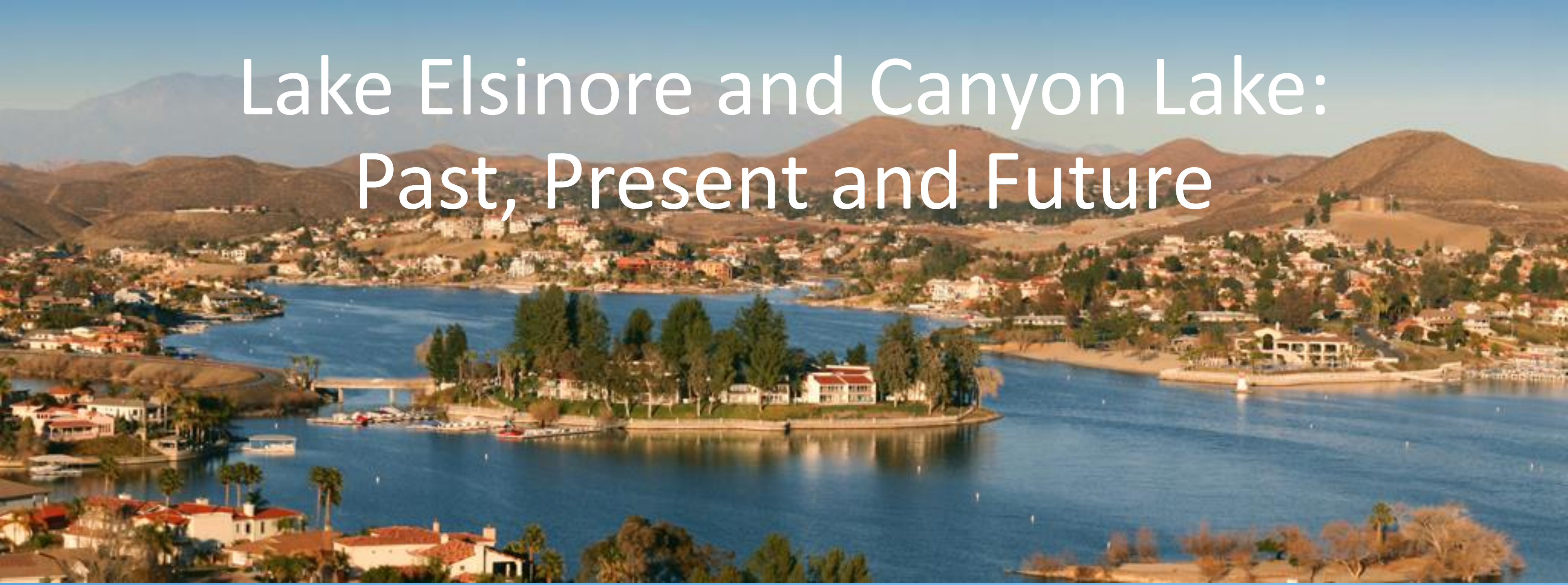
Lake Elsinore and Canyon Lake: Past, Present and Future



