SEPTEMBER 2021

Water Year 2021:
An Extreme Year

California Department of Water Resources
California Natural Resources Agency
State of California

An Extreme Year

Water Year 2021 (October 1, 2020 to September 30, 2021) was an extreme year in terms of temperature and precipitation, and it followed a Water Year 2020 that was likewise warm and dry. Water Year 2020 was California's fifth driest year based on statewide runoff; Water Year 2021 has ended up as second driest. The Colorado River Basin, an important supply for Southern California, continued dry in Water Year 2021, with storage in Lakes Mead and Powell reaching new record lows. State emergency proclamations for drought were issued in April (Sonoma and Mendocino counties), May (Klamath River, Sacramento-San Joaquin Delta, and Tulare Lake watershed counties), and July (selected coastal and eastern Sierra counties), resulting in 50 counties being covered under the emergency proclamations.

This two-year dry period continues the theme of aridity California has been experiencing in the 21st century, including the three-year drought of 2007-2009 and the five-year one of 2012-2016. The latter drought was ended (for most, but not all, of the state) by a Water Year 2017 that was California's second wettest in terms of statewide precipitation. However, Water Year 2018 reverted to dry conditions that were only briefly relieved by a modestly above normal Water Year 2019. California's hydrologic conditions are increasingly resembling those that have been experienced in the Colorado River Basin this century, where predominantly dry conditions are interspersed with an occasional wet year.

As indicated in the time series of California statewide minimum temperature (Figure 1), extreme conditions that once were rare are occurring with increased frequency. California's climate is transitioning to a warmer setting in

Above: *Announcement of the April drought emergency proclamation on the dry lakebed at Lake Mendocino on the Russian River. The Coyote Dam embankment and intake structure can be seen in the background.*

Top: *The intake structure at San Luis Dam in August 2021. A danger advisory was issued in September warning people and their pets to avoid physical contact with lake water because of the potential health risks from algal toxins.*

which historical relationships among temperature, precipitation, and runoff are changing. It becomes increasingly difficult to rely on historical observations to predict water supply conditions, as was observed this spring when DWR's snowmelt runoff forecasts substantially over-estimated the runoff that occurred. DWR's median April 1st runoff forecasts for the Sacramento River Hydrologic Region, San Joaquin River Hydrologic Region, and Tulare Lake Hydrologic Region were overestimated by 68 percent, 45 percent, and 46 percent, respectively.

April 1st Sierra-Cascades snowpack, a commonly used indicator of expected water supply conditions, was 60 percent of average. However, streamflow in major Central Valley watersheds was on a par with that of Water Years 2014 and 2015, when snowpack had been only 25 percent and five percent, respectively, of average (Figure 2). Prolonged warm and dry conditions create a moisture deficit in the climate system, reducing runoff efficiency. Figure 3 compares Water Year 1977, California's driest water year based on statewide runoff, with Water Years 2014 and 2021. Each of these years was a second dry year following a significantly dry initial year, but the warmer setting in Water Years 2014 and 2021 resulted in an increased climatic water deficit. Impacts of warmer and dryer conditions include not only the obvious water supply impacts of reduced streamflow and water storage but also increasingly observed watershed impacts such as increased wildfire damage and more prevalent harmful algal blooms.

Figure 1. Temperature Extremes Are Occurring More Frequently

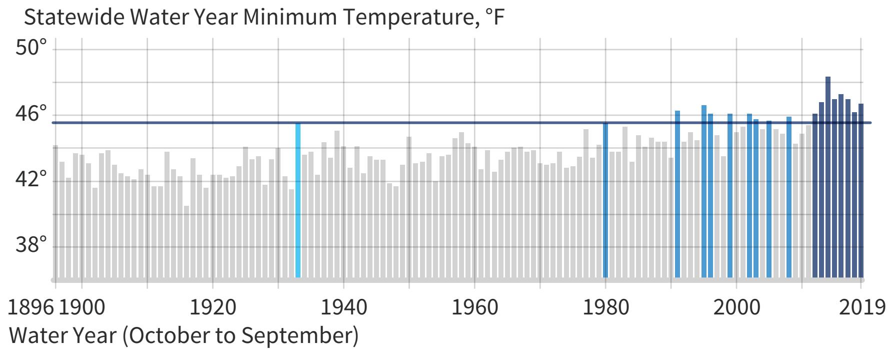
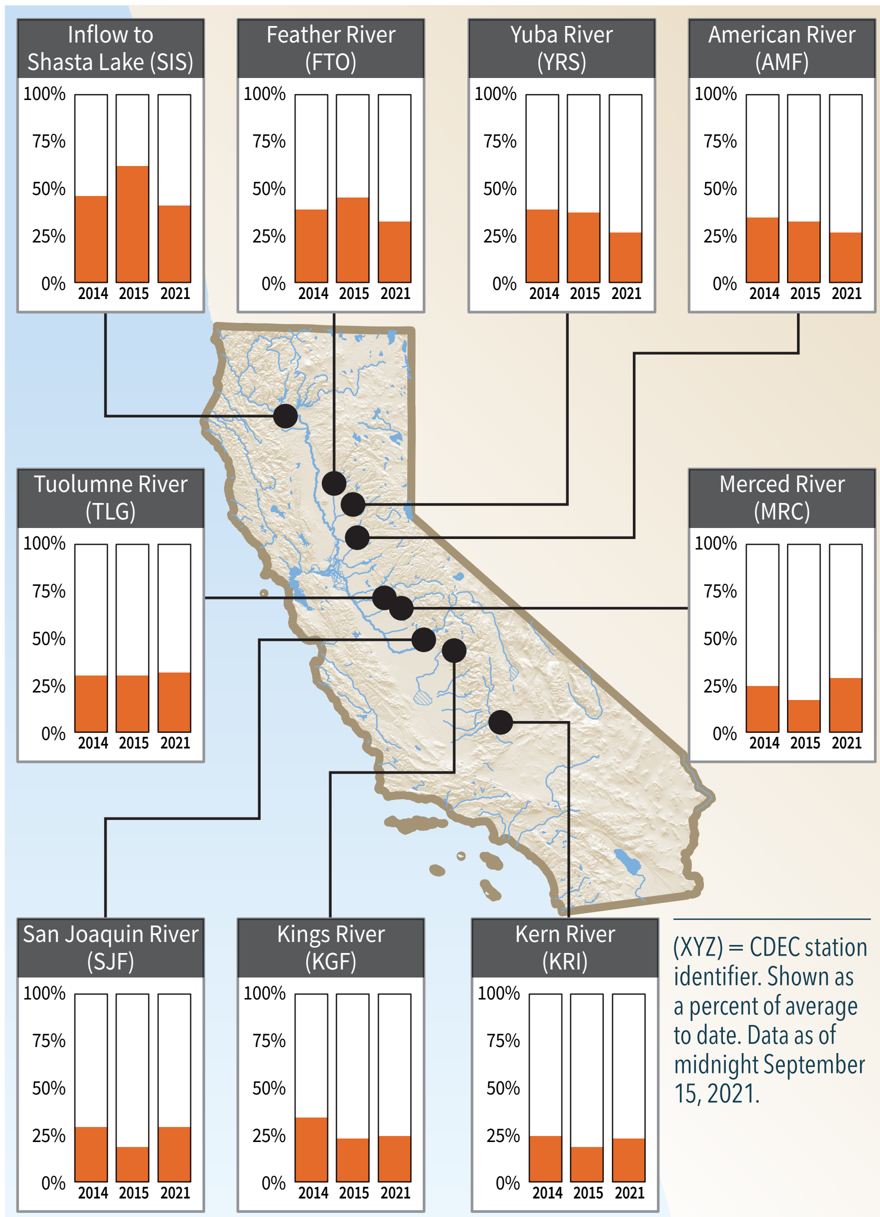


