- Data insights

Photo: NID

Sierra Nevada Mountain Precipitation & Snowpack Trends

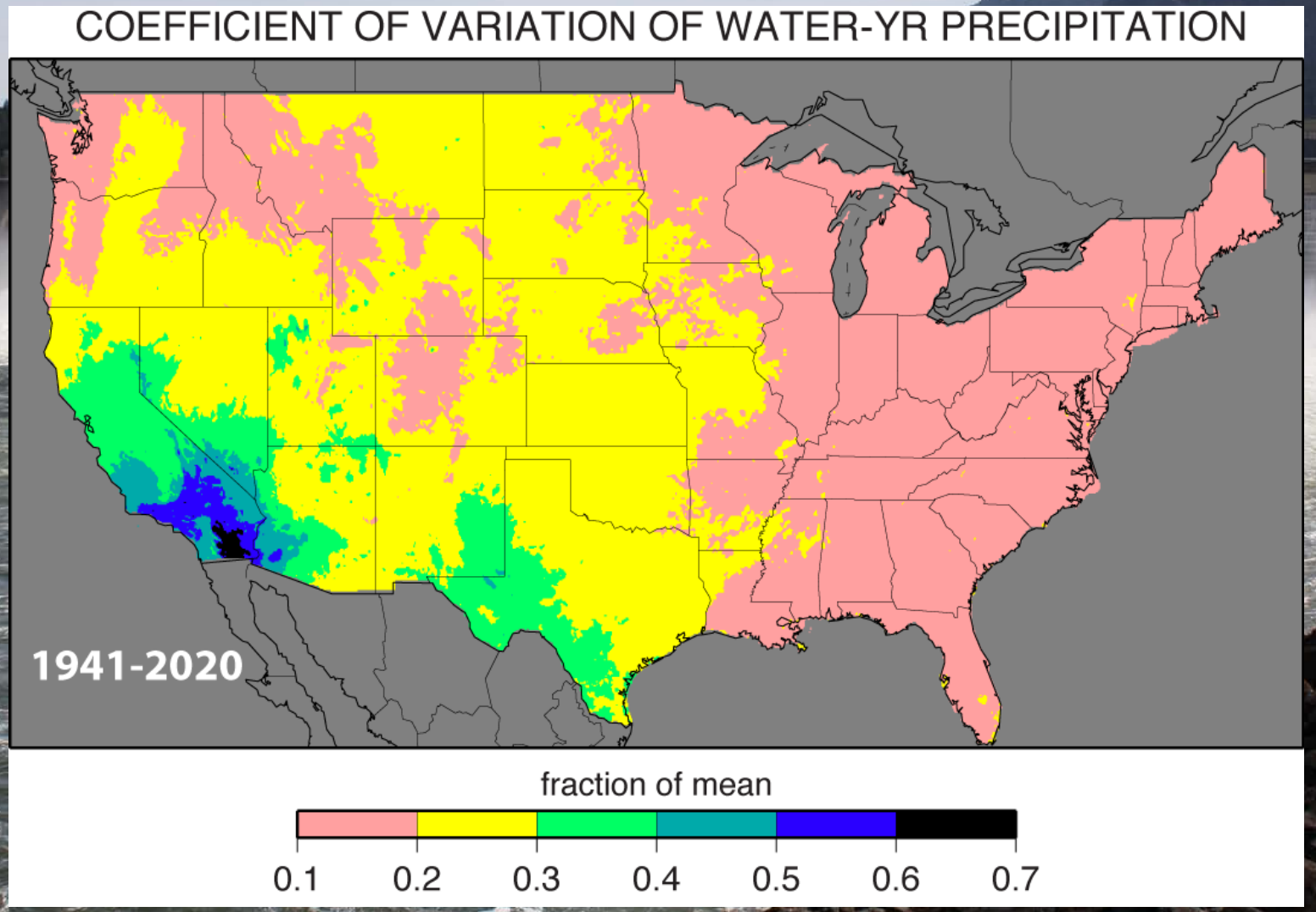
WEST CONSULTANTS

WATER | ENVIRONMENTAL | SEDIMENTATION | TECHNOLOGY

yubanet.com

https://www.eastbaytimes.com/

Extreme Variability in the West



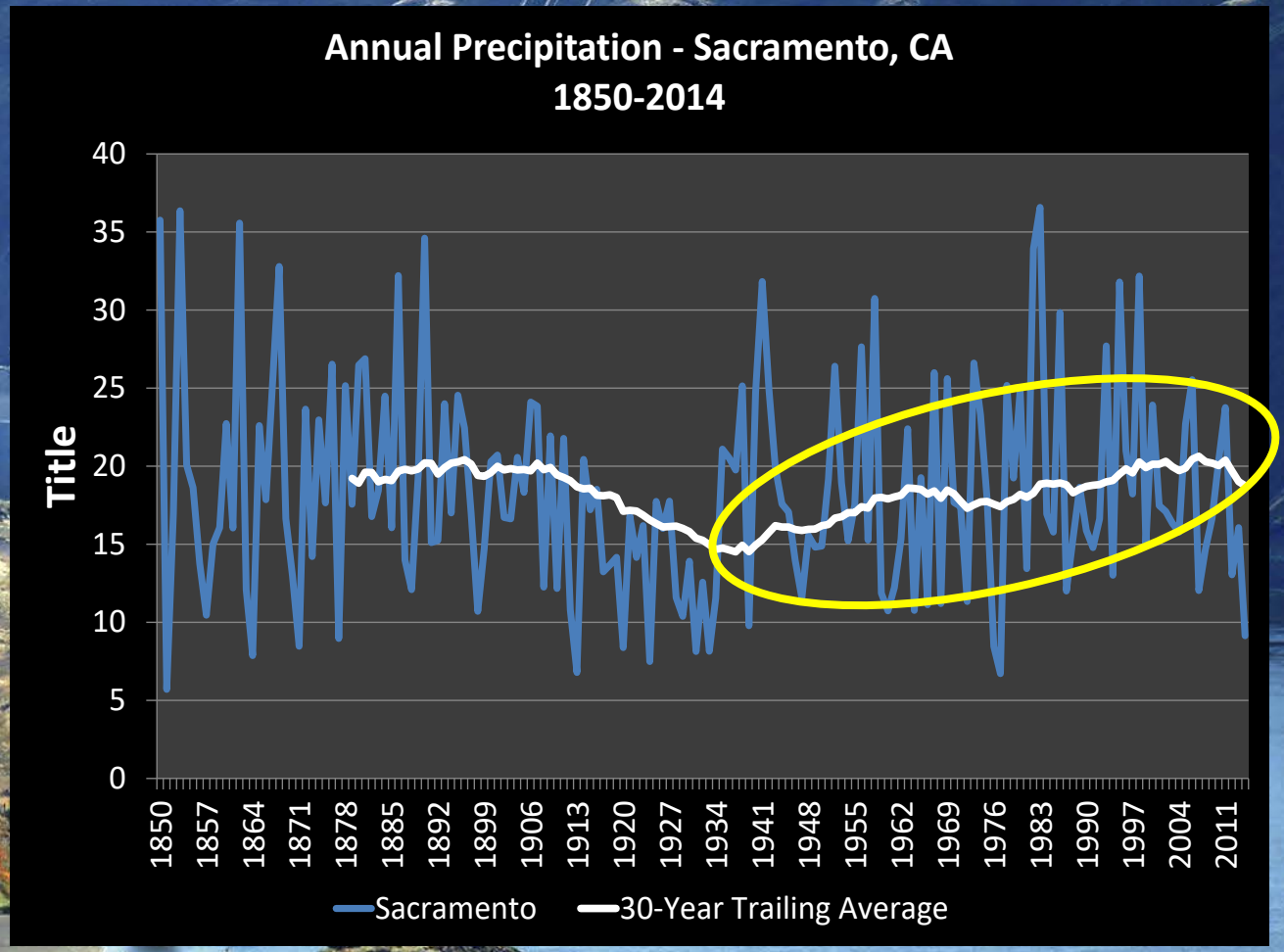
Bonneville Dam

Source: CA DWR Photo taken April 9, 2017. Snowpack around a home in Soda Springs, California.

Source: CA DWR Phillips Station on April 1, 2015

Long-Term Trends?

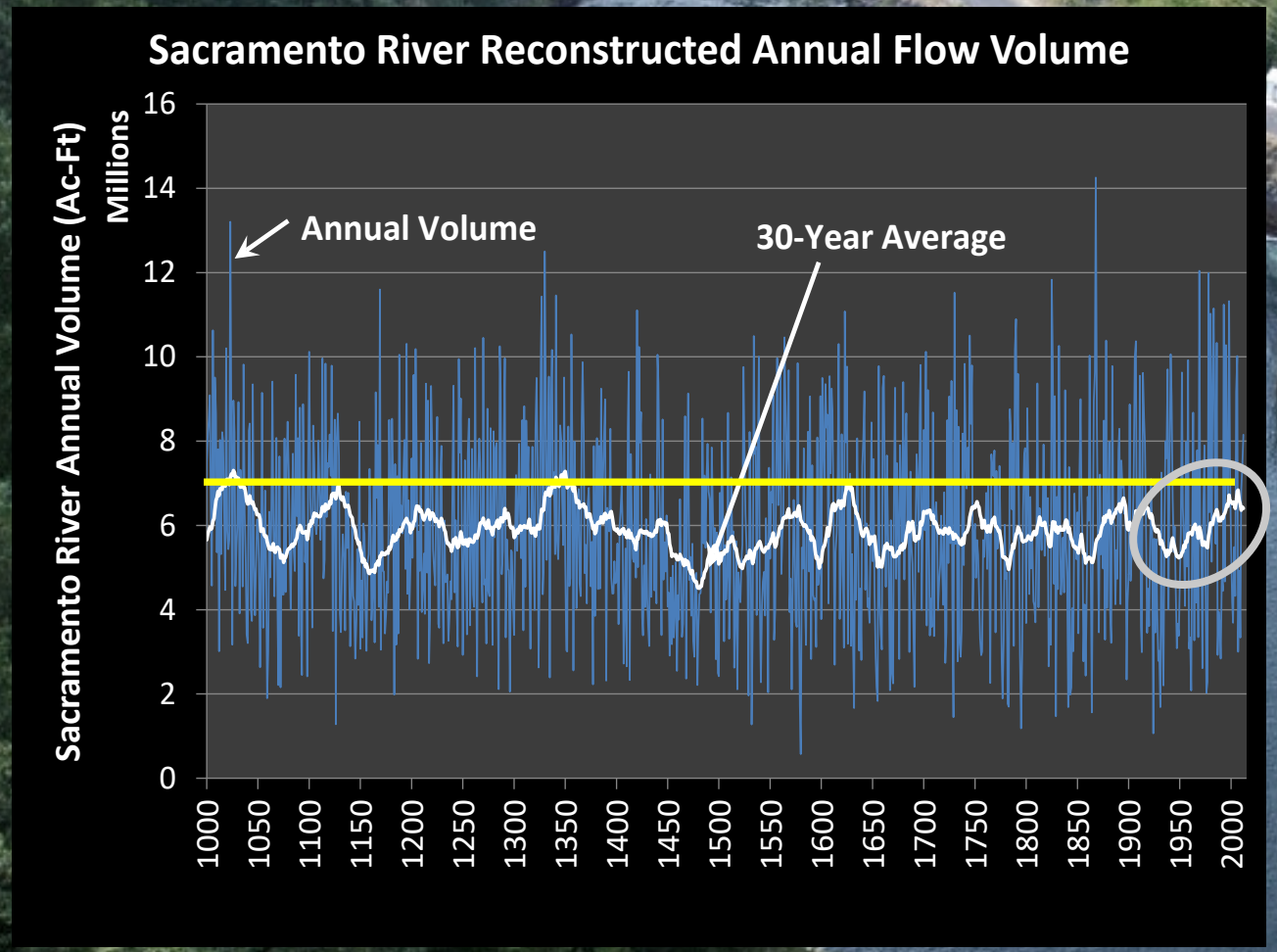
Annual Precipitation



Lower Granite Dam


Looking back in time

Looking Back 1100 Years…

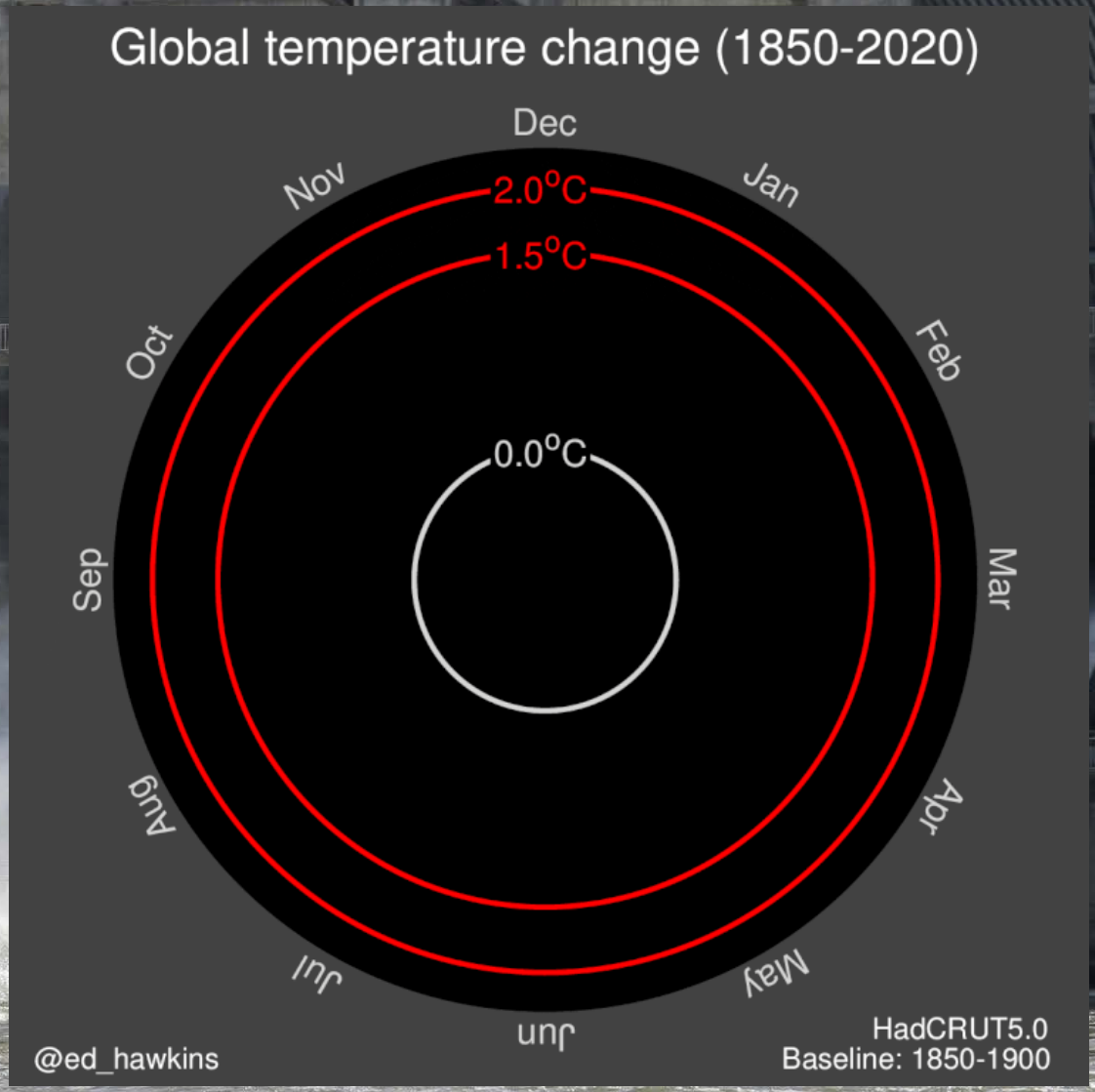


Detroit Dam

Climates Change.

