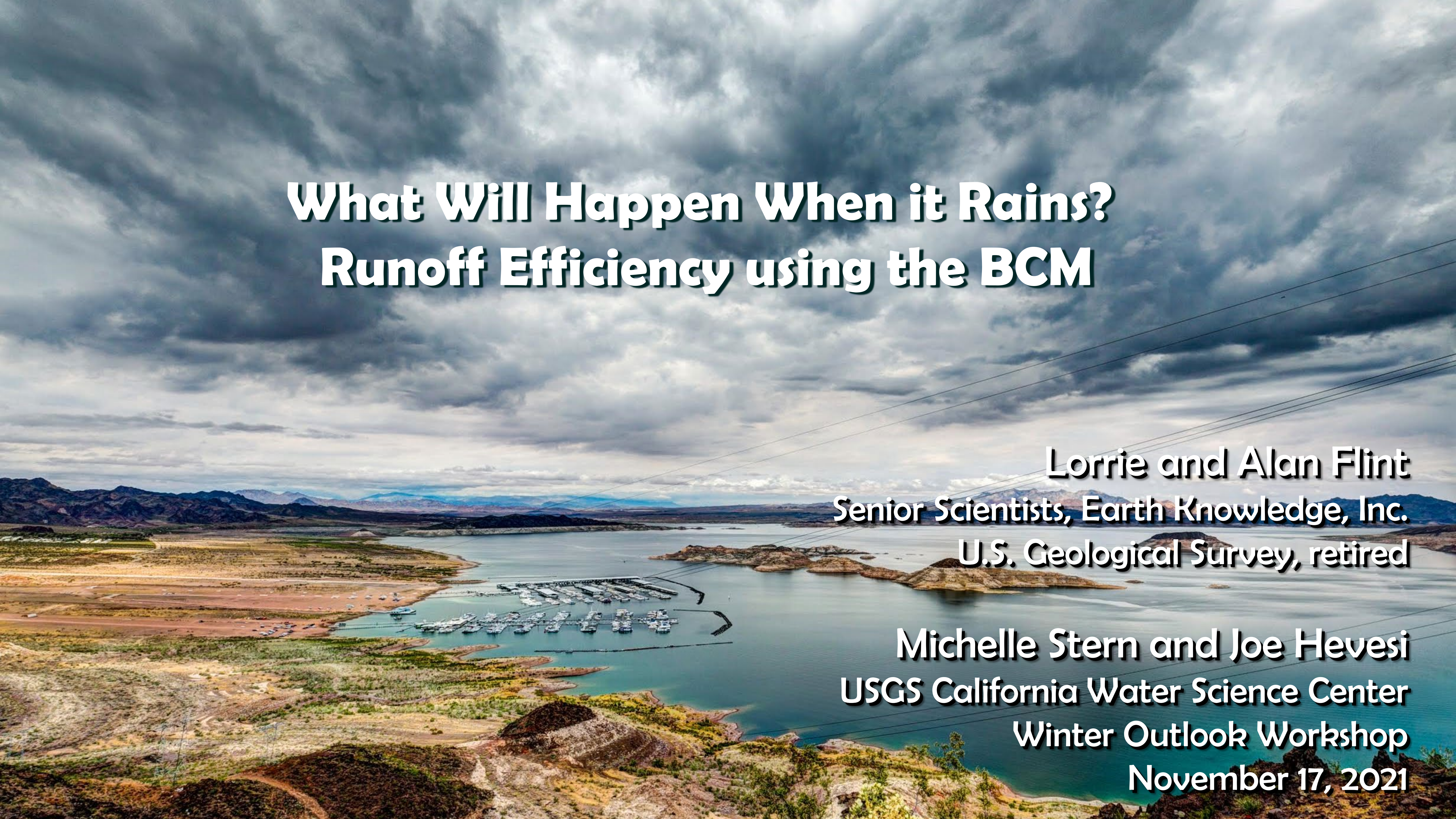
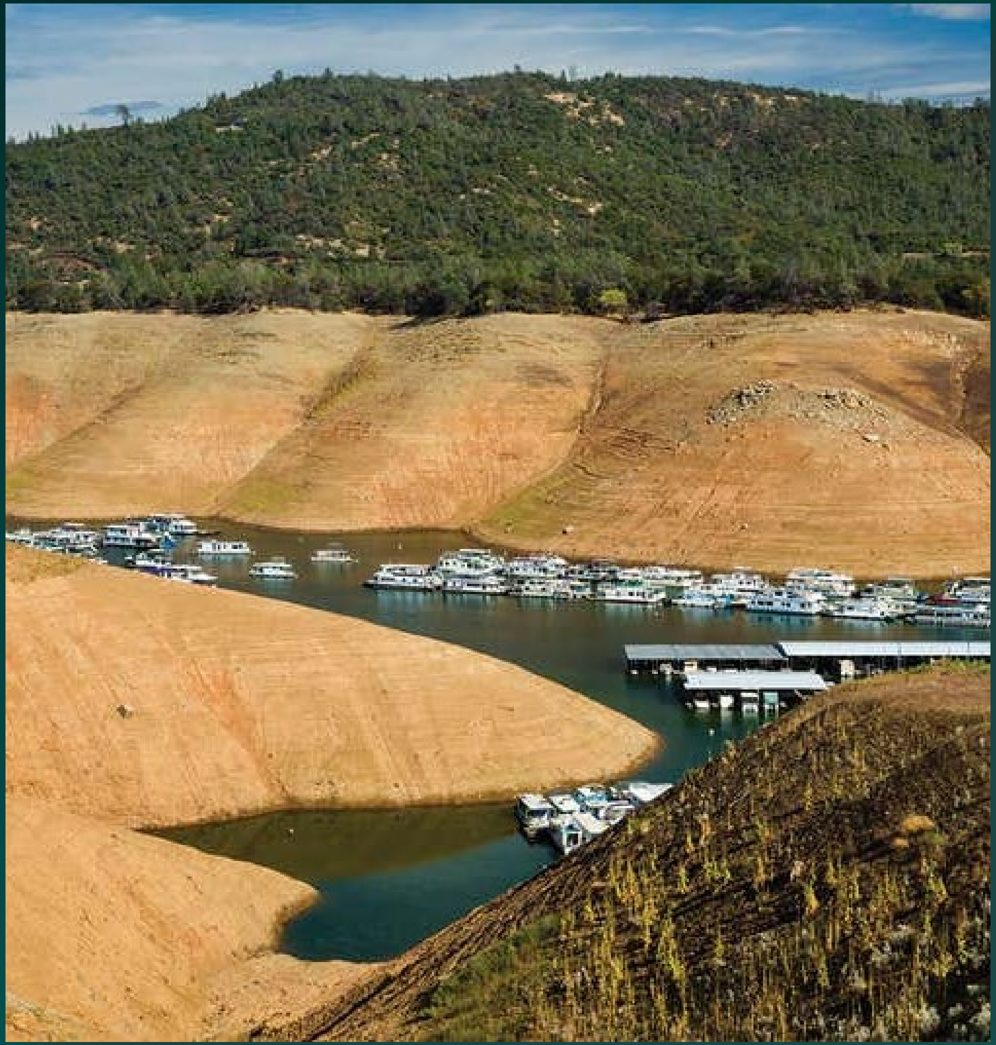


What Will Happen When it Rains?
Runoff Efficiency using the BCM

Lorrie and Alan Flint
Senior Scientists, Earth Knowledge, Inc.
U.S. Geological Survey, retired

Michelle Stern and Joe Hevesi
USGS California Water Science Center

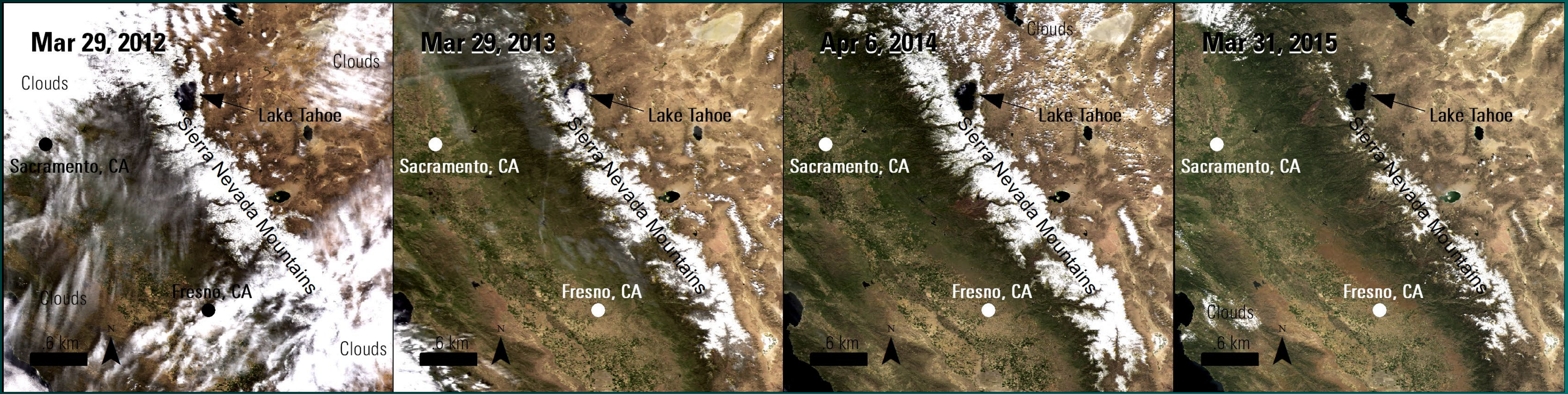
Winter Outlook Workshop
November 17, 2021



Characterizing Drought and Impacts on Resources

Both Water Supply and Landscape

- Water supply drought, lack of recharge and runoff, is a shorter-term impact that can be ameliorated with shorter wet periods
- Even if reservoirs are full, longer droughts can reduce recharge to the aquifer
- Landscape droughts are exacerbated by dry conditions and HOT temperatures, drying out the vegetation, soils, and unsaturated zone and take much more to reverse



Sierra Nevada Snowpack

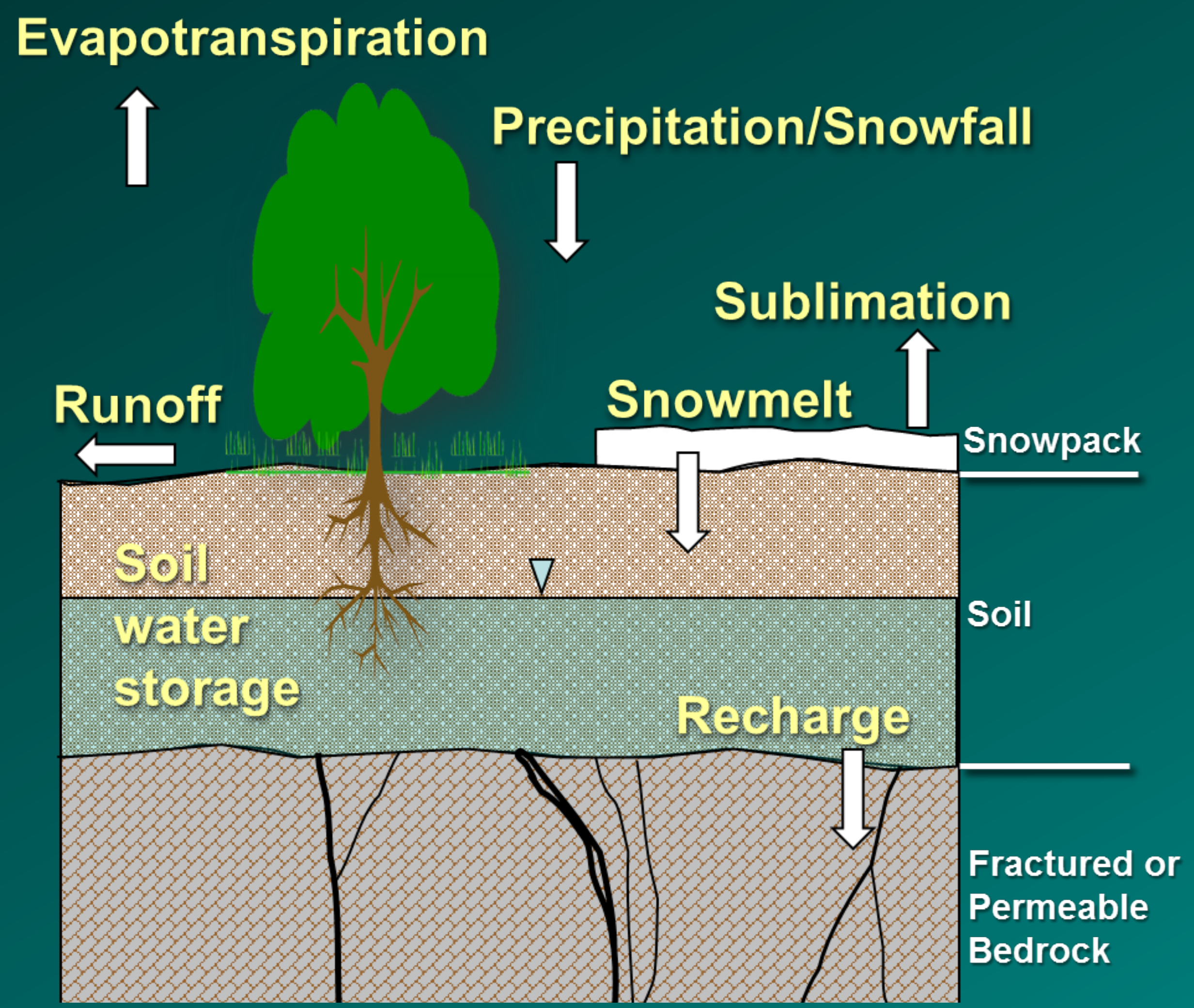
Snow Drought

- Large indicator of drought conditions because it incorporates both precipitation and temperature
- It doesn't tell you what it takes to get out of drought as it differs year to year
- Hydrologic modeling can use this climate information to accumulate drought conditions over time and better characterize the environment

Characterizing Drought and Impacts on Resources

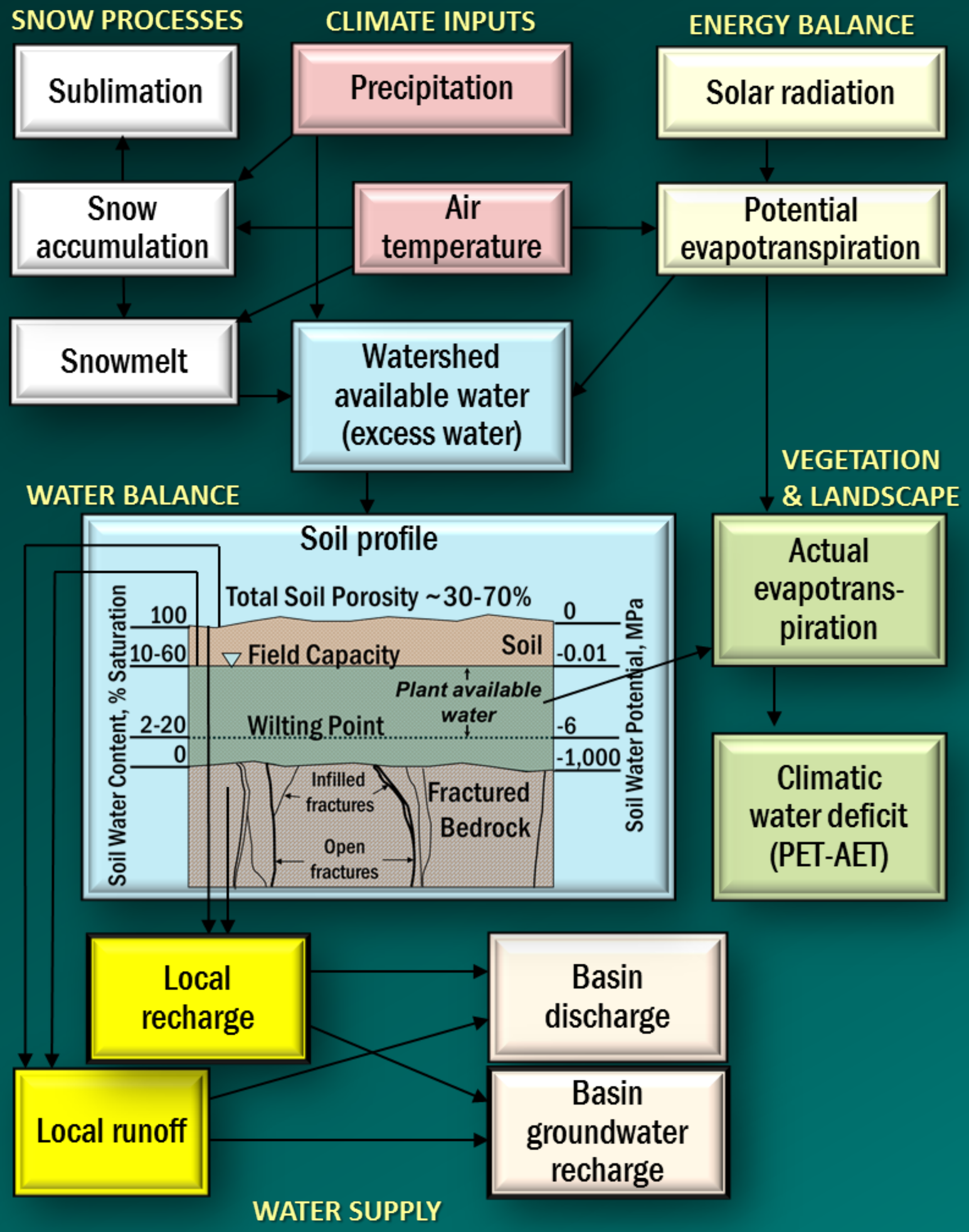
- Tools in the toolbox:
  - Monitoring to understand current and antecedent conditions
  - Remote sensing to spatially distribute data
  - Modeling to forecast water supply and climate extremes
  - Modeling to analyze the range of accumulated drought conditions across the state
- The Basin Characterization Model
  - Under development since 2007, with DWR since 2010
  - Published as a USGS code in 2021

The Water Balance



Precipitation = Evapotranspiration + Runoff + Sublimation + Recharge + ΔSoil Water Content

