Drought & Lessons Learned

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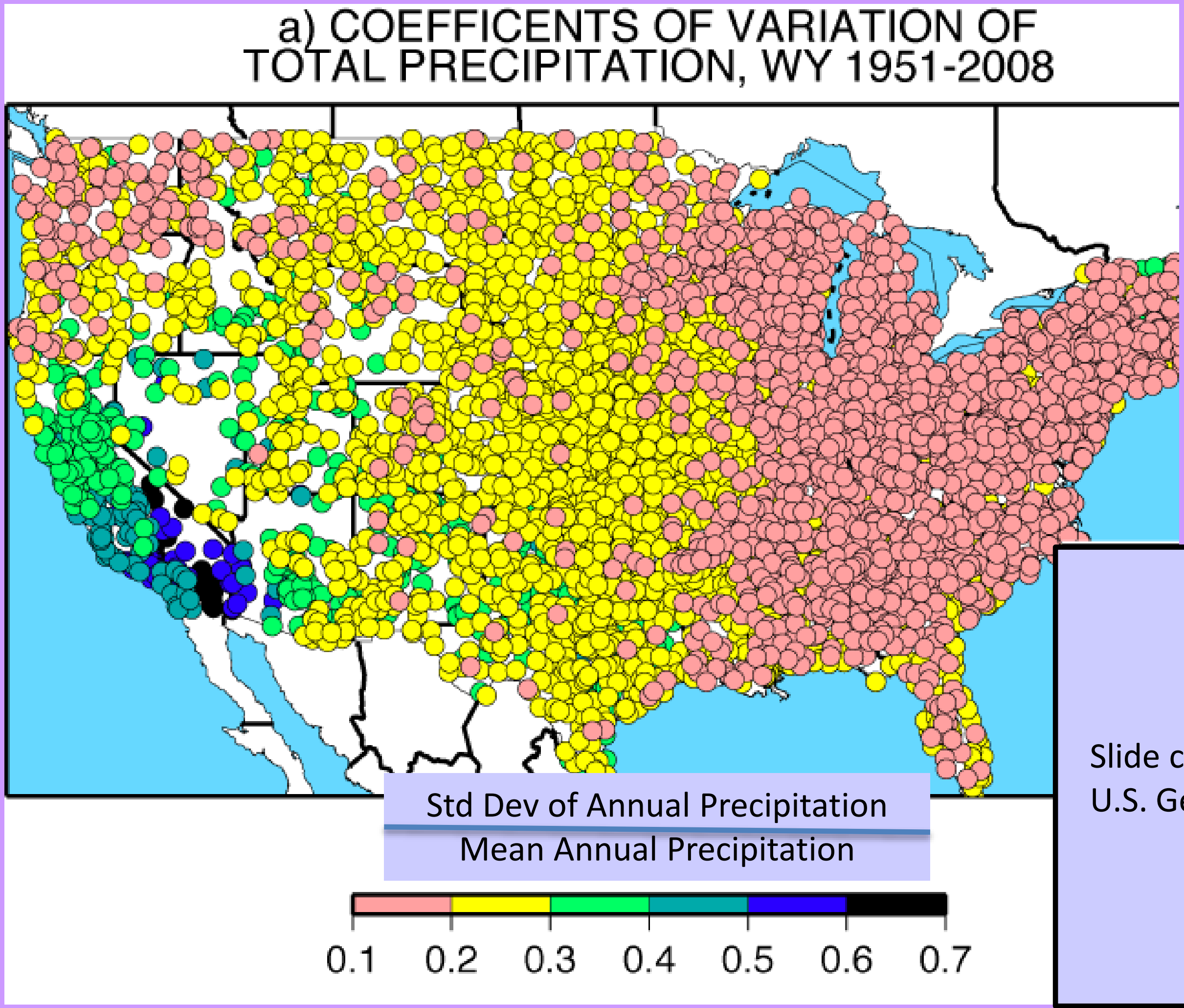
First a Word About Defining Drought When Does "Dry" Become "Drought"?

- Meteorological drought
- Hydrological drought
- Regulatory drought
- Drought indices, US Drought Monitor
- Sector-based definitions
- **Drought is a function of impacts (which are typically regional or local)**

When Does “Drought” Become “Drought Emergency”?

- Depends on impacts, and ability to mitigate impacts
- Drought differs from traditional “emergencies” (flood, fire, etc) in its very slow timescale
- California Emergency Services Act
  - Role of local government (counties)
  - Role of state

Variability of Western Precipitation



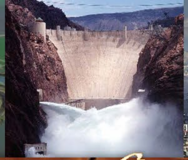
Slide courtesy of Mike Dettinger, U.S. Geological Survey