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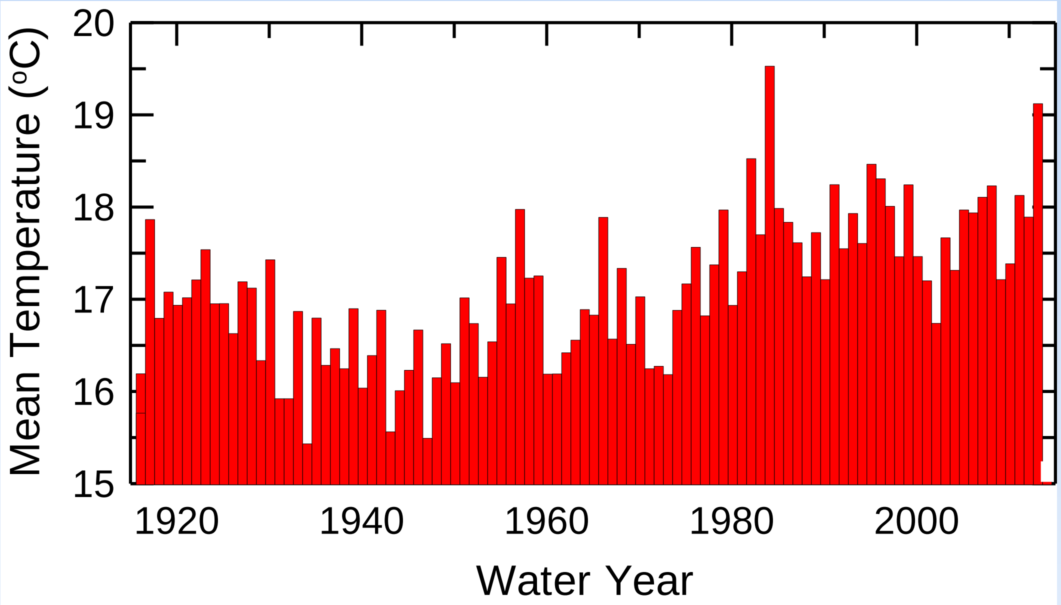
Introduction

- An extensive set of field and laboratory measurements and long-term computer simulations have provided important new insights into Lake Elsinore and Canyon Lake
- The objective of this presentation is to share some of the results from these studies and to use this new understanding about their past to better understand and guide their future

A Look at the Past 99 Years (1916-2014)

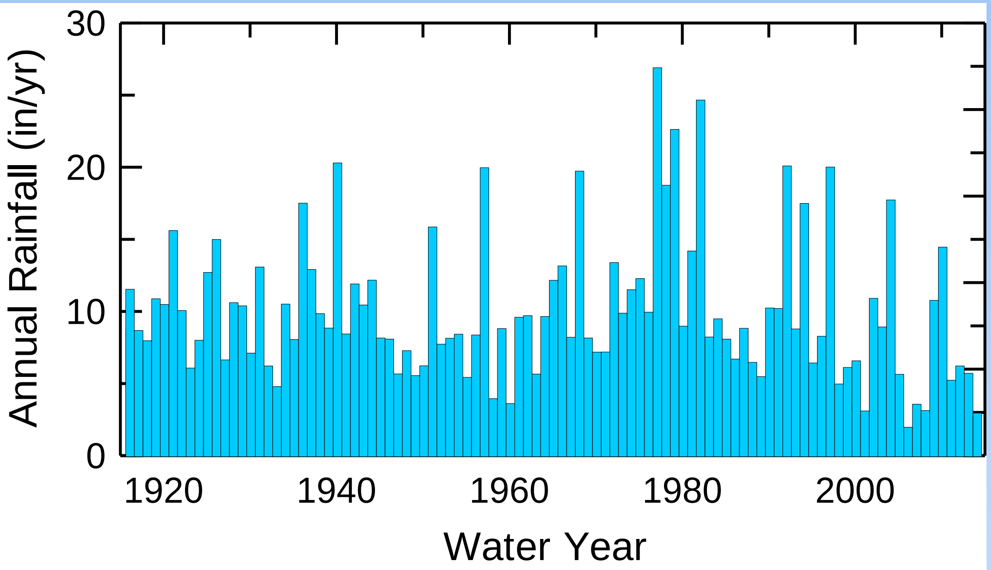
- We are fortunate to have records of daily rainfall, air temperature and San Jacinto River flows into Lake Elsinore extending back to 1916
- To understand our lakes, it is important to understand the natural variability of our region's climate

Annual Temperature (NOAA)