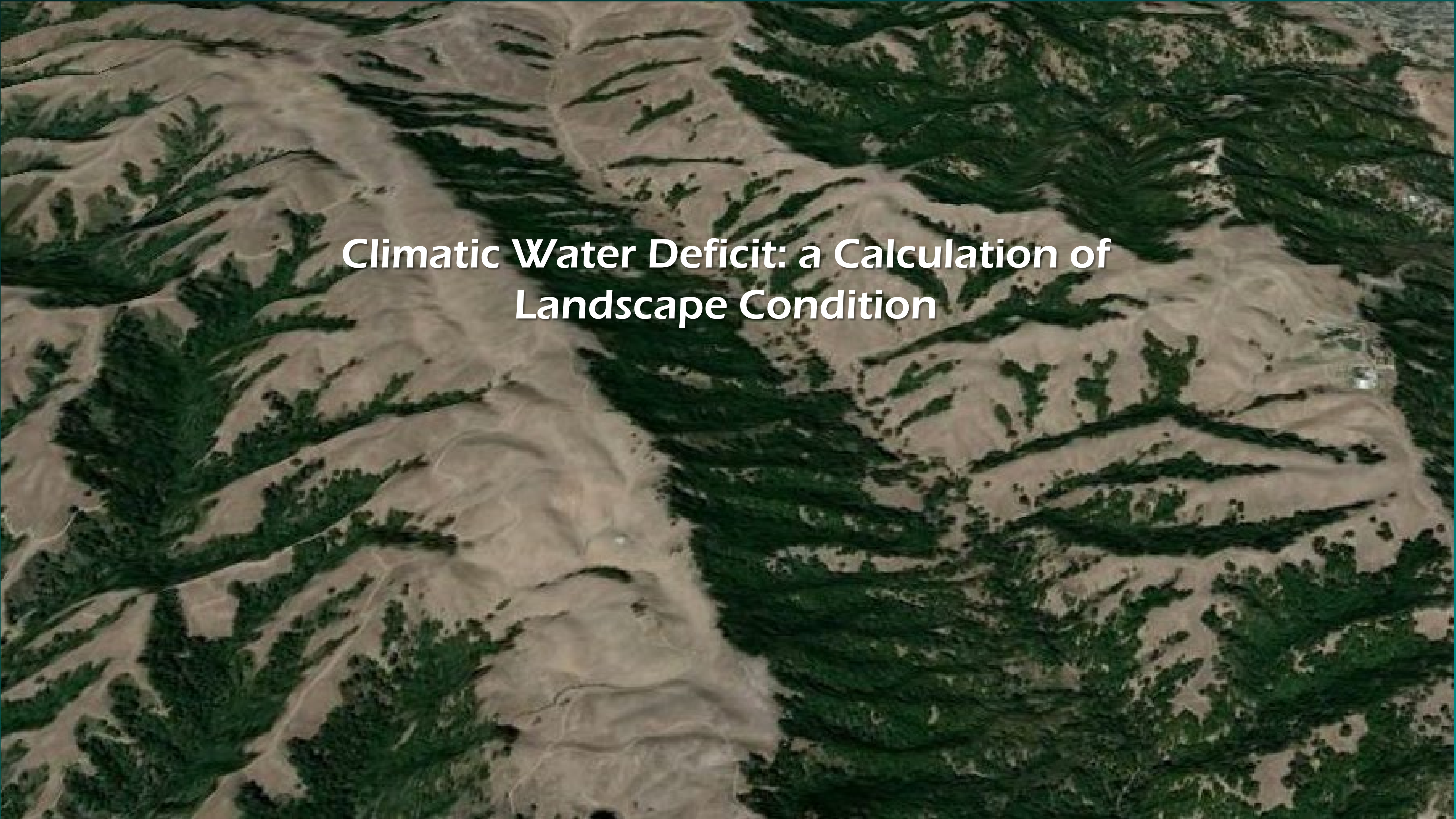
Basin Characterization Model



A grid-based water balance model

- Uses gridded climate data downscaled to fine spatial scales 270-m (historical and future)
- Develops a rigorous energy balance
- Incorporates detailed soil properties and estimates of bedrock permeability
- Calculates spatially distributed water supply as recharge and runoff
- Calculates climatic water deficit as an estimate of demand and stress

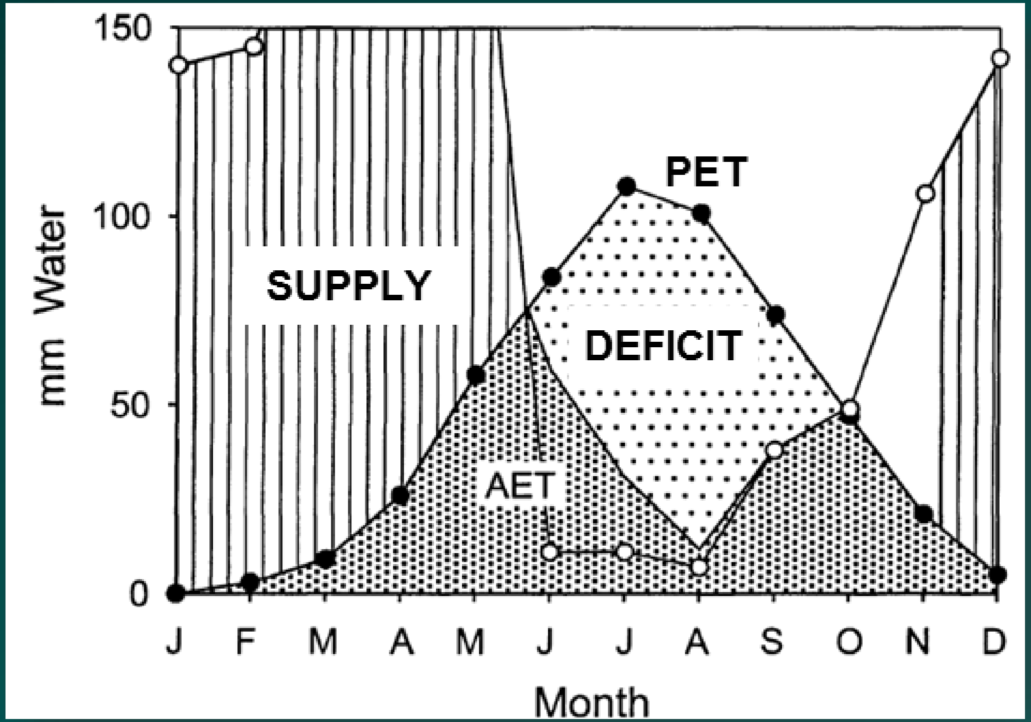
Climatic Water Deficit: a Calculation of Landscape Condition



Climatic Water Deficit

Annual evaporative demand
that exceeds available water

Potential – Actual Evapotranspiration

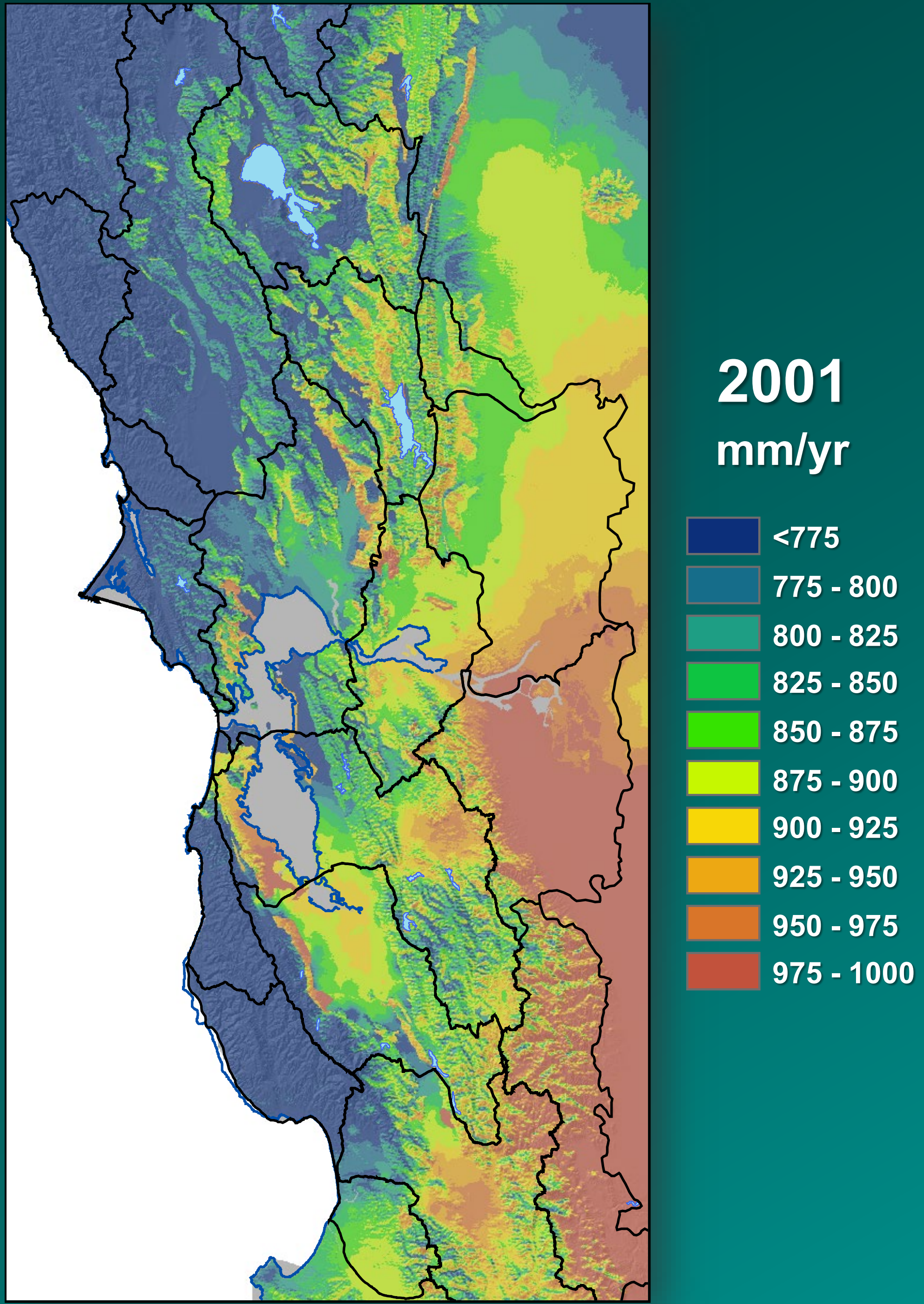


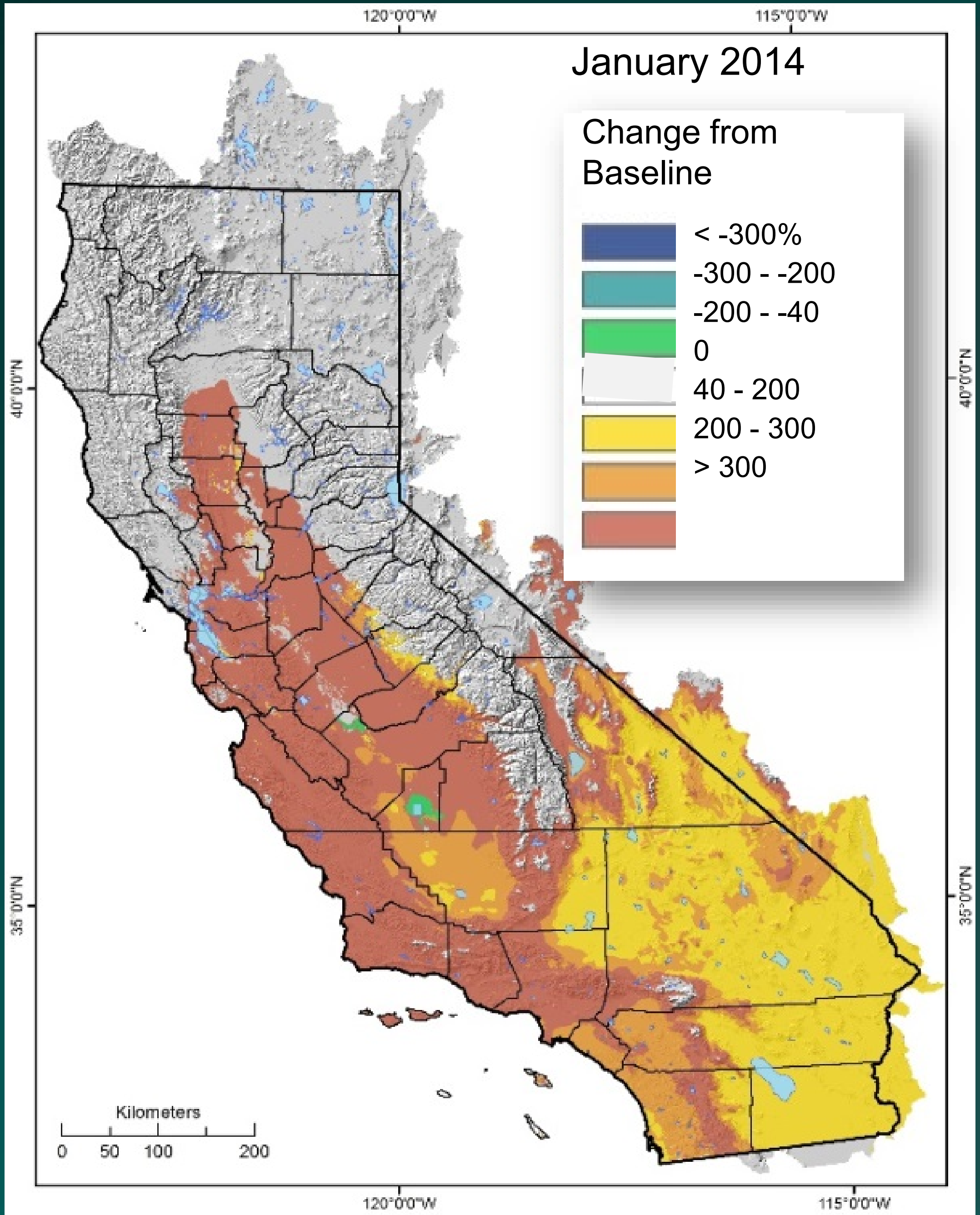
- Integrates climate, energy loading, drainage, and available soil moisture storage
- Addresses irrigation demand
- Defines level of stress on landscape
- The earlier the snowmelt the higher the annual CWD
- The hotter it is the higher the potential evapotranspiration, and the higher the accumulated CWD over the season
- When accumulated over multiple seasons it can describe the loss of water from a deep unsaturated zone

Climatic Water Deficit

When calculated over a region it is obvious where cooler, wetter places are and where it is hot and dry

North and south facing slopes are notable due to the energy loading in potential evapotranspiration

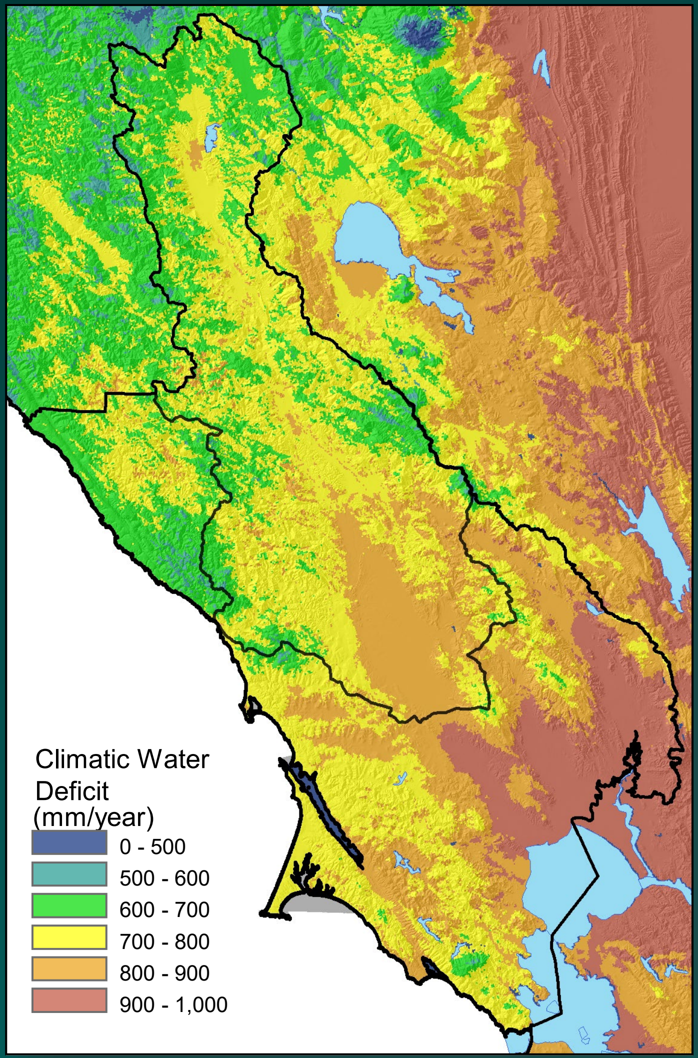




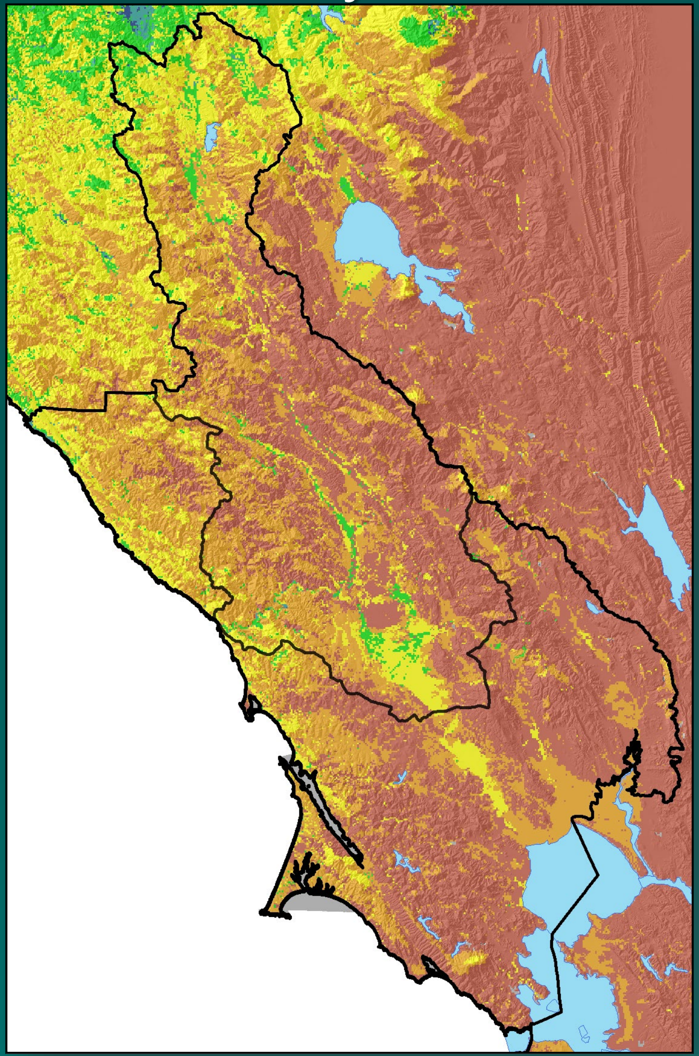
Drought Indicator: CWD can be used to indicate drought severity and landscape stress