Dettinger et al, 2011

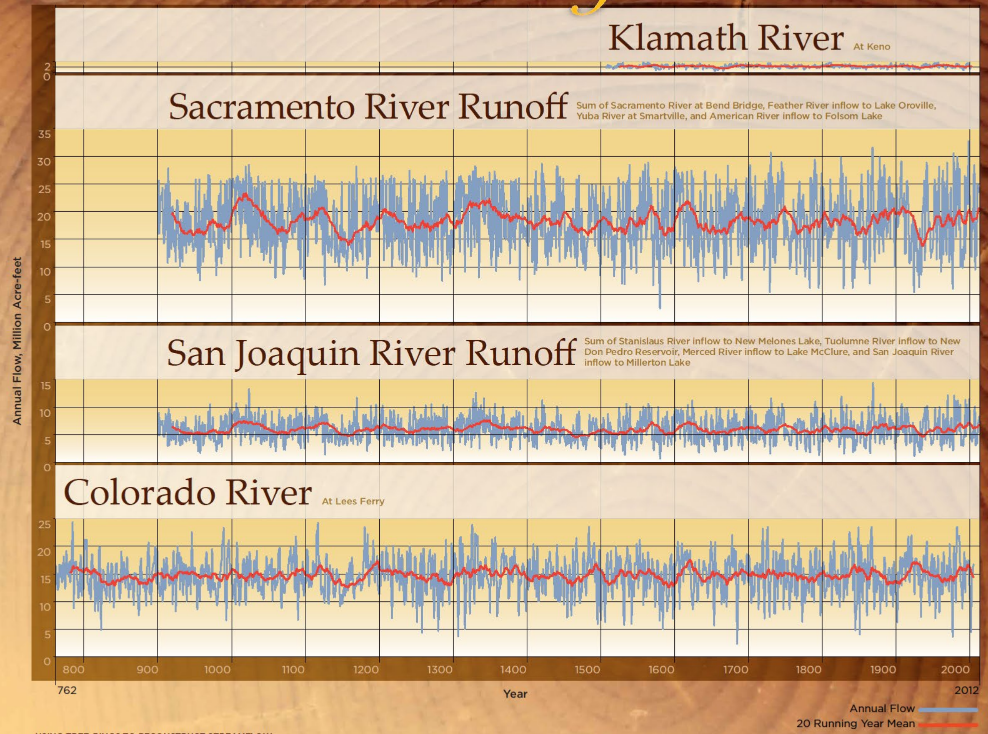
Droughts in the Holocene








Reconstructed Streamflows & Drought Periods



USING TREE-RINGS TO RECONSTRUCT STREAMFLOW

A tree-ring reconstruction is a set of tree-ring width data that have been calibrated with an instrumental or gaged record of a hydrologic or climatic variable such as annual streamflow or precipitation. The reconstruction, based on a statistical model that describes the relationship between tree growth and the gage record, extends that record back hundreds of years into the past.

Tree growth in dry climates is limited by water availability. Trees that provide the best information about hydroclimatic variability are those particularly sensitive to variations in moisture. These include species such as blue oak, ponderosa pine, Douglas fir, and western juniper, usually growing at lower elevations in sparse stands on dry and rocky sites where soil moisture storage is minimal.

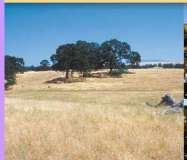
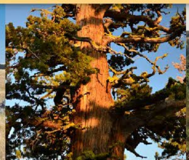
Tree-ring reconstructions of hydroclimatic variables are developed from tree-ring chronologies. A tree-ring chronology is a time-series of annual values derived from the ring-width measurements of 10 or more trees of the same species at a single site. To create a tree-ring chronology, cores from the sampled trees at each site are cross-dated (i.e., patterns of narrow and wide rings are matched from tree to tree) to account for missing or false rings, so that every annual ring is absolutely dated to the correct year. Then all rings are measured to the nearest thousandth of a millimeter using a computer-assisted measuring device. After growth-related trends unrelated to climate are statistically removed, the ring width values from all sampled trees for each year are averaged to create a time series of annual ring width indices. The complete series of ring width indices from a site is called a tree-ring chronology.

Once a gaged record of interest is selected for reconstruction, a set of tree-ring chronologies from the region near the gage is calibrated with the gage record to form a reconstruction model. A statistical technique called multiple linear regression is commonly used. The reconstruction is evaluated by comparing the observed gage values with the reconstructed values by assessing the amount of variance in the gage record that is explained by the reconstruction.