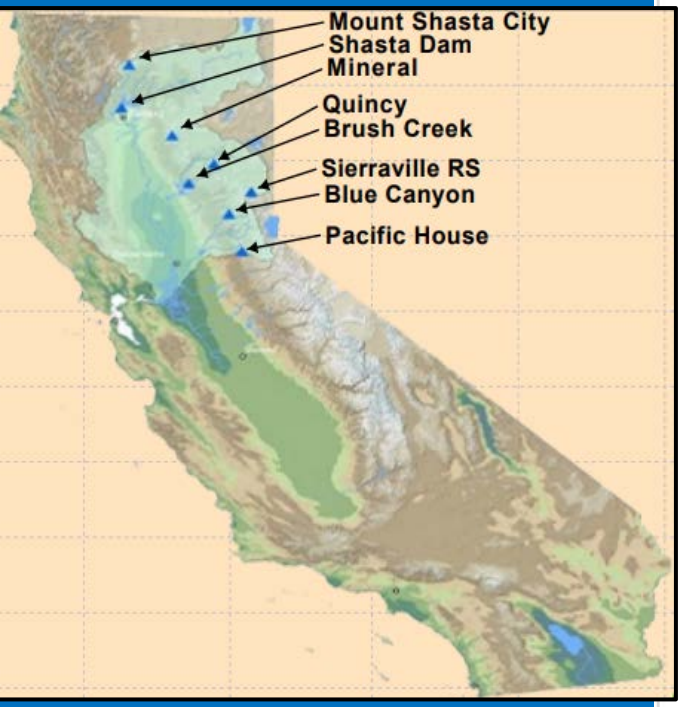
That’s What Climates Do.

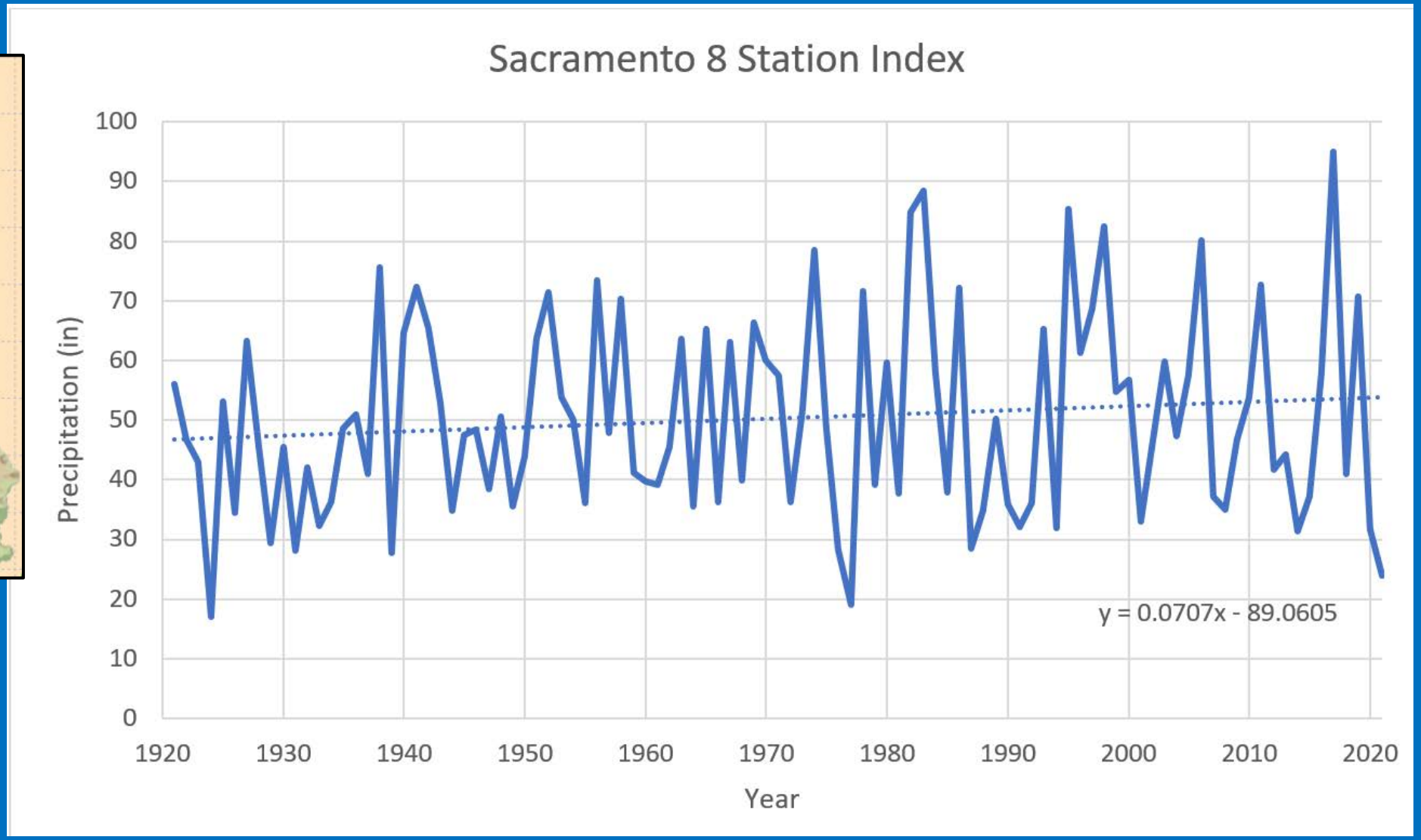
Messing with Mother Nature!



Lower Granite Dam

Sacramento River Basin Precipitation

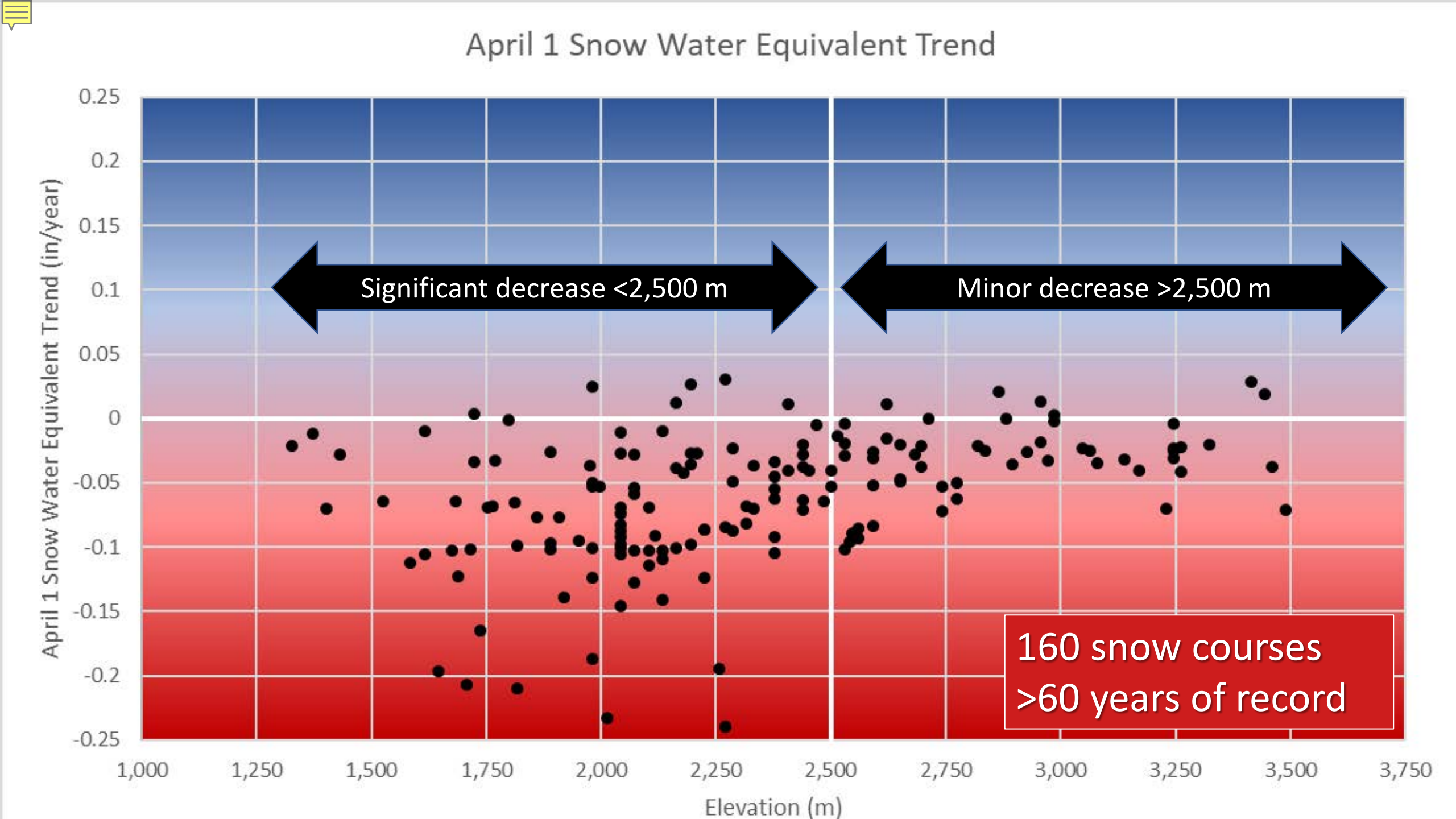


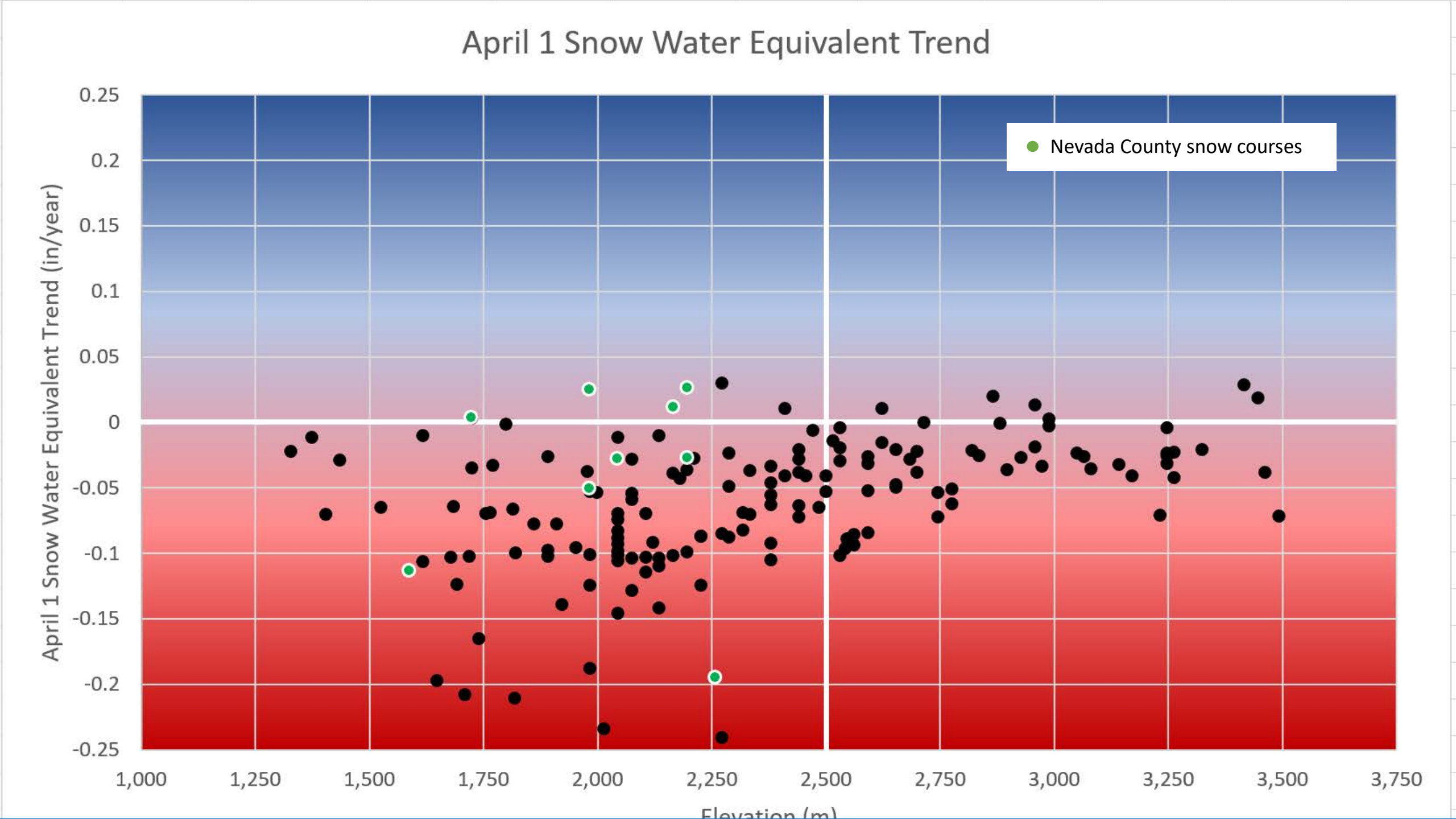


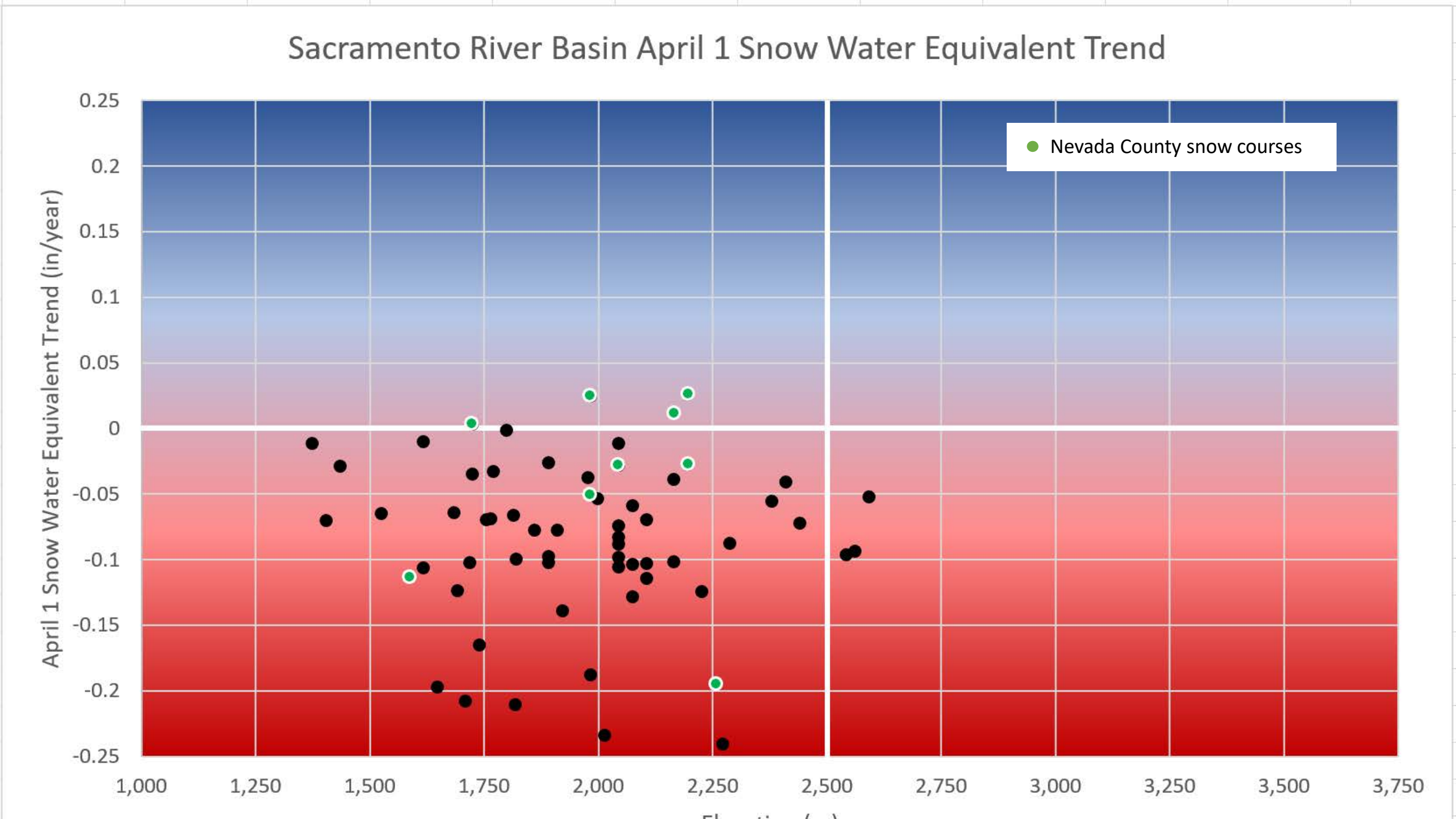

April 1 Snowpack
Source: CA DWR Phillips Station on April 1, 2021

California Cooperative Snow Surveys

Source: CA DWR Phillips Station taken January 30, 2020.