Figure 2. Comparison of Natural Flow at DWR Forecast Points on Selected California Rivers



(XYZ) = CDEC station identifier. Shown as a percent of average to date. Data as of midnight September 15, 2021.

Figure 3. Climatic Water Deficit from U.S. Geological Survey Basin Characterization Model

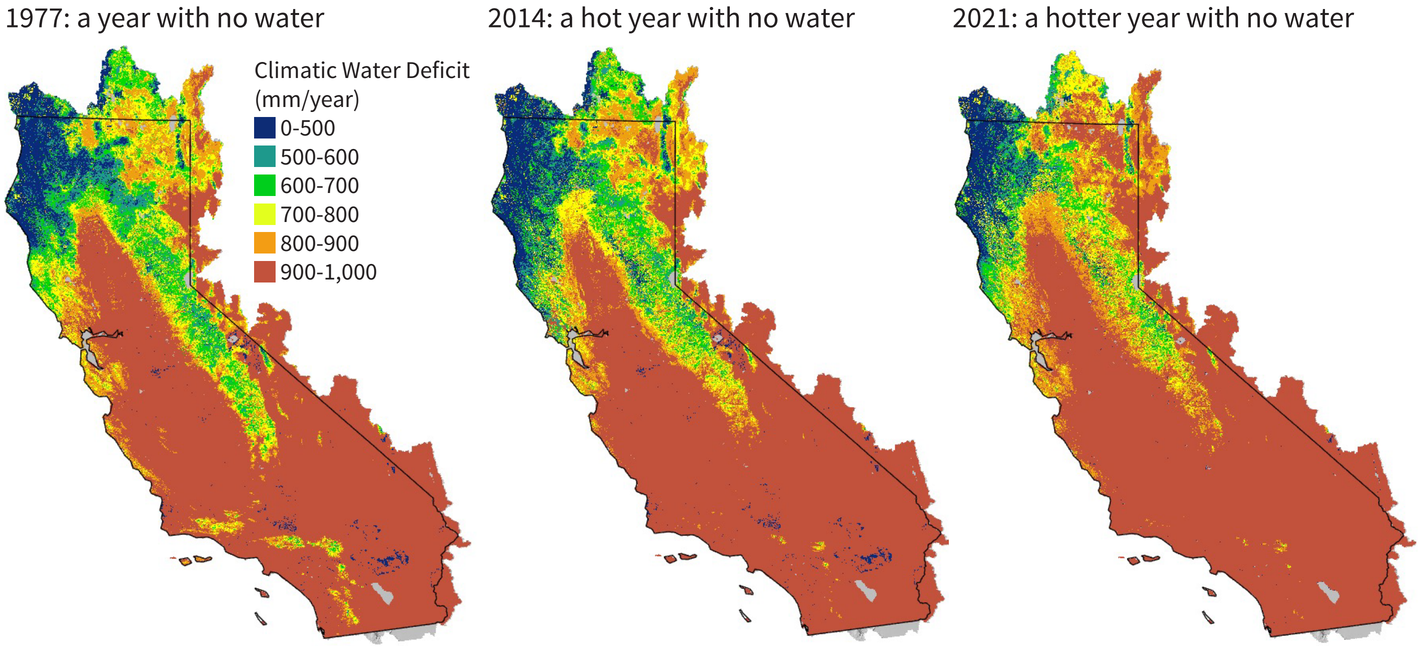
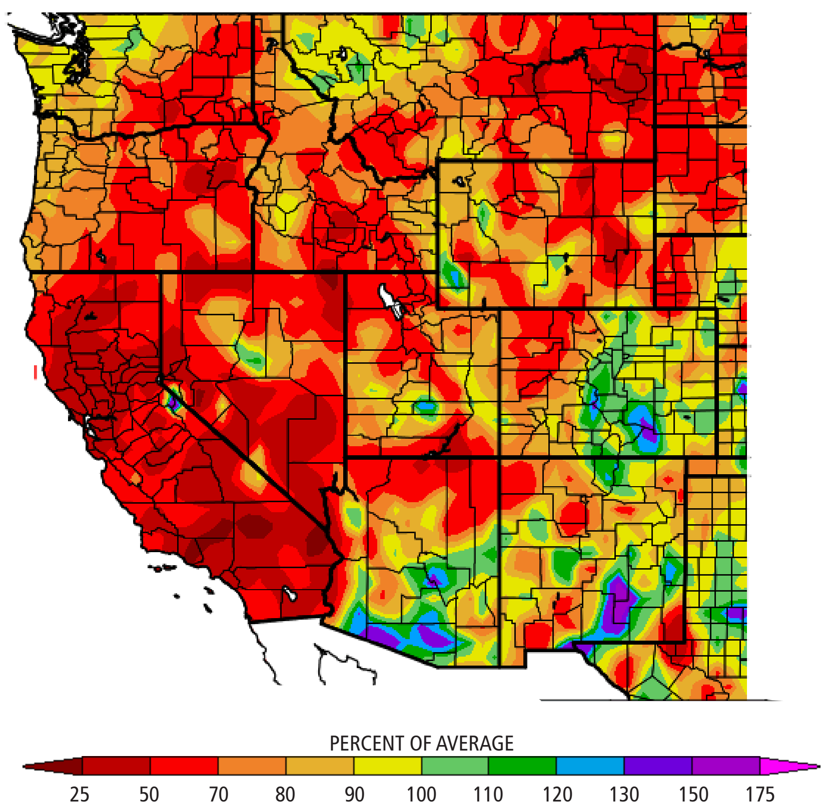