DROUGHTS PRIOR TO THE HISTORICAL RECORD

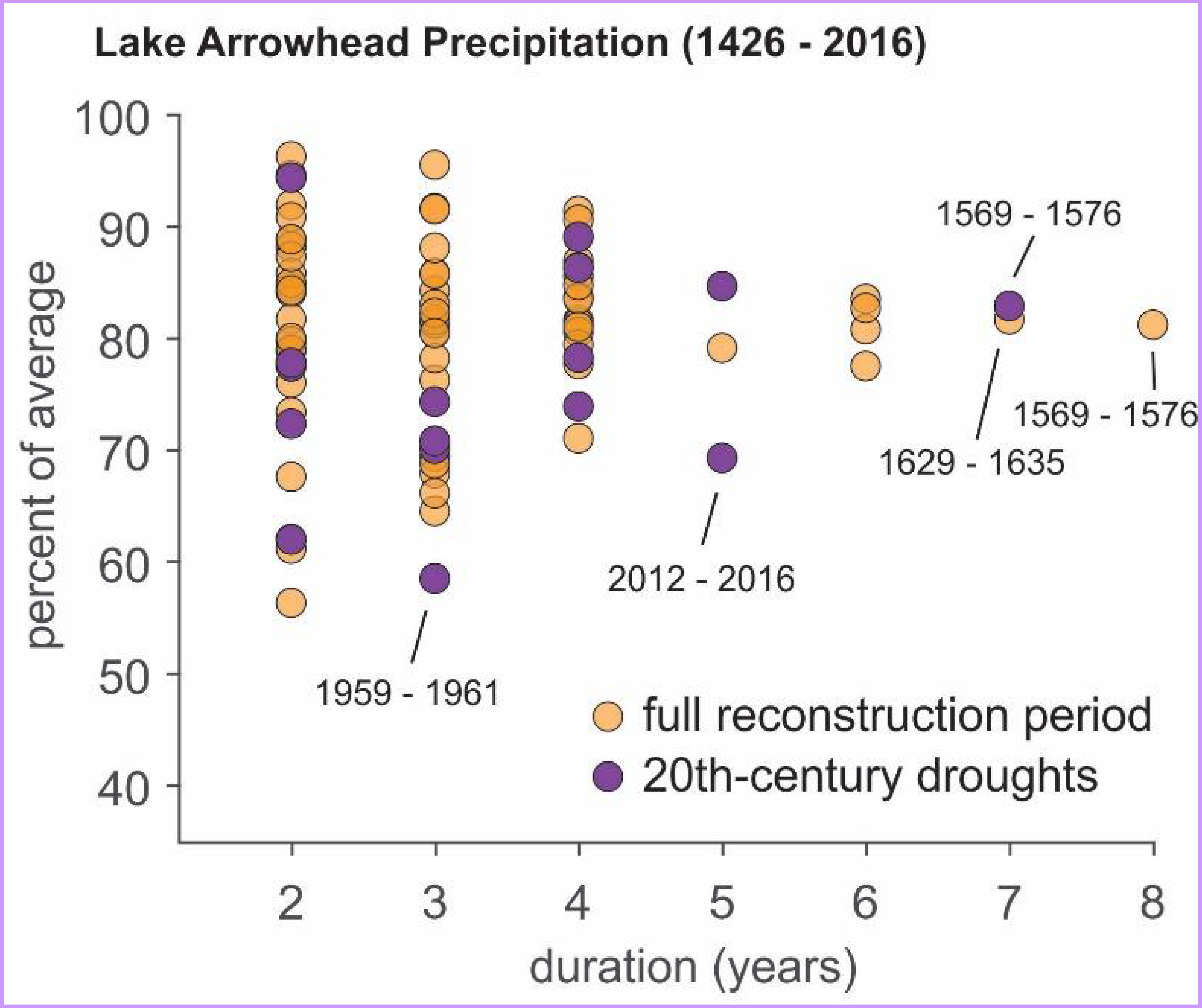
The period of reliably measured streamflows for rivers throughout the West seldom reaches beyond 100 years, which represents only a fraction of climatologically modern time. As these streamflow reconstructions show, there have been droughts prior to the historical period that were more severe – particularly in duration – than those in the measured record. The reconstructed record captures a broader range of hydrologic variability than does the historical record, making reconstructions useful for drought preparedness planning. Of particular interest from a scientific perspective is the Medieval Climate Anomaly, a time during which sustained severe drought gripped much of the western United States, as exemplified illustrated in the Sacramento, San Joaquin, and Colorado River reconstructions.

Data source: Work performed by the University of Arizona under contract to the California Department of Water Resources. CDWR Agreements 4600003882 (David Meko, 2006) and 4600008850 (David Meko, Connie Woodhouse, Ramzi Touchan, 2014)

