

CDFW will work with DWR and the Water Board to identify waterways where long-term State investment in monitoring infrastructure is warranted as agencies implement SB 19, the 2019 law that requires development of a plan to address gaps in the State's stream gauge network.

Additional funding will be needed to upgrade the water supply infrastructure at many CDFW-owned sites, including hatchery water treatment and water conservation improvements.

2.6 WATER CONSERVATION

Major drought response activities undertaken

The 2012–2016 drought was the first time the State imposed mandatory urban water use reductions on all urban suppliers. Due to its regulatory authorities, the Water Board led mandatory water use reduction efforts. DWR's most visible activity was administration of the Save Our Water public outreach program, which was carried out by the Association of California Water Agencies (ACWA) under

a DWR grant. DWR was also directed to lead an initiative to partner with local water districts to update the State's Model Water Efficient Landscape Ordinance (MWELO) and to replace 50 million square feet of lawns and turf with drought-tolerant landscapes.

State-mandated urban water use reduction began with an initial request for a voluntary statewide 20 percent reduction in outdoor urban water use followed by a series of mandatory water use restrictions imposed via emergency regulations adopted by the Water Board. The regulations targeted specific types of behavior and required local water suppliers to reduce demand for water in their service areas. A chronology of the evolution of the restrictions over the course of the drought is summarized in the sidebar.

There were no State-mandated conservation requirements imposed on agricultural water use directly comparable to those for urban water use. As described in Section 2.3.3, however, reduced surface water availability resulted in both a greater dependence on groundwater and a substantial reduction—approximately 500,000 acres—in irrigated acreage (fallowing). Moreover, some reductions in urban and agricultural water diversions occurred during the normal process of water rights administration (curtailments for junior priority users). Through a 2015 executive order, agricultural water suppliers were required to include drought management plans in their 2015 update of Agricultural Water Management Plans, and a new requirement was imposed on smaller agricultural water suppliers (those serving 10,000 to 25,000 acres of irrigated land) to prepare drought management plans.

In May 2015, the Water Board adopted an emergency conservation regulation, in response to the Governor's April 2015 Executive Order B-29-15, requiring a 25 percent reduction in overall potable urban water use statewide. The regulation distributed urban water suppliers among nine tiers of water use reduction, ranging from 4 percent to 36 percent based on overall water use. The regulation required monthly reporting on suppliers' conservation achievements, enabling the Water Board to determine if water suppliers were on track for meeting their conservation standards, and it allowed the Water Board to take enforcement action when necessary. The actions were designed to safeguard the state's remaining water supplies in preparation for a possible fifth year of drought.

The Water Board modified its emergency regulations to a "stress test" approach to better account for local climate zones and differences in reserve supplies. Under the stress test approach, suppliers were to assess their supply sources based on the assumption that the next three years' precipitation would be the same as in Water Years 2013–2015 and reduce their water use if they identified a shortfall between projected water availability and demands. Of the 411 water suppliers covered by this requirement, 83 percent passed the three-year stress test and would not be subject to mandatory water use reductions, 9 percent would need to implement some level of reductions, and 8 percent did not submit stress test results and would be subject to the previously imposed water use reduction tiers (Figure 2.11).

The May 2016 Executive Order B-37-16 addressed aspects of the ongoing State regulatory process for drought but focused largely on "making water conservation a California way of life." It directed the Water Board and DWR to develop new permanent water use reduction targets that would build from and expand on the savings from a requirement enacted in 2009 calling for a 20 percent reduction in per capita water consumption by 2020.

The April 2017 Executive Order B-40-17 lifted the statewide emergency proclamation and resulted in termination of the mandatory drought emergency water conservation requirements. The Water Board reviewed the state's water supply conditions and lifted the stress test requirements and remaining mandatory conservation standards for water suppliers. Monthly reporting of water use and prohibitions against wasteful practices, such as watering lawns after rainfall, remained in place. Executive Order B-40-17 also directed continued actions related to

Chronology of State-Mandated Reductions in Urban Water Use

- January 2014. A proclamation of statewide emergency due to drought calls for State agencies, led by DWR, to execute a statewide water conservation campaign built on the existing Save Our Water campaign and calls for Californians to reduce their water use by 20 percent. Local water agencies are asked to immediately implement their water shortage contingency plans. DWR subsequently executed an $11 million contract with the Association of California Water Agencies (ACWA) for Save Our Water.

- April 2014. A proclamation of a continuing state of emergency orders the Water Board to adopt emergency regulations directing urban water suppliers not already implementing drought response plans to limit "outdoor irrigation and other wasteful water practices." The Water Board was to request by June 15 an update from water agencies on actions to reduce water usage. The proclamation further orders that homeowners association provisions prohibiting compliance with conservation requirements are void and unenforceable.

- July 2014. Water Board Resolution No. 2014-0038 (emergency regulations) prohibits specified uses (e.g., washing sidewalks and driveways with potable water) and orders urban water suppliers to implement provisions of their water shortage contingency plans that impose mandatory restrictions on outdoor irrigation of ornamental landscapes and turf with potable water, or limit customers' outdoor irrigation to two days per week or achieve equivalent water use reductions. It further orders suppliers to submit monthly monitoring reports to the Water Board.

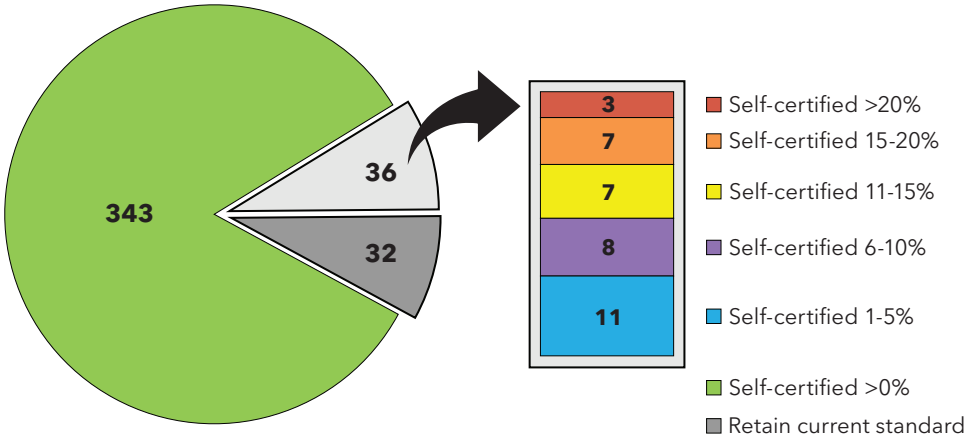
- March 2015. Water Board Resolution No. 2015-0013 readopts and edits the sunsetting July 2014 regulations.

- April 2015. Executive Order B-29-15 directs the Water Board and the California Public Utilities Commission (CPUC) to impose restrictions on water suppliers to achieve a 25 percent reduction in potable water use through February 2016, including commercial, industrial, and institutional users. It further directs the Water Board and CPUC to direct suppliers to develop rate structures and pricing mechanisms including "surcharges, fees, penalties" to maximize water conservation. It orders the Water Board to prohibit irrigation with potable water of ornamental turf on public street medians, and irrigation at newly constructed homes, excepting drip and microspray systems, and requires urban suppliers to provide monthly information on water usage, conservation, and enforcement "on a permanent basis." The executive order directs DWR to update the State Model Water Efficient Landscape Ordinance through expedited regulations; the ordinance is intended to reduce landscape water use, including limiting the portion of landscapes that can be covered in turf. Additionally, the executive order requires DWR to lead an initiative in partnership with local agencies to replace 50 million square feet of lawn with drought tolerant landscapes, with DWR to provide funding for replacement programs in underserved areas. It also orders the California Energy Commission to adopt emergency regulations establishing standards to improve efficiency of plumbing fixtures such as toilets and faucets.