Landscape drought: The influence of temperature

1977: A year with no water

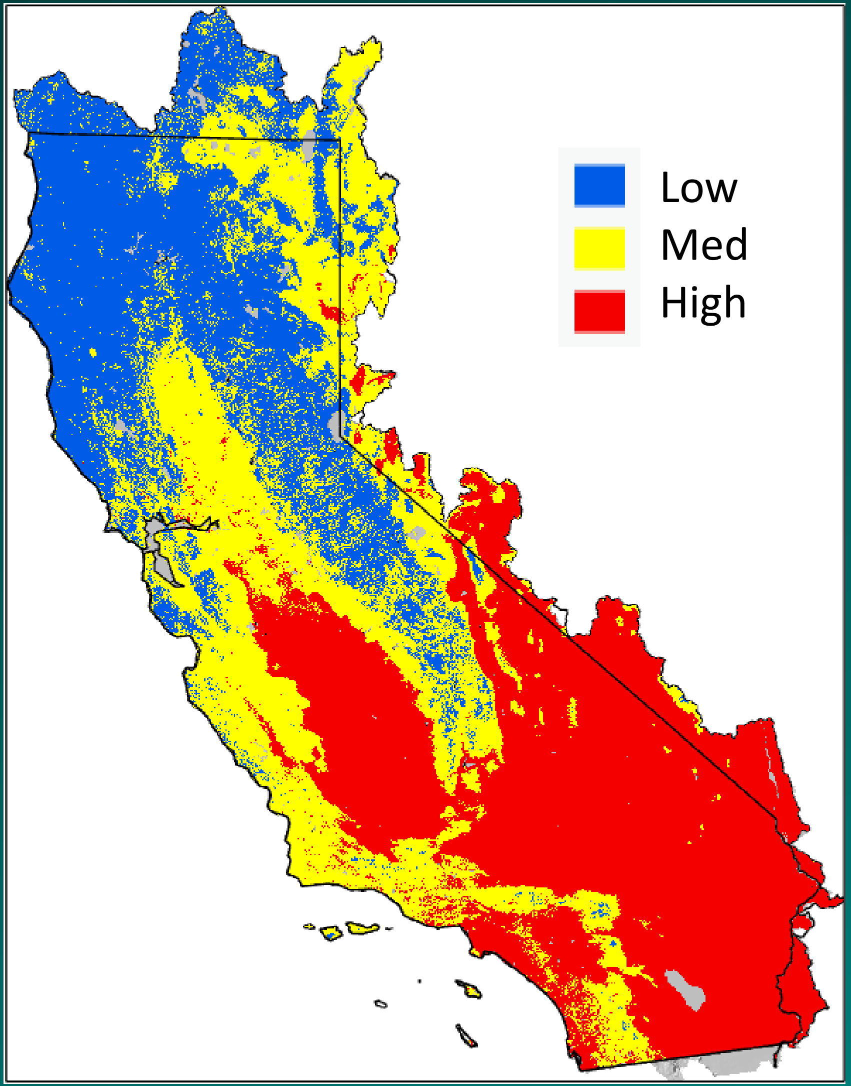


Jan 2014: A HOT year with no water

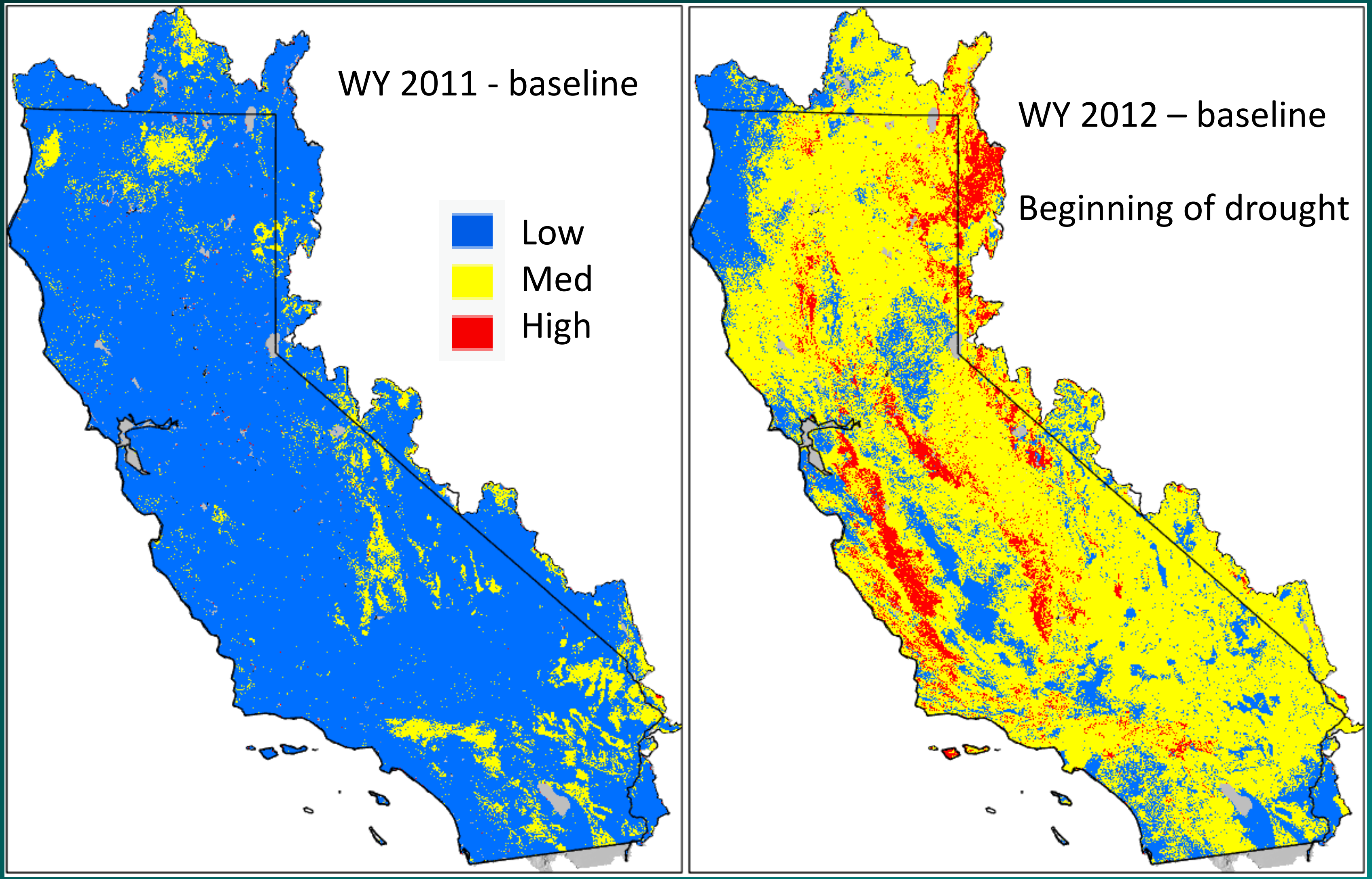


Using CWD as a drought indicator

WY 1981-2010 baseline (All units mm/year)

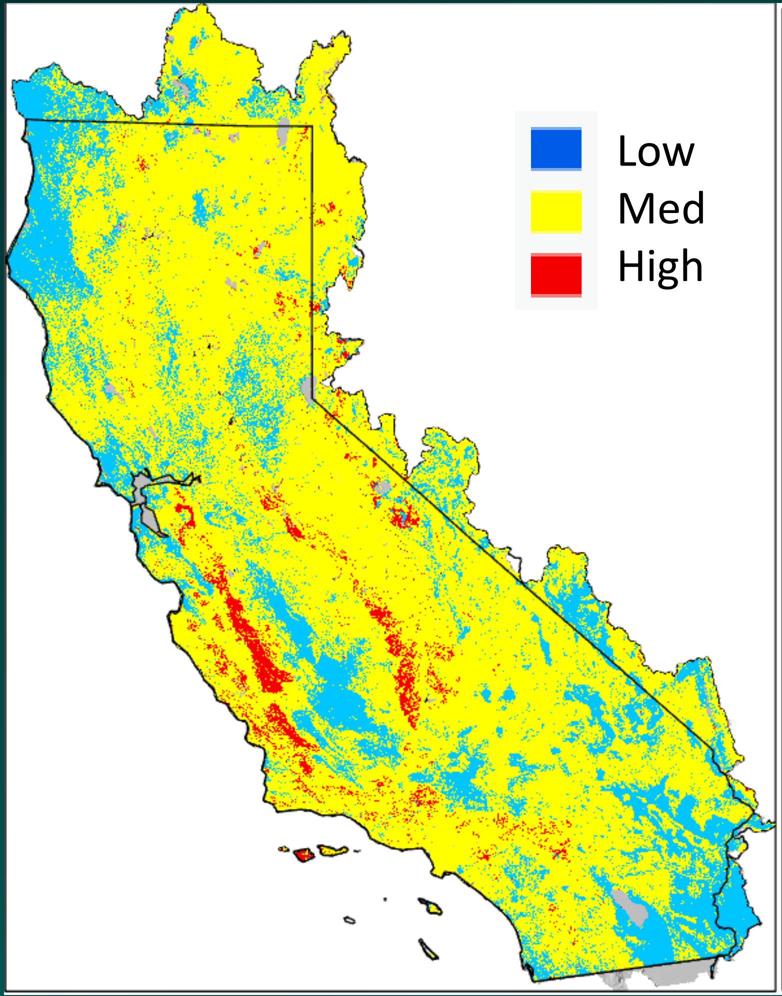


To analyze drought conditions since 2011
Subtract current year from baseline 1981-2010