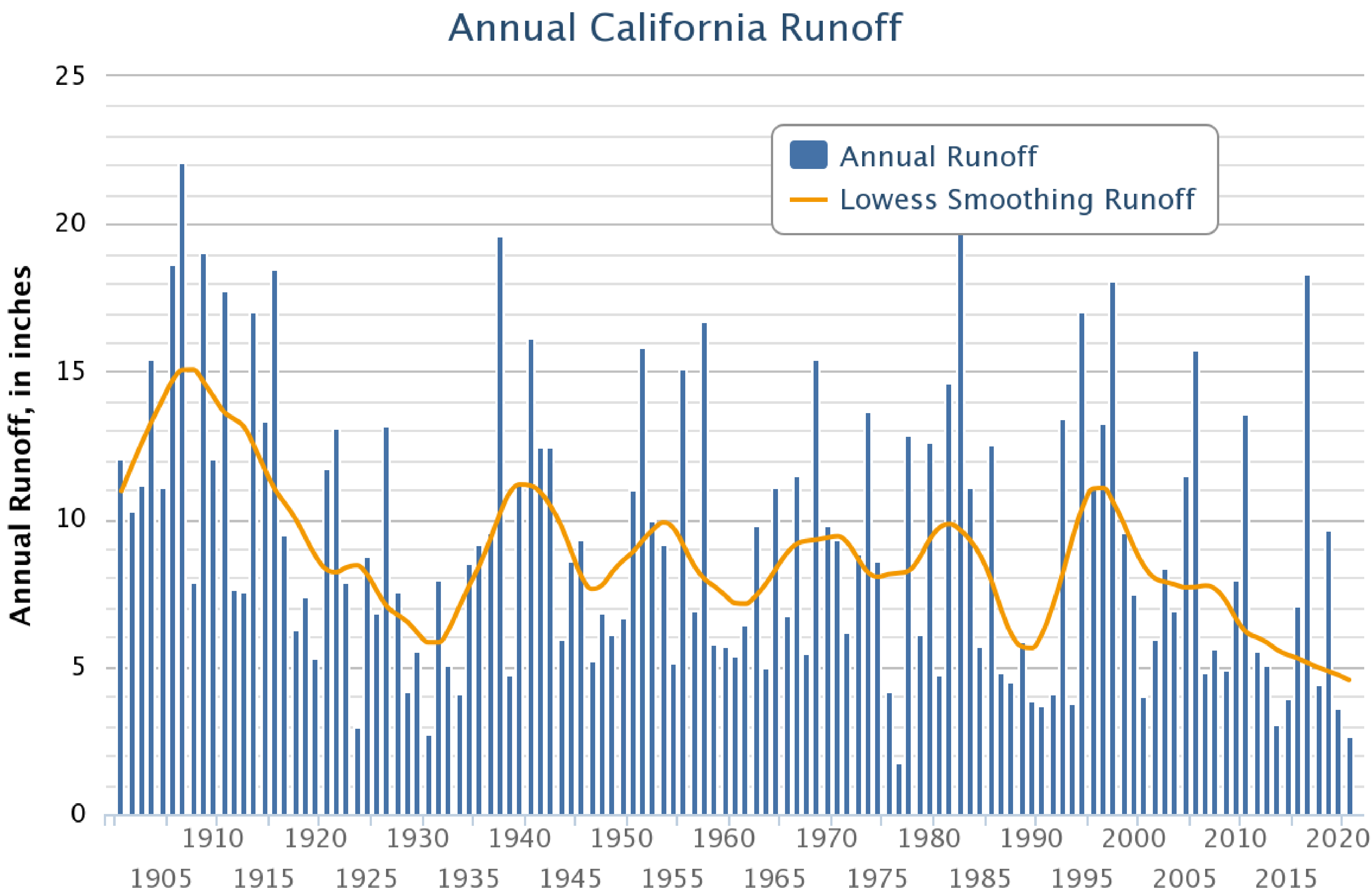


Southern California Local Sources Example



Courtesy of University of Arizona

USGS Calculated Statewide Runoff



California's 20th & 21st Century Statewide Droughts (consecutive dry years)

- 1918-20
- 1922-24
- 1929-34
- 1947-50
- 1959-61
- 1976-77
- 1987-92
- 2007-09
- 2012-2016
- 2020- ??