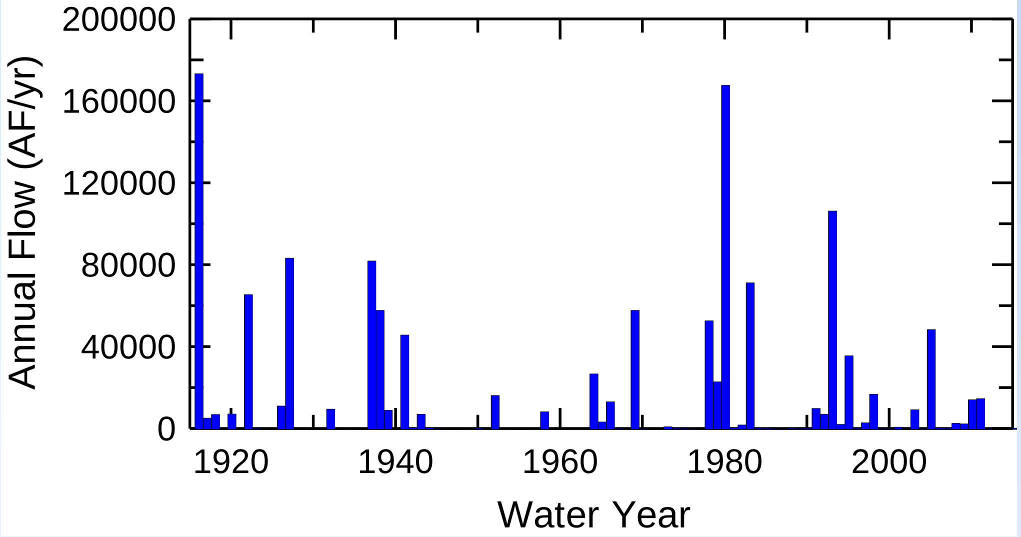
Min = 15.4 °C (1934)
Max = 19.5 °C (1984)
Mean = 17.1 °C
ΔT/yr = 0.016 °C/yr
1.6°C vs 1.0 °C globally

Annual Rainfall



Min = 2.04” (2006)
Max = 26.97” (1977)
Mean = 10.1”
Median = 8.89”

Annual San Jacinto River Flow (USGS #11070500)