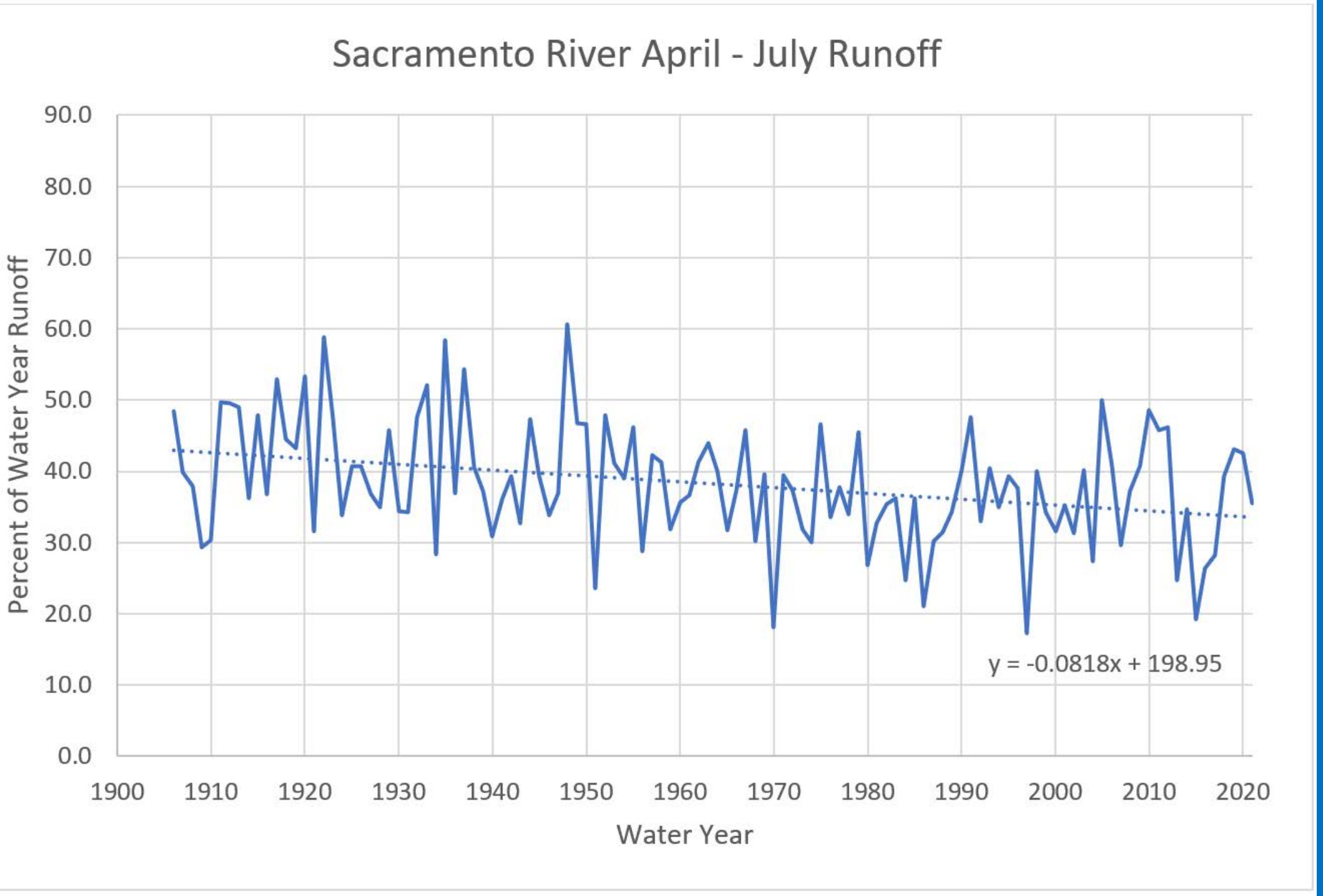

April 1 Snow Water Equivalent Trend
April 1 Snow Water Equivalent Trend (in/year)
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
Significant decrease <2,500 m
Minor decrease >2,500 m
160 snow courses
>60 years of record
1,000
1,250
1,500
1,750
2,000
2,250
2,500
2,750
3,000
3,250
3,500
3,750
Elevation (m)


April 1 Snow Water Equivalent Trend
Nevada County snow courses
April 1 Snow Water Equivalent Trend (in/year)
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
1,000
1,250
1,500
1,750
2,000
2,250
2,500
2,750
3,000
3,250
3,500
3,750
Elevation (m)

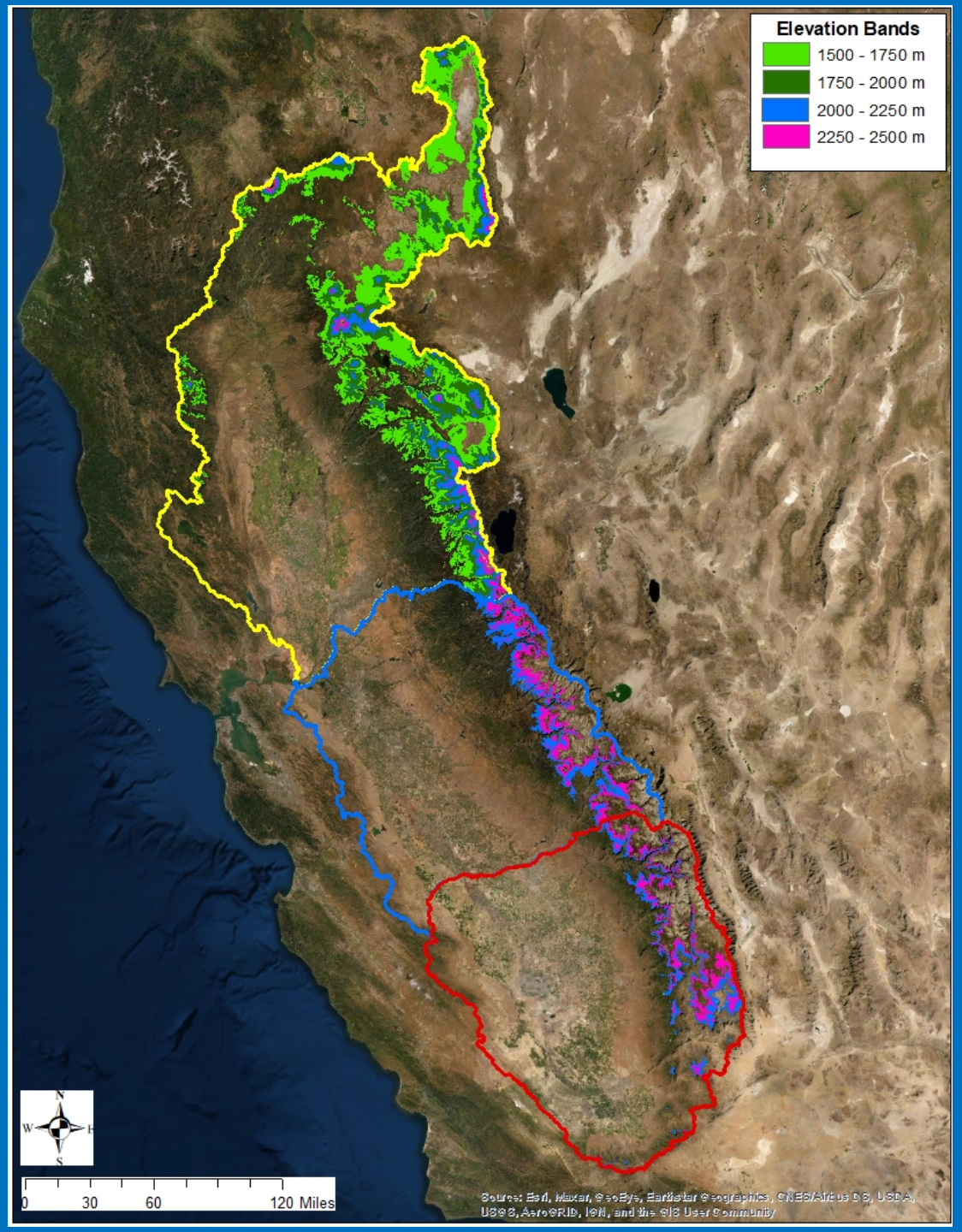

Sacramento River Basin April 1 Snow Water Equivalent Trend
April 1 Snow Water Equivalent Trend (in/year)
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
1,000
1,250
1,500
1,750
2,000
2,250
2,500
2,750
3,000
3,250
3,500
3,750
Nevada County snow courses

Summary of Precipitation and April 1 SWE Changes

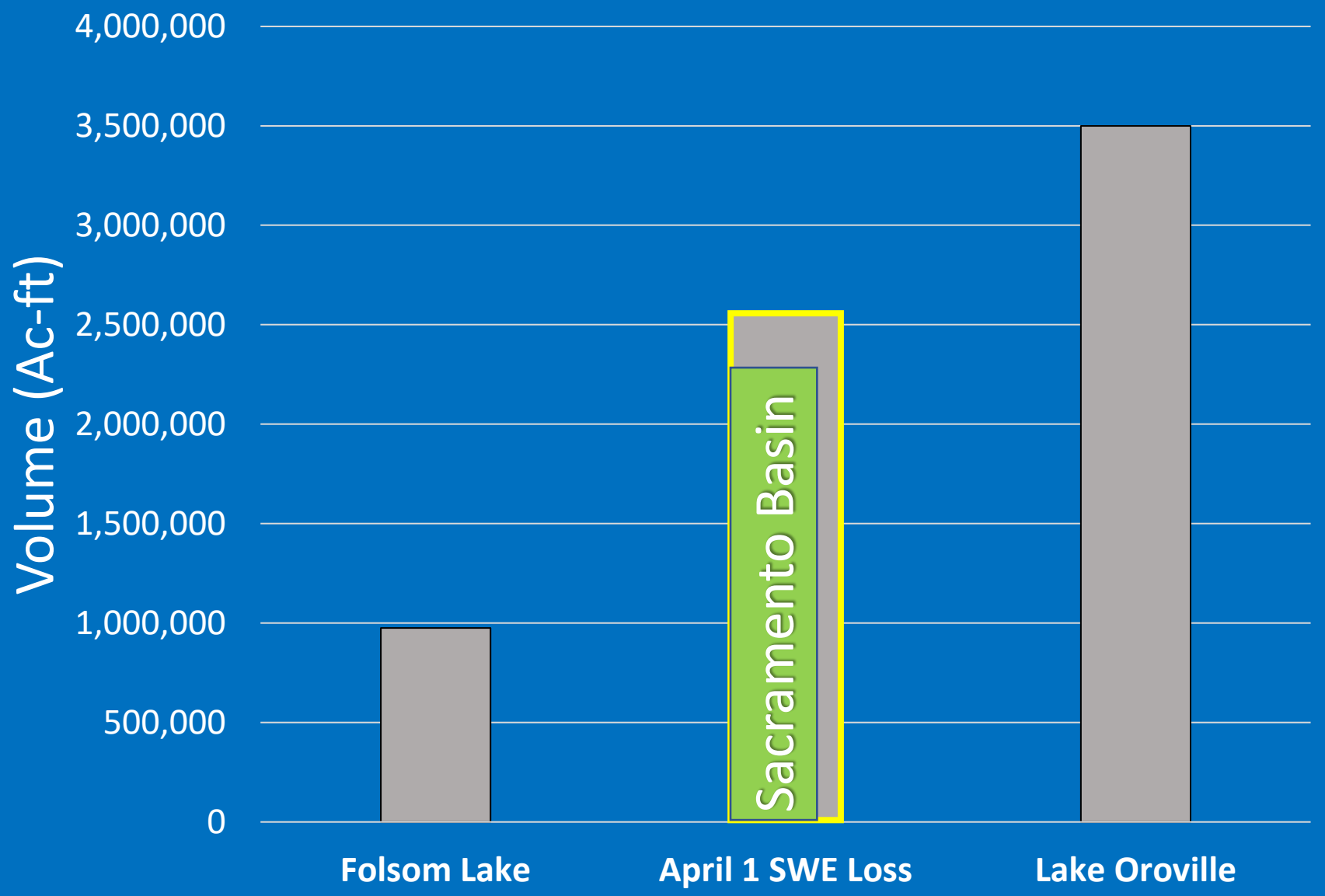
Basin	April 1 SWE Change (in/60 years)	Precipitation Change (in/60 years)
Sacramento River	-5.0	+4.2

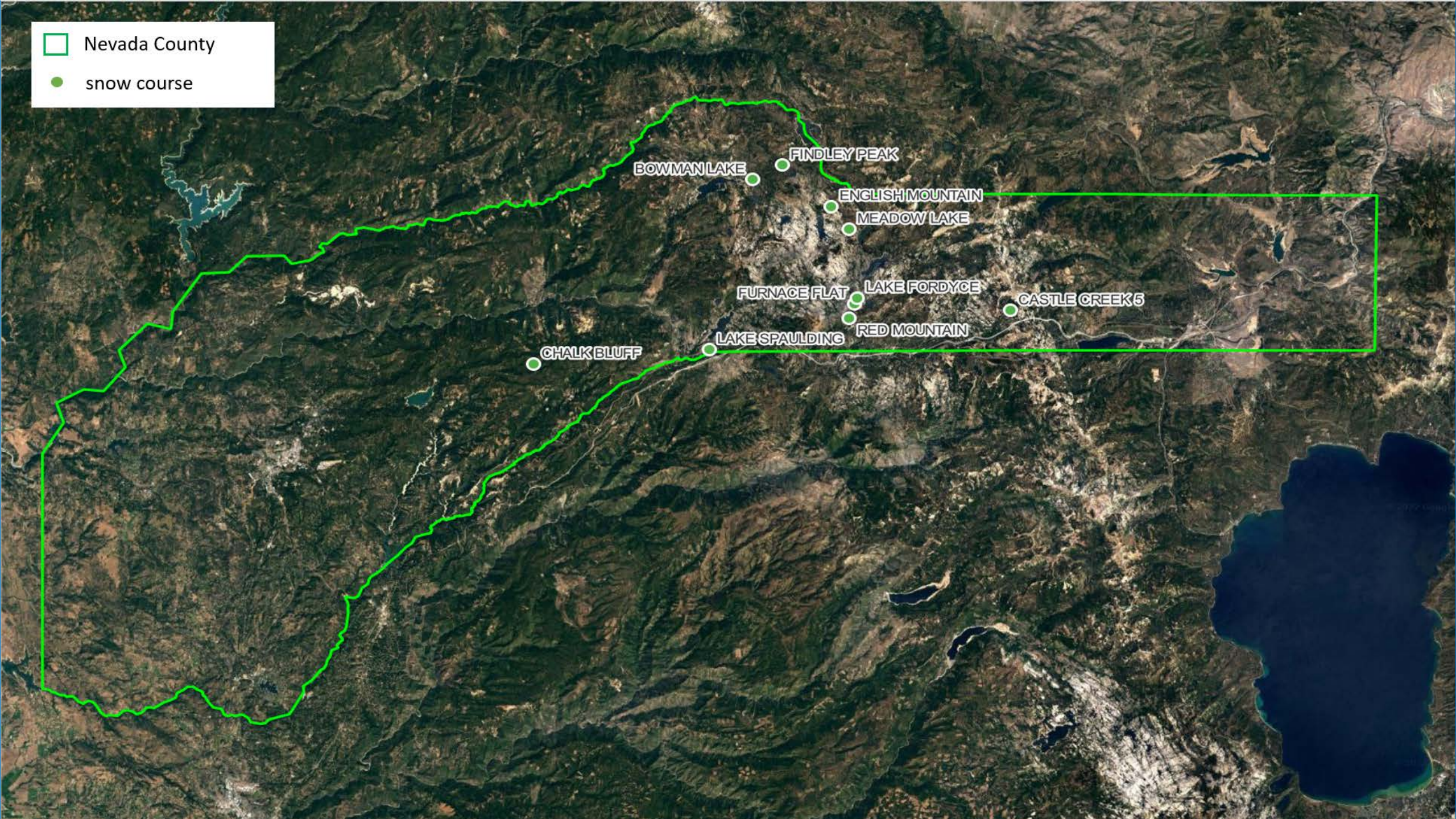

Sacramento River April - July Runoff
Percent of Water Year Runoff
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Water Year
y = -0.0818x + 198.95