- May 2015. Water Board Resolution No. 2015-0032 (emergency regulations) places water suppliers into one of nine water reduction tiers, which are assigned a water use reduction amount ranging from 4 percent to 36 percent based on overall water use. (For example, the San Francisco Public Utilities Commission is assigned an 8 percent reduction, while the City of Redding must reduce water use by 36 percent.) Other requirements of the prior emergency regulations are carried forward.

- November 2015. Executive Order B-36-15 directs the Water Board to extend urban water use restrictions through October 2016, and to consider modifying its restrictions to address uses of potable and non-potable water and to incorporate insights gained from the existing restrictions.
- February 2016. Water Board Resolution No. 2016-0007 revises prior emergency regulations, including, where applicable, a reduction in mandated water use reductions of up to four percentage points to reflect regional climate differences.
- May 2016. Executive Order B-37-16 (making water conservation a California way of life) directs the Water Board to adjust emergency regulations through January 2017 "in recognition of the differing water supply conditions across the state," and to also develop by January 2017 a proposal to achieve a mandatory reduction in potable water use that "builds off the mandatory 25% reduction called for in Executive Order B-29-15 and lessons learned through 2016." It further orders the Water Board to permanently prohibit practices wasting potable water, such as hosing off sidewalks and driveways and irrigating ornamental turf on public street medians. The order directs DWR to work with the Water Board to develop new permanent water use reduction targets, building off the existing legal requirement for a 20 percent reduction by 2020, with the targets to be customized to the unique conditions of each water agency, and to generate more statewide reduction than existing requirements. It further directs DWR and the Water Board to permanently require urban suppliers to issue a monthly report on their water use, amount of conservation achieved, and any enforcement efforts.
- May 2016. Water Board Resolution No. 2016-0029 calls for water suppliers to self-certify their supply reliability, substituting a "stress test" approach for the previous water use reduction tiers approach. Suppliers are to assess their water supply availability assuming the next three years' precipitation is the same as it was in Water Years 2013–2015, and to implement water-use reduction measures if they identify a shortfall between projected demands and supplies associated with the three-year projected precipitation. Suppliers not carrying out a stress test are required to reduce their water use at mandated tiered levels.
- August 2016. The Water Board releases results of the "stress test" submittals for 379 water suppliers. Most of the suppliers passed the stress test, meaning that no state-mandated water use reduction is required. Thirty-six suppliers identify a need for some level of mandated water use reduction, and 32 suppliers do not submit a stress test analysis and are required to meet the March 2016 water use reductions.
- February 2017. Water Board Resolution No. 2017-0004 adopts emergency regulations to continue mandatory water use reductions, which prohibit wasteful practices and set a conservation mandate for water suppliers that do not have enough water to withstand three more dry years ("stress test"), in response to the pending February 28, 2017, sunset date of the regulations adopted by Resolution 2016-0029.
- April 2017. Executive Order B-40-17 lifts the proclamation of statewide drought emergency and directs the Water Board to rescind those portions of its emergency regulations that require a water supply "stress test" or a mandatory conservation standard. It directs the Water Board to continue development of permanent prohibitions on wasteful water use and requirements for reporting water use. (The Water Board voted to make monthly reporting mandatory on April 21, 2020.) It further orders the Water Board and DWR to continue implementing actions called for in Executive Order B-37-16 (making water conservation a California way of life).

Figure 2.11: Results of Water Board "Stress Test" Process for Setting Mandatory Urban Water Use Reductions



The above results include one supplier new to reporting that also submitted "stress test" information, bringing the total number of urban water suppliers to 411.

"making water conservation a California way of life." Subsequently, 2018 legislation codified the State's role in efficient urban water use, including setting a statutory standard for indoor residential water use and requiring the Water Board—in coordination with DWR—to adopt standards for outdoor residential water use; outdoor commercial, industrial, and institutional water use; and water loss.

Major challenges encountered

Although ample statewide data were available for reservoir storage amounts, water project allocations, and water levels in major groundwater basins, data were lacking on fractured rock groundwater resources (important for small water systems in rural areas), real-time urban water use, and, importantly, the likely duration of drought conditions.

Past California droughts had demonstrated that larger urban water suppliers were generally well-prepared to weather multiyear droughts. But the two particularly dry years of 2014 and 2015, record warm temperatures, and extensive news media coverage of a severe 10-year drought in parts of Australia amplified uncertainty that helped lead to the imposition of mandatory urban water use reductions. Many water districts complained that the mandatory water targets were too inflexible and failed to account for local water supplies, local conditions, and other factors. As ratepayers conserved and water sales fell, many districts raised rates, added fees, tapped reserves, or delayed infrastructure projects to cover fixed costs and cope financially. The availability of current data on urban water use likely would have reduced the uncertainty.

California homeowners who took advantage of rebates offered by DWR or a local water district to replace turf with drought-tolerant landscaping found themselves in a gray area in terms of federal taxes. While the turf-removal rebates were exempt from California taxes by AB 2434, enacted in 2014, the U.S. tax code only provides tax exemptions for rebates that are related to improving energy efficiency, not water-saving measures. The State and water districts including the Metropolitan Water District of Southern California (MWD), which invested $340 million in a turf-rebate program during the drought, sent 1099 forms to rebate recipients and advised them to work with tax experts to figure out how to handle any federal tax implications of the rebates.

Notable State successes

Given that half the water used in urban areas goes to irrigated landscapes, the 2015 update of the MWELO will save significant amounts of water in coming decades. Local governments must set landscape requirements for new or

retrofitted developments that meet or exceed the MWELO.

DWR and local water districts exceeded the State goal to replace at least 50 million square feet of lawn and turf with more drought-tolerant landscapes. Rebate programs funded by DWR and MWD, for example, have led to the removal of at least 167 million square feet of turf since 2015. That amounts to approximately 3,800 acres of converted landscaping.

The combination of mandatory urban water use reductions and extensive public outreach campaigns were successful in reducing water use. In the six months after the emergency regulation took effect, Californians reduced their water use by 25.5 percent. From June 2015 through February 2017, over 2.6 million acre-feet of water were saved through urban water conservation during the drought, enough to supply over 13 million people—more than a third of the state's population—for a year. This was at a time when the state as a whole experienced substantial shortfalls in agricultural supplies and environmental flows.

Past droughts had already demonstrated that Californians were responsive to voluntary education and outreach about water use reduction during drought. With the additional threat of mandatory penalties, almost all water suppliers covered by the Water Board's emergency regulations were able to reduce their use by the mandated amounts. Many communities weathered the drought without having to develop new supplies, which tend to be more costly than demand management measures. Relying on conservation and efficiency first moderated rate increases. Many communities have permanently banned some of the wasteful water uses the Water Board prohibited under the emergency regulations. Nearly three years later, water use rates remain low, suggesting that the savings may be locked in over the long-term and that Californians are making efficiency a way of life (Figure 2.12).

The Water Board's monthly reporting data helped to communicate conservation successes and shortcomings, informing and engaging the public, academics, media, suppliers, and other agencies.

Efforts where improvement is needed

State turf replacement grants discouraged the installation of hardscapes (such as concrete or gravel) as turf replacement. But hardscapes were allowed under some turf rebate programs funded by local agencies, allowing, in some areas, living landscapes to be replaced with materials that can increase urban heat island effects and contribute to greater stormwater runoff.