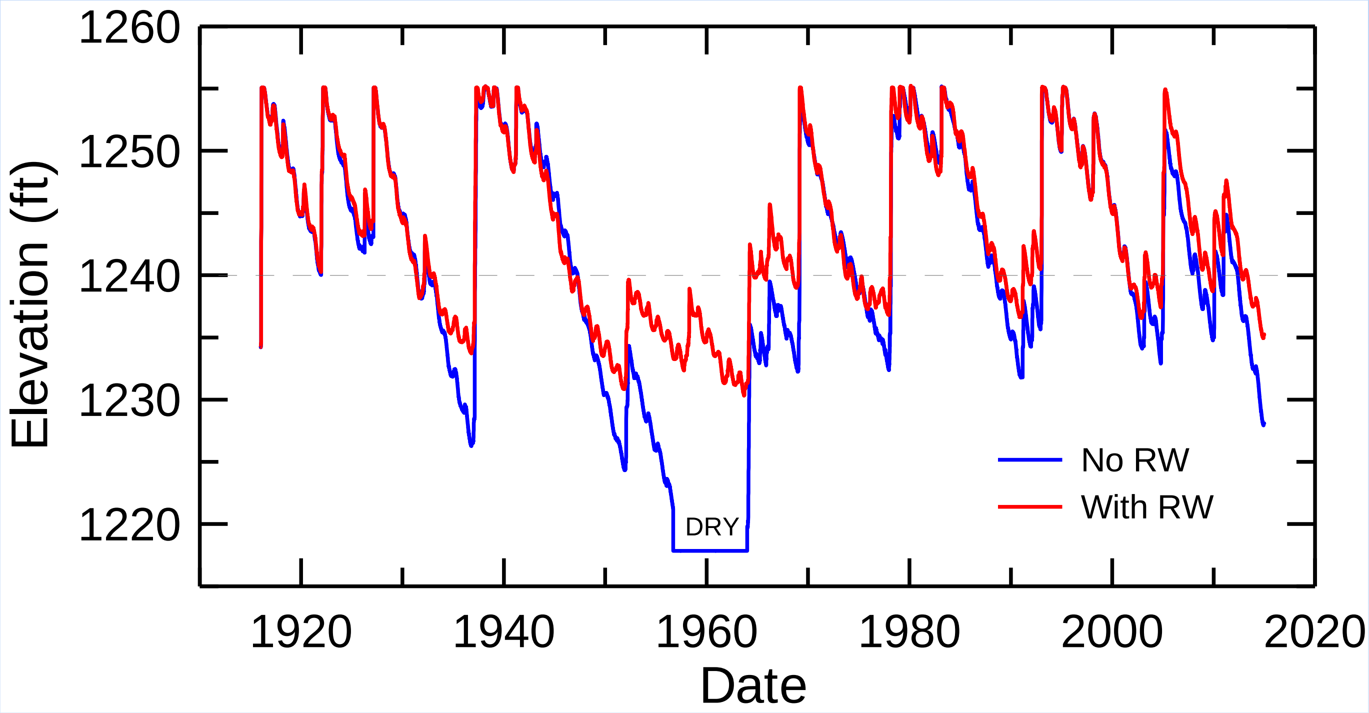


Min = 0 AF (5 yrs)
Max = >175,000 AF
25 yrs <100 AF
22 yrs >10,000 AF

- The hydrological and climatic conditions vary dramatically over time in the watershed
- We can use this data as input to numerical models for the lakes to understand how these factors affect lake level and water quality
- For example, we can calculate lake level and quantify the effects of recycled water addition on lake level in Lake Elsinore