Figure credit: Lorraine Flint, USGS (retired)

Figure 4. Percent of Average Precipitation

Water Year 2021 was California's second driest year based on statewide precipitation. (Water Year 1924 was California's driest year for that metric.)



Generated 9/16/2021 at Western Regional Climate Center (WRCC) using provisional data.
Figure credit: Western Regional Climate Center

Precipitation and Temperature

Water Year 2021 was dry statewide (Figure 4). It was a second dry year for Northern California and a second dry year in terms of statewide total precipitation. (Parts of Southern California had experienced above-average precipitation in Water Year 2020 but since Southern California's contribution to statewide precipitation totals is small, the water year was dry at the statewide level.) Communities experiencing less than half of their average annual precipitation included Ukiah, Redding, Santa Rosa, Sacramento, San Francisco, Bakersfield, Santa Barbara, and Los Angeles. The track of the most significant winter storms did not favor snowpack accumulation in the southern Sierra Nevada, as illustrated in Figure 5.

Final temperature rankings for Water Year 2021 are not yet available, but the ranking for the latest available 12-month period (Figure 6) illustrates recent overall warmth. California experienced its warmest ever statewide monthly average temperatures in October, June, and July according to the National Oceanic and Atmospheric Administration's National Centers for Environmental Information.

Reservoir and Groundwater Storage

California began Water Year 2021 with generally good reservoir conditions thanks to storage carried over from an above-normal Water Year 2019, although large Central Valley Project (CVP) and State Water Project (SWP) reservoirs in the Sacramento Valley (Shasta, Oroville, Folsom) lagged statewide averages then. Dry conditions in Water Year 2021 resulted in a drawdown of statewide reservoir storage to 60 percent of average by the end of the water year, a level similar to that observed in Water

Figure 5. Remotely Sensed Snow Water Equivalent from the Satellite-Based Moderate Resolution Imaging Spectroradiometer Sensor

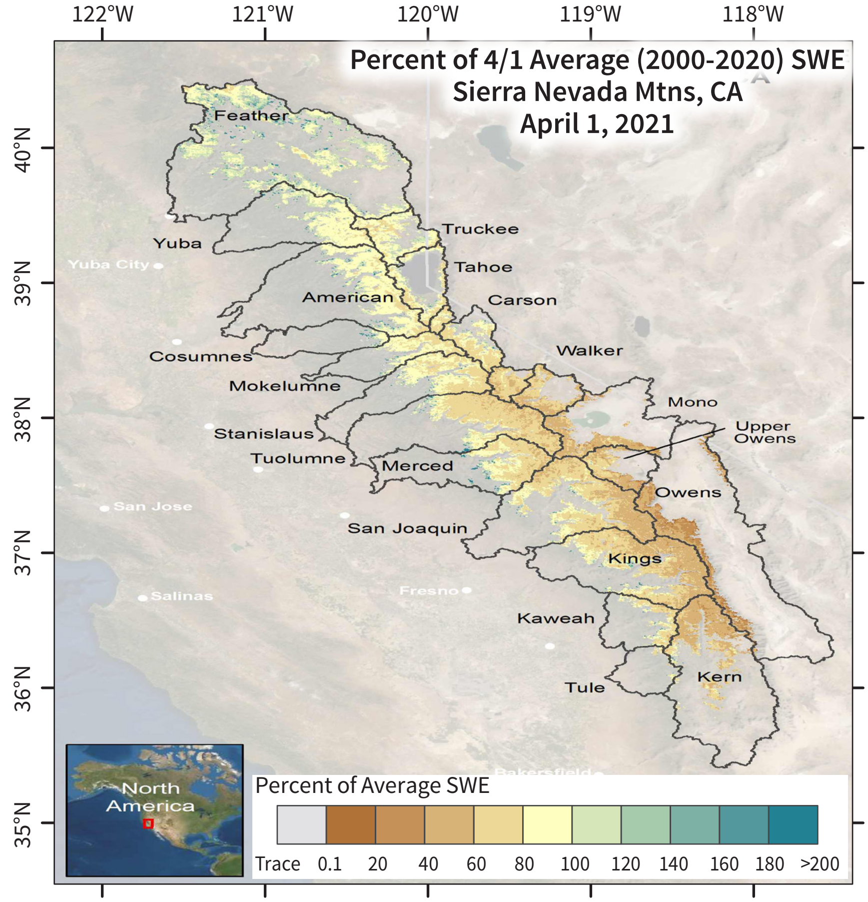


Figure credit: University of Colorado

Figure 6. Statewide Average Temperature Ranks

September 2020 - August 2021.