The 2012–2016 drought was the first drought in which widespread tree mortality was reported in urban settings, likely the result of a combination of low precipitation, high temperatures, and a lack of emphasis on tree care as local water districts imposed mandatory water use reductions. Statewide data to quantify the impacts of drought on California's urban tree canopy are not available; the California Department of Forestry and Fire Protection's (CAL FIRE's) urban forestry program compiled a statewide urban tree canopy survey in 2012 but has not yet updated that survey. 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. Other data are available

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.

only for trees on public property, such as parks or street medians, where local agencies inventoried trees under their jurisdictions. Loss of urban tree canopy due to drought is particularly significant considering the findings of a 2017 study funded by CAL FIRE and the U.S. Forest Service (USFS) (McPherson et al. 2017) that California has the lowest amount of urban tree canopy in the United States. Mature urban trees cannot easily be replaced, and even higher-water-use urban trees are a worthy investment of scarce water during a drought given the many benefits they provide from an ecosystem services standpoint, as well as a quality-of-life standpoint.

Recommendations for improving State response

Any imposition of mandatory water use reductions during drought should balance statewide, "we're-all-in-this-together" approaches with ways to account for local and regional differences in climate and water availability. Improving the State's ability to collect, manage, and analyze data on local water quality, available quantity of surface water, groundwater levels at a monthly time interval, number of sources at each water system, and water use would support this effort.

Maintaining locally appropriate urban environments is essential for urban quality of life and sustainability. Certain types of urban landscapes can provide important wildlife habitat, help manage stormwater runoff, and are increasingly important for climate change adaptation. Meeting urban water needs during droughts should account for meeting water needs of appropriate outdoor landscapes. Public messaging should incorporate the need to continue watering trees.

The State should provide training on the MWELO to city and county planners to ensure compliance with these State standards.

The State should support efforts to explicitly exempt rebates related to water efficiency in the U.S. tax code and to permanently reinstate—and broaden to other water conservation measures—the California tax exemption for turf-removal rebates (AB 2434 of 2014) that expired in 2019.

The Water Board's "stress test" during the drought showed that most large urban suppliers were prepared to withstand continuing severe drought hydrology, illustrating the value of having a water supply factor of safety against conditions that cannot be predicted. Having a factor of safety against the unforeseen is paramount because demand hardening will occur as Californians become more efficient in water use and adopt the requirements of "make water conservation a California way of life." Water agencies that approve new development on conserved supplies are increasing the drought vulnerability of their systems unless they make compensatory provisions for access to dry year supplies. Agencies should be prepared for the unexpected and not assume that emergency conservation measures will be sufficient in the absence of an adequate factor of water supply safety.

If emergency conservation is needed during drought, demand hardening will require suppliers to roll out more targeted measures. The State should work with stakeholders and local and regional water suppliers to investigate how to design affordable water rates that incentivize emergency savings and prevent major revenue shortfalls during drought and also to understand the market penetration of various efficiency devices.

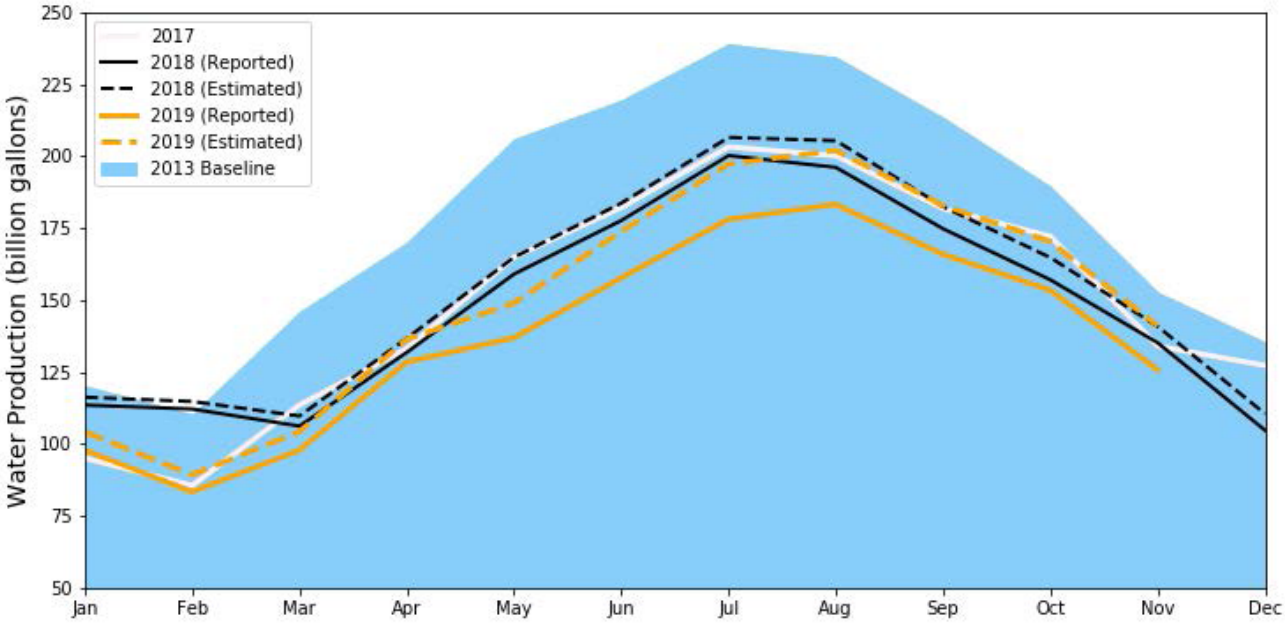
2.7 FIRE PROTECTION

Major drought response activities undertaken

Drought effects reverberate. They set the stage for elevated wildfire risk, which in some areas can be followed by the potential for post-fire debris flows in burned areas, such as the devastating 2018 debris flow in Montecito. Substantial water infrastructure was destroyed or damaged in the recent wildfires and Southern California debris flows, with the level of damage frequently exceeding historical precedents.

According to CAL FIRE data through 2018, four wildfires during the drought period ranked among the top 20 for greatest area burned in California: the Rush (Lassen

Figure 2.12: Statewide Urban Water Production as Compared to a 2013 Baseline



"Estimated" values represent the sum of reported values plus an estimate of production for suppliers which didn't report, based on previous years. (Figure Credit: Water Board)

County, 2012); Rim (Tuolumne County, 2013); Rough (Fresno County, 2015); and Soberanes (Monterey County, 2016) 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 Hetch Hetchy Reservoir, Cherry Reservoir, and Lake Eleanor, including damage to the Lower Cherry Aqueduct and the Holm Powerhouse and power distribution lines. The utility's estimated emergency response and infrastructure repair costs were roughly $40 million.

Although a wet 2017 marked the end of hydrologic drought for much of the state, the drought's effects on the landscape remained in the form of dead vegetation that could fuel later wildfires. Following the drought, Water Year 2018 marked a return to dry conditions statewide, with nearly all of the state experiencing below-average precipitation, and much of Southern California receiving half or less of its annual average precipitation. Water Year 2018 will be remembered not for its water supply conditions but for the new records set for wildfires and wildfire-related damages. The drought years had provided ample dead and dry vegetation which, followed by the very wet conditions of 2017 that encouraged heavy growth of grasses, set the stage for unprecedented wildfires.

Fires occurring during Water Year 2018 set records and impacted water systems from the Oregon border to Southern California. The October 2017 Tubbs Fire in Napa, Lake, and Sonoma counties surpassed the previous record for California's most destructive fire, devastating a highly urbanized area and causing extensive damage to the City of Santa Rosa's water distribution system. The December 2017 Thomas Fire in Ventura and Santa Barbara counties briefly ranked as the largest wildfire in the State's records, resulting in boil water orders for residents in Ventura, Santa Paula, and Ojai. In addition, this fire was followed by a January storm with heavy rainfall on the burned area, triggering massive debris flows in Montecito that resulted in the deaths of 23 people, destroyed water system infrastructure, and rendered water treatment plants

inoperable. The debris flows moved approximately 890,000 cubic yards of material, damaging or destroying 558 homes and causing an estimated $1 billion in damages. The July 2018 Carr Fire in Shasta and Trinity counties burned the area surrounding Reclamation's Keswick Dam and powerplant, requiring evacuation of plant operators and resulting in boil water advisories for residents served by several small community services districts. The July 2018 Klamathon Fire in Siskiyou County left the small community of Hornbrook without water for two months, and the Ferguson Fire near Yosemite National Park that same month closed portions of the park and caused a boil water advisory for the community of Yosemite West. At the start of Water Year 2019 (in November 2018), the Camp Fire in Butte County set an unfortunate record for being the state's deadliest wildfire. The fire killed 85 people and virtually destroyed the town of Paradise in Butte County, including much of the municipal water system.