21st Century & 20th Century Droughts Not the Same

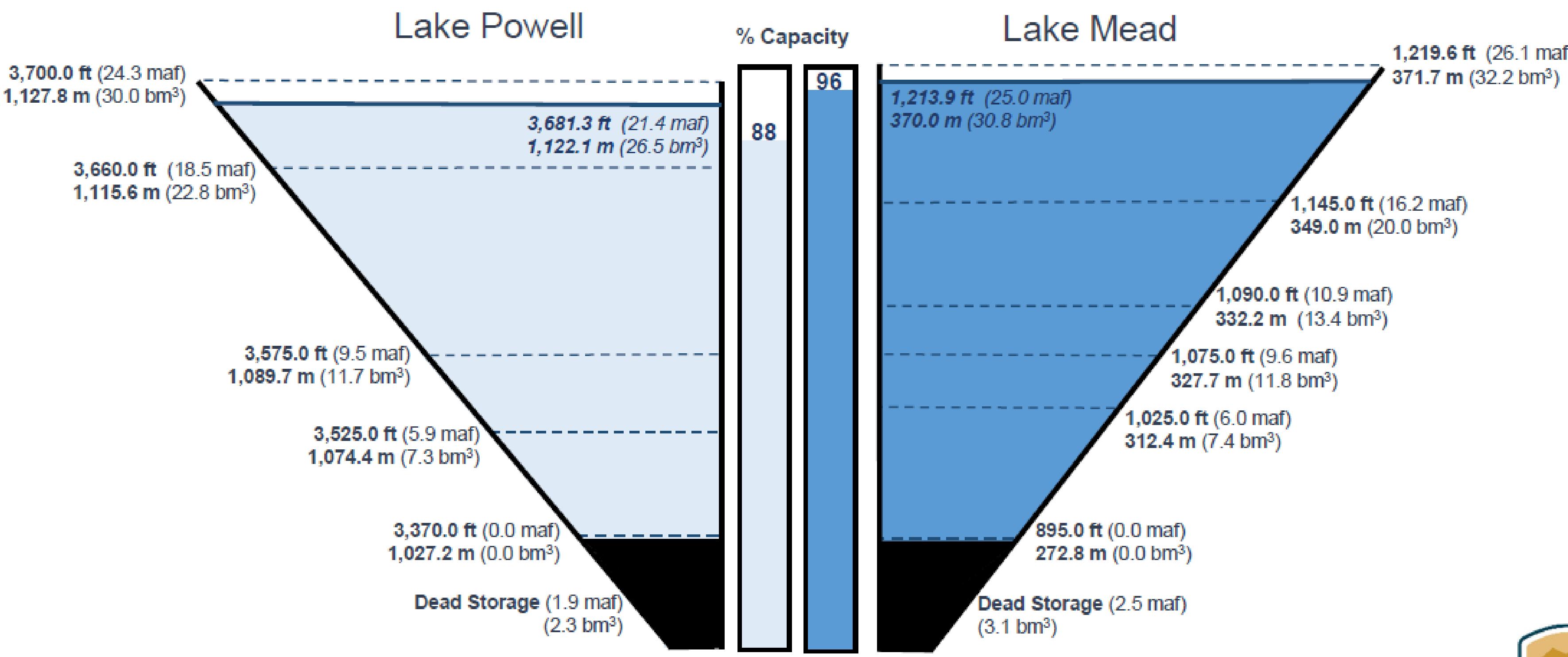
2012-16

- Included warmest years on record, record low statewide snowpack
- State response actions not seen since 1976-77
- First-ever zero CVP ag contractor allocations
- About 500,000 acres fallowed
- First-ever state emergency response for areas of dry private residential wells
- First-ever use of InSAR to monitor statewide land subsidence

California's Present Drought

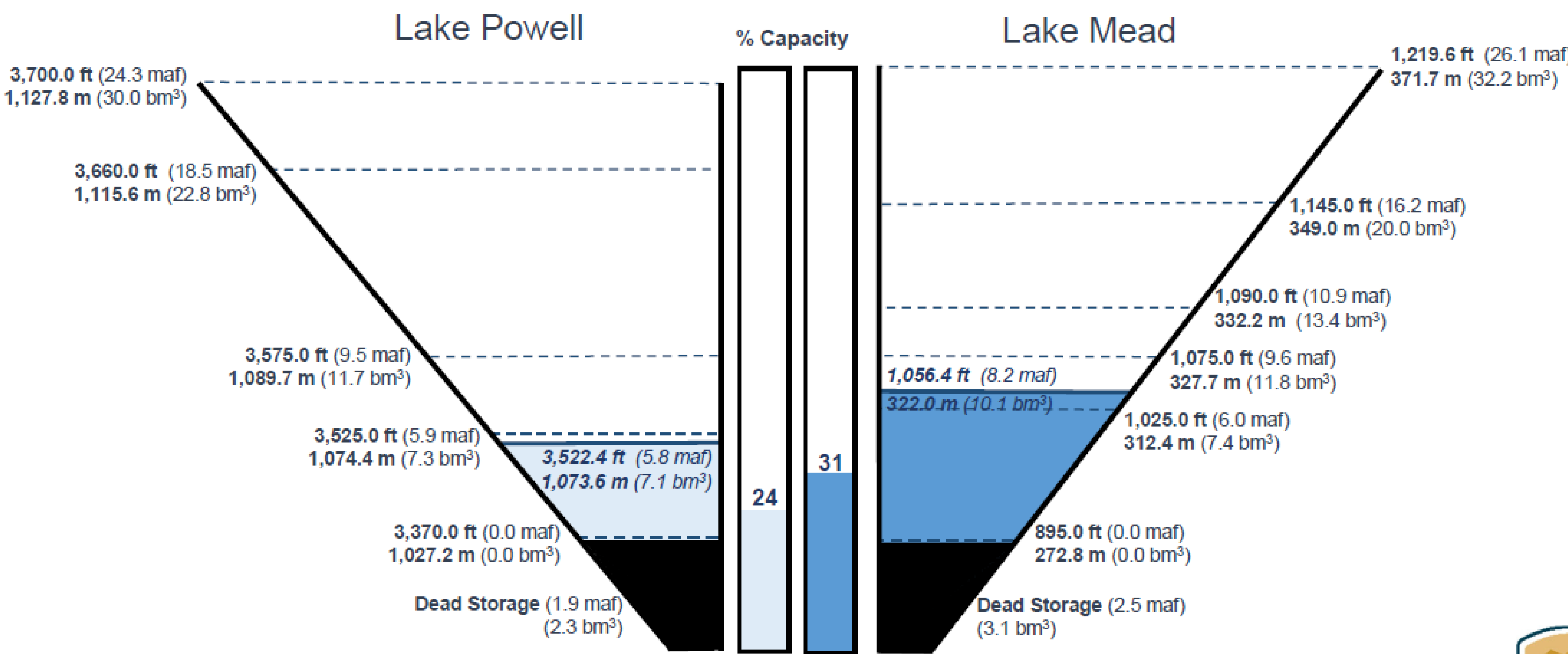
- Zero allocation to most CVP ag contractors in WY 2021 and 2022, CVP M&I health & safety allocation in WY 2022, 5% SWP allocation
- 2022 large-scale urban water use restrictions in Southern California due to infrastructure limitations
- First Lower Colorado River Basin shortage pursuant to the Interim Guidelines
- Record low Lake Oroville elevation in 2021, Hyatt PP unable to generate
- 70% statewide snowpack in WY 2021, yet runoff comparable to 2014-2015
- Groundwater impacts similar to San Joaquin Valley in 2012-16 now seen in parts of Sacramento Valley

Entering Current Drought
December 1999



Notes
- *Units: feet (ft); meter (m); million acre-feet (maf); billion cubic meters (bm³)*
- *Water stored in Dead Storage cannot be released or withdrawn from the reservoir and, therefore, is not available for use.*
- *Schematic is for illustrative purposes only and is not to scale.*

Current
April 25, 2022



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What Has Changed Over Decades?