Snowpack Region



Volume Comparison




Nevada County
snow course
BOWMAN LAKE
FINDLEY PEAK
ENGLISH MOUNTAIN
MEADOW LAKE
FURNACE FLAT
LAKE FORDYCE
CASTLE CREEK 5
RED MOUNTAIN
LAKE SPAULDING
CHALK BLUFF

Nevada County
April 1 Snowpack Change → -42,600 ac-ft

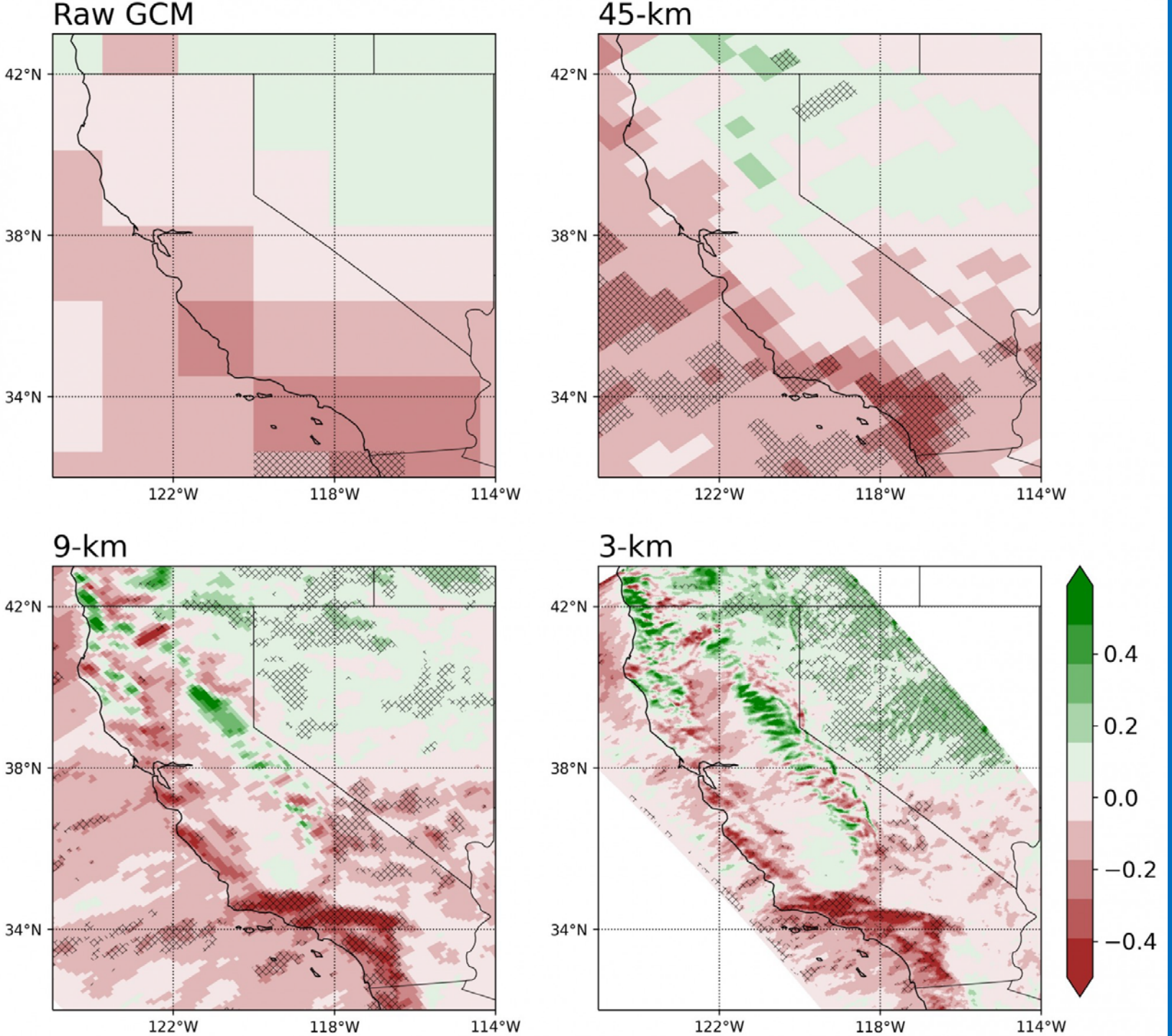
Van Giesen Dam, on Combie Reservoir

Planning Implications

- Consider
  - Bigger swings
  - Faster transitions

Discussion

Source: CA DWR Phillips Station. Photo taken February 27, 2020.


Raw GCM
45-km
9-km
3-km
42°N
38°N
34°N
122°W
118°W
114°W
0.4
0.2
0.0
−0.2
−0.4

Source: CA DWR Phillips Station taken February 27, 2020

Improved Reservoir Management

Photo: D. Curtis Folsom Dam February 28, 2019

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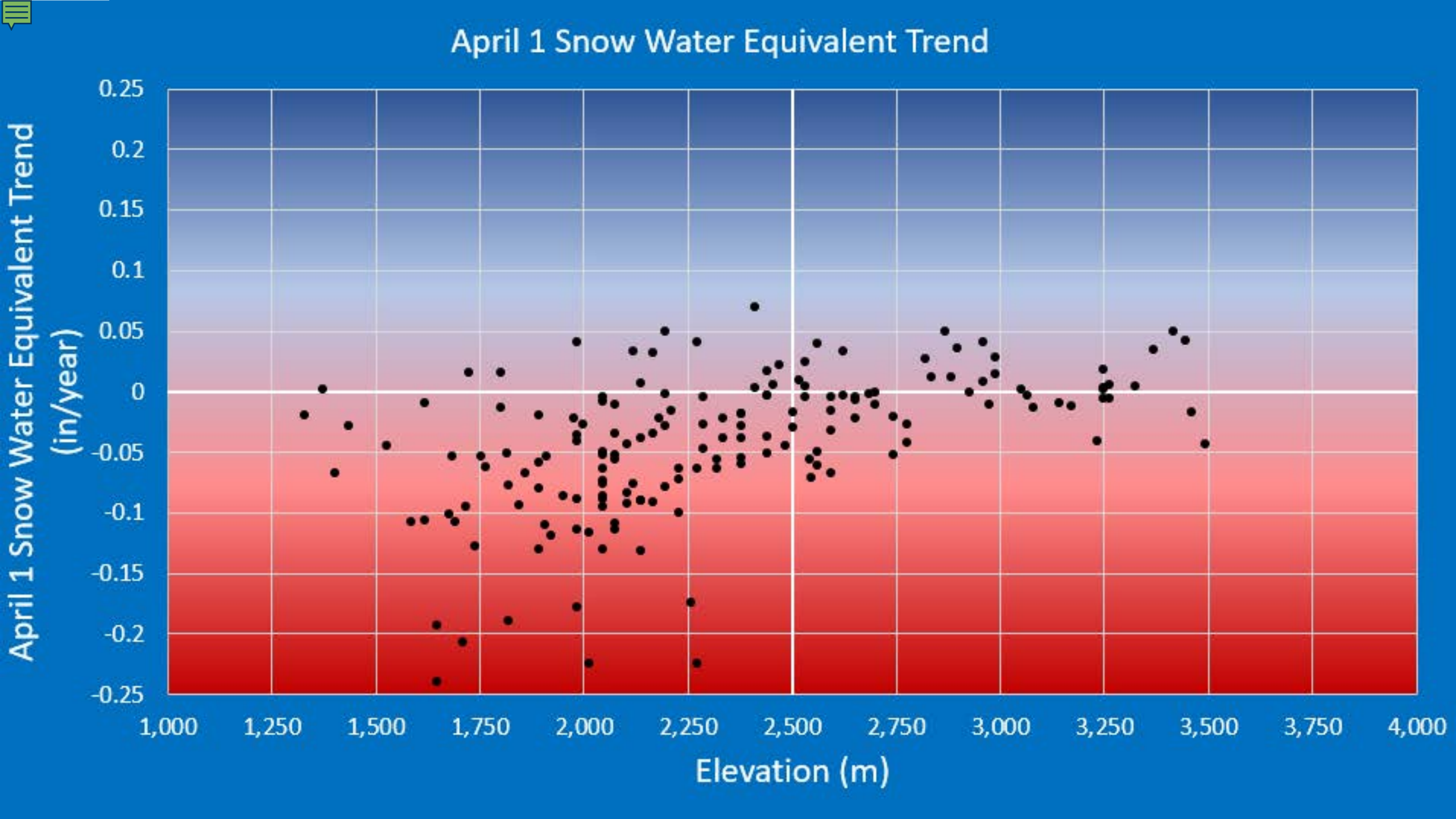
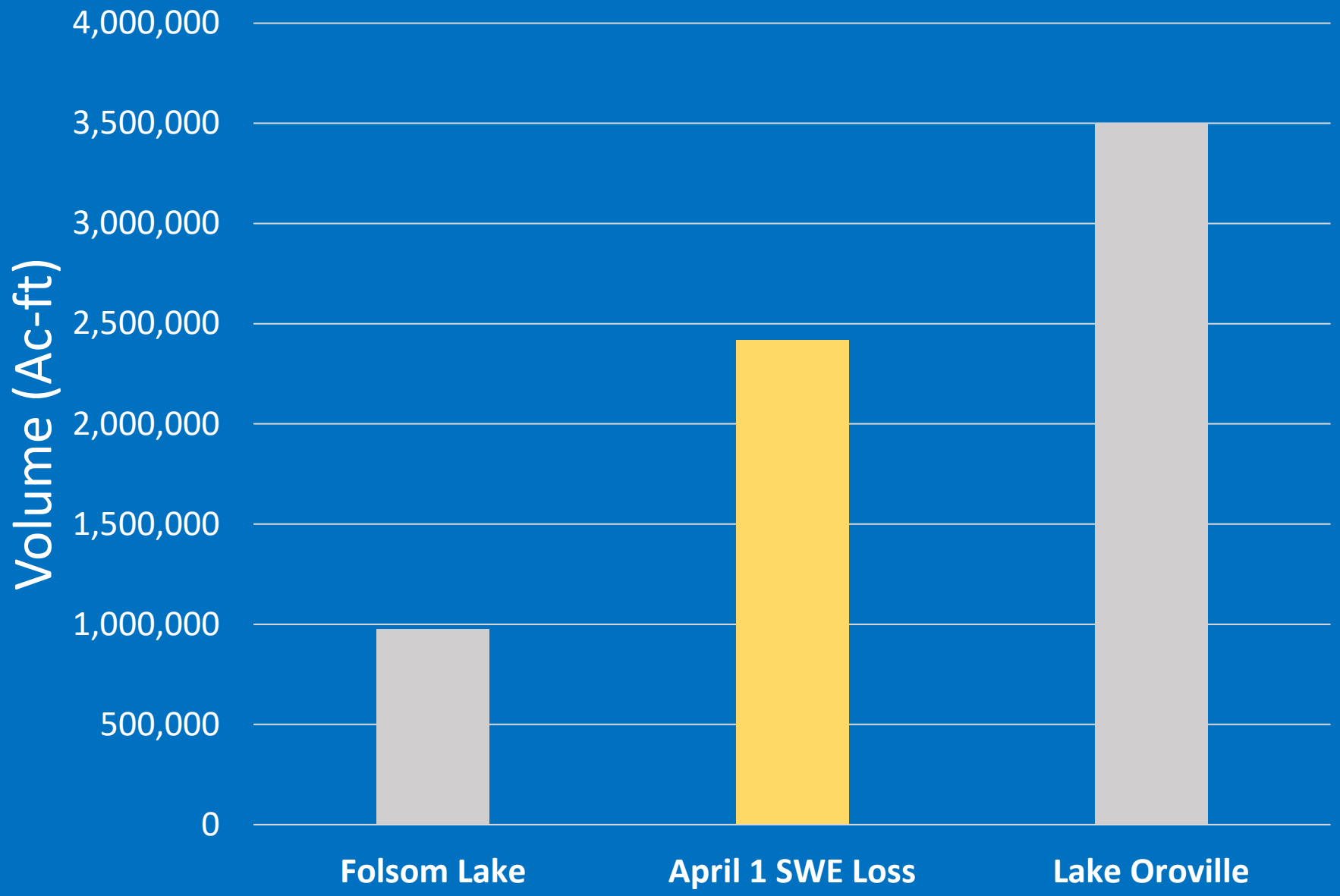
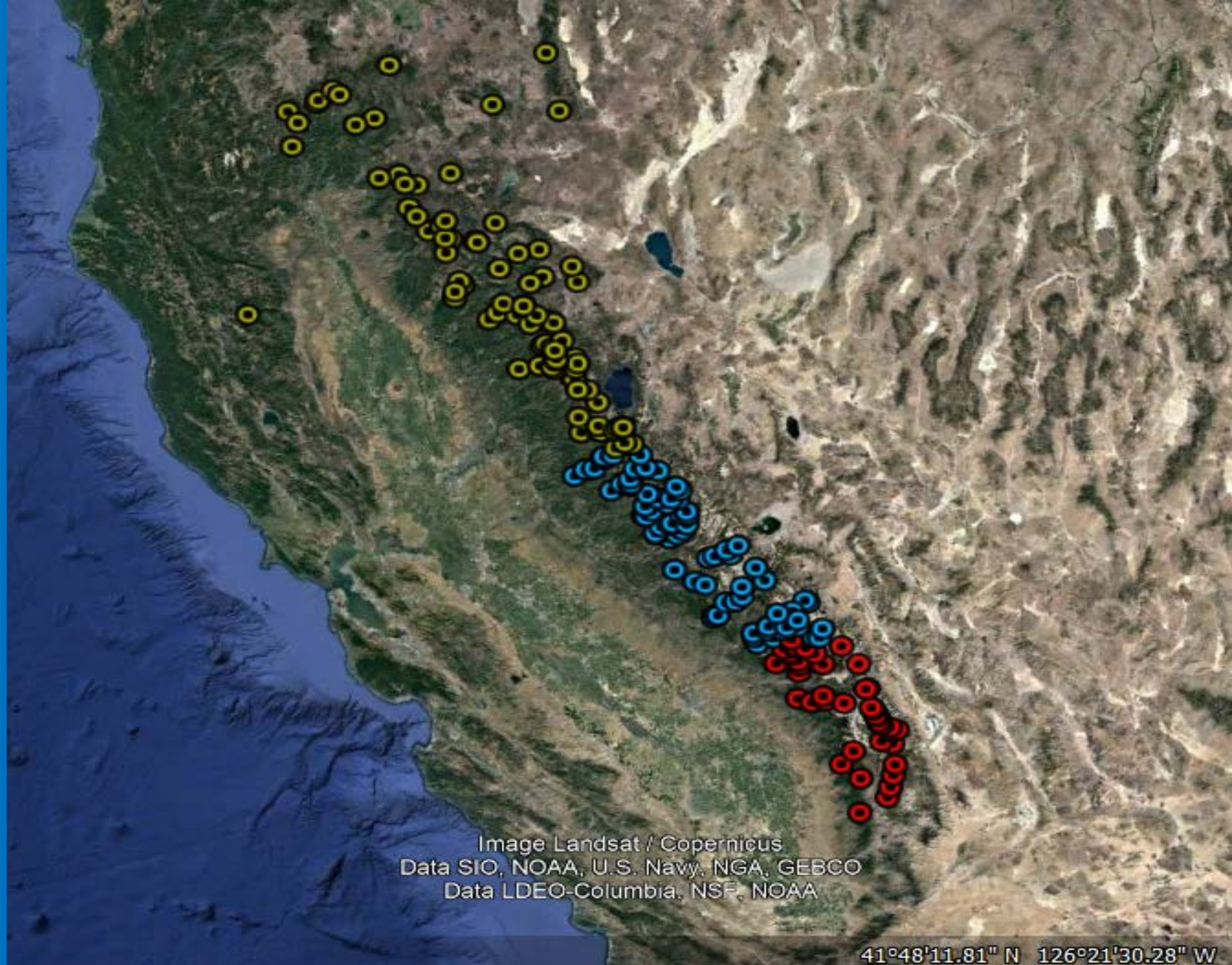