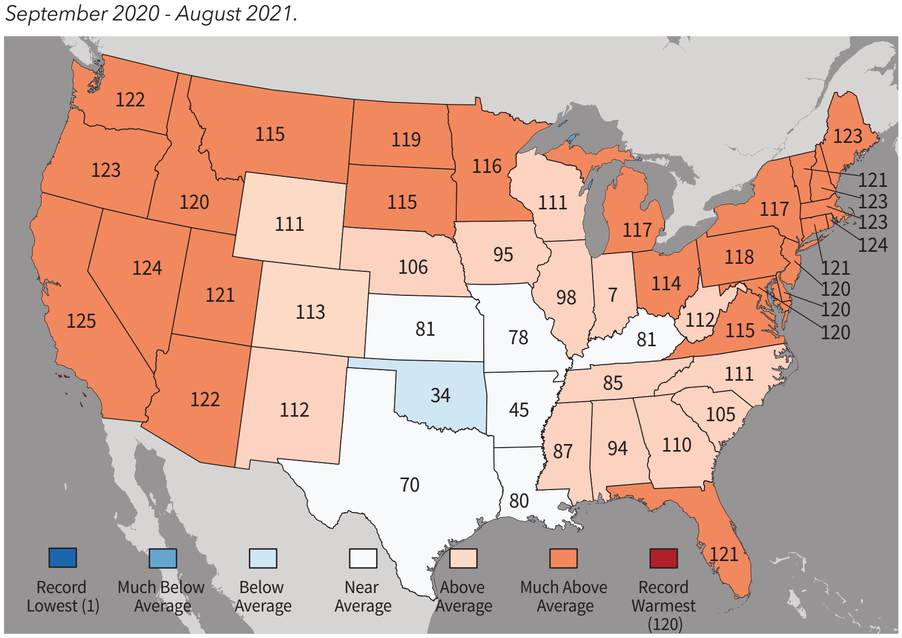


Figure credit: National Oceanic and Atmospheric Administration

Year 2015 during the prior drought but still far above the level of 36 percent of average seen in Water Year 1977, the state's driest year based on statewide runoff. SWP reservoirs were notably affected, with Lake Oroville setting a new record low and San Luis Reservoir reaching a second-lowest level of record (Figure 7). One of the drought response actions carried out in 2021 was construction of a temporary emergency salinity control barrier in the Delta to preserve upstream reservoir storage. In severely dry years reservoir releases dominate summer flow in the Sacramento River; for example, most of the water released from Lake Oroville supports fishery objectives and managing Delta salinity, not deliveries to project contractors.

Information about groundwater basin storage conditions (represented by changes in groundwater levels) does not reflect surface water hydrology with the same immediacy that reservoir storage does. Reporting of most groundwater level data lags that of surface water data, and groundwater levels in deeper confined aquifers may recover slowly from drought because multiple years are needed for recharge to occur. Looking at only single-year change in groundwater levels (spring 2020 to spring 2021, the most recently available data) shows that many of the reporting sites had no significant changes (Figure 8). Fall 2021 groundwater level data will not be available until later in the year.

Colorado River Basin

The Colorado River Basin began prolonged dry conditions in Water Year 2000. Water Year 2021 continued this trend, with unregulated inflow into Lake Powell for the water year being forecasted as of September 1st

Top: *Lake Oroville at the Enterprise Bridge in July 2021*

Below: *Temporary emergency salinity barrier installed at West False River in the Delta*