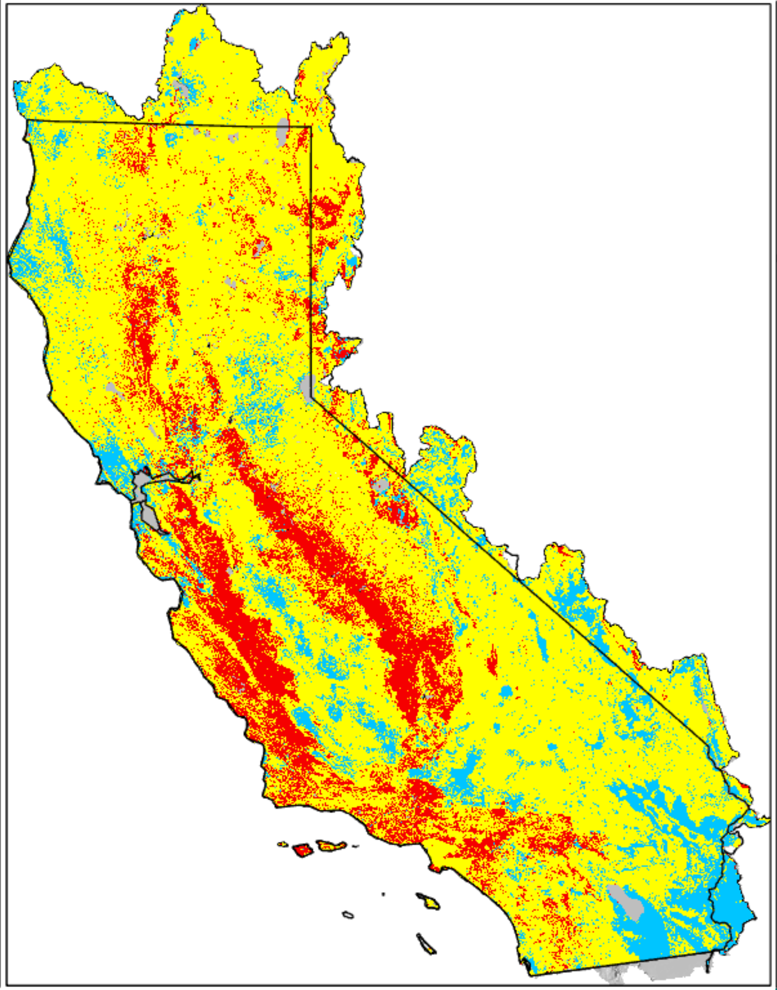


Accumulate Differences from Baseline over Water Years

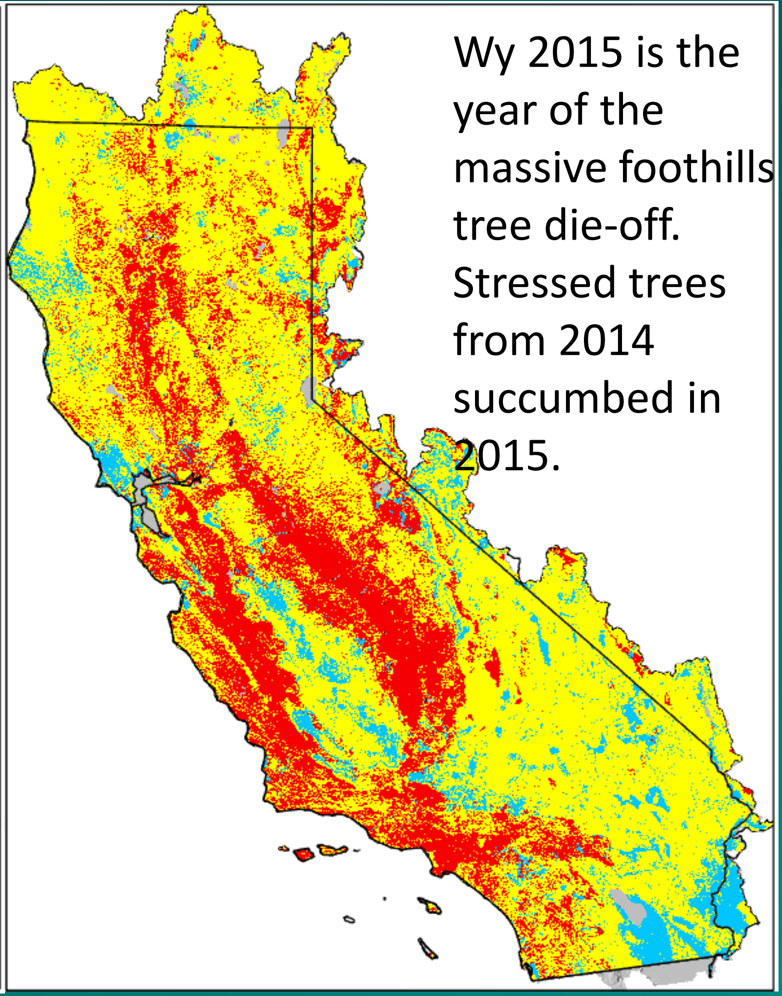
Wy 2012+2013



Wy 2012-2014

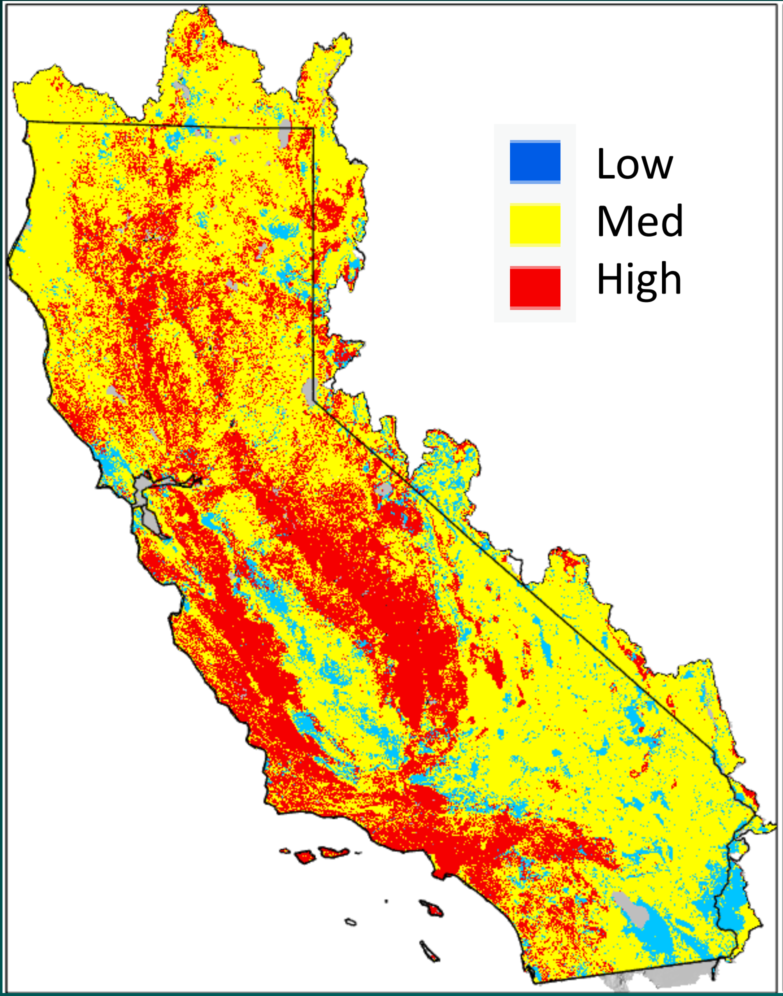


Wy 2012-2015

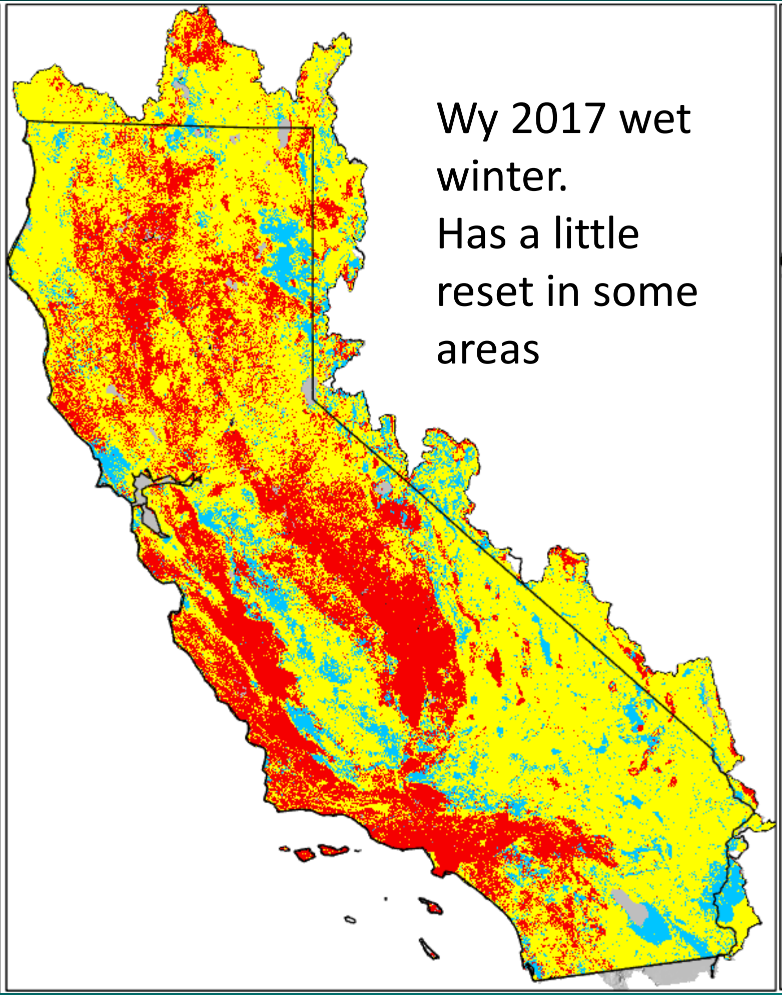


Accumulate Differences from Baseline over Water Years

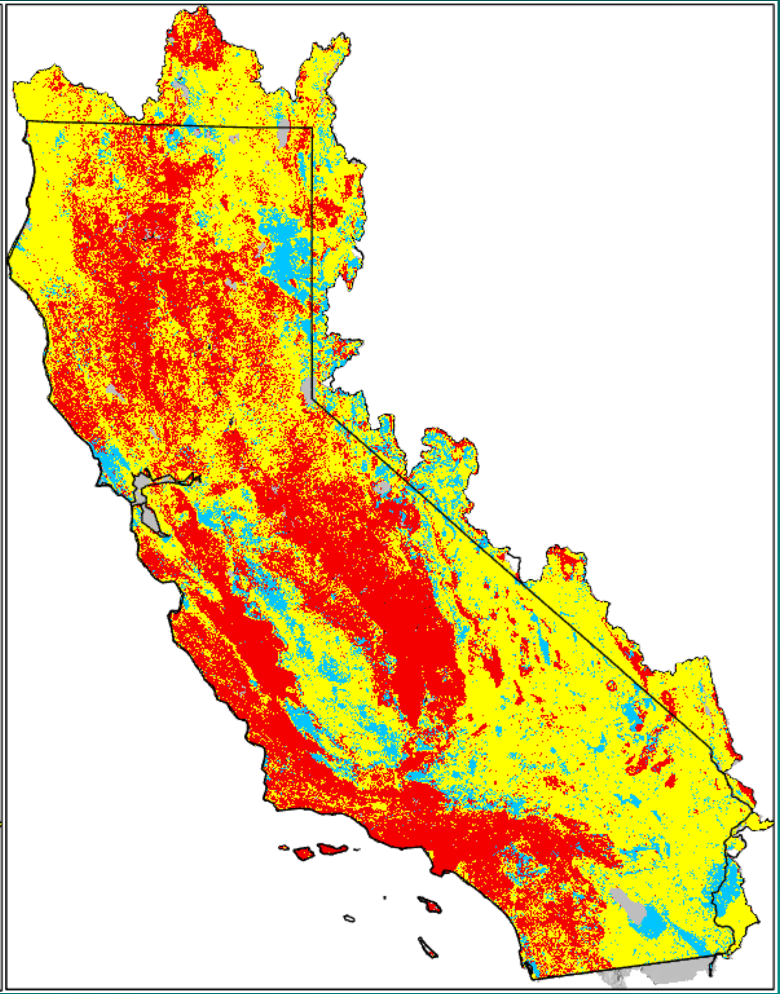
Wy 2012-2016



Wy 2012-2017

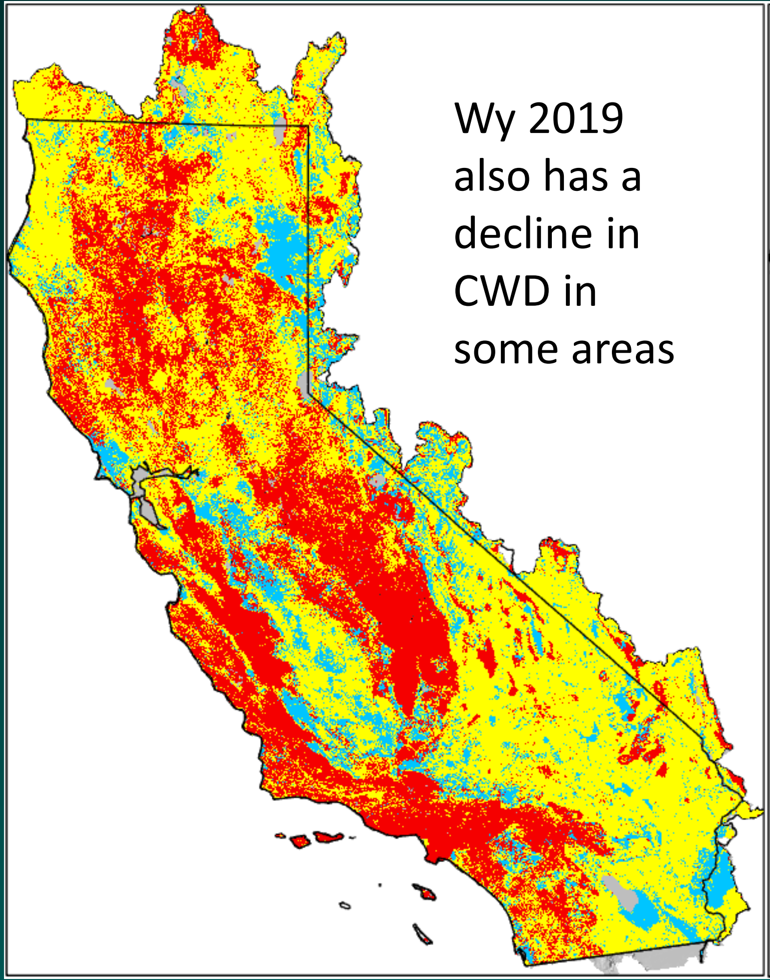


Wy 2012-2018

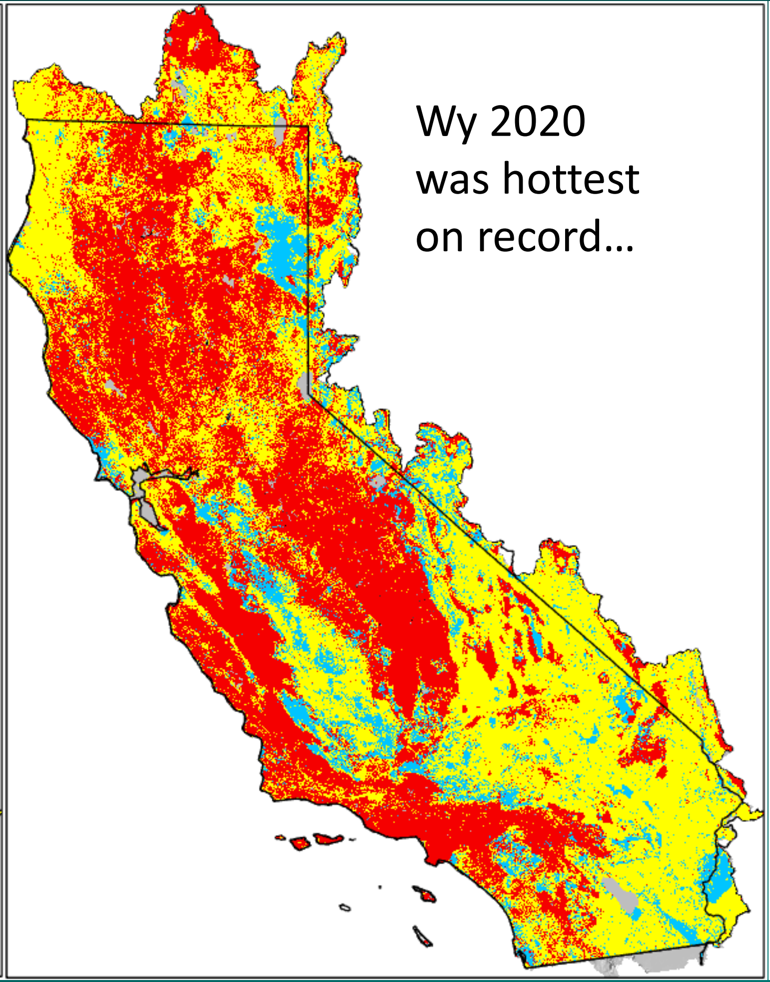


Accumulate Differences from Baseline over Water Years

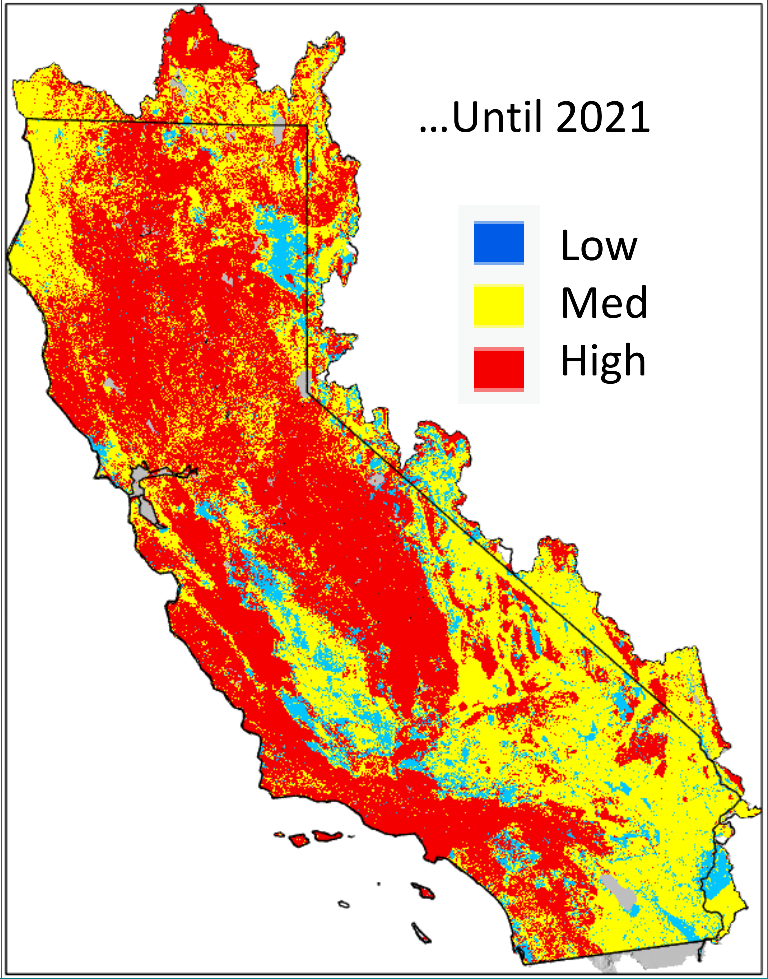
Wy 2012-2019

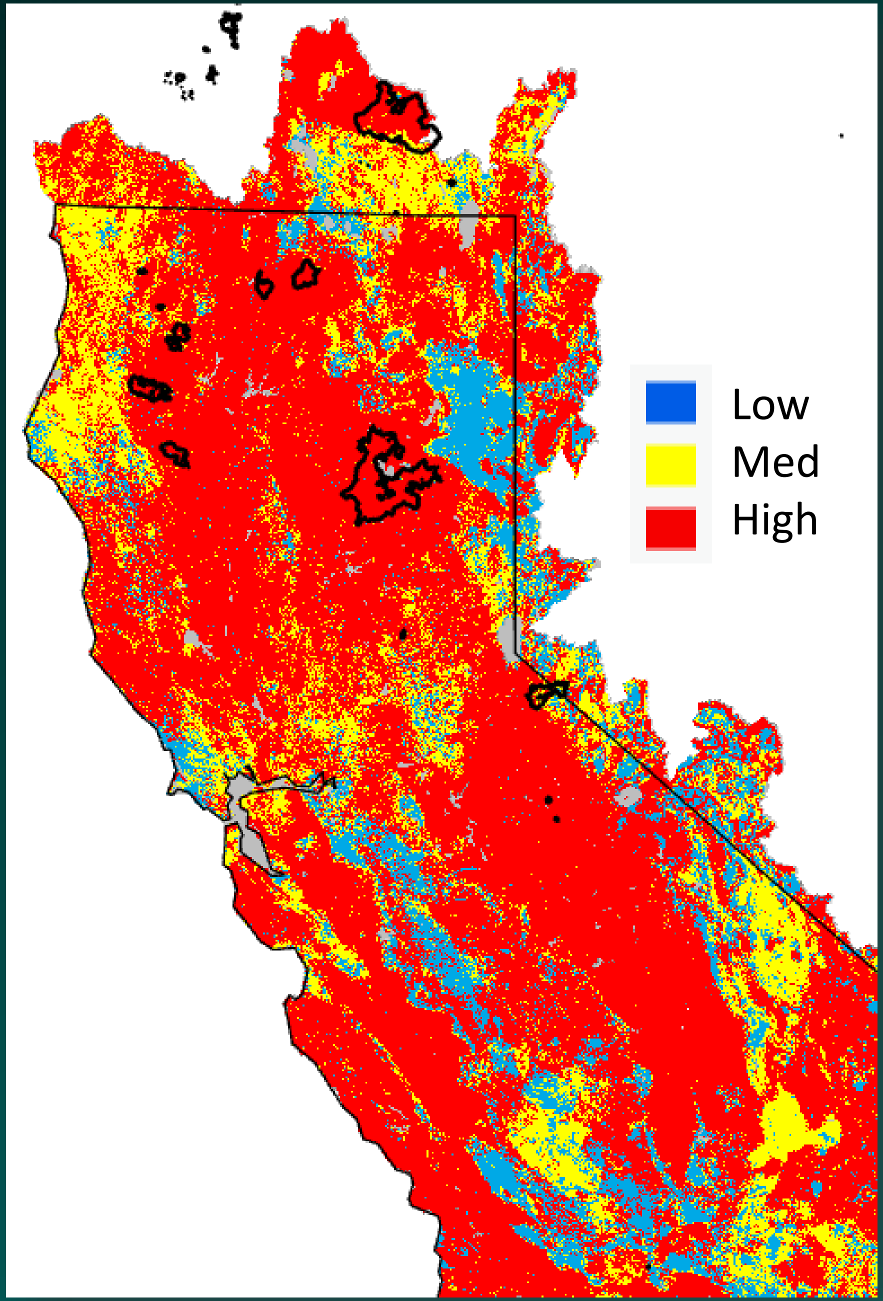


Wy 2012-2020



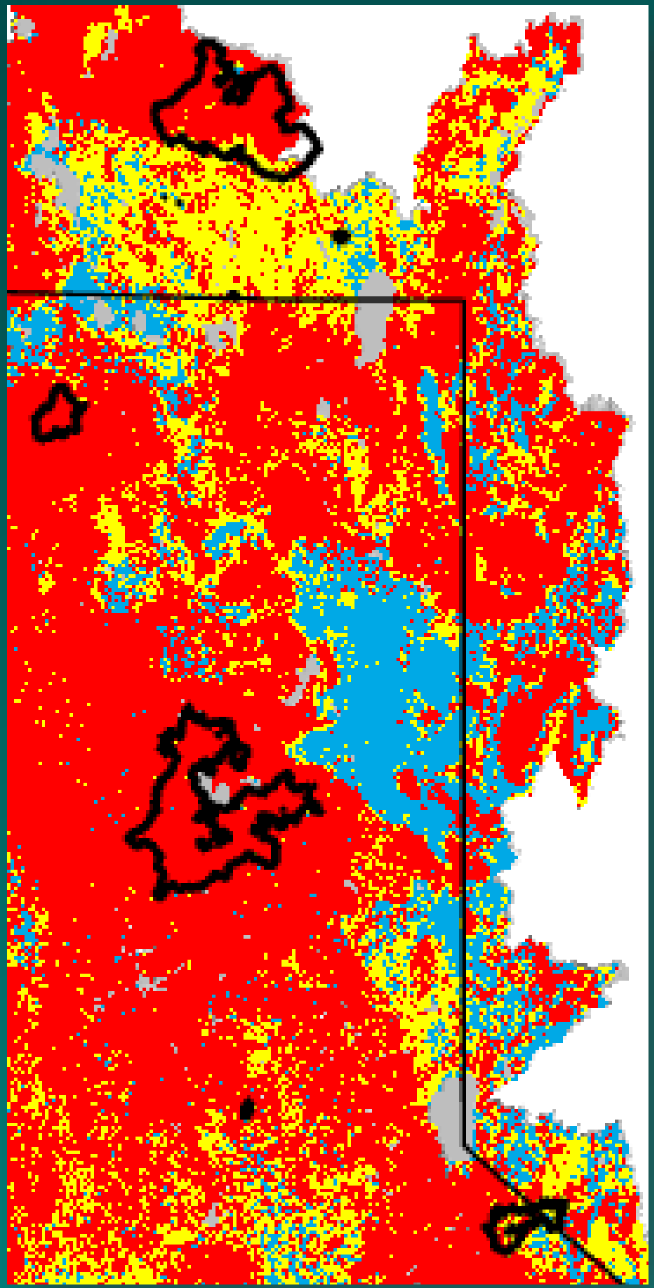
Wy 2012-2021

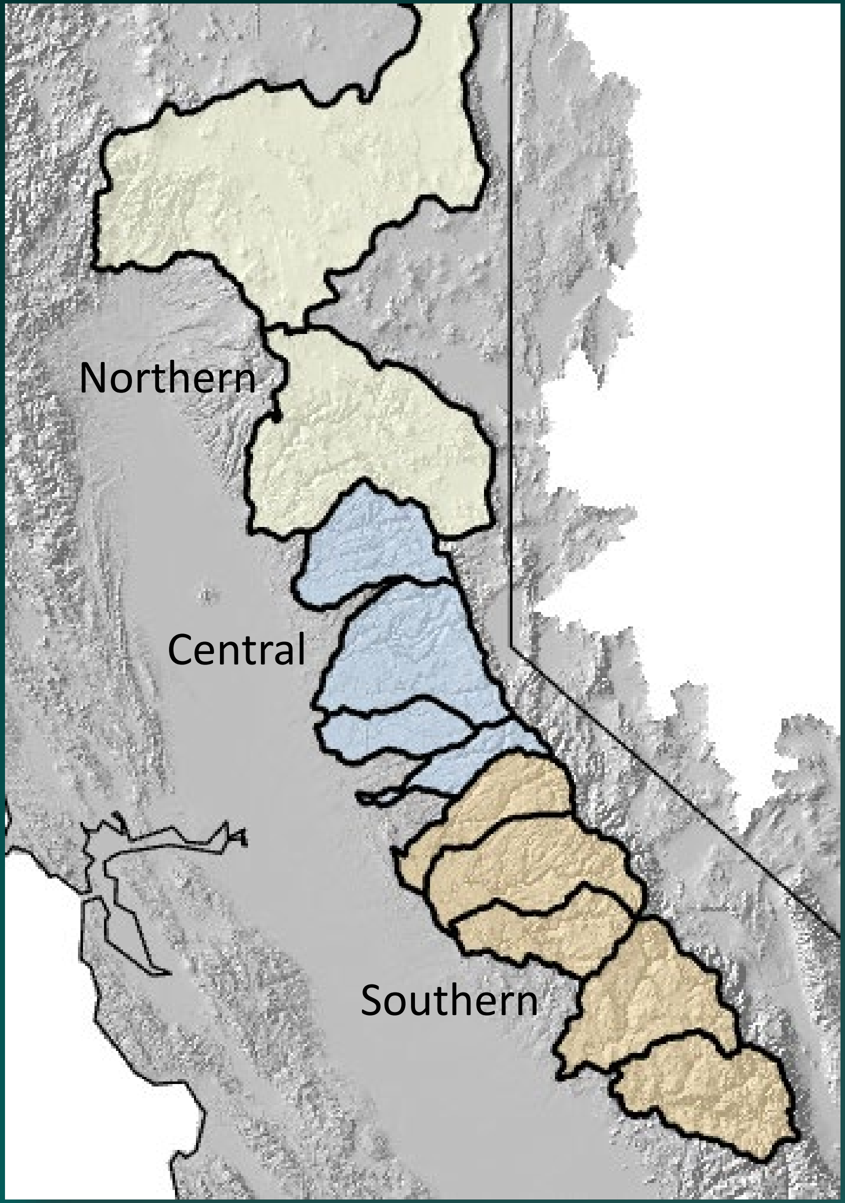




Wildfires this year are coincident with the highest accumulation of CWD

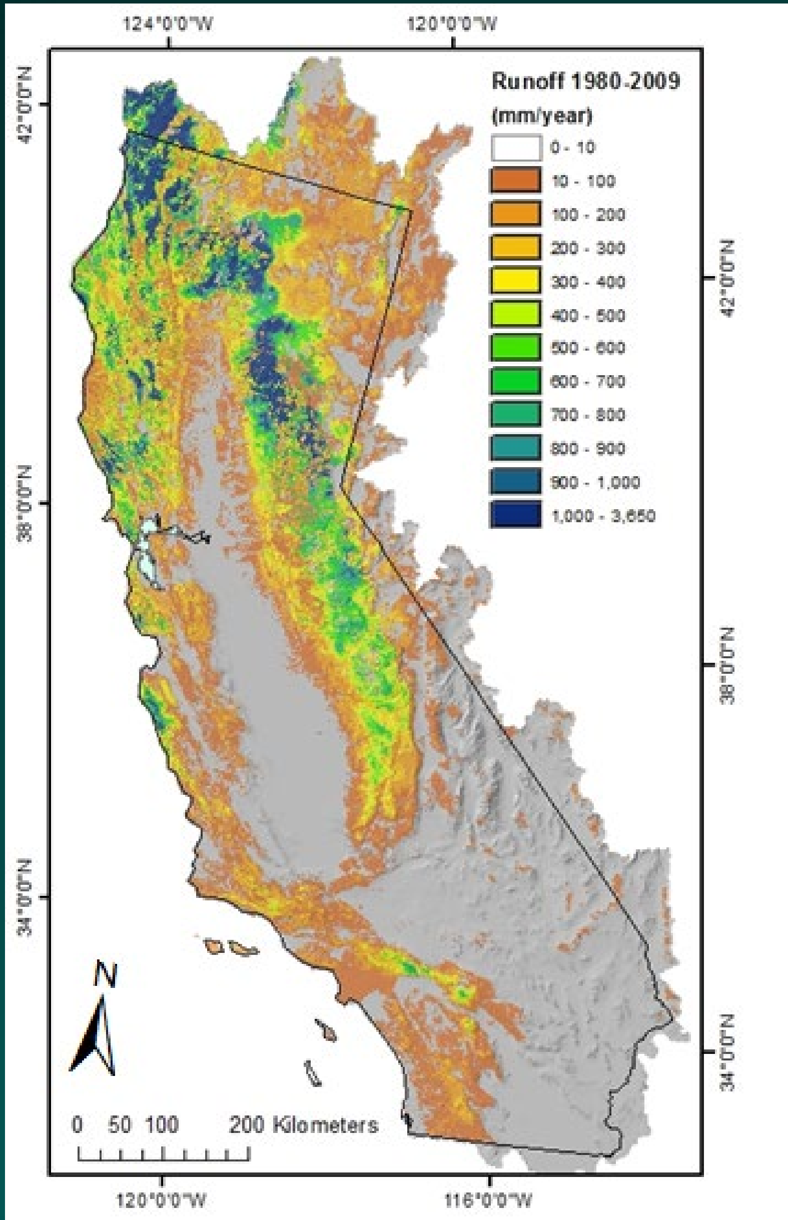
Note that fire perimeters stop at low CWD boundaries.