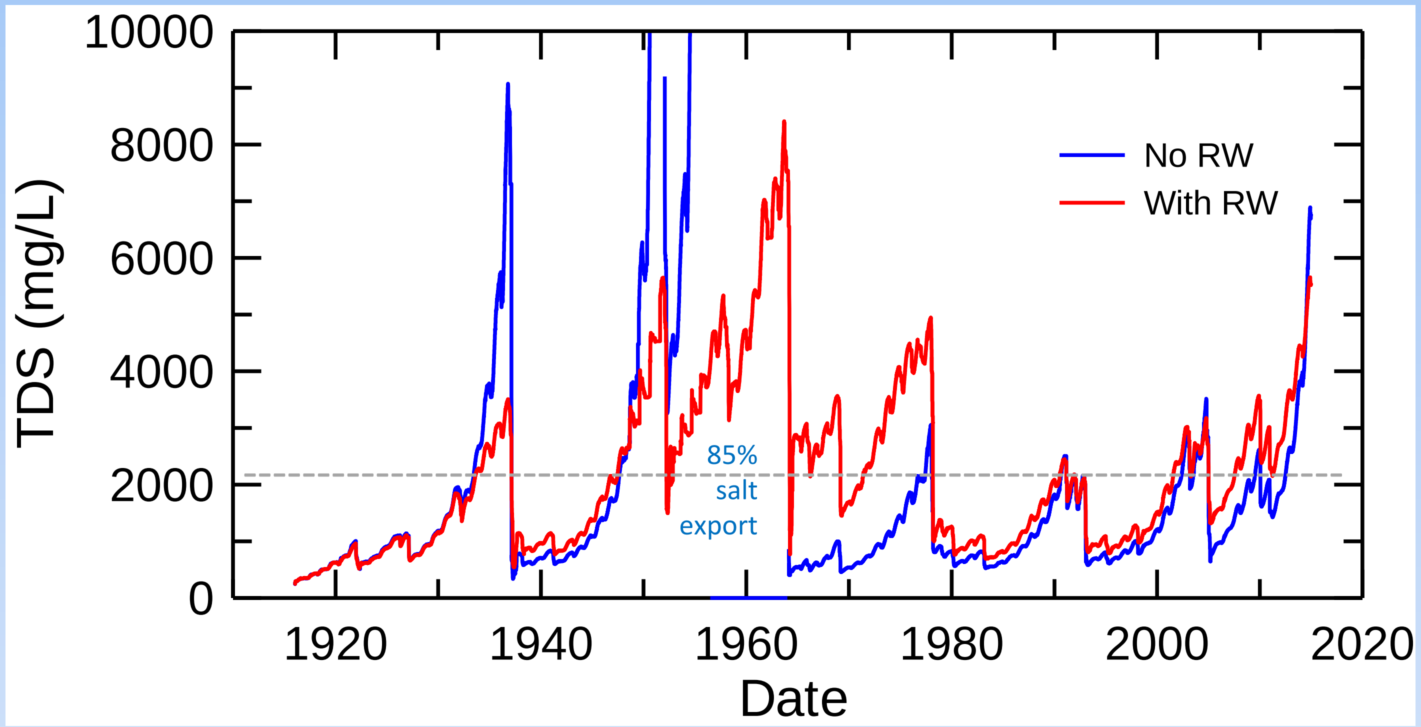
<u>Lake Level</u>

(LEMP)