Figure 7. Storage in Selected Major Reservoirs

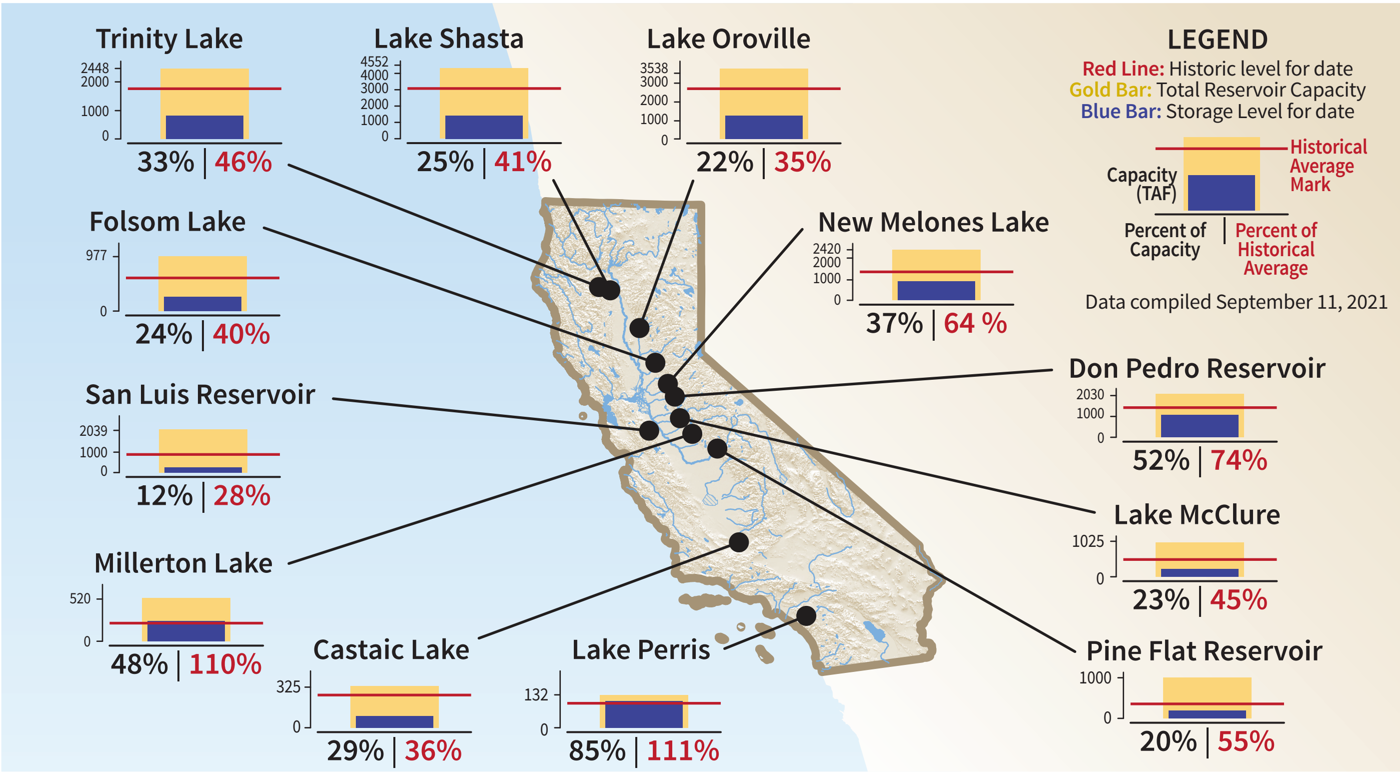
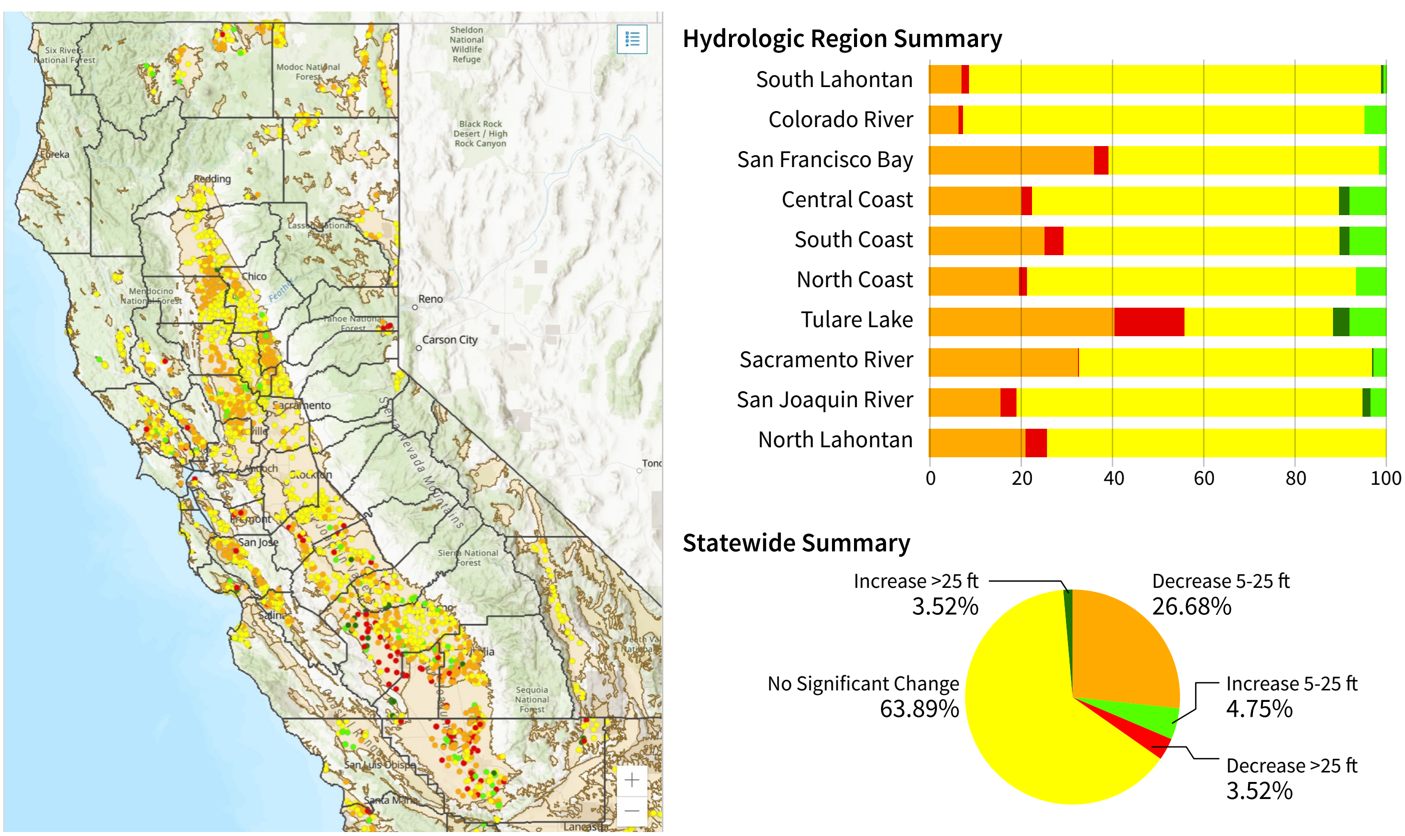


Figure 8. Statewide Groundwater Level Changes between Spring 2021 and Spring 2020



at 33 percent of average, despite watershed precipitation for the year being close to 80 percent of average with a slight boost from an active summer monsoon season. The prolonged dry conditions have taken a toll on storage in Lakes Mead and Powell, both of which reached record lows during the water year. The U.S. Bureau of Reclamation (USBR) began implementing provisions of the Upper Basin Drought Contingency Plan's Drought Response Operations Agreement, releasing water from Colorado River Storage Project reservoirs above Lake Powell to bolster Powell levels and reduce the risk of cavitation damage to the turbines at Glen Canyon Dam. Pursuant to the provisions of USBR's Interim Guidelines for Lower Basin Shortages and Coordinated Operations of Lake Mead and Lake Powell adopted in 2007, USBR announced a first-ever Lower Basin shortage for 2022, based on the projected elevation of Lake Mead (Figure 9). As provided for in the guidelines, the shortage determination is based on an August model study (Figure 9).