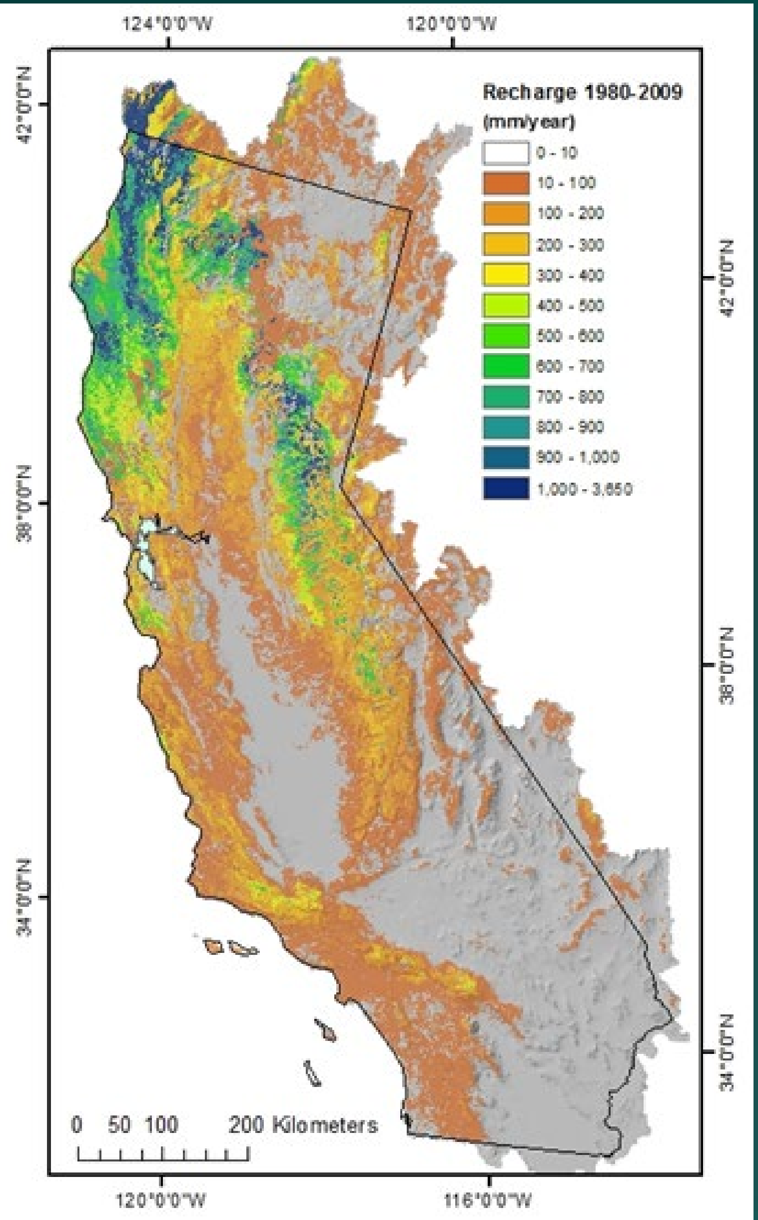


Sierra Nevada Water Supply Basins

Runoff



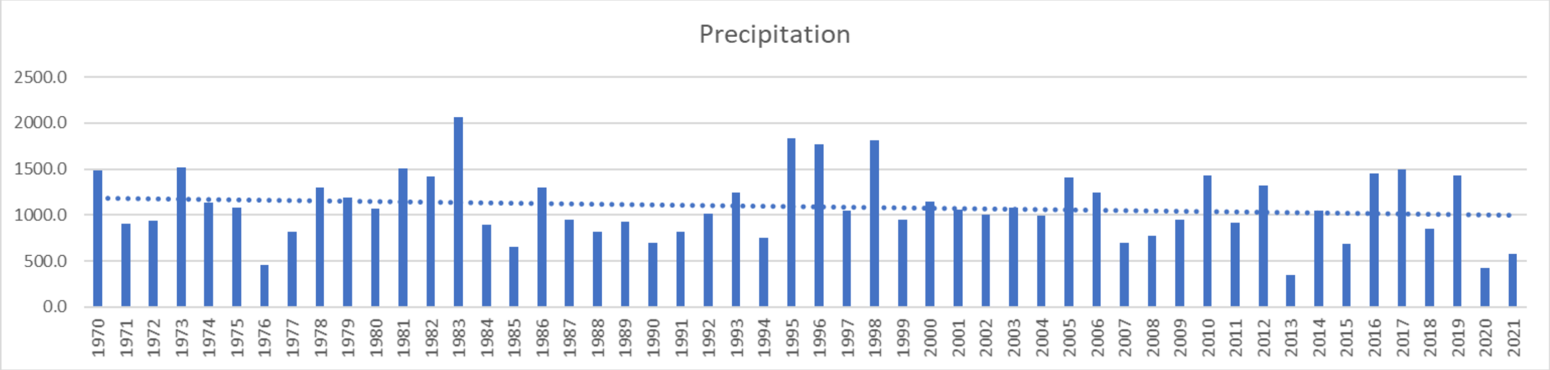
Recharge

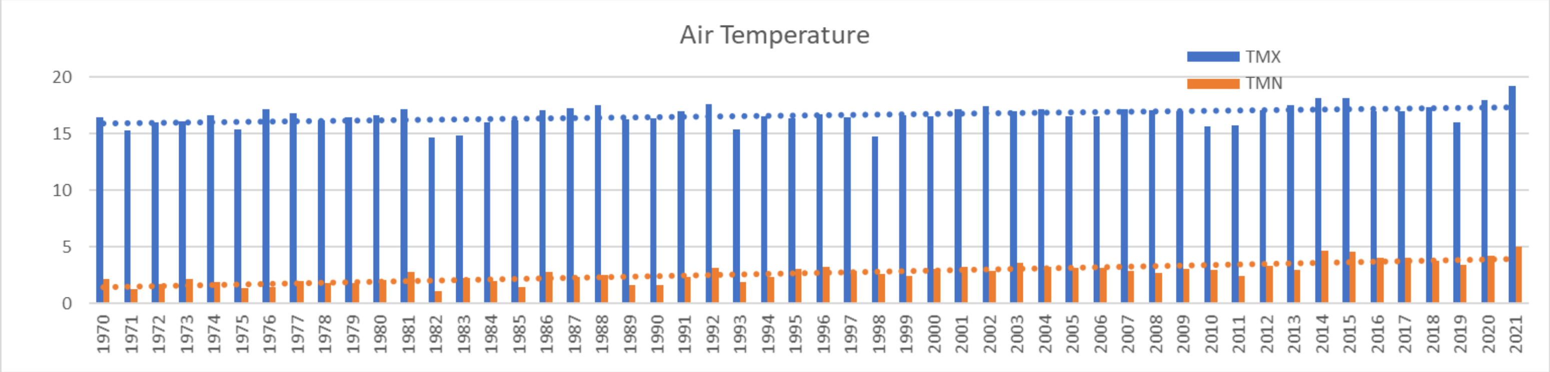


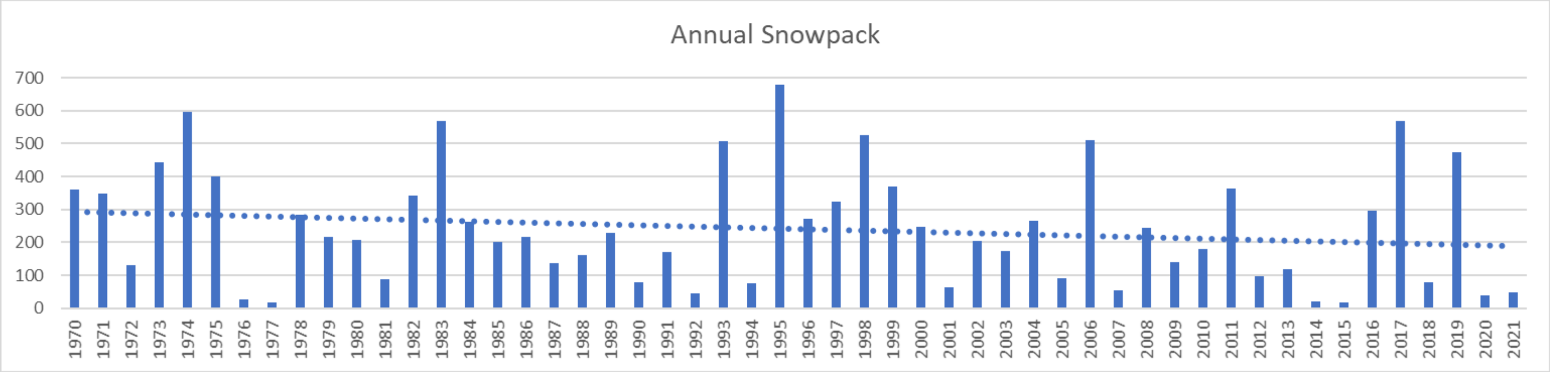
Recharge and Runoff are Water Supply

Long Term Climate Trends

Northern Sierra

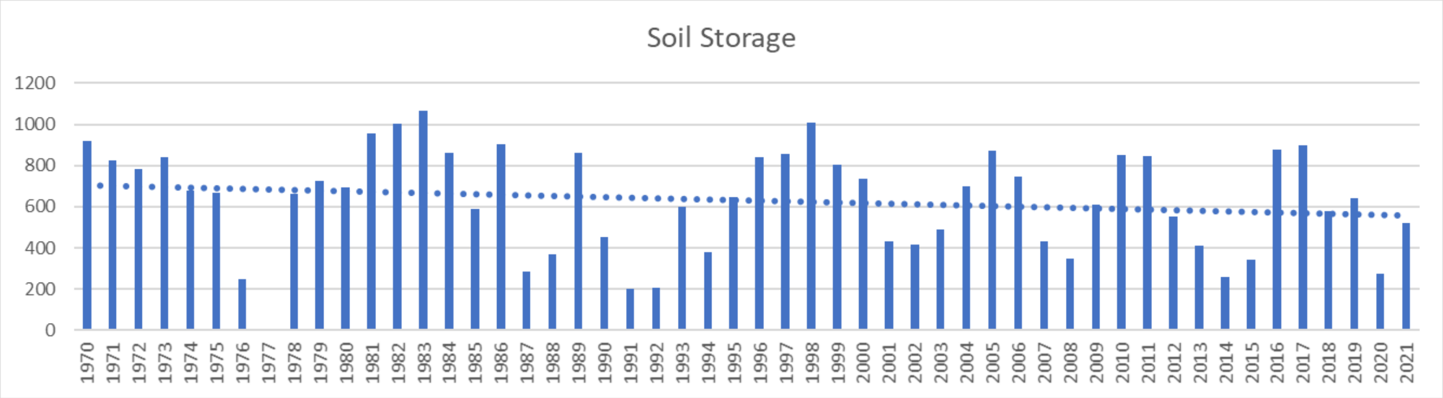


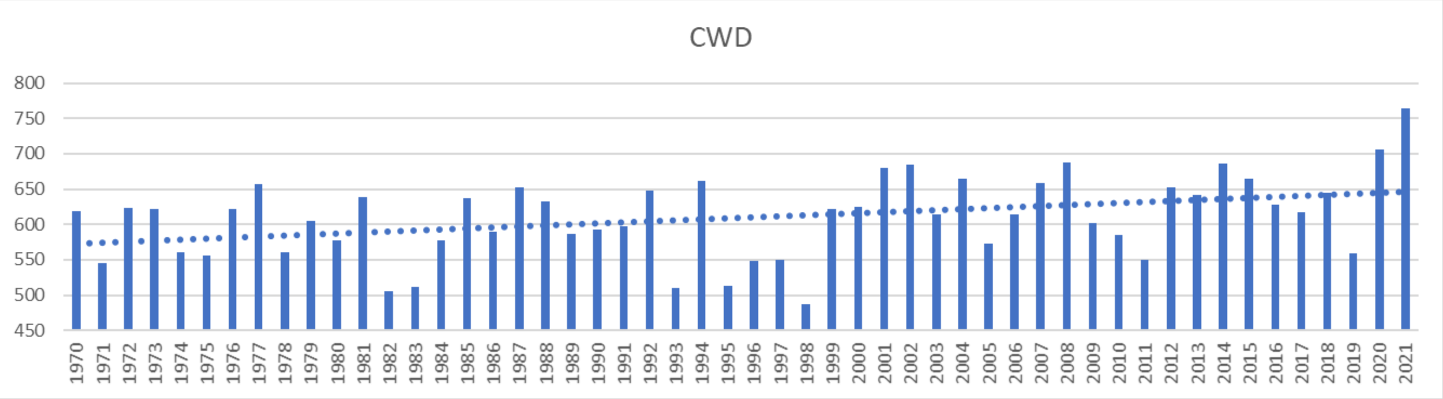


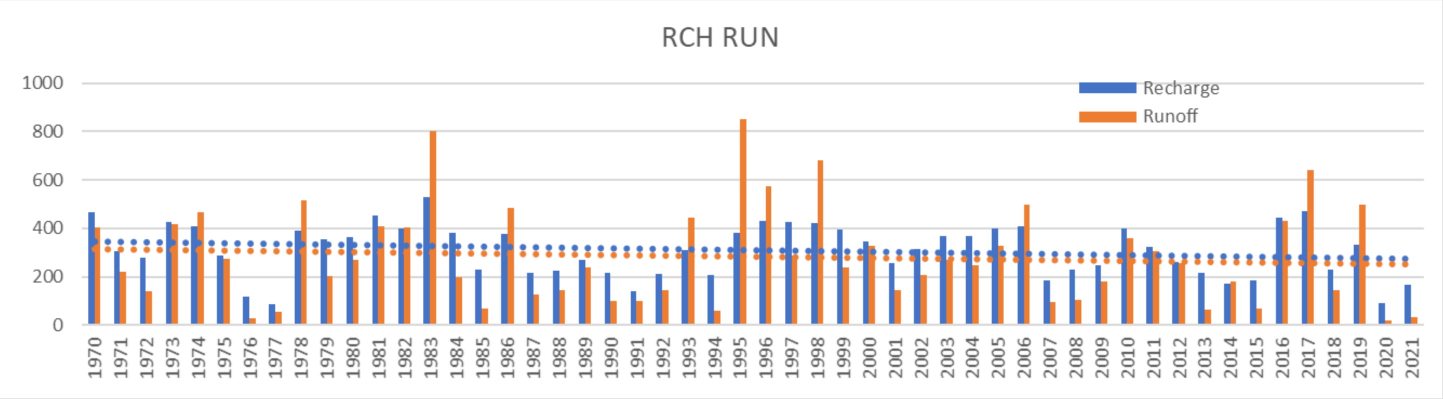


Long Term Hydrologic Trends

Northern Sierra







	Northern Sierra	Central Sierra	Southern Sierra
	Recharge + Runoff		
	Acre-feet per year		
WY1981-2010	10,284,910	7,173,061	7,720,228
WY2021	2,568,494	2,087,414	1,913,486
% difference (1981-2010)	-75%	-71%	-75%
	Percent of average (1981-2010)		
avg *110% precip	11%	10%	7%
avg * 120%	26%	26%	23%
avg * 130%	43%	41%	39%
avg * 140%	59%	57%	56%
avg * 150%	76%	73%	73%
avg * 160%	93%	89%	90%

How much precipitation will it take to return to average water supply conditions?