April 1 Snow Water Equivalent Trend
April 1 Snow Water Equivalent Trend (in/year)
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
1,000
1,250
1,500
1,750
2,000
2,250
2,500
2,750
3,000
3,250
3,500
3,750
4,000
Elevation (m)

Volume Comparison



Tools

- Python
  - Ulmo
  - Matplotlib
  - Scipy



Summary

Precipitation Index	Precipitation Trend (in/decade)
Northern Sierra	1.0
San Joaquin	0.60
Tulare	-0.10

Basin	Mean Elevation	Negative Trend	Positive Trend	Mean Overall Trend (in/decade)
All	2,326 m	78%	22%	-0.41
Sacramento River Basin	1,964 m	88%	12%	-0.70
San Joaquin River Basin	2,454 m	76%	24%	-0.26
Tulare Lake Basin	2,739 m	61%	39%	-0.15

Source: CA DWR Phillips Station taken January 30, 2020

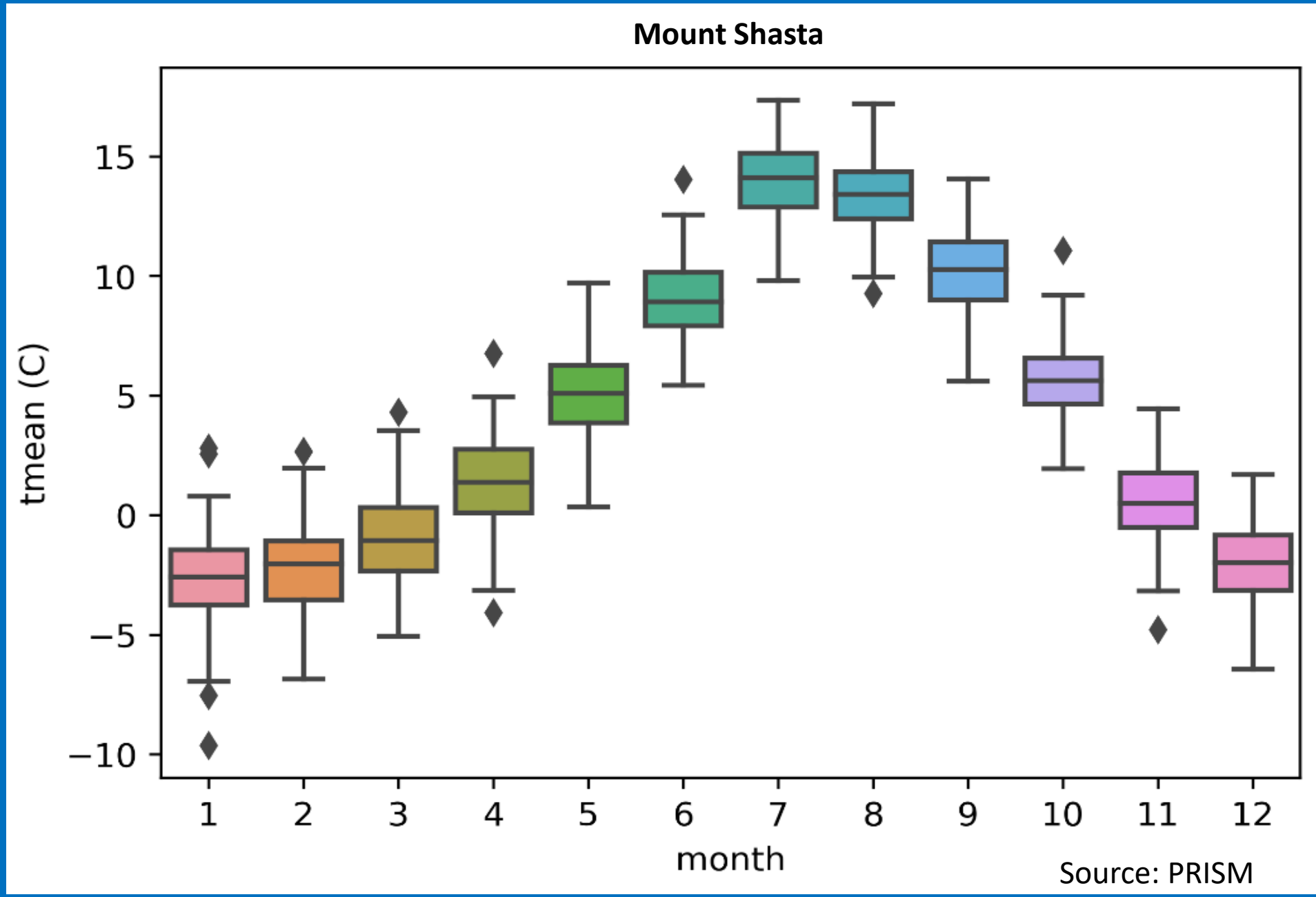
Snowpack

- Why study snowpack?
- Snow water equivalent - depth of water contained within snowpack
- What's significant about April 1?

Source: CA DWR

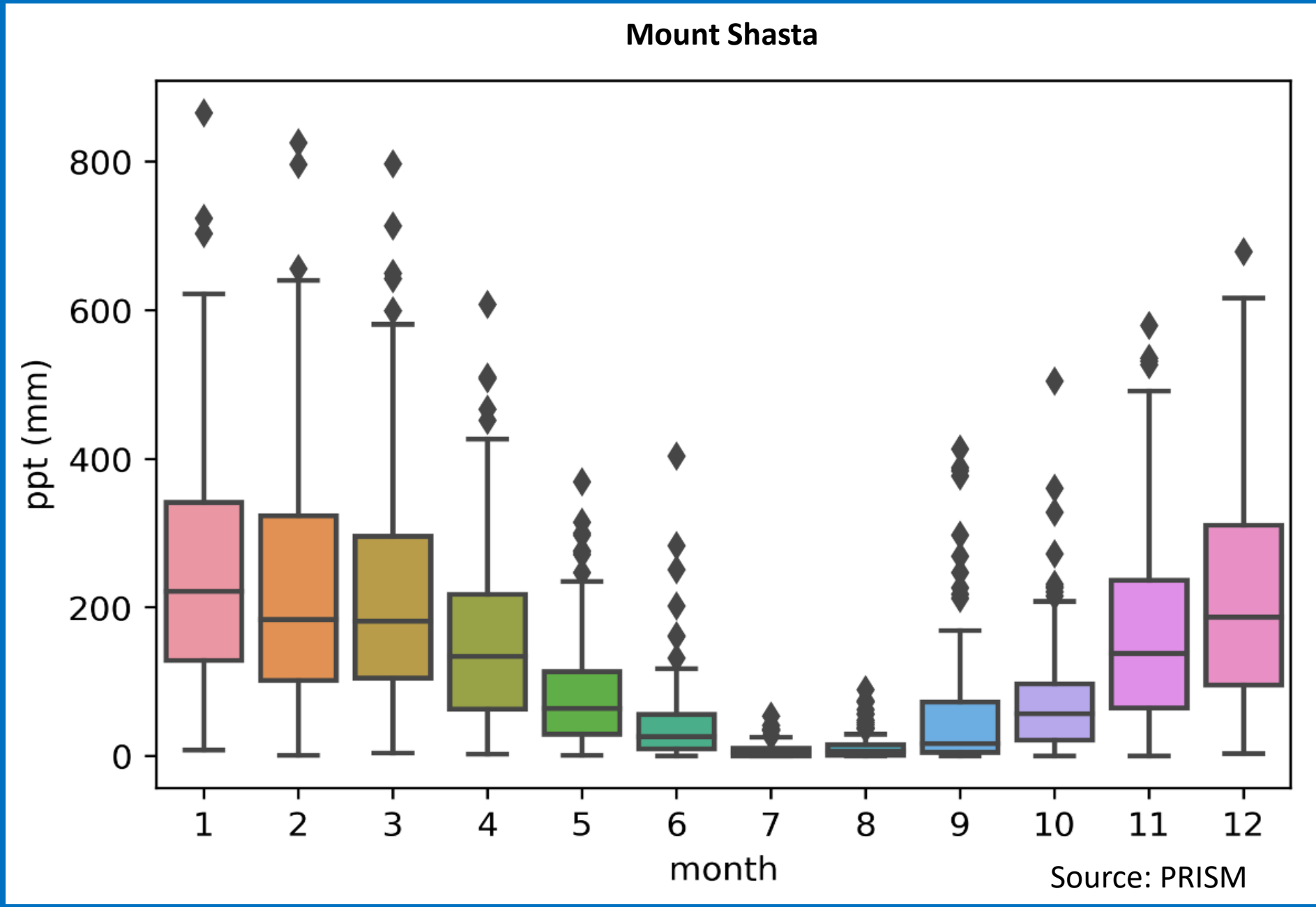
Climate

- Hot dry summers
- Mild wet winters



Climate

- Highly variable annual precipitation (Dettinger et al., 2011)
- Atmospheric rivers



Data

- California Department of Water Resources
  - California Cooperative Snow Surveys
  - Precipitation indices

Table 1. April 1 Snow Survey Data

Years of Record	Number of Snow Courses
>30	199
>60	166
>90	36

April 1 Snow Course Trends

Basin	Mean Elevation	Negative Trend	Positive Trend	Mean Negative Trend (in/decade)	Mean Positive Trend (in/decade)	Mean Overall Trend (in/decade)
All	2,326 m	78%	22%	-0.60	0.23	-0.41
Sacramento River Basin	1,964 m	88%	12%	-0.82	0.25	-0.70
San Joaquin River Basin	2,454 m	76%	24%	-0.42	0.26	-0.26
Tulare Lake Basin	2,739 m	61%	39%	-0.37	0.02	-0.15

April 1 SWE Trend with Elevation

Basin	Trend below 2,500 m (in/decade)
All	-0.59
Sacramento River Basin	-0.71
San Joaquin River Basin	-0.39
Tulare Lake Basin	-0.57

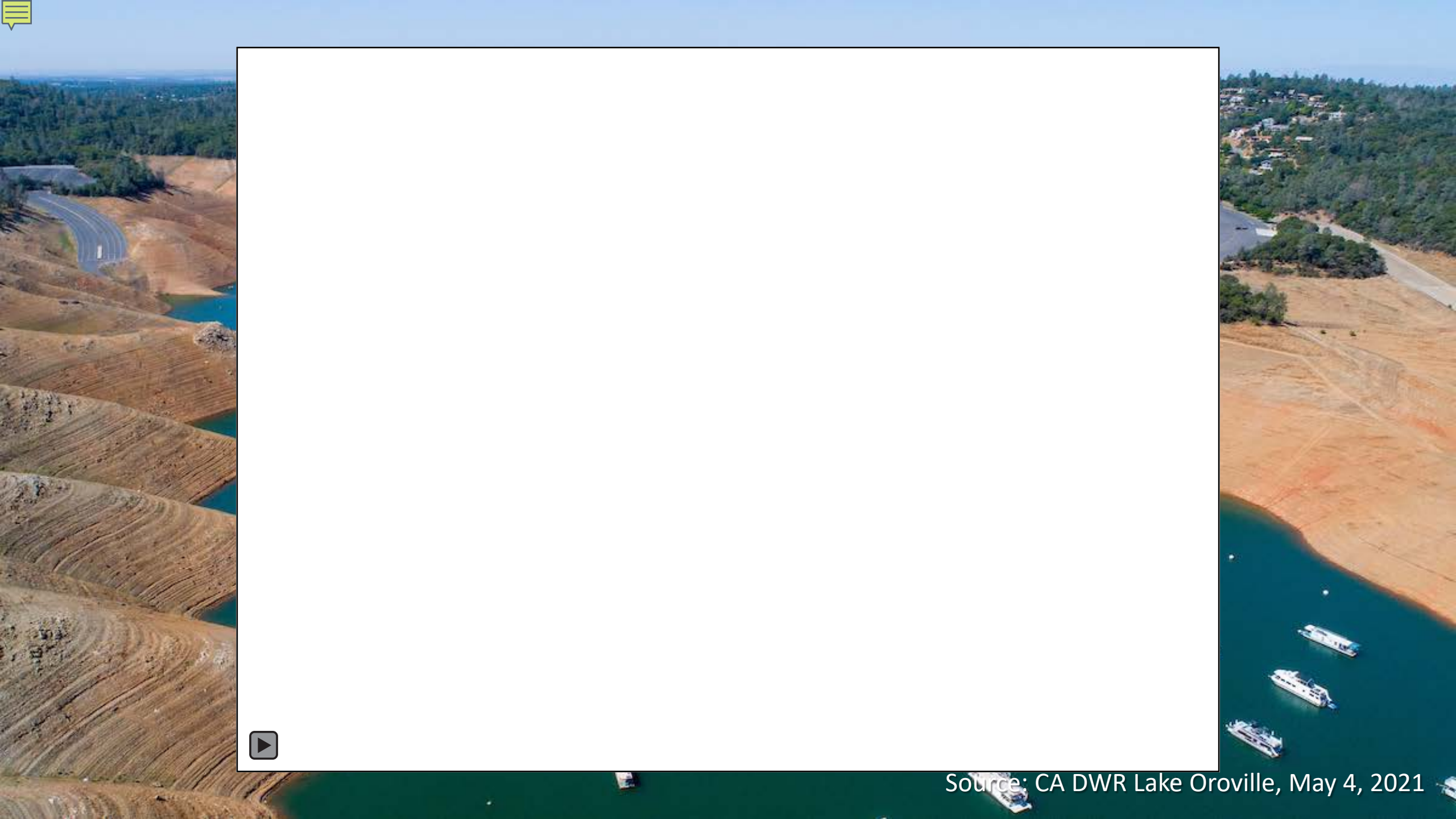
April 1 SWE Volume Change

Basin	Elevation Band (m)	Area (acres)	April 1 SWE Trend (in/year)	April 1 SWE Volume Change (acre-ft/decade)
Sacramento	1,500 – 1,750	2,441,841	-0.11	-223,835
	1,750 – 2,000	1,436,508	-0.07	-83,796
	2,000 – 2,250	601,042	-0.06	-30,052
	2,250 – 2,500	165,564	-0.07	-9,658
			Subtotal	**-347,342**
San Joaquin	2,000 – 2,250	379,501	-0.05	-15,813
	2,250 – 2,500	385,605	-0.02	-6,427
			Subtotal	**-22,239**
Tulare	2,000 – 2,250	336,431	-0.09	-25,232
	2,250 – 2,500	311,590	-0.03	-7,790
			Subtotal	**-33,022**
			Total	**-402,603**