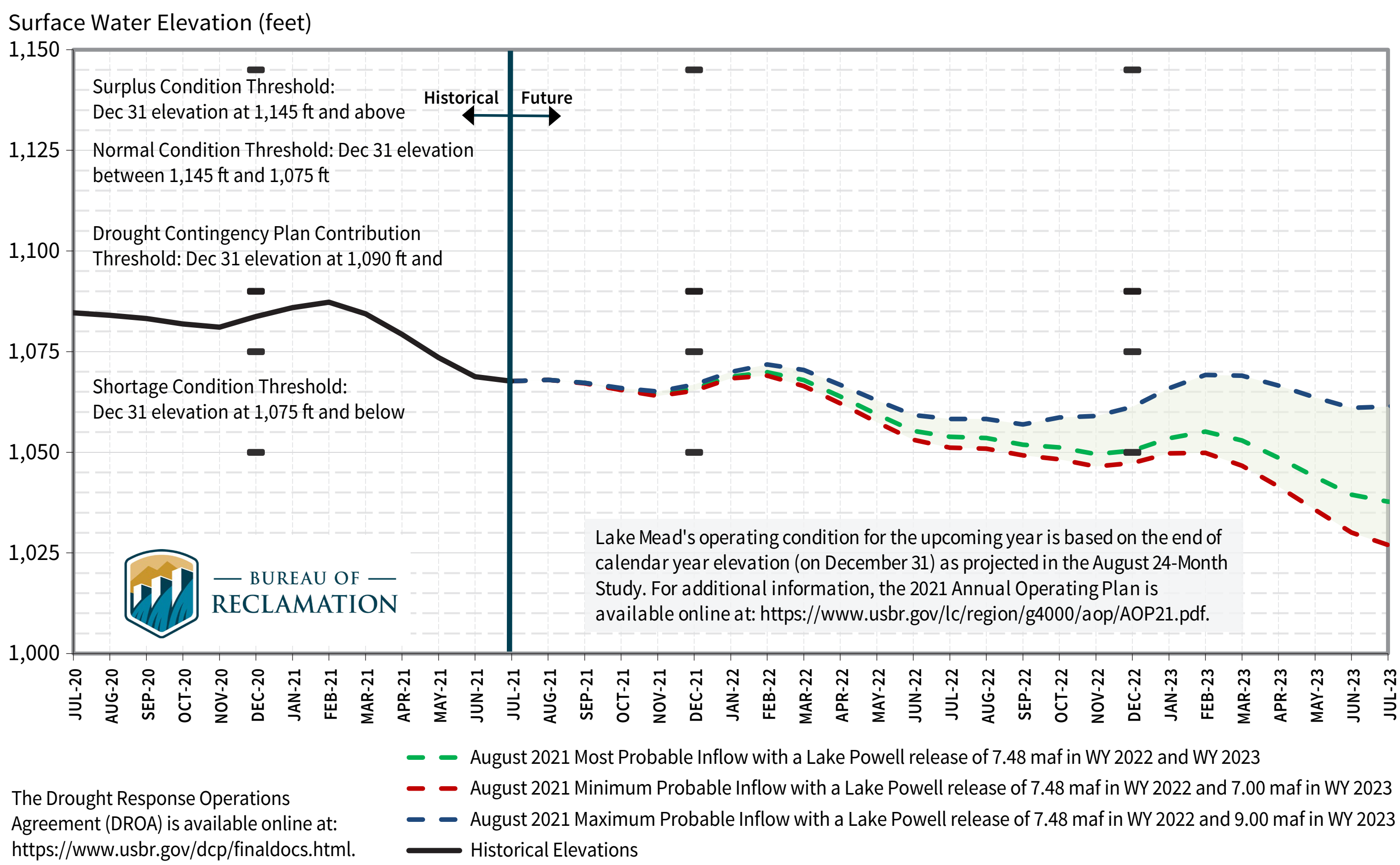
Under the Level 1 shortage Colorado River supplies to Arizona, Nevada, and Mexico will be reduced. Based on the projected elevation of Lake Mead, California's apportionment will not be affected in 2022. However, if dry conditions persist California has an increased risk of shortage in future years when Lake Mead could fall to the elevation that triggers a shortage to California. The present interim guidelines remain in effect through 2025, for operations in 2026. As provided for in the present guidelines, new guidelines are to be negotiated. When the present guidelines were negotiated the prospect of hitting the shortage trigger elevation was remote, illustrating the impact of prolonged dry conditions.

Water Supply Conditions

California's full Colorado River supply was the bright spot in the state's water supply picture for Water

Figure 9. Projected Lake Mead Elevations

Projections from the August 2021 24-Month Study Inflow Scenarios. Figure credit: USBR



The Drought Response Operations Agreement (DROA) is available online at: https://www.usbr.gov/dcp/finaldocs.html.

Year 2021, thanks to the massive reservoir storage capacity on that system. Other water projects did not fare as well. USBR's CVP had a zero allocation for its agricultural contractors north and south of the Delta; Friant Division contractors received a 20 percent allocation. Most CVP urban contractors received 25 percent of historical supplies; American River contractors and Contra Costa received 55 percent. The CVP settlement contractors (senior water rights holders) received 75 percent. USBR's Klamath Project contractors relying on the project's A Canal that diverts water from Upper Klamath Lake, including California contractors in Siskiyou and Modoc counties, had no summer irrigation deliveries. SWP contractors had a five percent allocation. Irrigators supplied by local agencies owning some of the largest Central Valley reservoirs (Modesto, Turlock, and Merced irrigation districts) had allocations ranging from two and a half to three feet per acre.

The State Water Resources Control Board (SWRCB) issued curtailment orders to limit diversions in the upper and lower Russian River watersheds, Scott and Shasta river watersheds, and Sacramento-San Joaquin Delta watershed. SWRCB's initial order in August for the Delta watershed curtailed all pre-1914 appropriative rights in the San Joaquin River watershed and all pre-1914 appropriative rights in the Sacramento River watershed and the Legal Delta with a priority date of 1883 or later. The CVP and SWP in the Delta watershed and Sonoma Water in the Russian River watershed had earlier filed temporary urgency change petitions with SWRCB seeking modifications to water rights terms and conditions to preserve upstream reservoir storage. Sonoma Water had projected that Lake Mendocino would reach dead pool by October unless its release requirements were modified.

Impacts of reduced surface water supplies affect groundwater usage, which increases in dry years when surface supplies are cut back. Decreased surface supplies for irrigation can affect shallow (typically residential) wells that are either normally recharged by agricultural canal seepage and irrigation or are impacted by increased agricultural pumping. Clusters of dry residential wells were reported in the Klamath Project service area and in Glenn County near the Tehama-Colusa Canal service area, both areas with zero federal irrigation allocations.