Due to the relative absence of winter storms and record warm conditions, it was observed that the wildfire season (particularly in Southern California) was becoming virtually year-round, requiring an extended readiness capability from CAL FIRE. Drought emergency funds provided for some of the aircraft support needed by CAL FIRE for wildfire response and allowed CAL FIRE to purchase additional equipment and respond to drinking water supply shortages at its facilities.

CAL FIRE also played a lead role in responding to the widespread tree mortality caused by the drought. The drought's five-year duration, coupled with high temperatures, weakened trees throughout the state and made them vulnerable to bark beetle infestation, with particularly acute impacts in the central and southern Sierra Nevada. The rapid and abundant tree mortality resulted in the October 2015 issuance of a State 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,

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

and structures—a proclamation that was subsequently extended by Executive Order B-42-17. CAL FIRE was an active member of the Tree Mortality Task Force, which brought together State and federal agencies, counties, utilities, and others following the emergency proclamation.

A USFS spring 2017 aerial survey estimated that 129 million trees had died in California's forests since 2010. While some trees may be killed relatively quickly by drought or drought-related insect damage, others may decline slowly; the full extent of drought-related tree mortality may not be apparent until well after hydrologic drought has ended. Large areas of standing dead trees remaining on the landscape create a wildfire risk that persists after the end of hydrologic drought conditions.

Recognizing the increasing frequency of damaging fires, challenging fuel conditions, and impaired forest health due to drought, CAL FIRE took actions to reduce immediate drought impacts and prepare for future droughts, including identification of high-hazard zones following the widespread tree mortality and removal of dead trees representing a public safety threat in the highest-hazard zones. CAL FIRE and the USFS coordinated on implementation of fuel reduction projects and forest restoration efforts across ownership boundaries. CAL FIRE also explored options for encouraging biomass utilization associated with removal of trees killed by bark beetles.

Major challenges encountered

The drought's record warm temperatures and very dry hydrology resulted in a year-round wildfire season in parts of the state, requiring greater commitment of resources for firefighting than that historically experienced. The increased firefighting workload reduced the availability of crews for fuel management projects. Fuel loads increased in many parts of the state because of the extensive and severe tree mortality.

Lack of infrastructure for biomass utilization reduced feasibility of fuel treatment in many areas, and economic constraints hindered utilization of the dead wood. Most tree mortality occurred on federal lands, and response coordination with federal land managers was challenging.

There was limited monitoring information on drought stress, bark beetle outbreaks, and beetle population dynamics.

Notable State successes

SB 859 enacted in 2016 encouraged use of forest biomass from high-hazard zones as part of the State's renewable energy portfolio and created a working group for expanding wood product markets.

A master Good Neighbor Agreement pursuant to federal Farm Bill authorities was executed in 2016 between the California Natural Resources Agency and the USFS, providing a broad ability for State-USFS coordination on forest restoration and hazardous fuels reduction projects.

The substantial State funding commitment (nearly $1 billion over five years) for forest health projects will aid in managing future wildfire risk.

Efforts where improvement is needed

Increased forest management to treat forests before major stressors such as drought and bark beetle infestations occur would aid in managing wildfire risk. Investments in fuels reduction and other management projects could be prioritized for projects that offer multiple benefits, such as wildlife habitat and recreation.

Recommendations for improving State response

Large-scale forest restoration is needed in California because of decades of fire exclusion practices, a legacy of large tree removal, and a warming climate. Current limited resources often go to address immediate impacts and public safety hazards following major fires, leaving long-unburned forest areas vulnerable to future catastrophic fires. Proactive rather than reactive forest management allows for up-front formulation of multi-benefit projects. Climate change is expected to increase the length of fire seasons and the number of large, intense fires in California and other western states (Williams et al. 2019, Goss et al. 2020). These fires are expected to have greater impacts on watersheds and increase post-fire erosion.

Improving the health of headwater forests in California–and in the Sierra Nevada in particular, where approximately 60 percent of the state's developed surface water supplies originate–will provide an array of social, economic, and environmental benefits across multiple sectors and geographies. The best way to realize these benefits is to reestablish and maintain lower densities of trees, which will help make these forests more resilient to drought, catastrophic wildfire, and bark beetle epidemics. Increasing the pace and scale of headwater forest management can reduce the risk of severe wildfire and lower the threat of post-fire erosion. CAL FIRE should continue collaborating with the USFS in the dissemination of and response to annual tree mortality survey results, including funding research and monitoring. Additionally, CAL FIRE's urban forestry program tree survey is a valuable tool for assessing the impacts of drought and mandated urban water conservation programs on the state's urban tree canopy and should be continued.

The active wildfire seasons experienced during the drought and the catastrophic fires in the subsequent years illustrate the need for increased attention to multi-hazard planning by water suppliers. DWR, in collaboration with the Water Board, CAL FIRE, and the Department of

Conservation, should review opportunities for encouraging greater emphasis on multi-hazard planning for urban suppliers.

2.8 EMERGENCY HUMAN ASSISTANCE

Major drought response activities undertaken

Assistance related to emergency drinking water is described in the preceding drinking water section.

Institutional response actions taken in this drought built upon and expanded the direct State social services assistance for drought impacts first seen in the 2007–2009 drought. The prior drought had seen limited use of California Disaster Assistance Act funds to provide supplemental assistance to local governments and nonprofit organizations for food bank programs in the San Joaquin Valley that were used to help mitigate impacts of the loss of agricultural jobs caused by drought. Social services assistance was greatly expanded in the 2012–2016 drought and was especially focused on rural San Joaquin Valley communities affected by job losses or reduced work availability due to cutbacks in agricultural production.

By the spring of 2017, the Department of Social Services had provided more than two million boxes of food to community food banks in drought-affected counties. More than half of the food distribution occurred in the Tulare Lake Basin (Fresno, Kings, Tulare, and Kern counties); other counties receiving assistance included Merced, Santa Cruz, Santa Barbara, Riverside, and Imperial.

The Department of Community Services and Development (CSD) 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 for employment support services, such as training and placement. CSD used a federally funded community services block grant for the pilot project to help low-income households pay their water bills. CSD also administered a direct-install toilet retrofit program for disadvantaged communities under a Proposition 1-funded contract with DWR, using CSD's existing network of local service providers.

The Department of Housing and Community Development entered into contracts with entities such as local housing authorities (e.g., the Housing Authority of Tulare County) and nongovernmental organizations (e.g., La Cooperativa) to provide relocation and rental assistance to households without a potable water supply.

Major challenges encountered

Efforts were needed to define which areas were eligible for drought emergency assistance because of drought-specific impacts, such as loss of work due to agricultural water shortages. San Joaquin Valley counties, for example, have areas of both urban and rural poverty, and there was concern that meeting potential needs in preexisting urban disadvantaged areas not deplete the resources intended for rural farmworker communities directly affected by drought.

Notable State successes

Existing relationships with counties and local nongovernmental organizations such as food banks facilitated the distribution of assistance to residents, especially in disadvantaged communities. The assistance could not have been provided so efficiently without the partner organizations.

Efforts where improvement is needed

It would have been helpful to have had more lead time regarding the start of the drought emergency to allow assistance programs to come up to speed more rapidly once the emergency was proclaimed.