- Extensive interconnections now among largest water projects & urban suppliers
- Much greater experience with water transfers
- New groundwater management legislation
- Beginning in mid-1990s, substantial state grant funding for local projects
- It’s getting warmer
- Wildfire risk increasing
- Increased acreage of permanent plantings
- Land subsidence in historically unaffected areas
- Small water system/private well owner problems becoming more widespread

More Recent Changes

Old

- Multi-year drought normal in reconstructed paleo & historical records
- Severely reduced CVP & SWP allocations
- Groundwater overdraft & land subsidence
- Impacts in San Joaquin Valley

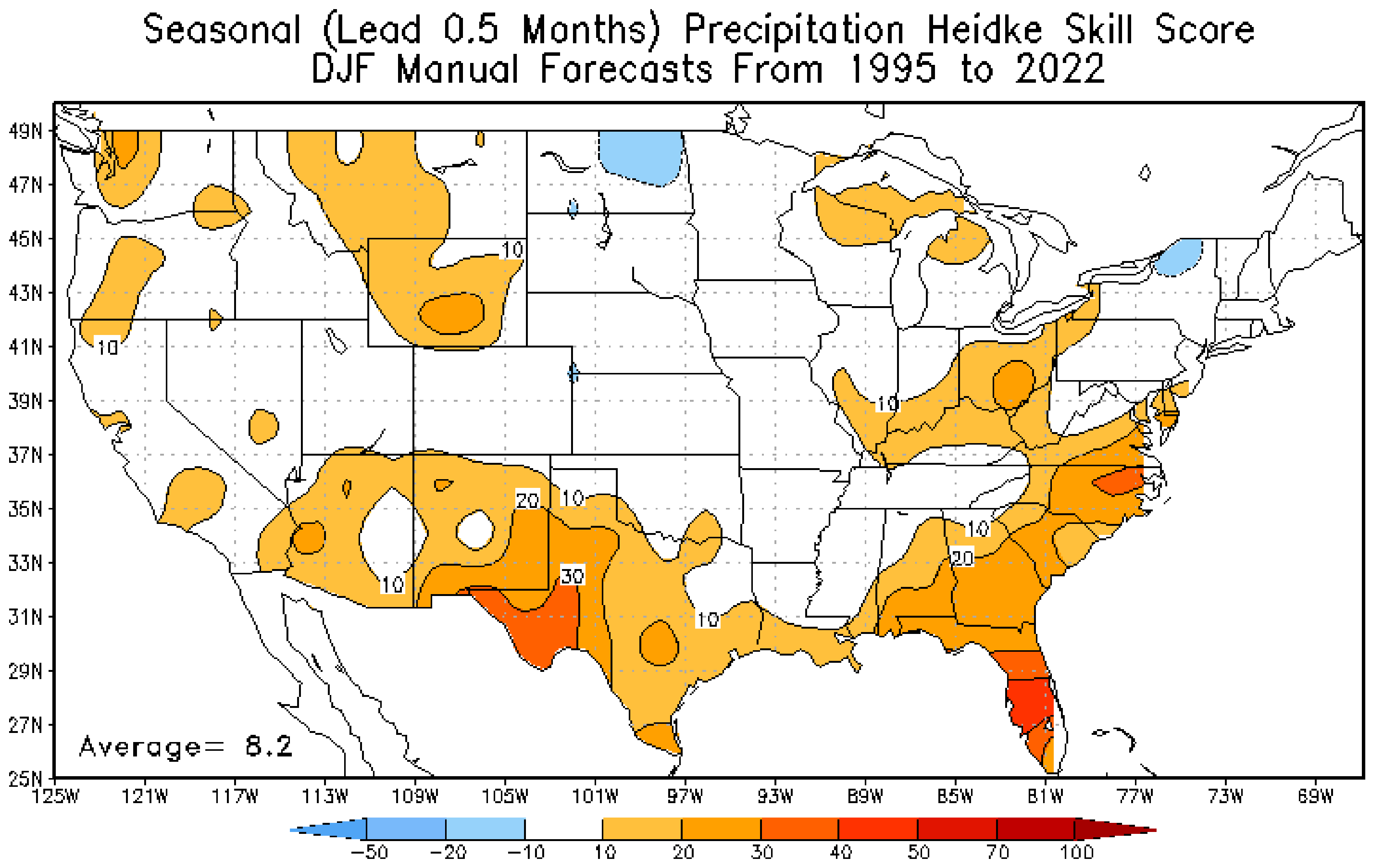
New

- Droughts occur in warming climate, exacerbates impacts
- First Lower Colorado River Basin shortage declared, SWP & CVP health & safety allocations
- Early stages of SGMA implementation
- Impacts in Sac Valley