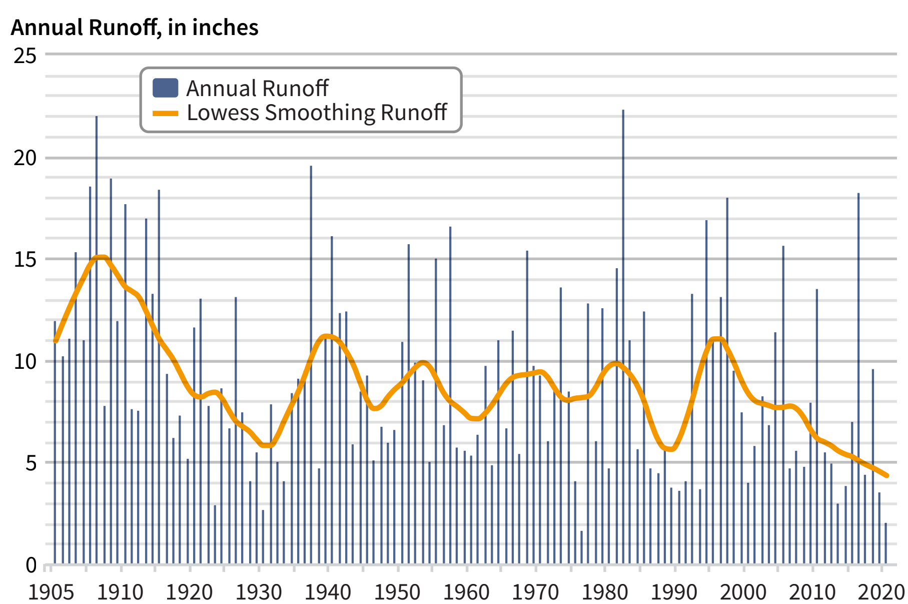
Prospects for WY 2022

Accurately predicting seasonal precipitation and reliably answering the question if California's coming winter will be wet or dry is not within present scientific capabilities. The National Weather Service's Climate Prediction Center produces precipitation outlooks for the winter months important to California's water supply, but the historical skill of these outlooks is minimal. The high annual variability in California's annual precipitation means that any year could hold the possibility for record wet conditions, such as those of Water Year 2017, or for continued dry conditions. Improving the ability to make seasonal precipitation predictions is critically needed to support drought preparedness and response.

California's observational record shows that La Niña years are often, but not always, associated with dry conditions in Southern California.

Figure 10. Statewide California Runoff

2020 and 2021 water year data are provisional and subject to change. Figure credit: U.S. Geological Survey



Apart from this relationship, the status of the El Niño-Southern Oscillation conditions does not by itself provide an indication of potential water supply outcomes. Presently the National Oceanic and Atmospheric Administration calls for a 70 to 80 percent chance of La Niña conditions in the coming winter.

The present severely dry conditions will affect the quantity of runoff that occurs from the coming wet season. Figure 10 illustrates California's overall dry trend in recent years, setting the stage for the low runoff efficiency observed in Water Year 2021. The latest model runs of the USGS Basin Characterization model suggest that 140 percent of average annual statewide precipitation would be needed to achieve average statewide runoff, reflecting the moisture deficit in the climate system. When precipitation occurs under conditions of severe moisture deficit, an increased amount of that precipitation replenishes depleted soil moisture and is taken up by vegetation, reducing runoff efficiency. For the upper Colorado River Basin (the watershed tributary to Lake Powell), and estimated 165 percent of average annual precipitation would be needed to achieve average runoff. Figure 11 shows how cumulative climatic water deficit explains the Basin's poor runoff performance in Water Year 2021 and contributes to the low expectations for 2022.

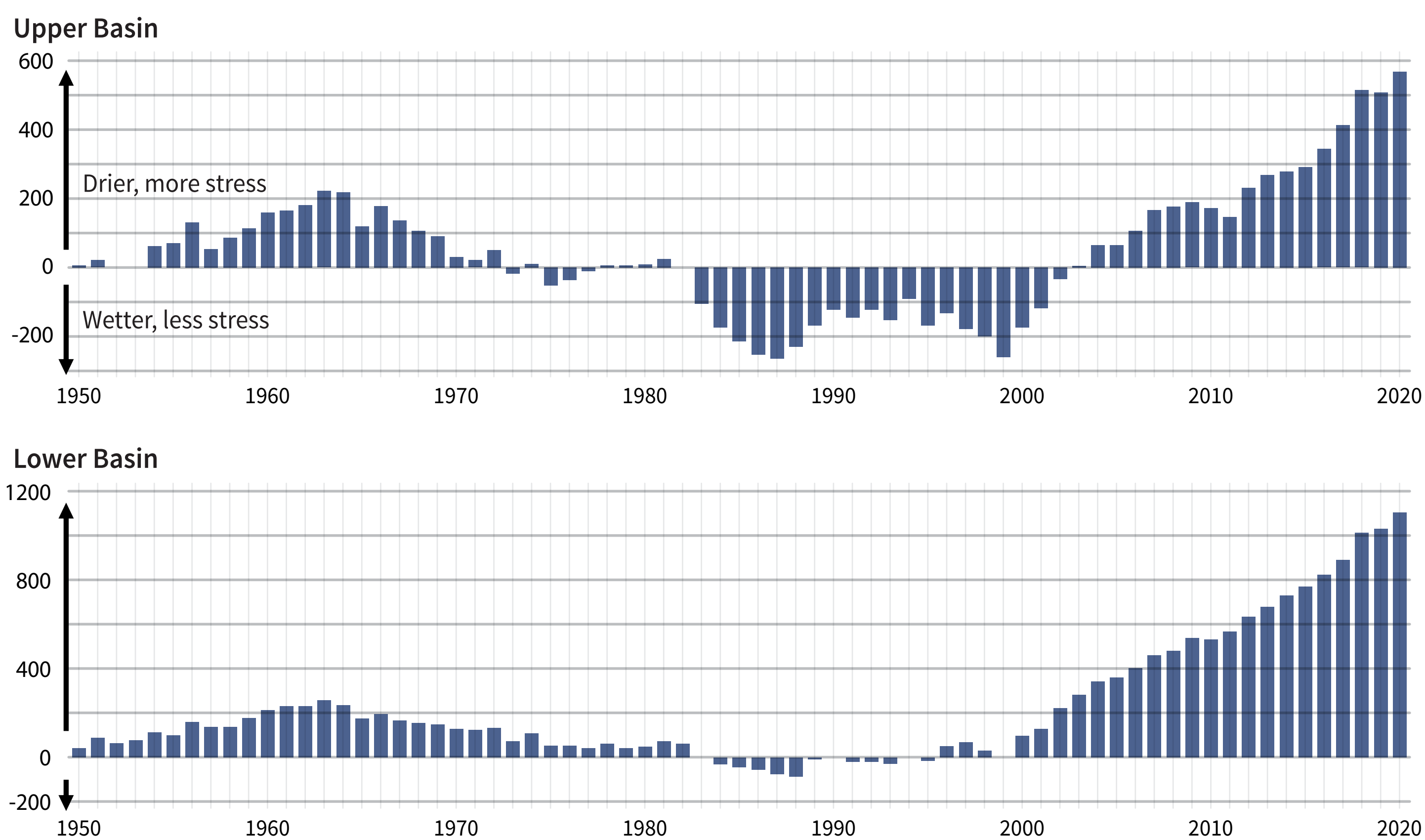
It should also be expected that other impacts expected with warm and dry conditions are likely to persist in 2022. It was observed during California's 2012-2016 drought that harmful algal blooms, such as the one illustrated in the San Luis Reservoir photograph, are being more commonly observed (Figure 12) and that wildfire damage is increasing. According to CAL FIRE statistics for the top 20 wildfires by category, all but two of the largest fires and two of the most damaging fires have occurred from 2000 onward. The 2021 Dixie Fire became the state's second-largest fire.