Recommendations for improving State response

There was relatively low interest in assistance for temporary relocation due to drought-related job losses (e.g., loss of farm work), as residents generally preferred to remain in their communities or make more permanent arrangements to settle elsewhere. Thought should be given on how to best to prioritize emergency housing assistance for drought response.

2.9 AGRICULTURE

Major drought response activities undertaken

Emergency drought legislation enacted in early 2014 (SB 103) included $10 million for the State Water Efficiency and Enhancement Program (SWEEP), administered by the California Department of Food and Agriculture (CDFA) in cooperation with the Water Board and DWR. The program provides grants to agricultural operations for implementation of water conservation measures that result in increased water use efficiency and reduced greenhouse gas emissions. Initial funding for SWEEP came from the State's cap-and-trade carbon auction proceeds. Eligible system components included (among others) soil moisture monitoring, drip systems, low pressure irrigation systems, pump retrofits, variable frequency drives and installation, of renewable energy to reduce on-farm water use and energy.

Legislation enacted in 2009 had required that agricultural water suppliers serving more than 25,000 irrigated acres (large suppliers) initially adopt agricultural water management plans (AWMPs) by December 2012, and then prepare and submit updates to DWR beginning in December 2015 and every five years thereafter. Suppliers serving 10,000 to 25,000 acres (medium suppliers) were not required to submit plans unless State funding was made available for that purpose. Executive Order B-29-15 in April 2015 directed DWR to require medium suppliers to prepare and submit AWMPs by July 2016; DWR was also directed to prioritize grant funding for plan development. The executive order further provided that plans of both large and medium suppliers were to include a drought management plan and quantification of water supplies and demands in 2013, 2014, and 2015, to the extent that data were available. In 2015, there were an estimated 54 agricultural water suppliers meeting the 25,000-acre threshold, representing approximately 4,074,400 irrigated acres. DWR conducted extensive outreach on plan preparation and offered technical assistance. In 2015, 47 agricultural water suppliers submitted AWMPs; 7 did not. No suppliers notified DWR of an AWMP in progress.

In 2016, there were an estimated 39 agricultural water suppliers in the medium category, representing approximately 594,600 irrigated acres. In that year, 26 agricultural water suppliers submitted AWMPs, 8 did not, and 5 suppliers notified DWR of AWMPs in progress.

UC Davis researchers using models and federal and State researchers using satellite data separately concluded that more than 500,000 acres of farmland in California were idled due to drought in 2015. UC Davis economists estimated the season farm-related job losses tied to drought at 7,500 in 2014 and 10,000 in 2015. CDFA partnered with the UC Agricultural Issues Center to conduct an economic analysis of drought impacts on the state's agricultural sector. The results helped inform and guide decision-making during the drought period and provide perspective on socioeconomic impacts to the southern Central Valley region, where 72 percent of drought losses occurred during 2014 and 2015.

Additionally, CDFA continued its cooperative agreement with the USDA's National Agricultural Statistics Service to prepare and distribute statistics on California agriculture. Statistical information includes estimates of planted and harvested acreage, production, stocks, and crop use. Yield and production forecasts are issued monthly during the growing season.

CDFA served as an informational resource for farmers, disseminating information and connecting farmers to USDA financial assistance programs.

Major challenges encountered

Agricultural water shortages, especially in the San Joaquin Valley, resulted in land fallowing and associated socioeconomic impacts to disadvantaged communities largely dependent on agricultural employment. State responses to these impacts—such as supporting food banks and emergency housing assistance—were described in Section 2.8.

DWR expended substantial staff resources on outreach and technical assistance for AWMP preparation, especially

for the medium agricultural suppliers who were preparing plans for the first time. Despite extensive outreach, not all water suppliers submitted the mandated plans, illustrating the limitations of voluntary compliance. (Other than loss of eligibility for some State financial assistance programs, the requirement for plan submittal had no enforcement provisions.)

Notable State successes

Since the SWEEP program's 2014 inception, CDFA has awarded $81.8 million in grants, resulting in an estimated savings of 117,000 acre-feet of water annually.

As described in Section 2.1, the USDA's Rural Development agency was an important partner in working with the Water Board and DWR to provide assistance to rural water systems experiencing drinking water shortages, many of them farmworker communities in the San Joaquin Valley.

Efforts where improvement is needed

The experience with AWMPs illustrated the need for enforcement tools to bolster their submission. Legislation enacted in 2018 provided DWR the authority to contract with a third party for correction of deficient AWMP submittals with the costs to be recovered from the water supplier and authorized DWR to levy fines not to exceed $25,000 for failure to submit an AWMP.

Agricultural water users need longer lead times for forecasts of water supply availability, and improved certainty in forecasts. Growers typically finalize annual planting decisions by February or March at the latest, and likewise, decisions about participating in water transfers. The very dry hydrology of 2014 and 2015 was particularly challenging because it was not known until relatively late in the season if allocations to CVP and SWP water rights contractors would be reduced; those supplies frequently drive the annual water transfer market. With both years' minimal snowpack conditions, the ability to estimate spring runoff was reduced to reliance largely on the longer-term precipitation forecasts that have little present skill. Water supply forecasting will be increasingly challenging as warming temperatures reduce snowpack accumulation, especially in the lower-elevation Sacramento River Basin. Better forecasting will also be needed as SGMA implementation grows and expands, because pumping limitations in many basins will reduce the ability to use groundwater as a shortage management tool.

Recommendations for improving State response

CDFA agricultural stakeholders found the process of making voluntary water transfers from Sacramento Valley sellers to south-of-Delta buyers to be confusing during the drought, in part because of annual changes in the process. For many years, DWR and Reclamation have jointly updated a technical white paper (most recently in 2019) explaining the process for obtaining approval to use SWP or CVP facilities for third-party water transfers; this document could be more broadly communicated to the agricultural community.

Annual variability in transfer activity reflects hydrologic conditions (e.g., no water available for transfer, no capacity available to convey water), and efforts could be made to improve forecasts of potential water supply availability at longer lead times. DWR should work with the research community to develop experimental forecasts of seasonal conditions at the beginning of the wet season and at its halfway point, and to communicate the implications of forecasted conditions for water transfers.

3

Acting on Lessons Learned from the 2012–2016 Drought

3.1 IMPROVE DROUGHT RESILIENCE AND REDUCE VULNERABILITY

In April 2019, with Executive Order N-10-19, Governor Gavin Newsom called on State agencies to prepare a water resilience portfolio to meet the needs of California's communities, economy, and environment through the 21st century. The executive order called for an integrated suite of actions that emphasize, among other principles, regional coordination, partnerships, use of natural infrastructure such as floodplains and wetlands, approaches that provide multiple benefits, and innovation and technology.

The administration's Water Resilience Portfolio, released in January 2020, emphasizes State support for regional diversification of water supplies through efficiency, recycling, stormwater capture, desalination, and protection and more sophisticated use of groundwater basins. The portfolio also emphasizes the need for regions to work with stakeholders including tribes and disadvantaged communities to develop drought contingency plans for communities and the environment. Water resilience includes protecting and enhancing ecosystems, and additional water supply development must be balanced and weighed in consideration of environmental needs. The Water Resilience Portfolio calls for establishment of regional instream flow metrics to help regions better protect fish and wildlife by quantifying the timing, quality, and volume of flows they need.

Drinking Water Supplies

Large urban water agencies have more capacity to prepare for and respond to drought than smaller systems, and most have historically experienced drought primarily in the form of financial impacts that are ultimately passed on to ratepayers. Investing in major regional interconnections that facilitate water transfers and support disaster preparedness improves drought resilience for large urban agencies. Having dedicated emergency storage and associated conveyance capacity is also important, especially in Southern California, where local reservoir storage capacity is relatively small. The storage projects put in place by MWD and the San Diego County Water Authority greatly improve regional capacity to endure drought, for example.