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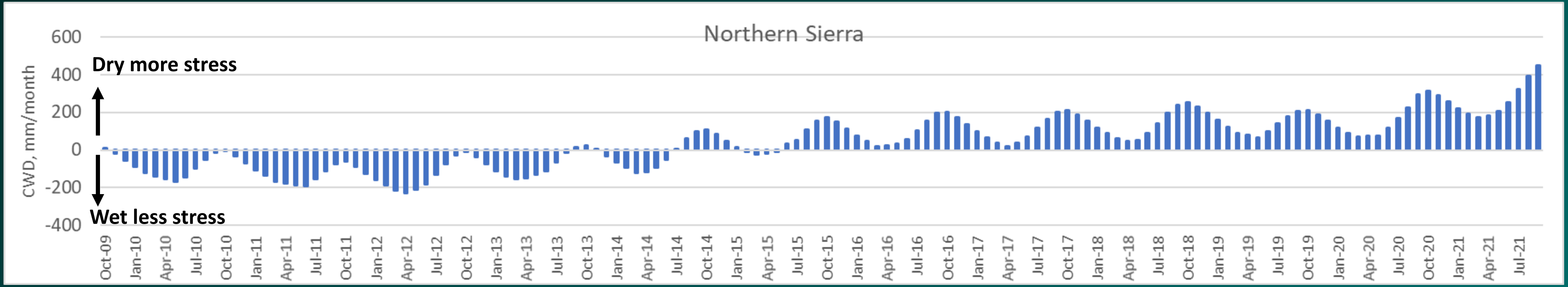
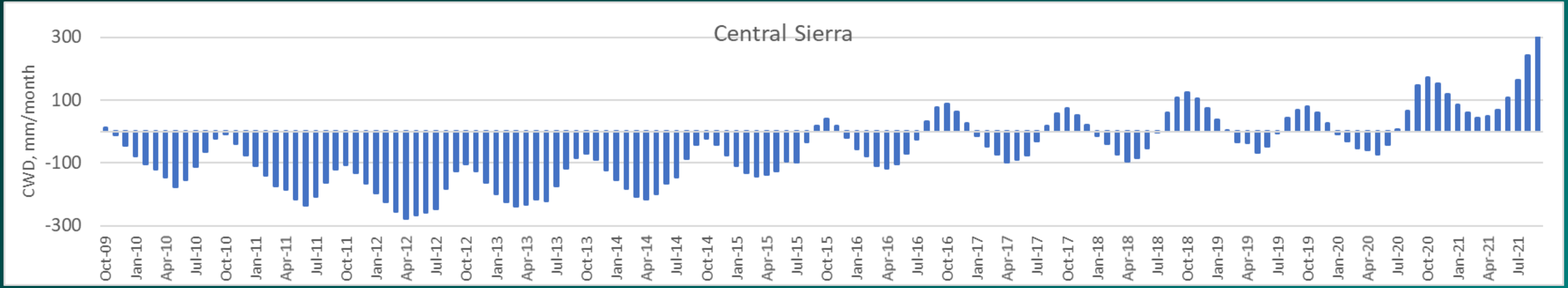
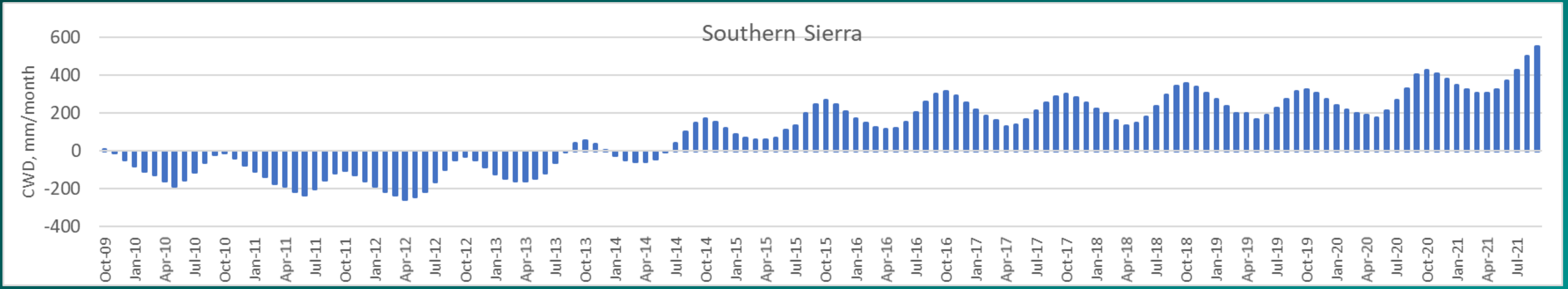
How much precipitation will it take to return to average water supply conditions?

In the last 50 years there has been precipitation in CA of 150% or more greater than average in 1983, 1995, 1996, and 1998.

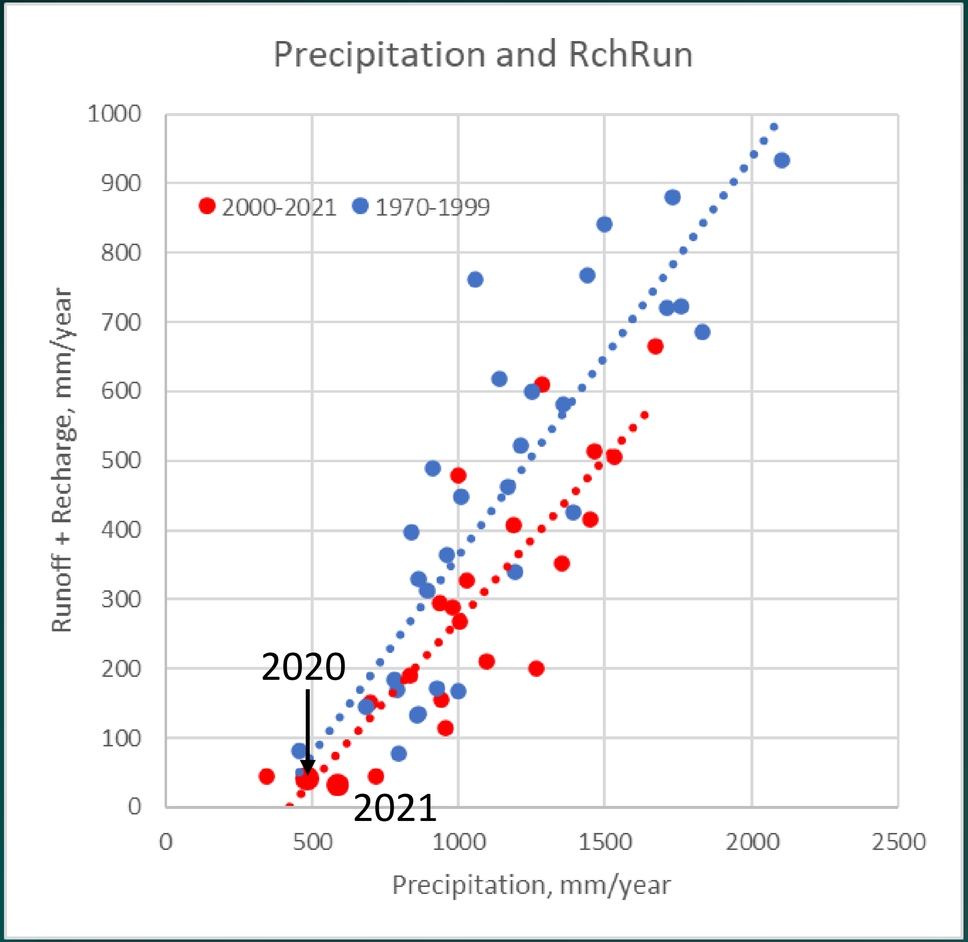
Cumulative Climatic Water Deficit monthly anomaly from 1981-2010 mean

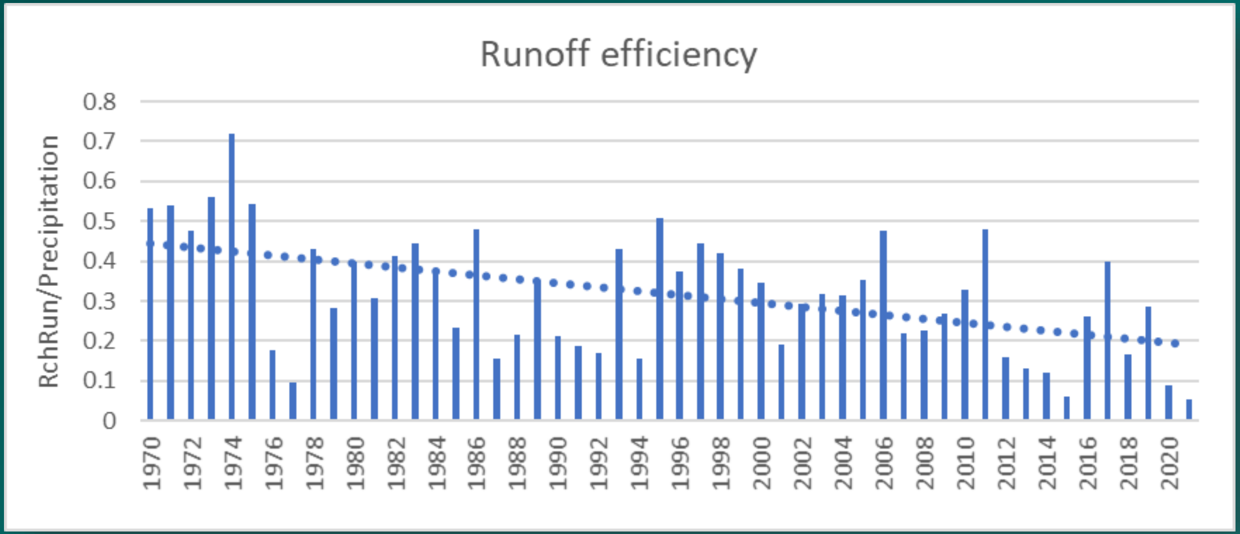




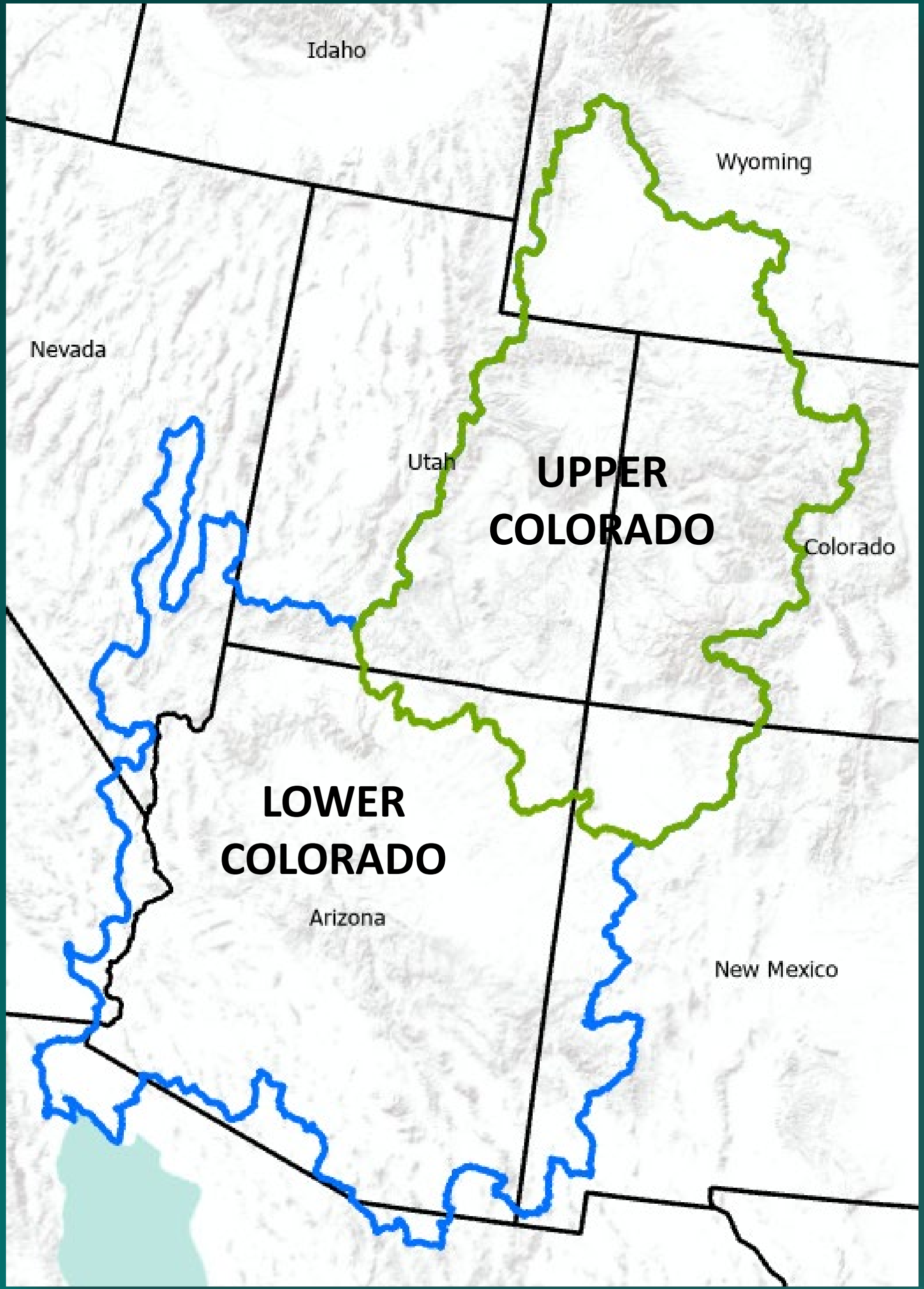


Sierra Nevada
Runoff Efficiency
1970-1999 vs 2000-2021



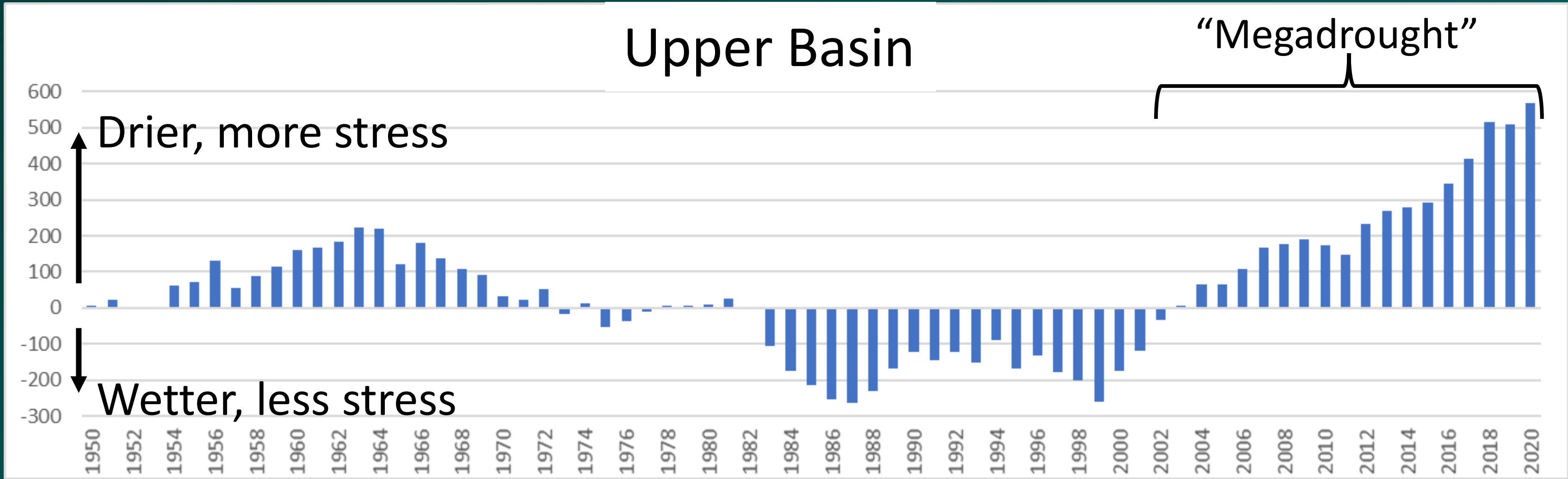


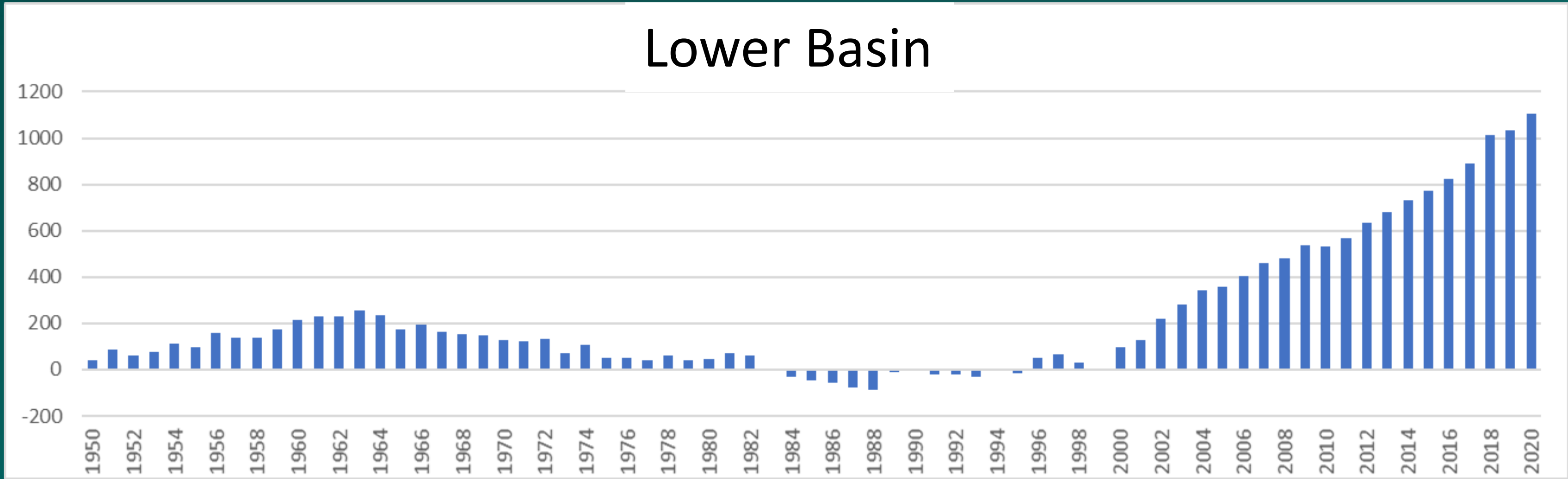
Colorado River Basin



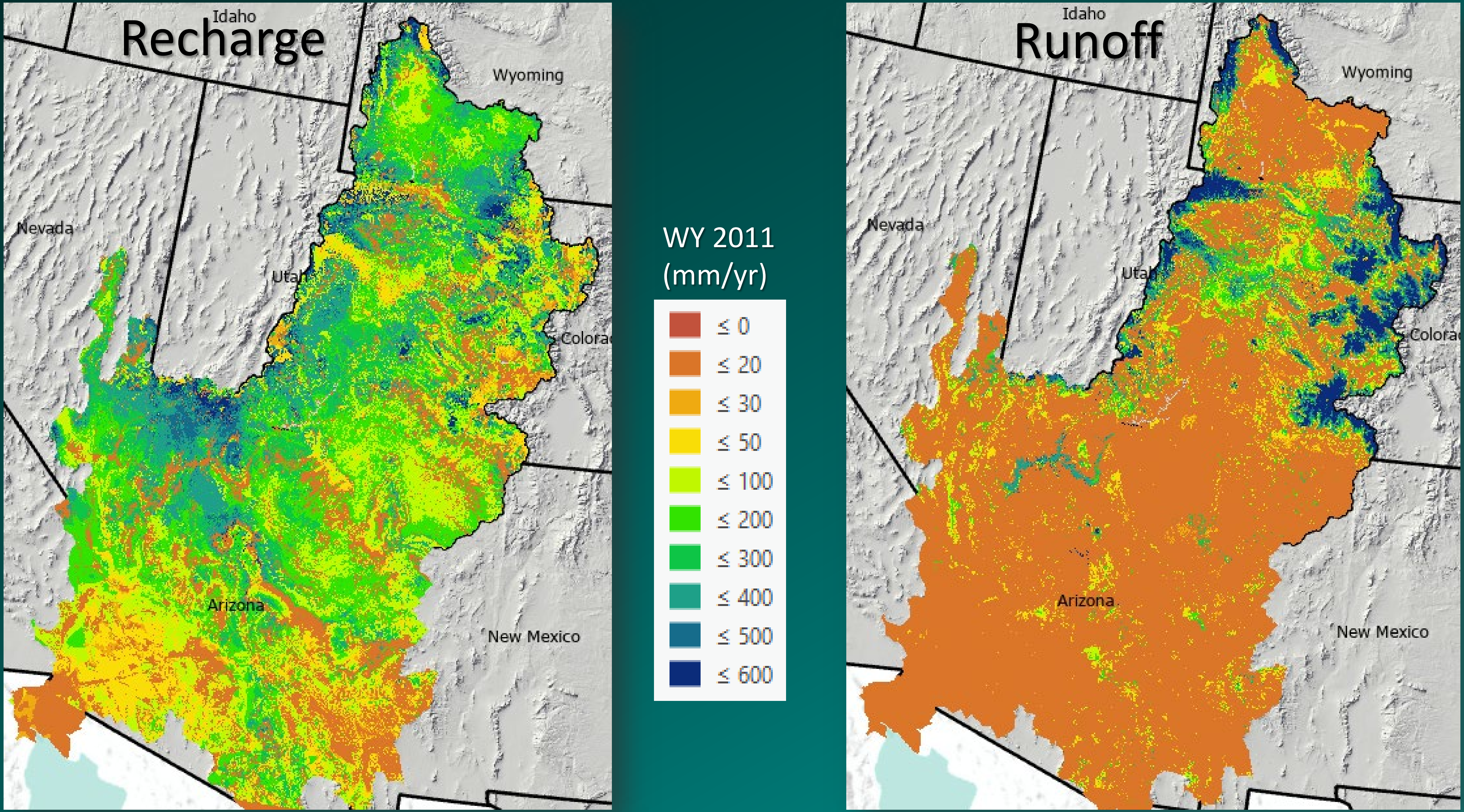
Drought Evolution in the Colorado River Basin