Jan 18, 2014

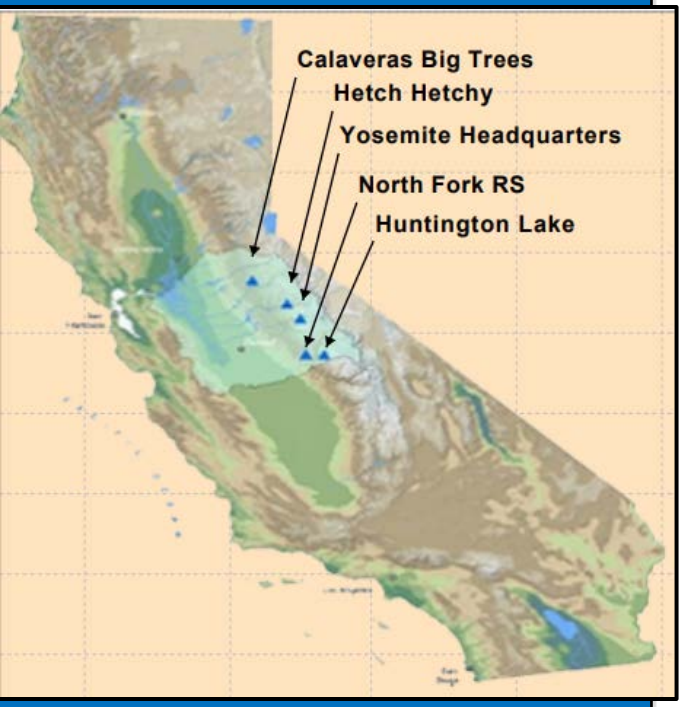
Jan 18, 2013

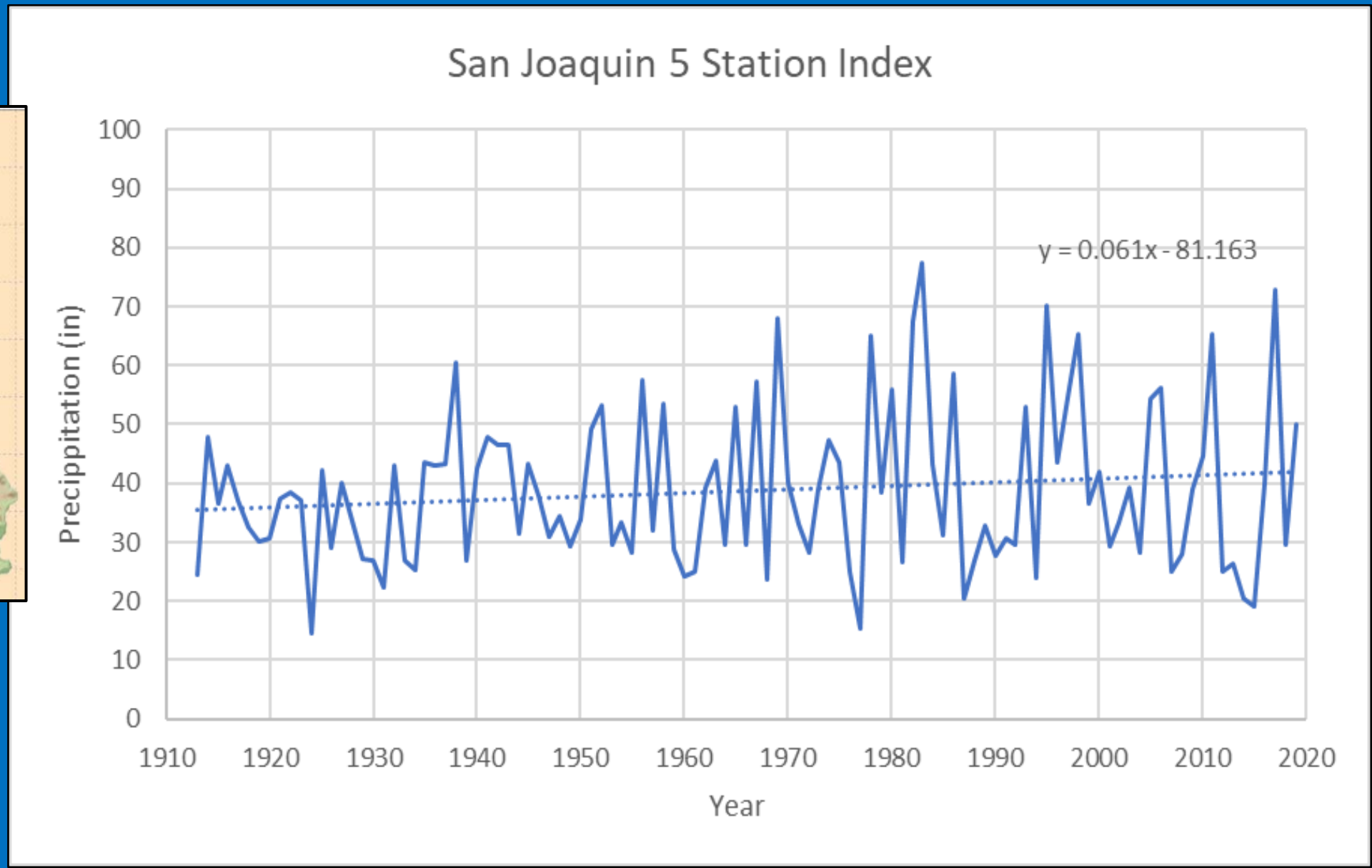
Source: NOAA



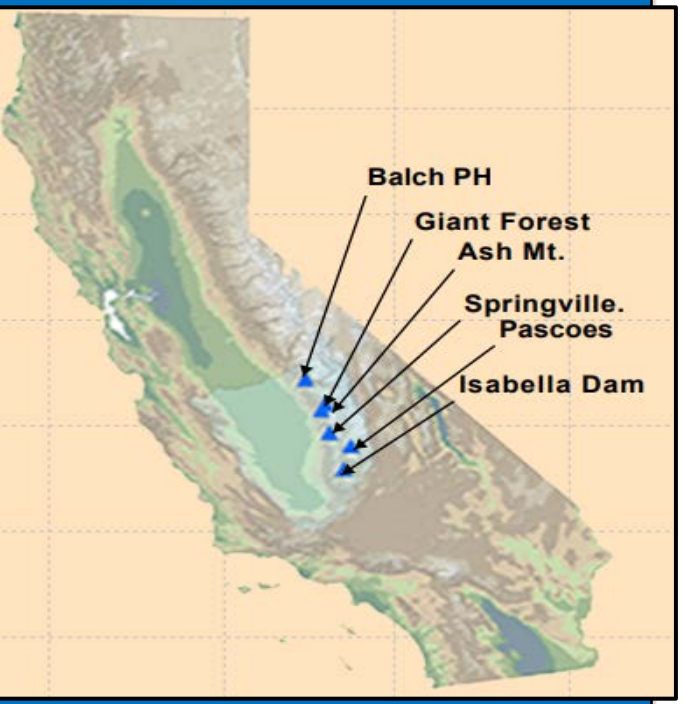
Source: CA DWR Lake Oroville, May 4, 2021

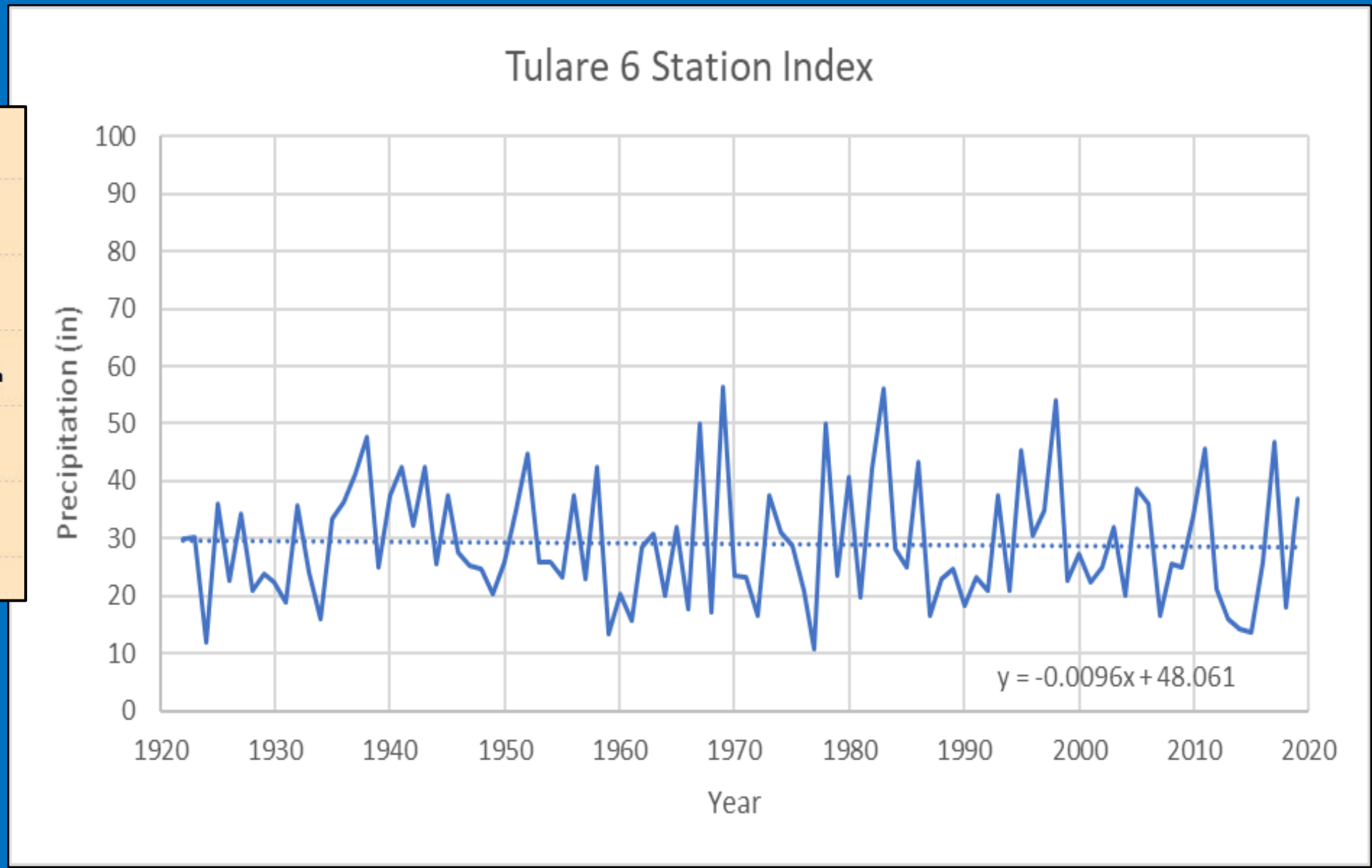
San Joaquin River Basin Precipitation





Tulare Basin Precipitation





California Cooperative Snow Surveys

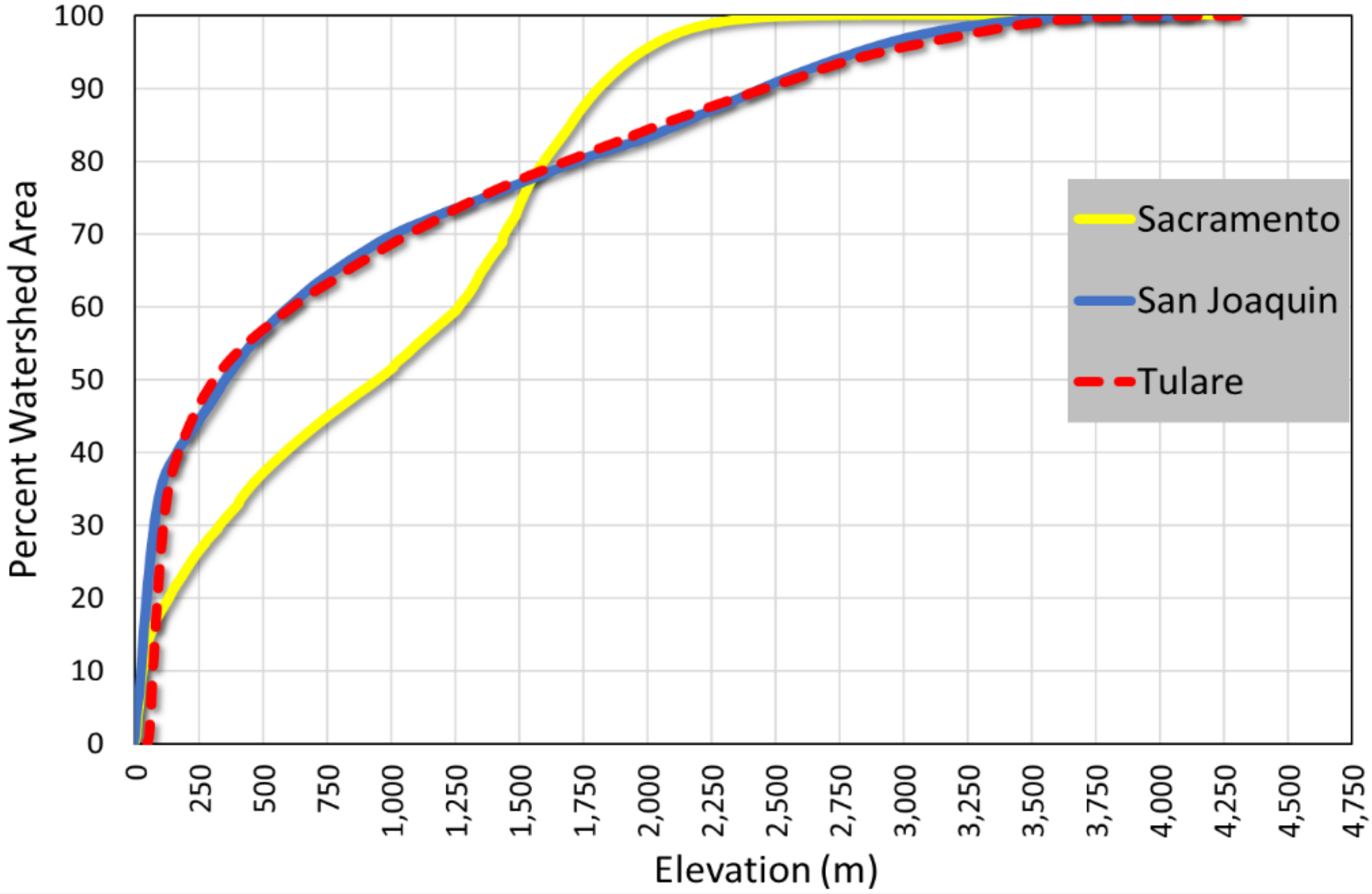
Years of Record	Number of Snow Courses
>30	199
>60	166
>90	36