Improving Water Supply Forecasting

The significant overestimation in DWR's spring 2021 forecasts of

Figure 11. Accumulated Climatic Water Deficit in Colorado River Basin

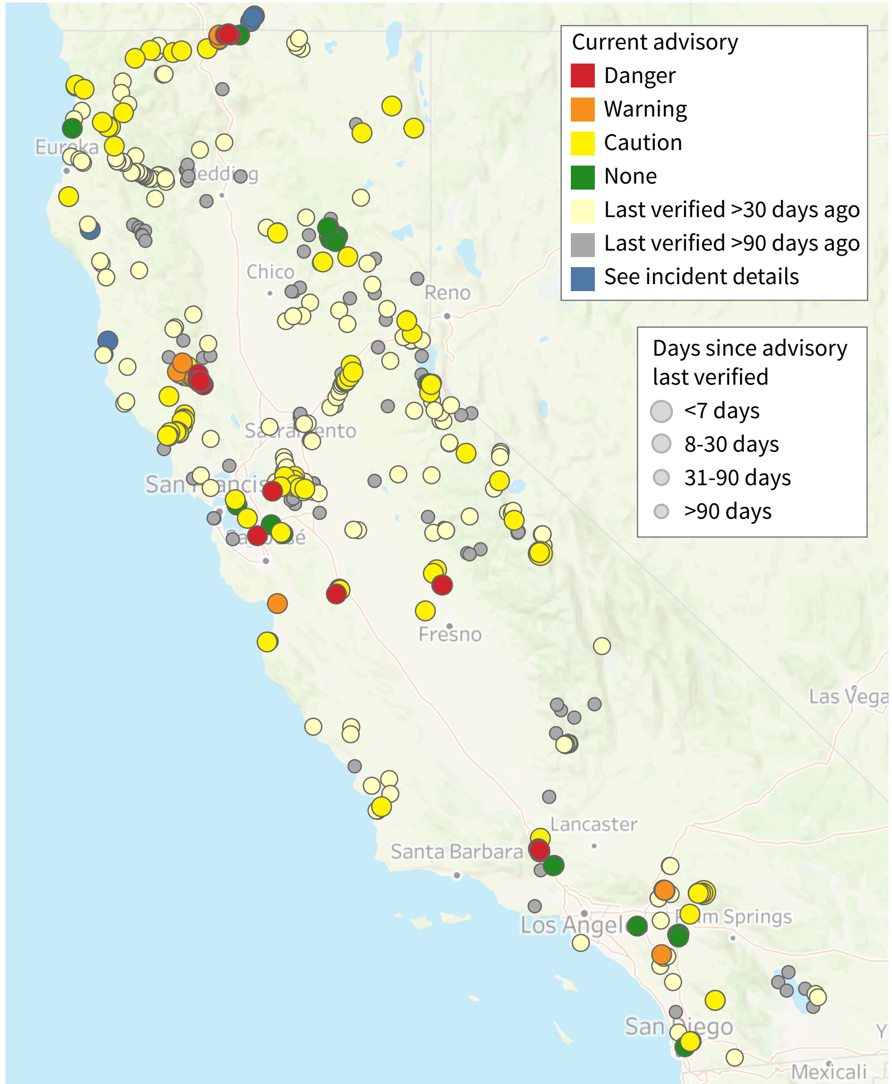
Figure credit: U.S. Geological Survey



snowmelt runoff forecasts illustrate the importance of shifting away from statistical approaches that rely on a historical record no longer reflective of observed conditions, including the need to invest in the data to support better forecasting. DWR is beginning a transition to physically based watershed models that have the capability to address a changing climate and to use gridded data sets, including remotely sensed snowpack observations. DWR has also been investing in near-term experimental statistical seasonal precipitation forecasts to fill a gap in drought preparedness and response information until such time as the federal government can improve its dynamical weather and climate models to provide the forecasts necessary for supporting water management. DWR's Water Year 2022 snowmelt runoff forecasts will begin a transition to the new approaches in the Sacramento River watershed.

Figure 12. Harmful Algal Blooms Reported to Date in 2021

Figure credit: State Water Resources Control Board



Helicopters load up on water on August 24, 2021, to fight the Caldor Fire, which destroyed much of Grizzly Flats and damaged the town's water distribution system. Photo Credit: CAL FIRE

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