Accumulated CWD Difference from 1951-1980 mean

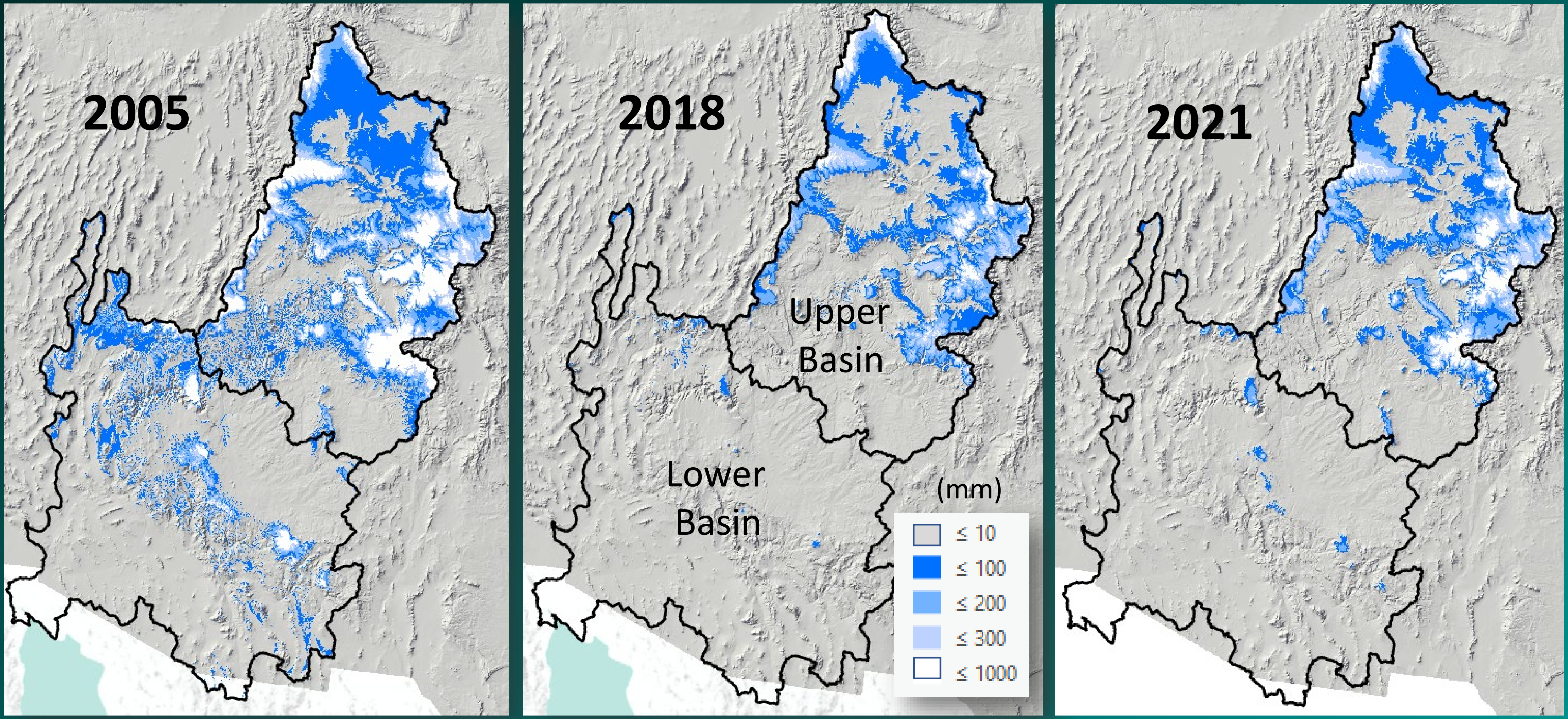




Colorado River Basin Annual Water Supply

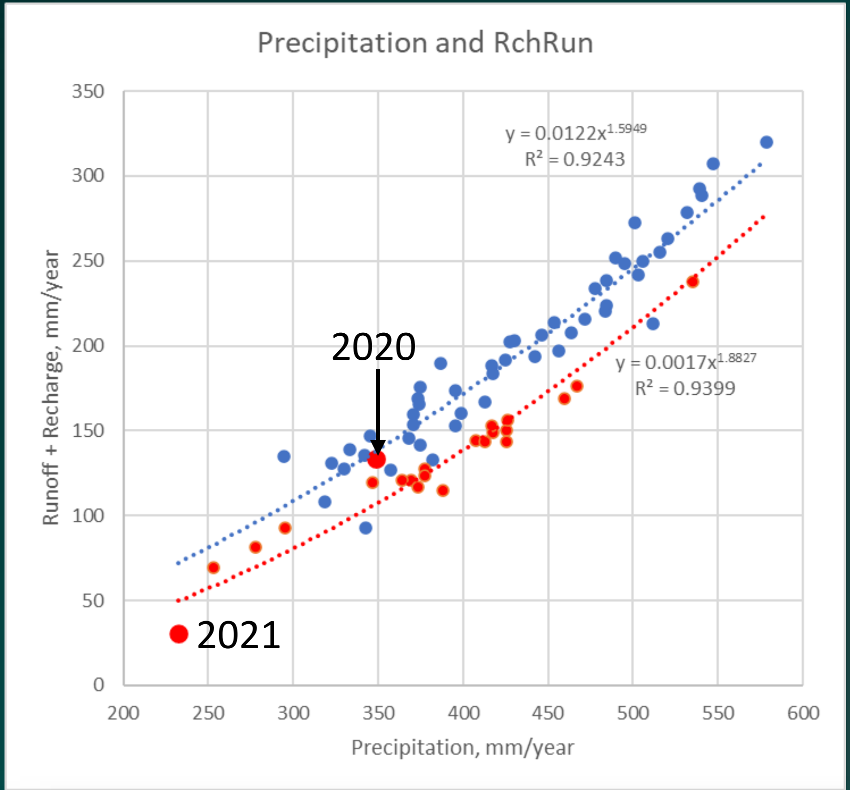


April 1 Snow Water Equivalent

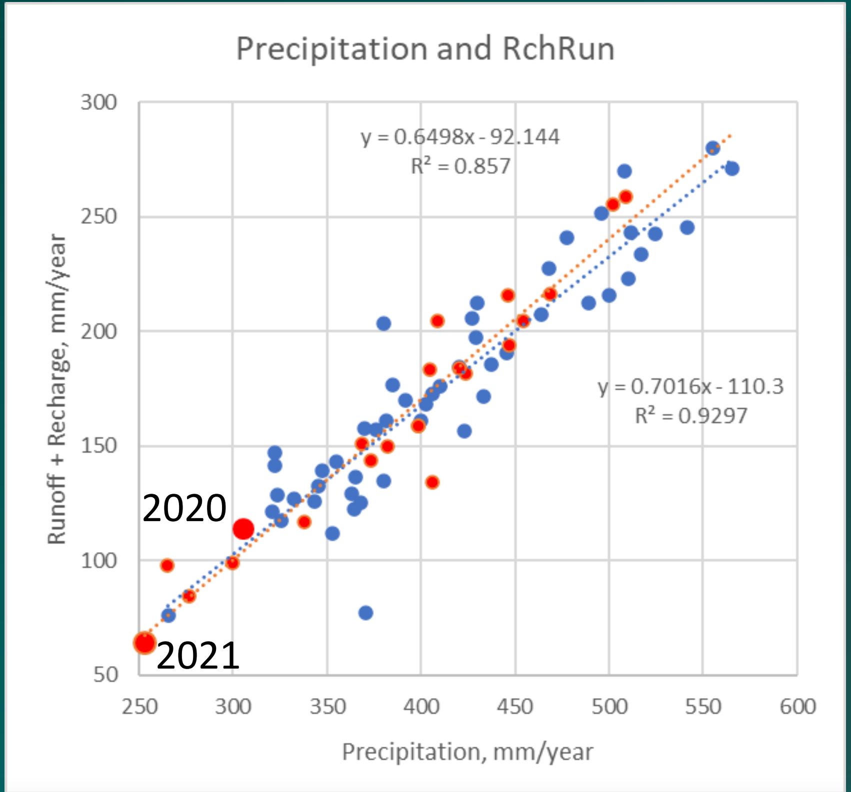


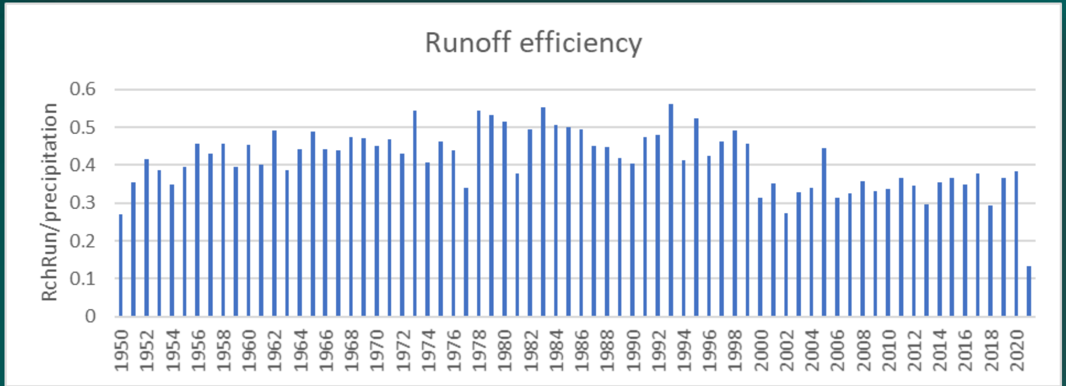
Runoff Efficiency 1950-1999 vs 2000-2021

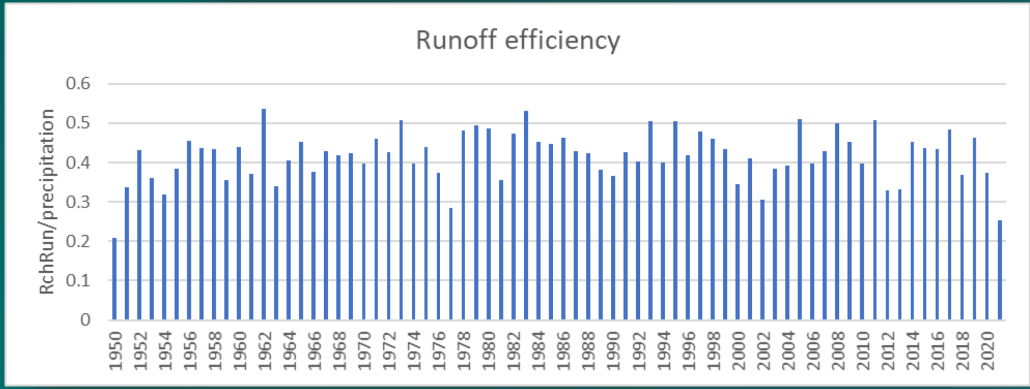
Lower Basin



Upper Basin



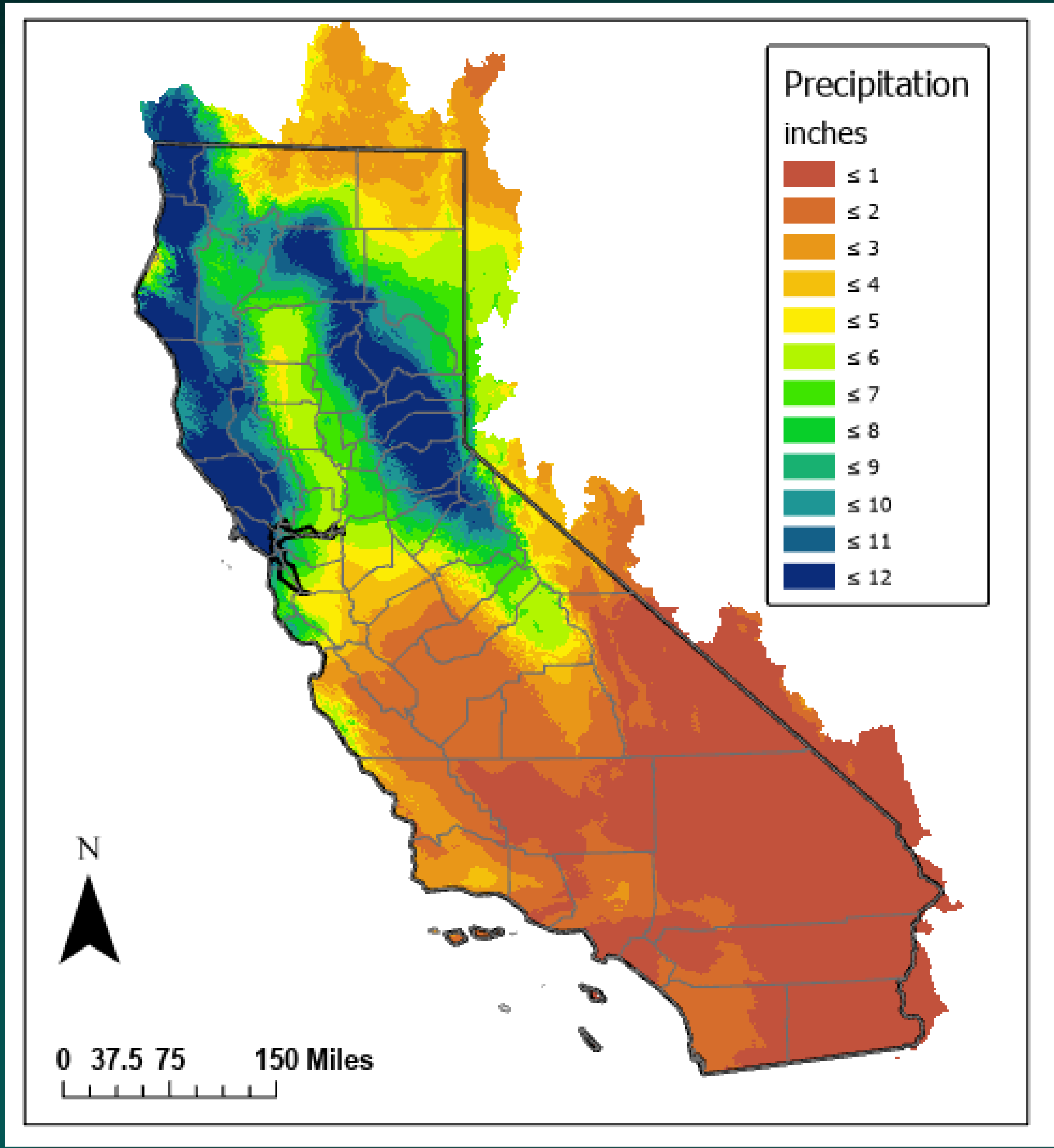




	Upper Basin	Lower Basin
	Recharge + Runoff	Recharge + Runoff
	Acre-feet/year	
% difference (1981-2010)	-70%	-75%

	Upper Basin	Lower Basin
	Recharge + Runoff	Recharge + Runoff
	Acre-feet/year	
WY1981-2010	25,695,209	40,793,662
avg * 10% precip	11,646,737	25,674,071
avg * 20% precip	13,880,870	30,364,497
avg * 30% precip	16,376,078	35,915,185
avg * 40% precip	18,960,553	41,904,041
avg * 50% precip	21,634,296	48,331,065
avg * 60% precip	24,397,307	55,196,256
avg * 70% precip	27,249,585	62,499,616
	Percent Difference from 1981-2010	
	Recharge + Runoff	Recharge + Runoff
avg * 10% precip	-55%	-37%
avg * 20% precip	-46%	-26%
avg * 30% precip	-36%	-12%
avg * 40% precip	-26%	3%
avg * 50% precip	-16%	18%
avg * 60% precip	-5%	35%
avg * 70% precip	6%	53%