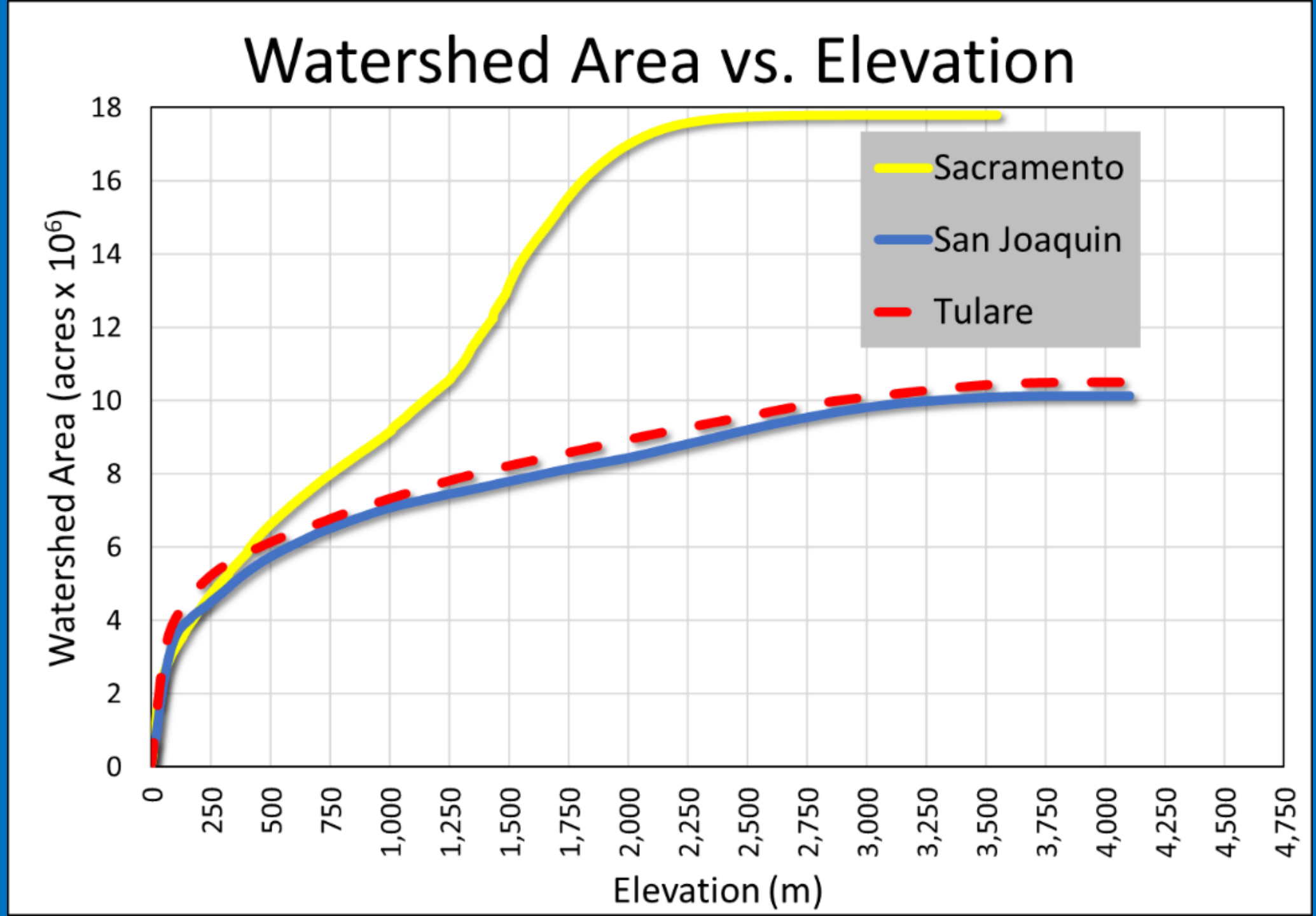
Source: CA DWR Phillips Station photo taken January 30, 2020

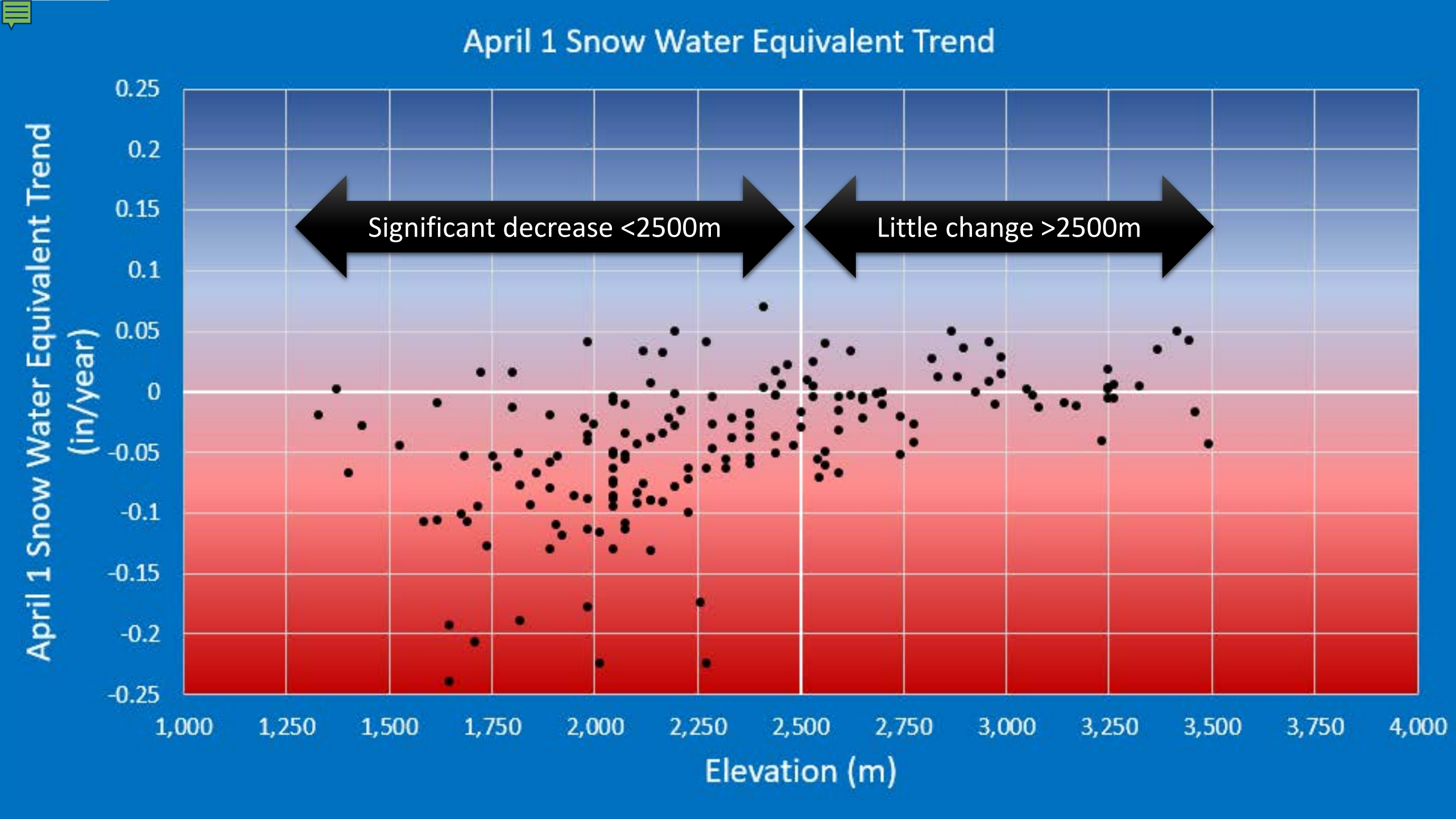
Major Watersheds

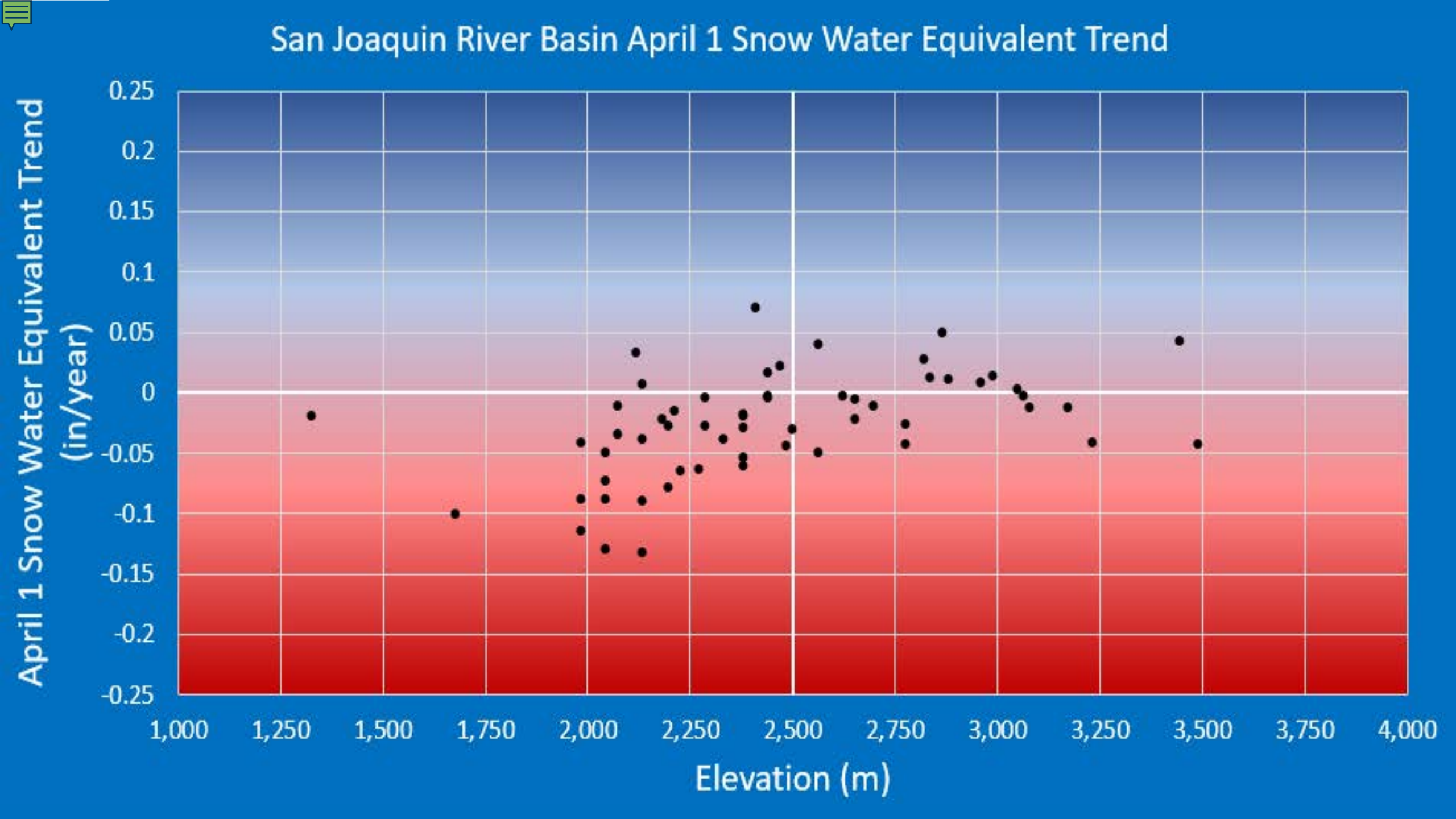
- Sacramento River
- San Joaquin River
- Tulare Basin

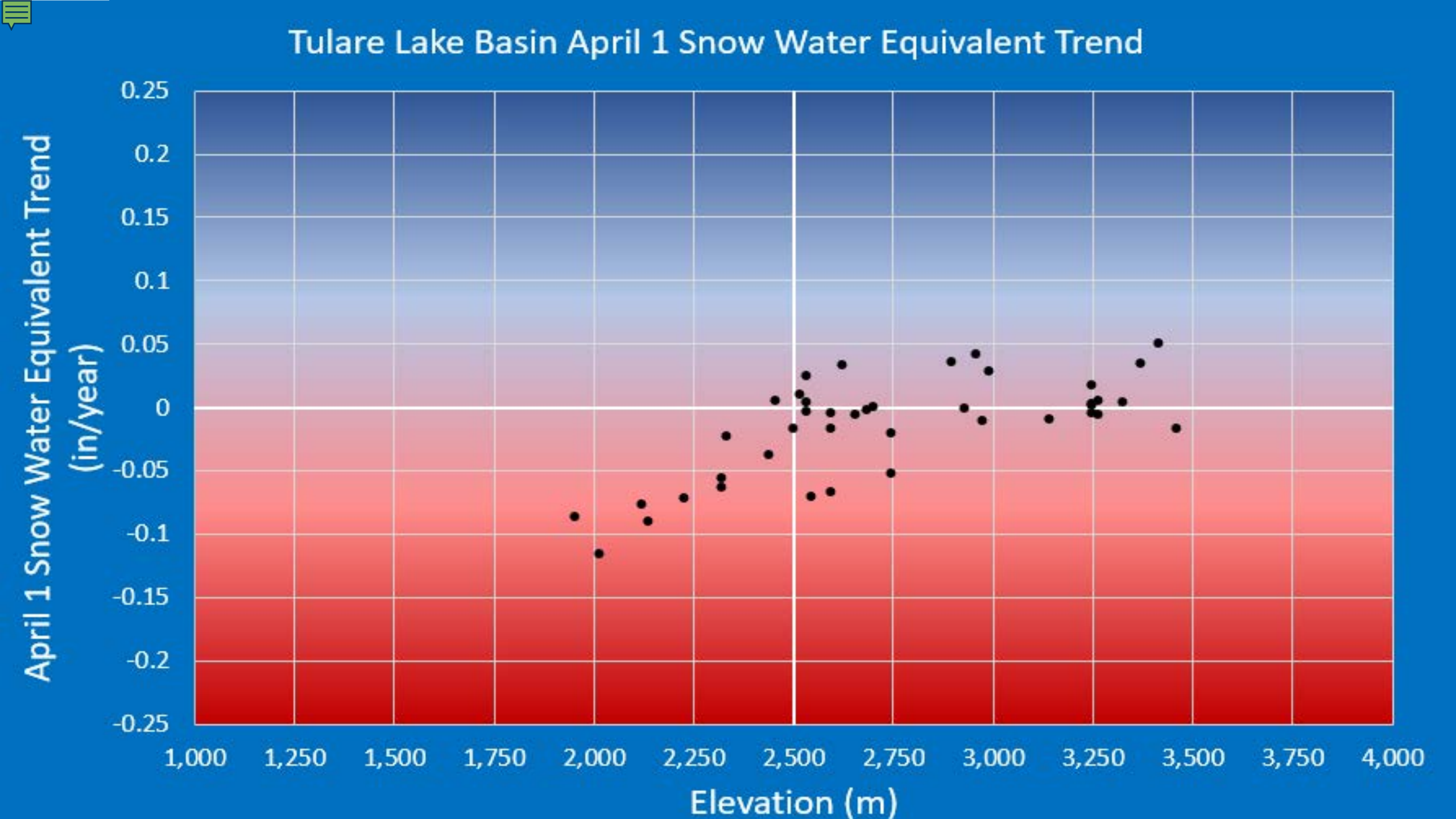
Watershed Elevation Curves

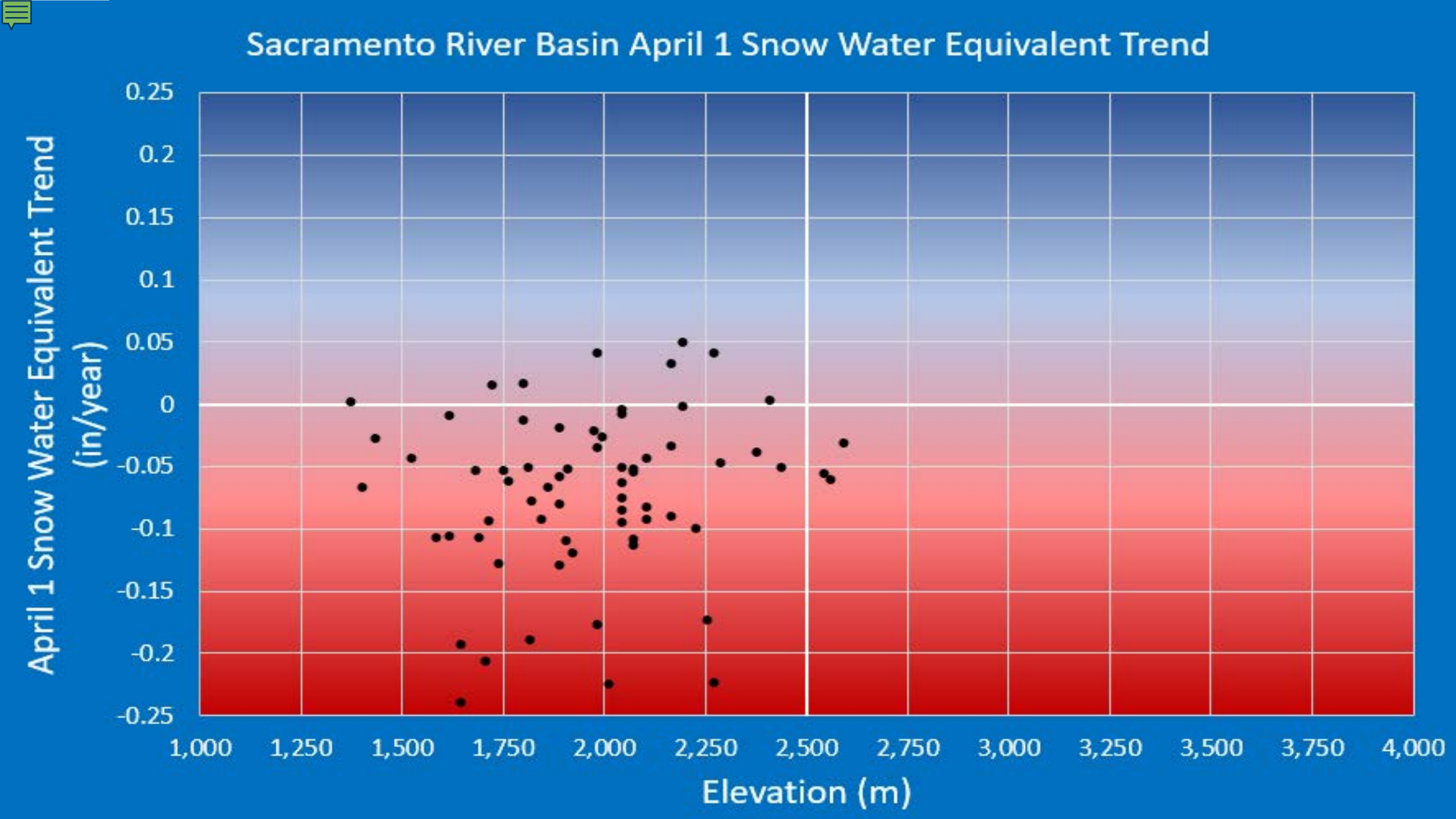



Watershed Area vs. Elevation
Watershed Area (acres x 10^6)
18
16
14
12
10
8
6
4
2
0
0
250
500
750
1,000
1,250
1,500
1,750
2,000
2,250
2,500
2,750
3,000
3,250
3,500
3,750
4,000
4,250
4,500
4,750
Elevation (m)
Sacramento
San Joaquin
Tulare