Some regions and communities have experienced vulnerability in multiple droughts, requiring drinking water suppliers to call for severe levels of emergency conservation, to ban new connections, or to seek emergency State assistance. Historically California's North Coast and Central Coast regions have stood out in terms of risk, with communities such as the City of Willits and the City of Santa Barbara obtaining State emergency assistance in multiple droughts. Smaller water systems with limited supplies, as indicated by connection bans, face greater risk in drought, including Redwood Valley County Water District in Mendocino County and the City of Cambria. Drought resilience is improved with access to sufficient supplies to

provide a factor of safety against the unpredictable and with strategies and plans for adapting behavior and water system operations as conditions change.

Implementation of the Safe and Affordable Drinking Water Act of 2019 should help some communities avoid drinking water crises in the next drought. The law calls for the Water Board to provide interim water to 75 drinking water systems or schools, planning assistance for 100 systems, and permanent solutions for 100 systems by the end of 2020.

One of two major conservation laws enacted in 2018 (AB 1668) directed DWR, in consultation with the Water Board, to create a list of small water suppliers and areas of households on private supplies that may be at risk of drought and water shortage, and to prepare recommendations on development and implementation of countywide drought and water shortage contingency plans for them. DWR released a public review draft of that report, prepared with assistance from a County Drought Advisory Group, in April 2020. The draft report found that most of the state's counties have small water suppliers ranking in the top 10 percent risk category, and that 68 percent of the systems overall are in fractured rock groundwater areas. There are opportunities to use existing planning processes, such as local hazard mitigation plans, general plan elements, and Safe Drinking Water Act emergency plans, to carry out drought and shortage contingency planning for vulnerable systems and communities.

Technical assistance needs of small water systems can include leak detection, groundwater level monitoring, updating system service area maps, or emergency plan preparation. The Water Resilience Portfolio calls for financial and technical assistance and training to reduce drought risk to tribal and under-represented communities with small water systems and private wells.

Increasing Wildfire Risk

California's recent large catastrophic wildfires have created a new category of drought-related vulnerability—the vulnerability of water supply and wastewater infrastructure

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

to wildfire damage. Wildfires not only destroy infrastructure directly but also damage watersheds and cause erosion and sedimentation, shutting down water treatment plants and filling reservoirs with sediment. The drought vulnerability of the already at-risk Santa Barbara area was further worsened when debris flows after the Thomas Fire filled in much of the reservoir storage capacity of two small mountain reservoirs serving Santa Barbara and Montecito. Typical water shortage contingency planning, such as that required for urban water management plans, was not designed to take into account emerging risks associated with catastrophic wildfires. A new focus on multi-hazard planning and risk management will be needed and is emphasized in the Water Resilience Portfolio.

Environmental Impacts

The 2012–2016 drought demonstrated that fish and wildlife managers usually have few plans or resources to manage droughts. Developing, in advance, contingency plans for watersheds in the event of extended drought could help wildlife managers avoid making tradeoffs among species and put in place mechanisms to sustain flows and stream temperatures as drought deepens, such as voluntary water conservation and instream flow agreements with water users. The Water Resilience Portfolio calls for the

development of regional contingency plans for climate-driven stressors for fish and wildlife and ecosystems.

Top priorities for advance planning include setting and implementing instream flow requirements for protection of fish and wildlife and habitat. Where instream flow resource information and data are available, agencies should develop a stakeholder-driven process to facilitate local cooperative approaches for managing human and environmental needs during droughts or other low-flow conditions. The Water Resilience Portfolio calls for the establishment of regional instream flow metrics and analyses. It also calls for the State to bring together regulators, water users, public water agencies, and other stakeholders to develop voluntary solutions to water supply and ecosystem protection.

The last drought highlighted the need to modernize water and energy infrastructure at State hatcheries and wildlife refuges. Wildlife managers used emergency funds to drill new wells, install pipelines, and install water recirculation systems and chillers to keep fish alive in difficult circumstances. Many other upgrades that would improve the efficiency and operation of such facilities, regardless of drought, have yet to be made, but such investments are called for in the Water Resilience Portfolio.

3.2 MAKE KEY POLICY DECISIONS AND INVESTMENTS AT LONGER LEAD TIMES

Lead time is critical in making water management decisions. Water management decisions are made at lead times ranging from just a few days (operating a reservoir during the winter flood season) to a year or more (allocating State resources for drought response). Often the decisions made at the longest lead times are the most impactful in terms of minimizing risks and costs. Drought is a slow-onset phenomenon that provides the opportunity for effectively taking advantage of lead time to plan for response actions. However, California's relatively compressed wet season (Figure 3.1) provides a short lead time for decision-making within the wet season.

Drought Response

Drought is defined by its impacts, and one dry year typically does not constitute drought for water uses associated with managed systems (Table 1.4). The potential for drought response actions begins to occur in a second consecutive dry year, depending on hydrologic severity and other factors. Experience in past droughts has provided good understanding of realistic lead times associated with actions such as the approval process for water transfers using CVP and SWP facilities, installing temporary emergency barriers in the Delta, or procuring and installing equipment for fish hatcheries. Example lead times associated with potential State drought response actions include those below.

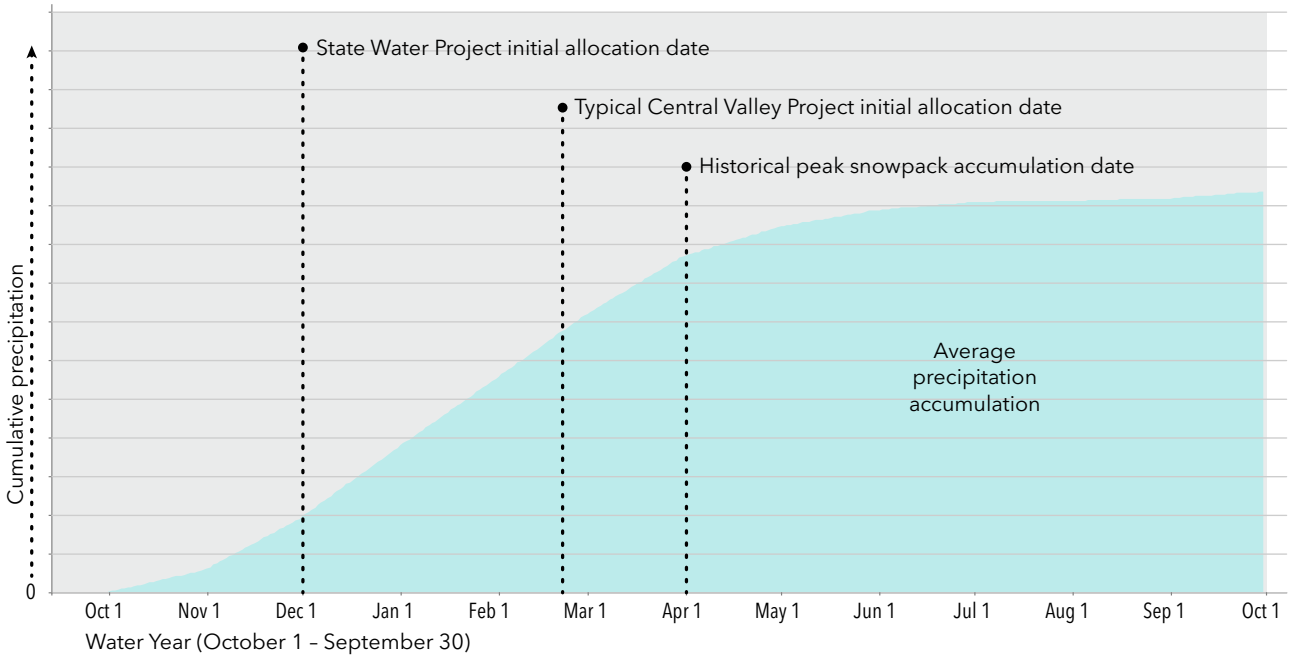
End of the wet season in a second dry year:

- Publicly notice the intent to make State financial assistance available for drought-related local agency projects, subject to the availability of funding, if the next winter is dry to encourage agencies to begin formulating projects.
- Begin contacting the operators of water systems with known high drought vulnerability to assess water shortage risk in the event of a third dry year.