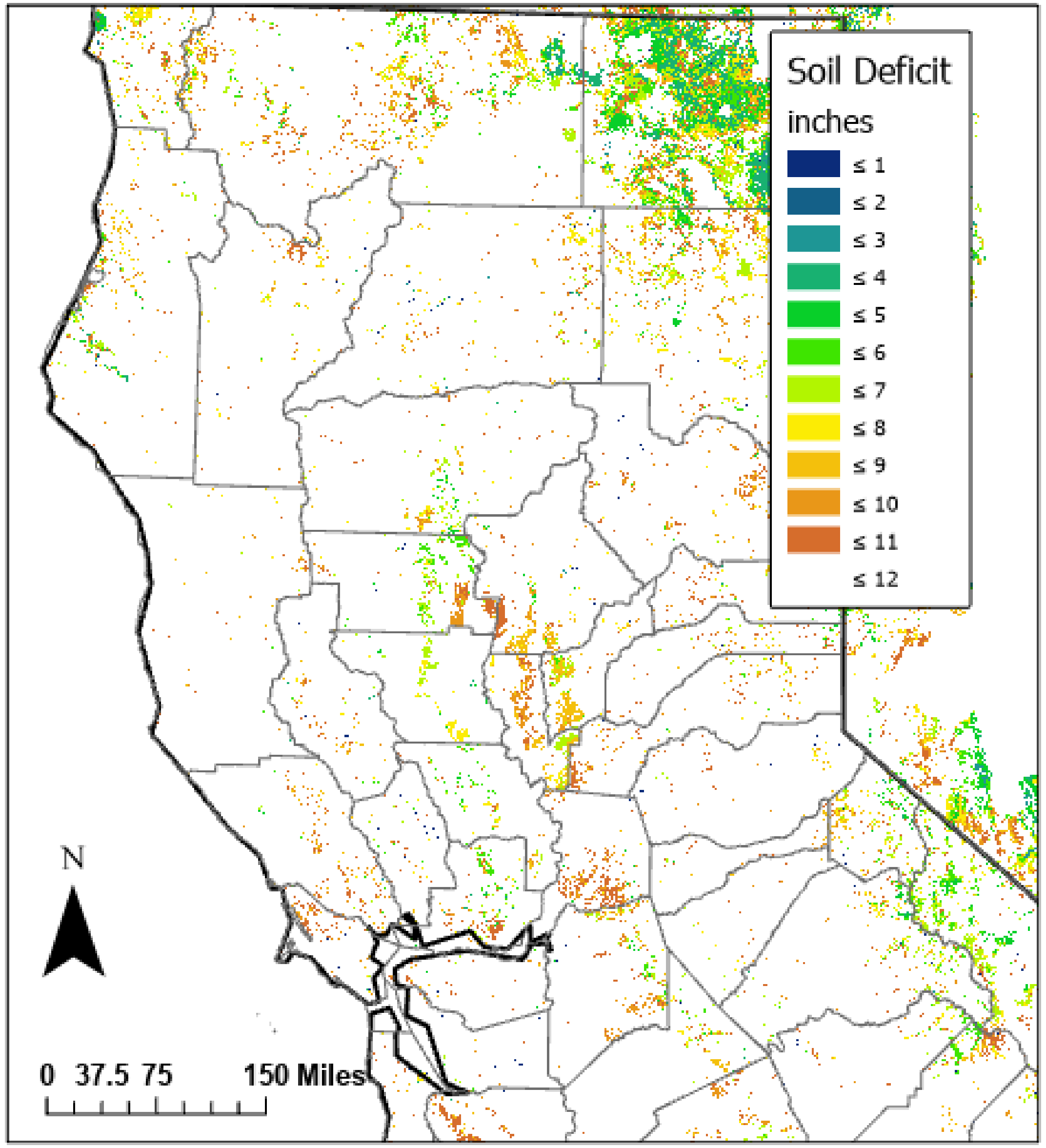
To return the basin to average water supply conditions it takes about 140% of average precipitation for the lower basin, and about 165% for the upper basin.



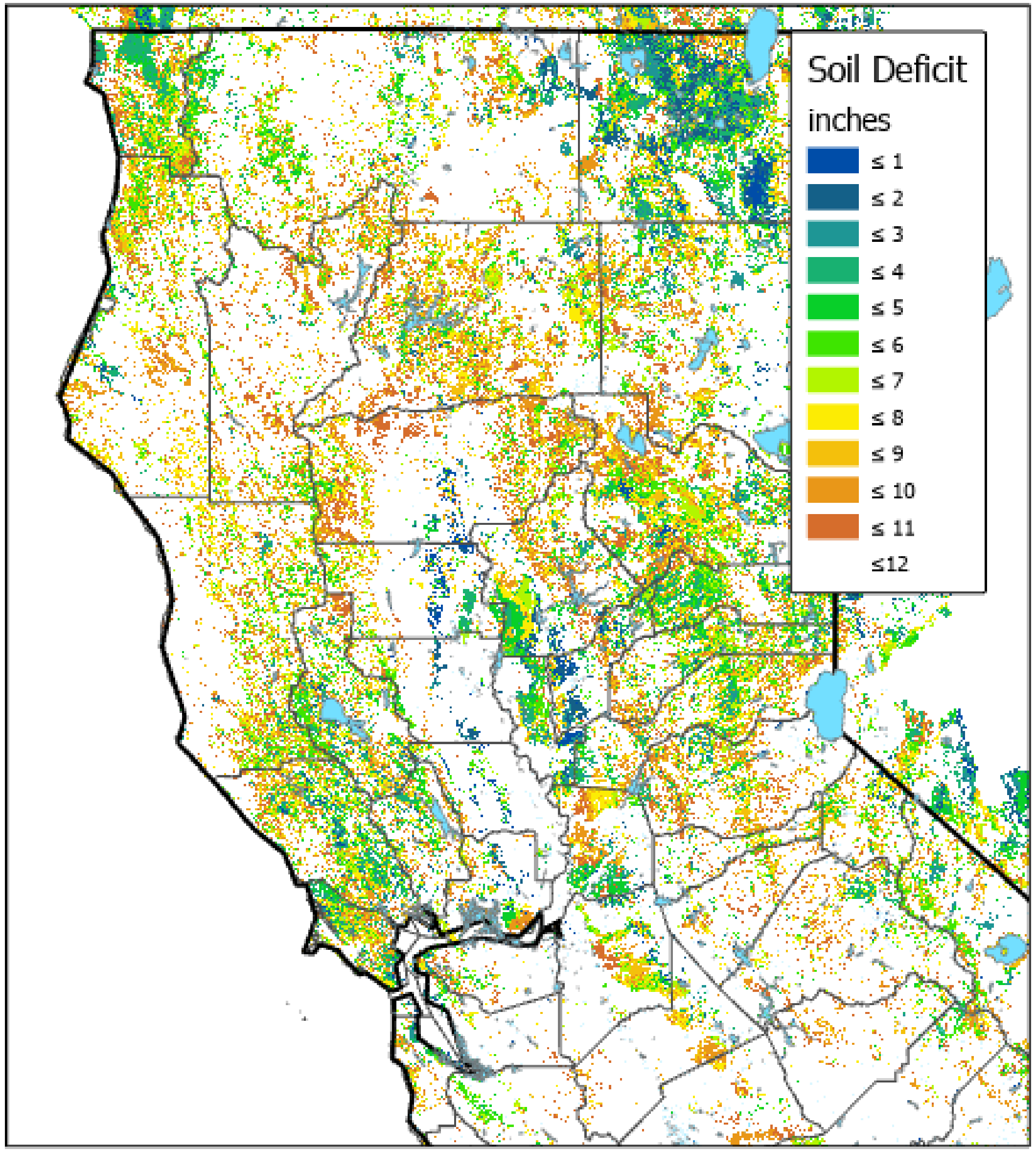
What did the AR5 that hit California in late Octgober do to help the drought?

How much rain would it take to fill up the dry soils and create some runoff?

October 1, 2021

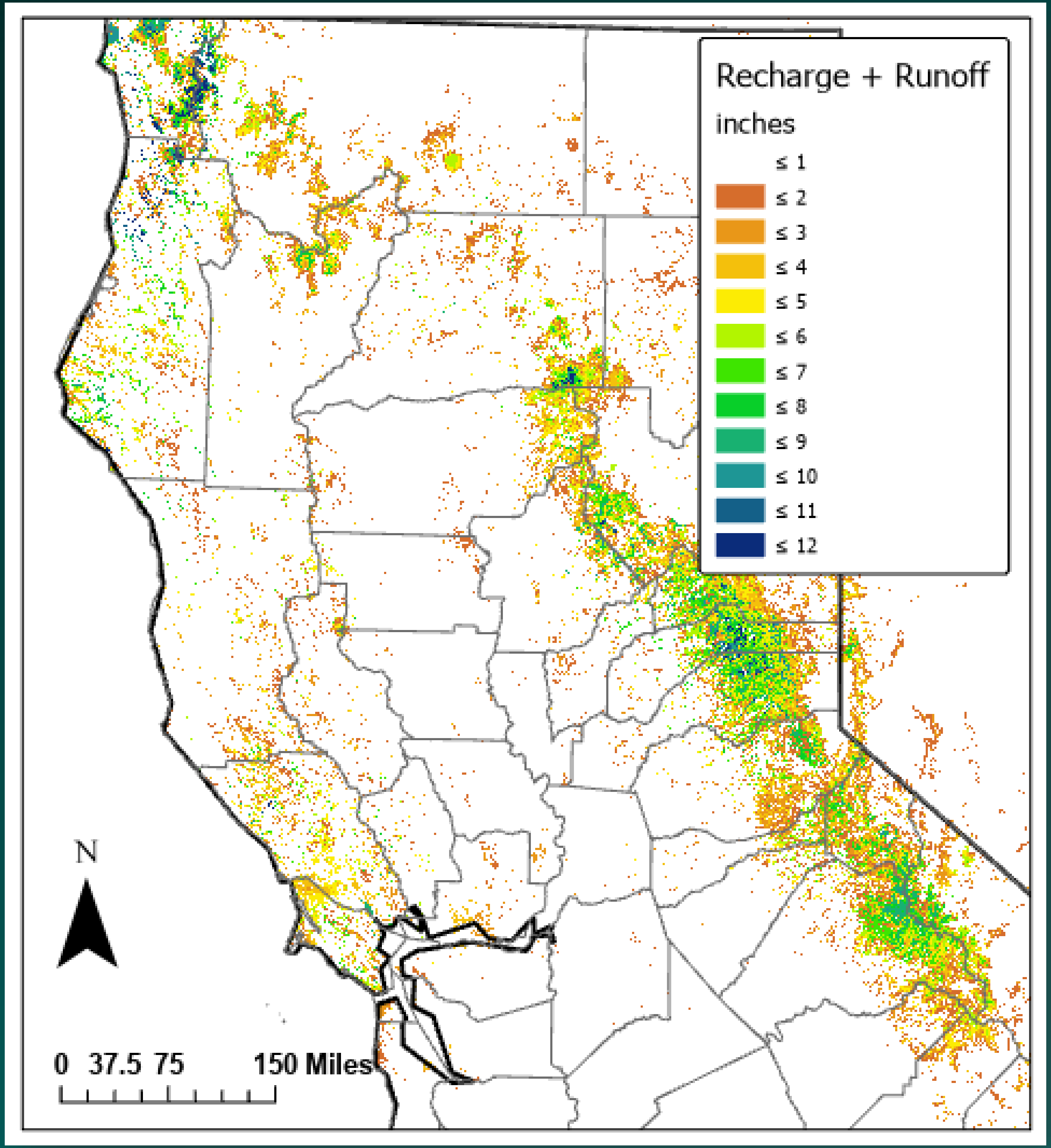


November 1, 2021



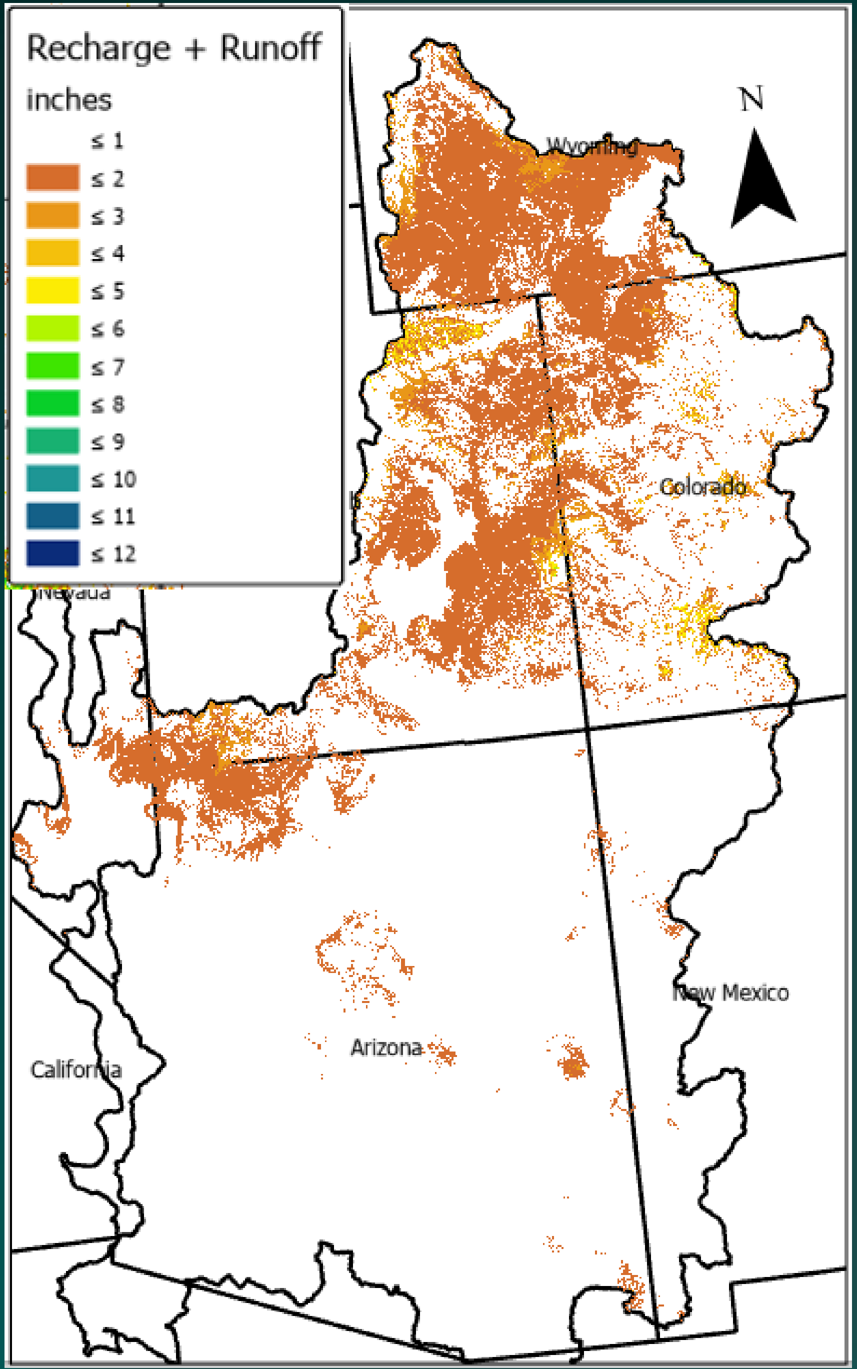
← This is Folsom on Oct 20, a lot of dry soil for rain to soak into.

This is Lake Mendocino →
As the AR5 passed over the Russian basin streamflows upstream of the reservoir went from 10 cfs to 2000 but quickly fell to only 100 cfs baseflow.



October 2021 water supply

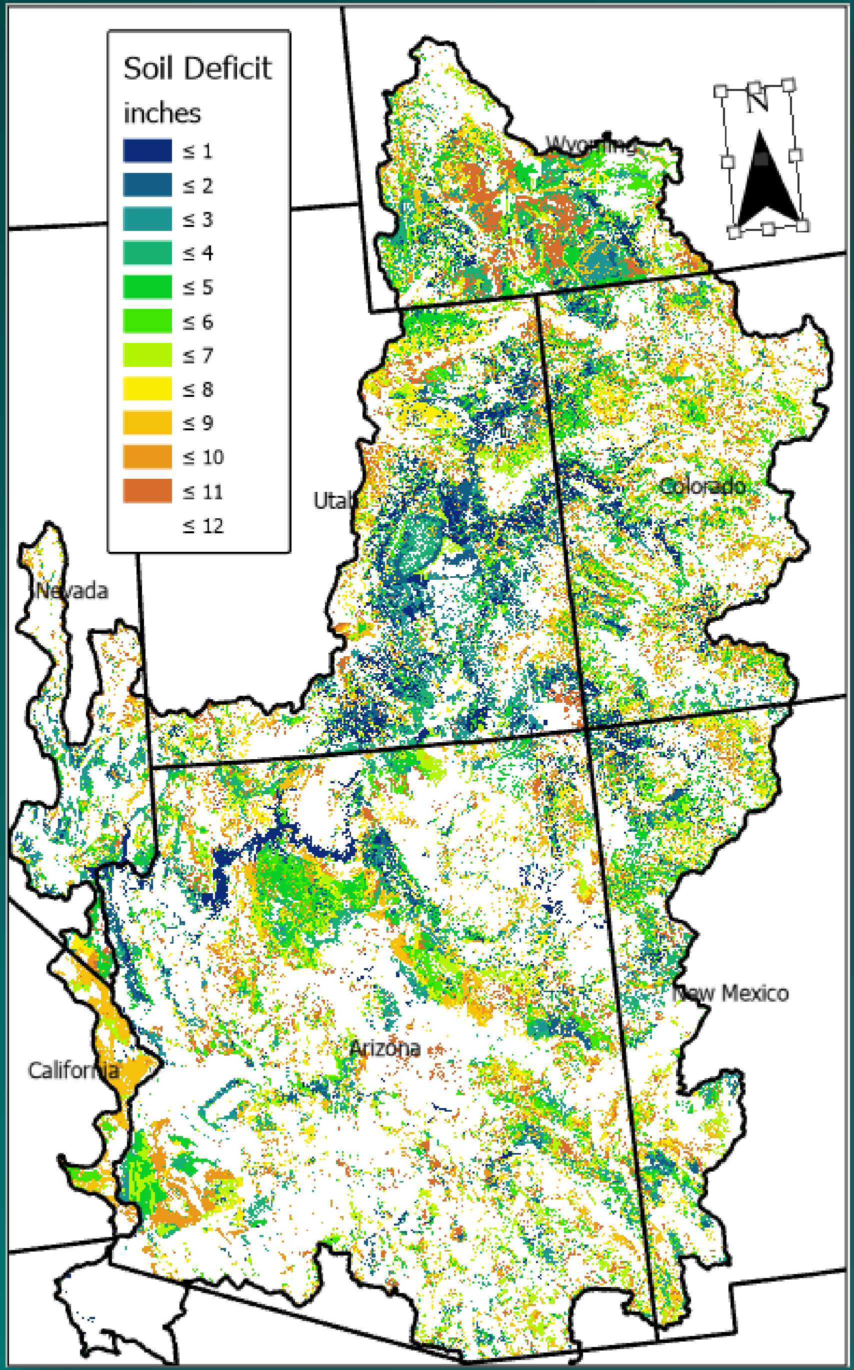
Runoff makes it to the reservoir first and recharge becomes baseflows



Colorado River Basin

October 2021
0-4” of water supply

Soil deficit will need to be filled before significant runoff and recharge occur this winter



Summary and Conclusions

- 2020 & 2021 were the hottest and driest years on record in the Sierra Nevada and the CRB.
- Increased landscape stress persists, in comparison to long term means and will likely take much longer than the water supply to recover.
- Runoff efficiency has declined in recent years for the Sierra Nevada and lower CRB, indicating that it will take more rain to fill soils and become runoff.

Summary and Conclusions

- Water balance modeling can be used to characterize the spatially variable hydrologic processes that lead to drought effects and highlight where on the landscape management actions could be prioritized.
- It can be used to update antecedent conditions and provide information to inform forecasts.
- Monitoring and modeling should combine to inform resource management.