April 1 Snow Water Equivalent Trend
April 1 Snow Water Equivalent Trend (in/year)
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
Significant decrease <2500m
Little change >2500m
1,000
1,250
1,500
1,750
2,000
2,250
2,500
2,750
3,000
3,250
3,500
3,750
4,000
Elevation (m)

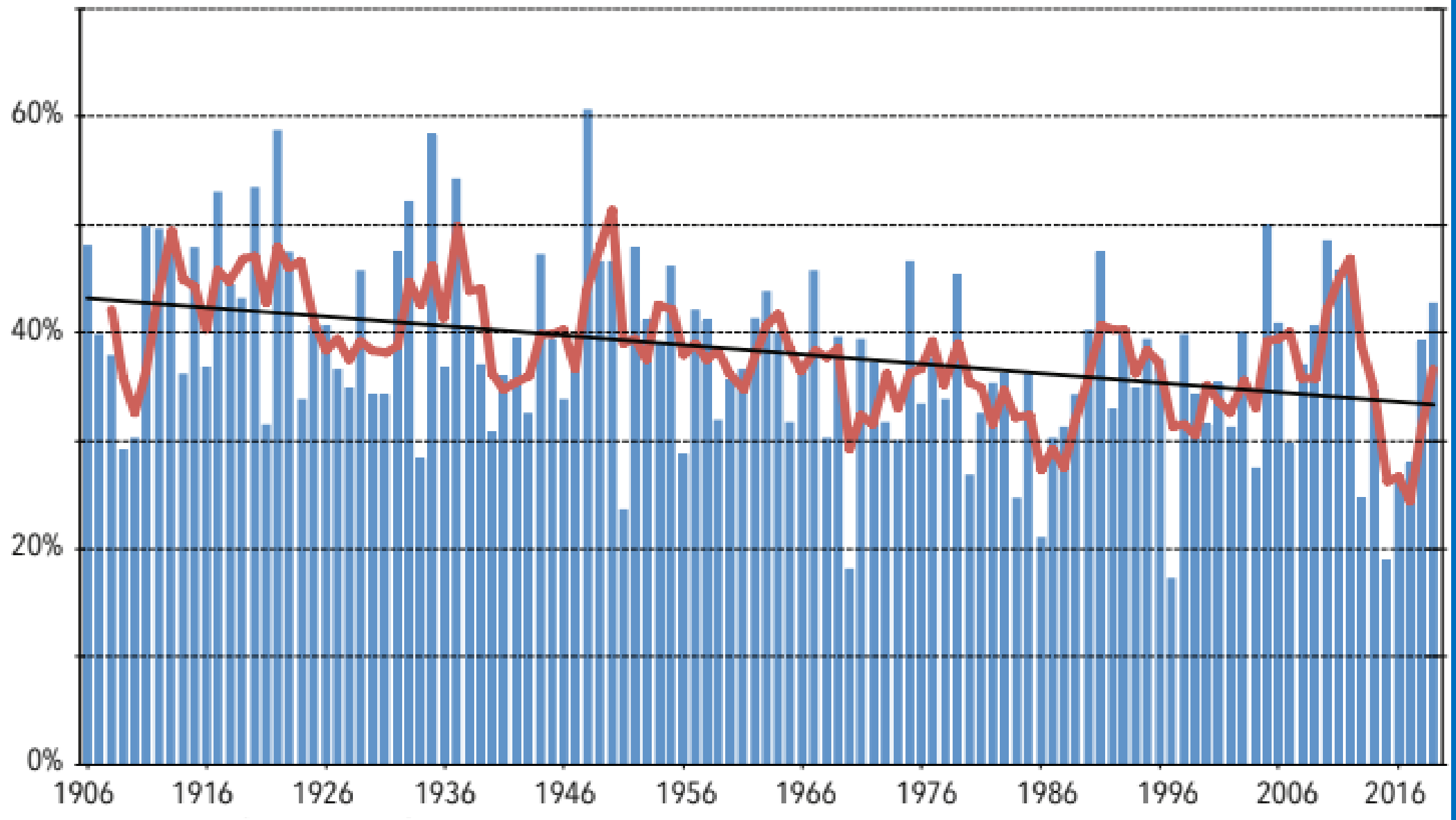

San Joaquin River Basin April 1 Snow Water Equivalent Trend
April 1 Snow Water Equivalent Trend (in/year)
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
1,000
1,250
1,500
1,750
2,000
2,250
2,500
2,750
3,000
3,250
3,500
3,750
4,000
Elevation (m)


Tulare Lake Basin April 1 Snow Water Equivalent Trend
April 1 Snow Water Equivalent Trend (in/year)
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
1,000
1,250
1,500
1,750
2,000
2,250
2,500
2,750
3,000
3,250
3,500
3,750
4,000
Elevation (m)

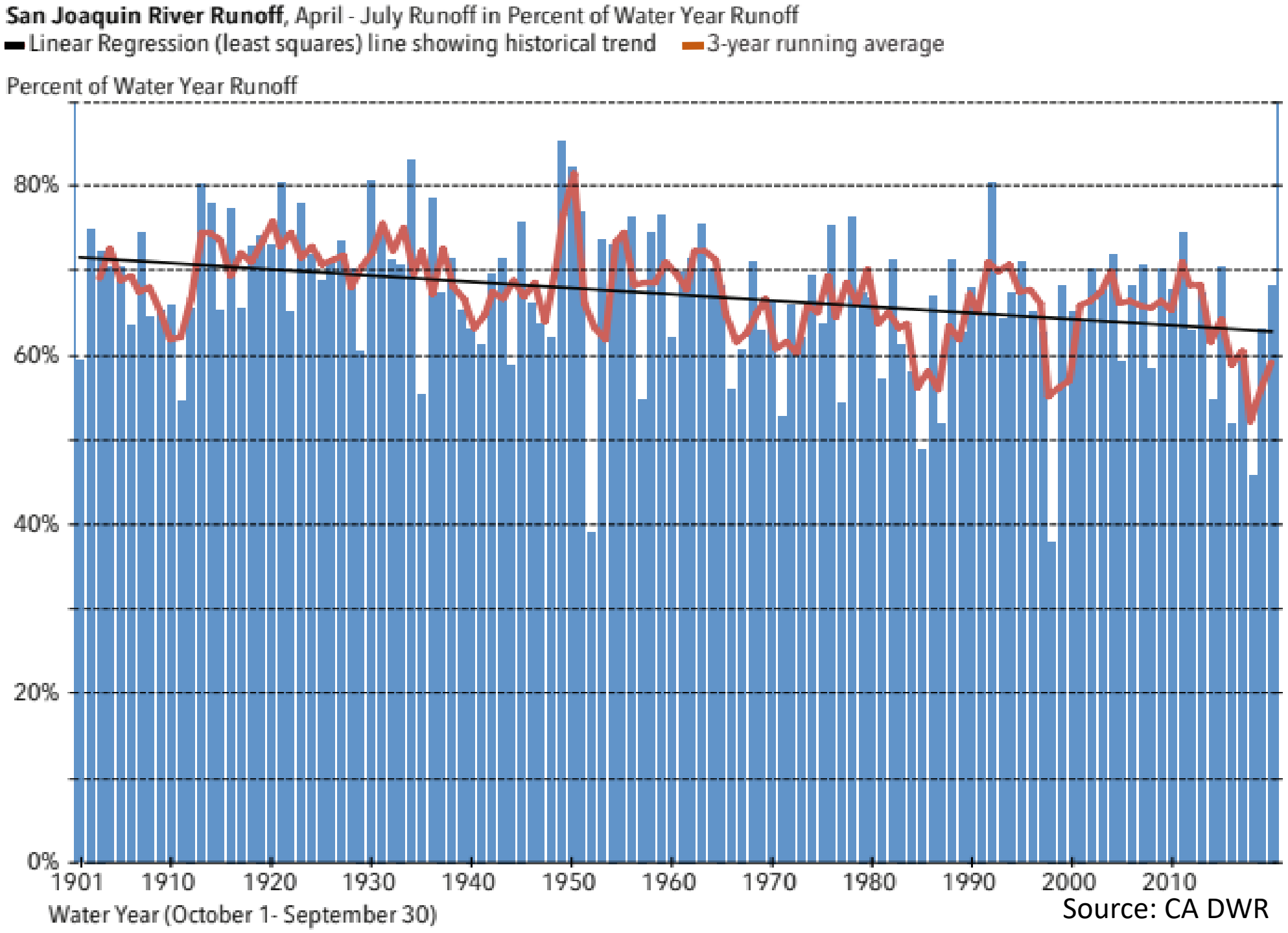

Sacramento River Basin April 1 Snow Water Equivalent Trend
April 1 Snow Water Equivalent Trend (in/year)
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
1,000
1,250
1,500
1,750
2,000
2,250
2,500
2,750
3,000
3,250
3,500
3,750
4,000
Elevation (m)

Sacramento River Runoff, April - July Runoff in percent of Water Year Runoff

Linear Regression (least squares) line showing historical trend — 3-year running average



Source: CA DWR



Source: CA DWR


WEST
Consultants, Inc.
Water
Environmental
Sedimentation
Technology
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Hydraulics
Reservoirs
Sediment Transport
Water Resources
Climate Change
River Forecasting
Land Management
Fish Passage
Photo: American Rivers

WESTERN HYDROLOGICS
WATER & HYDROPOWER CONSULTING

Western Hydrologics was created in 2018 by Jeff Meyer and Jared Emery who have over 45 years of combined experience working in Sierra Nevada Watersheds. We specialize in assisting our water supply and hydropower clients address complex environmental planning, resource management, economic, and operational challenges. Our mission is to develop creative, innovative and comprehensive solutions to these challenges. Our services include:

- Water Supply and Operations Planning
- Hydropower Operations Forecasting
- Hydro-Economic Modeling
- Water Rights
- Stream Gaging
- SB 88 Compliance

DAVIDS ENGINEERING, INC

Mission

At DE, we think globally and act locally, empowering water managers to develop technical solutions that sustainably address the challenges of our rapidly changing world.

Vision

DE's vision is to develop thoughtful, proactive, and dynamic leaders that are ready to reimagine western water management with cutting-edge solutions.

Experience

Davids Engineering brings decades of experience with water use analyses and demand modeling in varied and complex landscapes and with diverse stakeholders and perspectives.

Project Team





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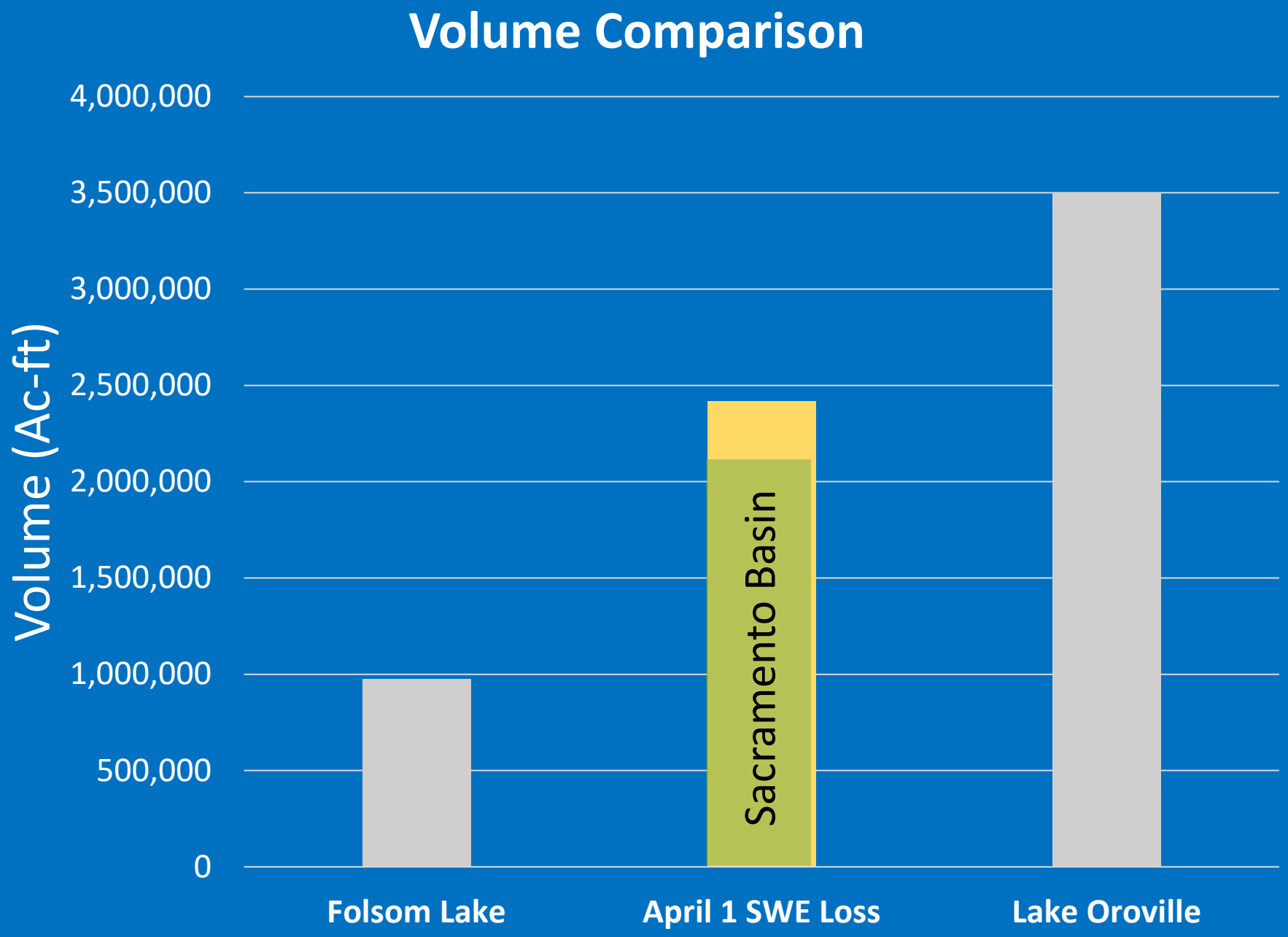
HDR


Volume Comparison
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Volume (Ac-ft)
Sacramento Basin
Folsom Lake
April 1 SWE Loss
Lake Oroville