Beginning of the wet season in a second dry year:

- Announce any plans or criteria associated with facilitating voluntary dry-year water transfers, exchanges, or banks.
- Identify previously unanticipated budget needs for continued dry conditions, such as enhanced water conservation technical assistance or seasonal staffing for CDFW.
- Begin developing specialized monitoring programs associated with dry conditions, including monitoring that may be associated with environmental permitting requirements.

Figure 3.1: Precipitation Accumulation Throughout the Water Year



Midway through the wet season if the water year to date has been dry:

» Begin planning for administration of water rights curtailments.

» Allocate resources for outreach and assistance to vulnerable small water systems.

» Review CVP and SWP operations plans based on observed hydrology to date and implications of continuing dry conditions.

» Negotiate contracts and agreements needed to support drought response, including contracts for ecosystem monitoring, impact assessment, and environmental regulatory compliance support for drought projects.

Drought Preparedness

Drought preparedness lays the foundation for effective drought response by putting in place tools, plans, and agreements that can be quickly deployed when sustained dry conditions evolve into drought. This is especially important for regulatory actions such as water rights administration, where long lead times are associated with administrative proceedings and the corresponding State agency workload is high, reflecting the thousands of permits involved. To avoid ad hoc decision-making and to ensure that water rights allocation decisions flow in a transparent, fair, efficient, and predictable way from State and federal laws, State agencies should work with stakeholders to build a drought decision-making framework before the onset of drought (Green-Nylen, et al. 2018).

Potential actions the State may take should be outlined in advance and communicated to stakeholders so that they, in turn, have the lead time they need to prepare their responses. The Water Board's temporary water rights permit process for using spring high flows for groundwater recharge is an example of a State decision where local agencies need lead time to prepare. Advance resolution of complex technical and regulatory issues, such as temperature management in the Sacramento River for anadromous fish, would also help reduce uncertainties and allow for better assessment of risks and unintended consequences associated with alternative management strategies.

Drought planning and response efforts should not wait until the middle of a drought emergency. Both CDFW and the Water Board received supplemental staff during the drought for two-year, limited-term positions, but those resources were removed once the drought was over. Dedicated drought planning and implementation should be considered permanent, ongoing needs and workloads, and should be staffed appropriately. Investing in planning now will reduce costs and workload during future droughts when measured over time.

3.3 IMPROVE MONITORING, DATA AVAILABILITY, AND FORECASTING TO SUPPORT DECISION-MAKING

Monitoring Needs

Water management relies on data obtained from a broad variety of monitoring programs. California's infrastructure for monitoring, observing, and collecting hydrologic data is aging, just as its water infrastructure is aging. Old instrumentation needs to be repaired or replaced, new technologies employed, and observation systems upgraded to meet 21st century requirements, including measuring high-elevation snowpack and adding temperature monitoring to stream reaches important to anadromous fish. Increased opportunities exist for employing satellite-based remote sensing technologies for monitoring snowpack, administering water rights, estimating water uses, monitoring land subsidence due to groundwater extraction, and detecting harmful algal blooms.

The 2012–2016 drought seriously challenged CDFW's ability to obtain near real-time data on streamflow and water temperature in smaller waterways that lack the instrumentation infrastructure of major river systems. CDFW invested substantial staff time and effort during the drought in manual collection of water quantity and quality data on important salmon streams. Strategic investments would ensure that better information is available the next time extended dry conditions force difficult decisions about water allocation. The Water Resilience Portfolio calls for an interagency team to build on implementation of SB 19 of 2019, which requires an assessment of the State's stream gauge network, and to assess and prioritize the most critical needs for instrumentation.

Forecasting Gaps

Precipitation (including snowpack) and streamflow observations and forecasts are crucial for operating State, local, and federal water infrastructure, and they help support decisions affecting flood risk management and water supplies for farms, fisheries, and cities. The key to improving lead time for drought decision-making is developing skillful precipitation forecasting ability beyond the two-week time horizon of a conventional weather forecast. Skillful forecasts a few weeks to months ahead, called sub-seasonal to seasonal forecasts, are a critical missing link for drought management and climate change adaptation. California has the nation's highest variability in average annual precipitation; the ending of the 2012–2016 drought by the second-wettest water year on record illustrates the potential for dramatic swings in the state's climate. National Weather Service long-range precipitation outlooks (issued at lead times from months to a year) have historically shown little capacity for predicting California's winter precipitation. A 2015 NOAA service assessment for California's drought found that the majority of the stakeholders NOAA interviewed identified improved seasonal precipitation prediction as one of the most important services NOAA could provide. The Water Resilience Portfolio includes several actions to improve the ability of regions to anticipate weather and climate conditions, including support of emerging forecasting technologies.

Estimating Water Supply Availability

In addition to better forecasting, a more robust understanding of the relationships among precipitation, snowpack, runoff, and water supply availability in Central Valley watersheds would be beneficial. A better understanding of these relationships would help reservoir operators manage supplies more efficiently. At the same

time, runoff estimates could be better integrated with water use data, allowing the Water Board to manage for senior water right holders and environmental considerations.

In the 2012–2016 drought, the Water Board used runoff estimates on a watershed scale to calculate water availability. Better automated gauging, remote sensing, improved spatial coverage through stream gauges, and improved hydrologic models would give the Water Board more accurate information on which to make water availability decisions and to communicate the decision-making process to water rights holders as early as possible so they could make informed water management decisions. Several actions in the Water Resilience Portfolio would support better data collection, including evaluating the potential to require telemetering of diversions of 500 acre-feet or more per year, down from diversions of 10,000 acre-feet per year.

Water Use Data

One of the most challenging data limitations during the last drought was the lack of up-to-date and accurate water use information. Prior to 2015, water use was only reported every three years; as a result, the State could not make well-informed decisions related to water availability and water use during the peak of the drought. A law enacted during the drought, SB 88 of 2015, improves the availability of water diversion and use data, requiring pre-1914 and riparian water users to report annually instead of once every three years. It also requires the larger diverters to record (telemeter) their diversions for the first time. Making the most of this additional information will require a robust data analytics strategy and process for ensuring SB 88 diversion data are accurate and useful. It will also require investing in tools and processes to modernize how data are reported and made available to the public. Water rights information should be made easily available to the public, and the Water Resilience Portfolio calls for the State to explore ways to rebuild the State's water rights database on an easy-to-use geospatial platform. The availability of water use and water rights information will be a critical component of developing local water agreements to manage watersheds and stream systems during future droughts.

3.4 IMPROVE CAPACITY TO COMMUNICATE ACROSS GOVERNMENTS AND TO THE PUBLIC

Natural disasters such as floods, earthquakes, and wildfires tend to unfold relatively quickly, within hours or days. In California, where water storage buffers variability in precipitation, the impact of drought builds over years. Responding to drought requires sustained coordination and communication. The 2012–2016 drought showed the value of regular, frequent coordination of water project operations across State and federal agencies. Similarly, the interagency Drought Task Force convened by the Governor in January 2013 provided a structure for timely sharing of activities, information, and direction. But drought seriously tested the public communications and coordination capacity of most State agencies. For example, in 2012–2016, without additional staff or funds, CDFW struggled to keep its State and federal partners, local governments, stakeholders, and the public informed about its wide-ranging drought response activities, including hundreds of separate fish rescues, monitoring vulnerable populations, and addressing a drought-related uptick in wildlife-human interactions, particularly with black bears. Similarly, the Water Board had to redirect many of its staff from core programs to drought response, delaying work on its normal responsibilities. The need for such important but time-consuming and staff-intensive activities should be anticipated and addressed in future droughts.