Key Drought Challenges, California's Progress Since 2007-09

- Statewide coverage of groundwater level data in major aquifers ✔
  - CASGEM legislation in 2009, SGMA legislation in 2014
- Small water systems E
  - Multiple legislative provisions for mandatory system consolidation beginning in 2016, long-term resilience funding legislation in 2019 ($130M annually for 10 years), DWR drought response grants in 2021 ($200M for small systems)
- Seasonal precipitation forecasting X
  - No improvement (requires action by NOAA)

Historical Skill of NOAA Seasonal Outlooks – Not Usable for Water Management



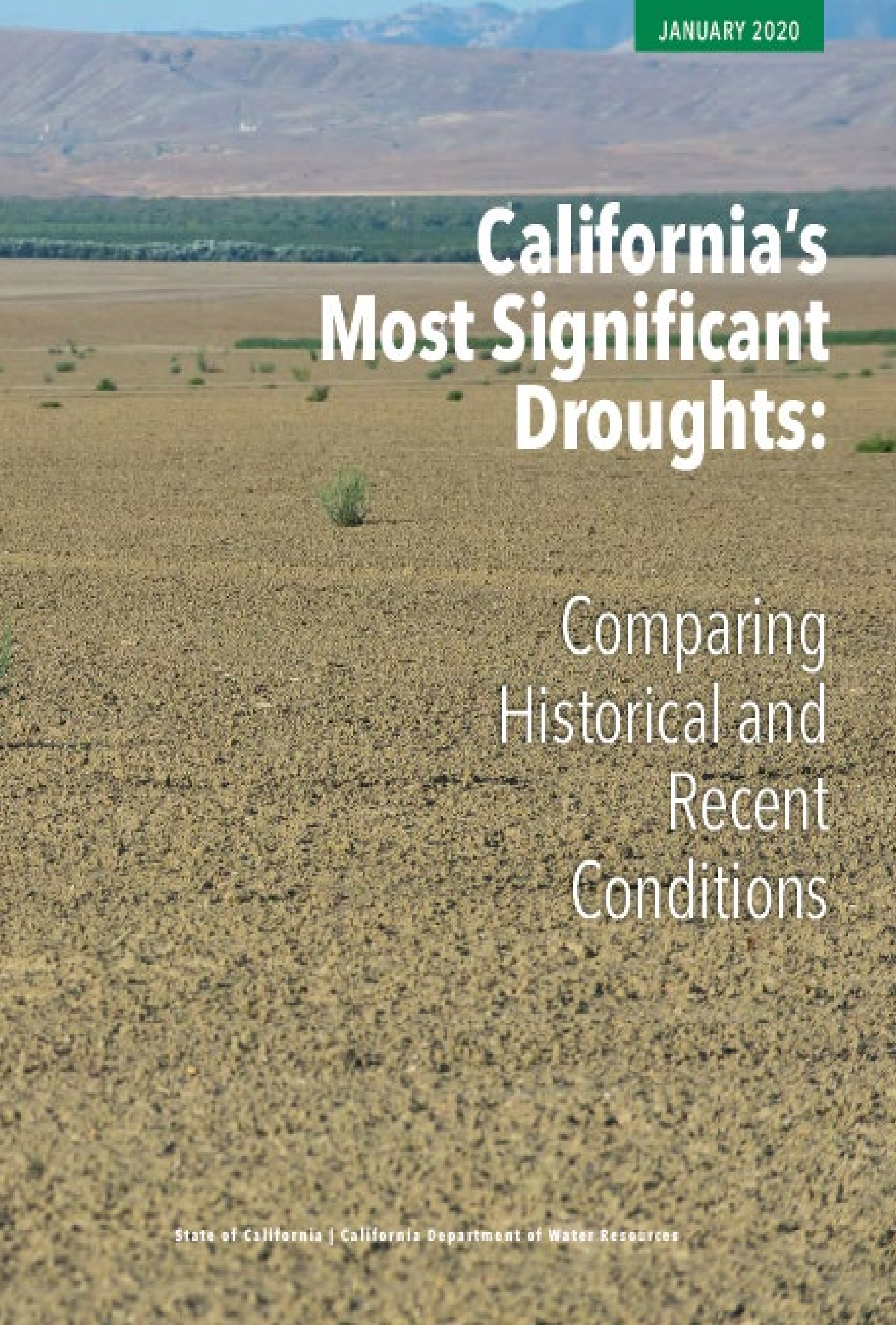
Catastrophic Wildfire Risk

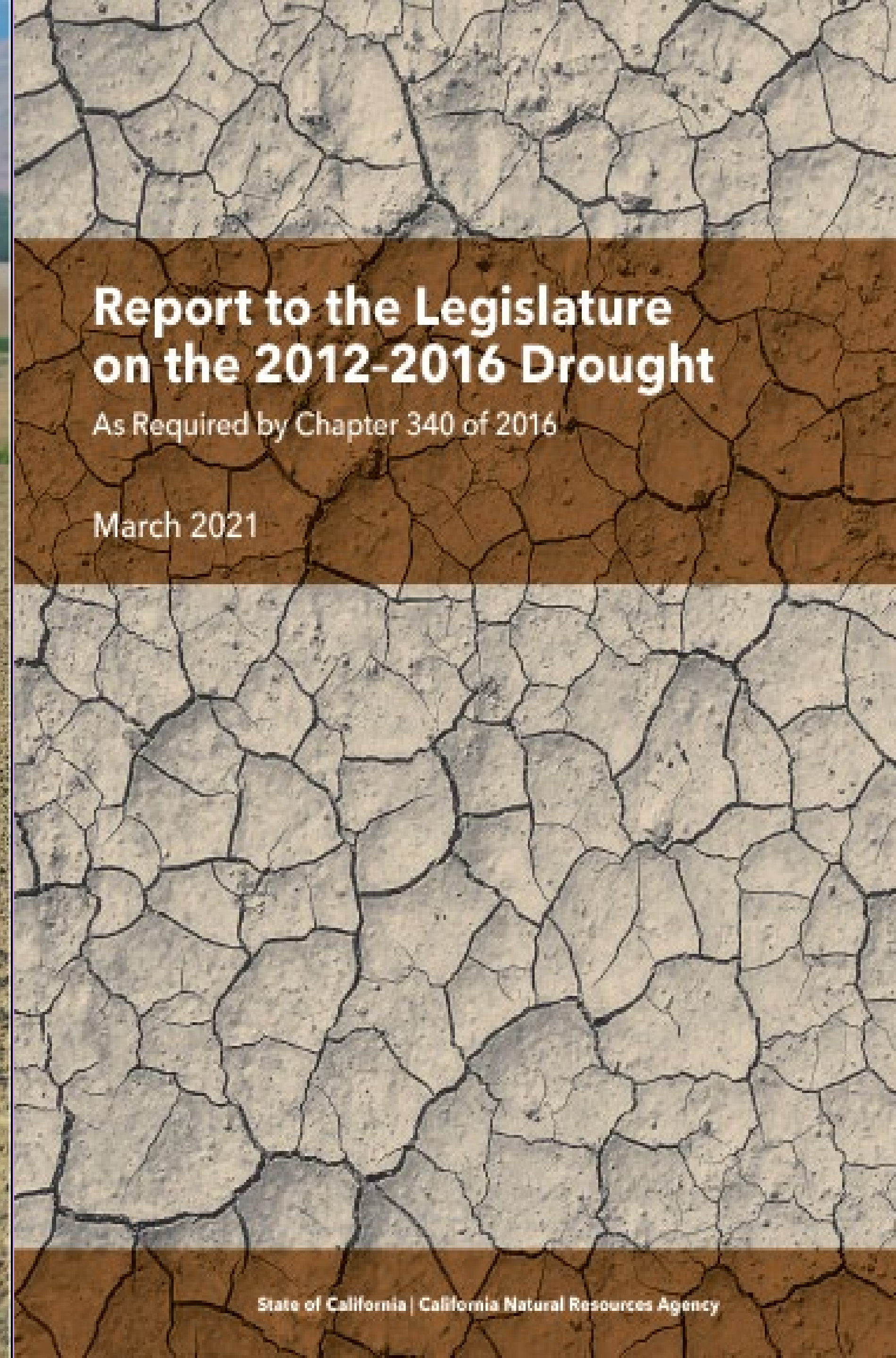
- 1991 Oakland Hills fire (25 lives lost)
- October – November 2003 Southern California wildfires (22 lives lost)
- October 2007 Southern California wildfires (1 million people evacuated)
- 2017 Tubbs Fire, 2018 Camp Fire, 2021 Dixie Fire (urban water distribution system destruction)
- All but 2 of the state's 20 largest & 20 most damaging fires have occurred from 2000 onward

Precautionary Evacuations at Hyatt & Keswick Powerplants

Wildfire Damage to Water Infrastructure

Lessons Learned from Past Droughts


JANUARY 2020
California's
Most Significant
Droughts:
Comparing
Historical and
Recent
Conditions
State of California | California Department of Water Resources


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

Lessons Learned From Past Droughts

- Impacts are highly site-specific, and vary depending on the ability of water users to invest in reliability
- Small water systems on fractured rock groundwater sources are most at risk of public health and safety impacts
- Larger urban water agencies can manage multiple years of drought with minimal impacts to their customers

Expected Impacts of Multi-Year Drought

- **Unmanaged systems**
  - Risk of catastrophic wildfire (health & safety, economic)
  - Non-irrigated agriculture (livestock grazing)
  - Fish & wildlife (e.g., salmonids)
- **Managed systems**
  - Small water systems (health & safety)
  - Irrigated agriculture
  - Green industry (urban water supplies)
  - Fish & wildlife (e.g., wildlife refuges, salmonids)
  - Other environmental (e.g., land subsidence)

Lessons Learned from Recent Droughts

- Act sooner when dry conditions emerge
- Recognize that increased temperatures are creating new or intensified impacts (e.g. wildfire)
- Cutbacks in historical irrigation deliveries affect shallow drinking water wells due to absence of groundwater recharge sources or compensatory construction of deeper irrigation wells
- Wildfire impacts
- Transition from thinking of drought as an occasional emergency to thinking in terms of creating resiliency in a more arid climate