3.5 INTEGRATE WITH CLIMATE CHANGE ADAPTATION

Warmer average temperatures are increasing evapotranspiration and altering precipitation patterns in California in ways that make the historical weather record unreliable. The extremes in the state's already highly

variable precipitation are intensifying. Ensuring reliable water supplies as climate risks change requires a multifaceted approach. Lessons learned from the 2012–2016 drought informed the preparation of the administration's Water Resilience Portfolio and highlight several aspects of drought preparation that warrant State focus. Preparing for the next inevitable drought fits within broader efforts to build the capacity of regions to cope as climate conditions change.

Appendix

SUMMARY OF RECOMMENDATIONS FOR IMPROVING DROUGHT RESPONSE

Drinking Water

- Implement the Safe and Affordable Drinking Water Act of 2019, which provides up to $130 million a year for 10 years to assist water systems serving disadvantaged communities to provide safe drinking water.
- State agencies should consider, as appropriate, actions such as connection moratoriums, system consolidation, and targeted technical or financial assistance to lessen the vulnerability of small water suppliers at risk of drought and water shortage.
- In future droughts, longer lead time for potential financial assistance could be achieved by providing public notice at the end of a second dry winter of the intent to authorize State financial assistance in the event of a third dry winter, subject to the availability of funding. Consider triggering immediate State financial assistance at the end of a second dry year for proactive measures to diagnose potential problems at small water systems.
- Consider expanding the triennial sanitary surveys conducted by the Water Board to include the adequacy of a water system's source.
- Streamline State financial assistance to help local agencies and small water systems in emergency funding situations.
- DWR and the Water Board should consider whether other methods of obtaining household water shortage information (dry wells) at a statewide scale are needed or feasible.
- Legislation enacted in 2001 (SB 221 and SB 610) requires that local land use agencies approving new development projects of 500 units or more verify that water supplies are available to serve the proposed developments. The drought resilience of developments approved under this 19-year-old law should be reviewed to gauge the effectiveness of the law and whether the 500-unit limit should be lowered, or other changes made, to prevent development without adequate water resources.

Water Rights

- The State should address temperature management in ecologically important streams prior to the next drought.
- Water rights information should be made easily available to the public by rebuilding the State's water rights database to include digital place of use, diversion, and case history information.
- Water Board staff should improve the quality and timeliness of its water demand data. The Water Board should make that information readily available, along with other public water rights information. Improved water use data–in particular, better temporal resolution and data quality assurance–are needed to support shortage analyses for water rights administration.
- The Water Board should consider modifying the current requirement that diverters of 10,000 acre-feet or more annually provide near real-time telemetered diversion data to apply to diversions of 500 acre-feet or more annually.

- The Water Board should seek opportunities to streamline water rights enforcement processes for protection of senior water rights holders. Earlier notices of likely unavailability of water under the diverter's priority, combined with adoption of regulations setting curtailment requirements, may help.
- Longer lead times are needed for effectively administering curtailments on the State's major river systems, and for supporting water rights holders' decisions to trigger temporary transfers or secure alternative supply sources.
- Dedicated State staff are needed to support ongoing drought planning and preparedness work, and these resources could be used during droughts to form the core of a larger drought response team.
- The Water Board should continue long-term planning efforts, including efforts to develop and implement instream flow objectives for the reasonable protection of beneficial uses, including fish and wildlife, and include drought provisions in these planning processes to the extent possible.

Water Supply

- The Water Board should continue to pursue development of a more proactive temperature management plan for Reclamation's Shasta Dam, to be developed early in the season before delivery decisions are made, in collaboration with Reclamation and in consultation with other resource agencies.
- Continue and expand investments to improve sub-seasonal to seasonal precipitation forecasting ability. Continue support for leading-edge remote sensing technologies for monitoring high-elevation snowpack to improve snowpack runoff forecasting.
- Invest in improved information technology to enable State agencies to take advantage of available opportunities to use satellite-based remote sensing data to estimate evapotranspiration and water use.
- Develop a tool for communicating the status of drought and statewide water supplies that can be easily understood by a general audience.
- Prior to drought, water suppliers that have received State emergency assistance in multiple droughts should be a special focus for drought preparedness assistance or technical, managerial, and financial capacity review.
- Regional water supply security in times of drought depends upon a diversified portfolio of supply sources. These sources will vary by region, but water use efficiency, recycling, and stormwater capture all can play important roles in building drought resilience. State policies and investments should continue to encourage such projects.

Water Quality

- Implement AB 834 and create an effective statewide system for monitoring, reporting, and tracking harmful algal blooms. Statewide programs should focus on minimizing erosion, fertilizers, and other nutrient-rich nonpoint sources of pollution.

Fish and Wildlife

- Allocate additional staff resources for drought preparedness, environmental resilience actions, technical support, and communication.

- Better account for species needs (including temperature) when making supply allocations at the start of a dry year.
- Develop instream flow science and data and make that data available to the public so that local groups can better plan for and manage their own watersheds.
- Identify waterways where long-term State investment in monitoring infrastructure is warranted as agencies implement SB 19, the 2019 law that requires development of a plan to address gaps in the State's stream gauge network.
- Upgrade the water supply infrastructure at many CDFW-owned sites, including hatchery water treatment and water conservation improvements.

Water Conservation

- Imposing mandatory water use reductions during drought should balance statewide, "we're-all-in-this-together" approaches with ways to account for local and regional differences in climate and water availability.
- Meeting urban water needs during droughts should account for meeting water needs of appropriate outdoor landscapes.
- The State should provide training on the Model Water Efficient Landscape Ordinance to city and county planners to ensure compliance with these State standards.
- The State should support efforts to explicitly exempt rebates related to water efficiency in the U.S. tax code and to permanently reinstate—and broaden to other water conservation measures—the California tax exemption for turf-removal rebates (AB 2434 of 2014) that expired in 2019.
- Agencies should be prepared for the unexpected and not assume that emergency conservation measures will be sufficient in the absence of an adequate factor of water supply safety.
- The State should work with stakeholders and local and regional water suppliers to investigate how to design affordable water rates that incentivize emergency savings and prevent major revenue shortfalls during drought and also to understand the market penetration of various efficiency devices.

Fire Protection

- Large-scale forest restoration is needed in California because of decades of fire exclusion practices, a legacy of large tree removal, and a warming climate. Proactive rather than reactive forest management allows for up-front formulation of multi-benefit projects. The health of California's headwater forests needs to be improved.
- CAL FIRE should continue collaborating with the USFS in the dissemination of and response to annual tree mortality survey results, including funding research and monitoring.
- Continue CAL FIRE's urban forestry program tree survey as a valuable tool for assessing the impacts of drought and mandated urban water conservation programs on the state's urban tree canopy.

» Review opportunities for encouraging greater emphasis on multi-hazard planning for urban suppliers, including potentially amending the Urban Water Management Planning Act.

Emergency Human Assistance

» Given the limited demand for it in the 2012–2016 drought, consider carefully how best to prioritize emergency housing assistance for drought response.

Agriculture

» More broadly disseminate to the agricultural community the regular updates of the joint DWR-Reclamation technical white paper explaining the process for obtaining approval to use SWP or CVP facilities for third-party water transfers.

» DWR should work with the research community to develop experimental forecasts of seasonal conditions at the beginning of the wet season and at its halfway point and to communicate the implications of forecasted conditions for water transfers.

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