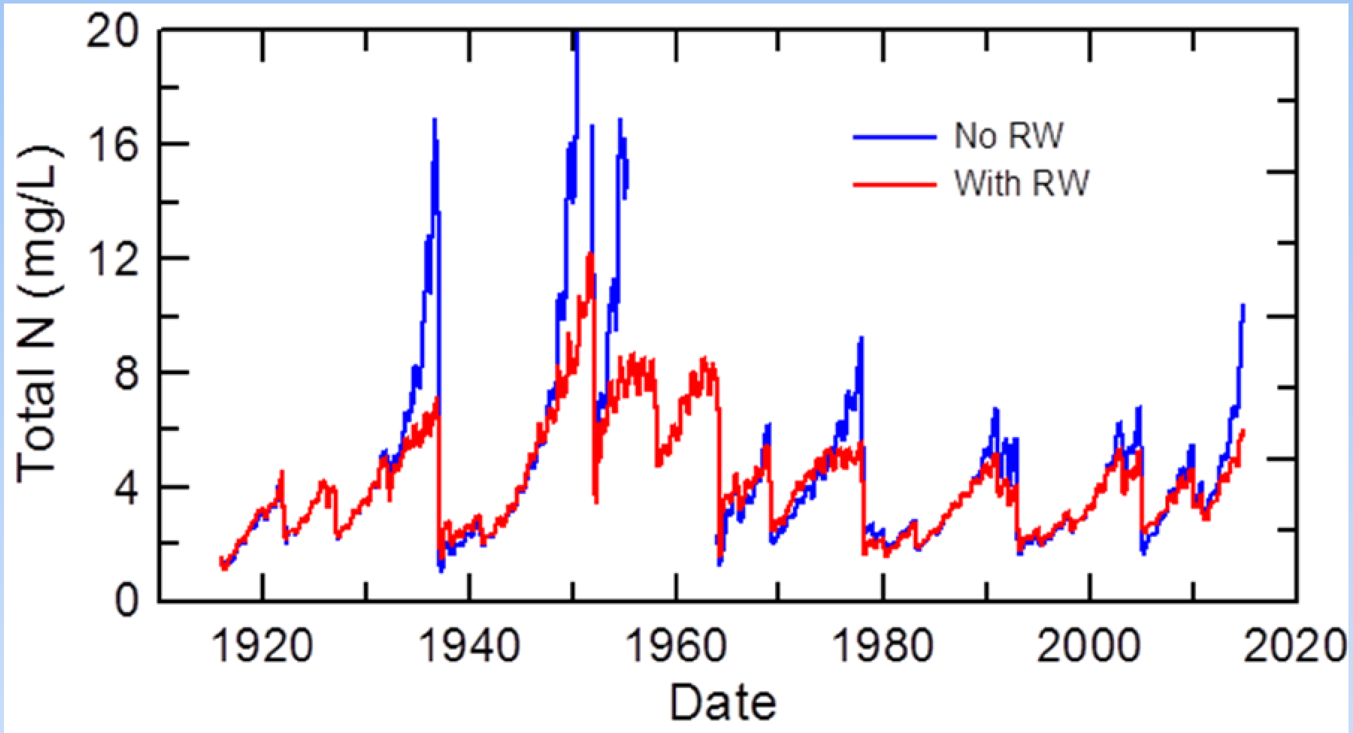
Salinity

- Salinity is recognized as a critical factor in health of Lake Elsinore



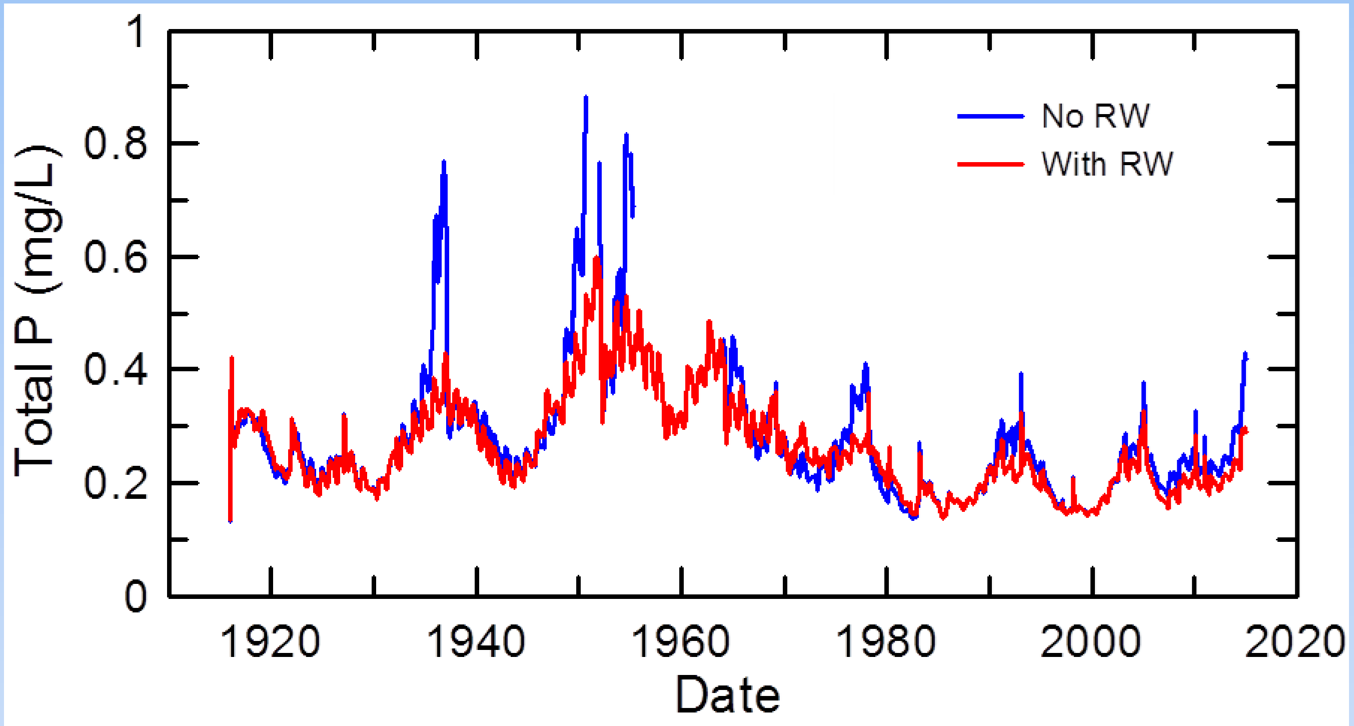
- Salinity concentrations without RW inputs varied in response to watershed inputs and evapoconcentration
- Input of RW maintains water in lake and prevents extreme TDS levels from developing (e.g, late 1930s and early 1950s)
- Flushing of salt out of lake during extreme runoff in 1978-79 normalized lake TDS levels with and without recycled water

Total N



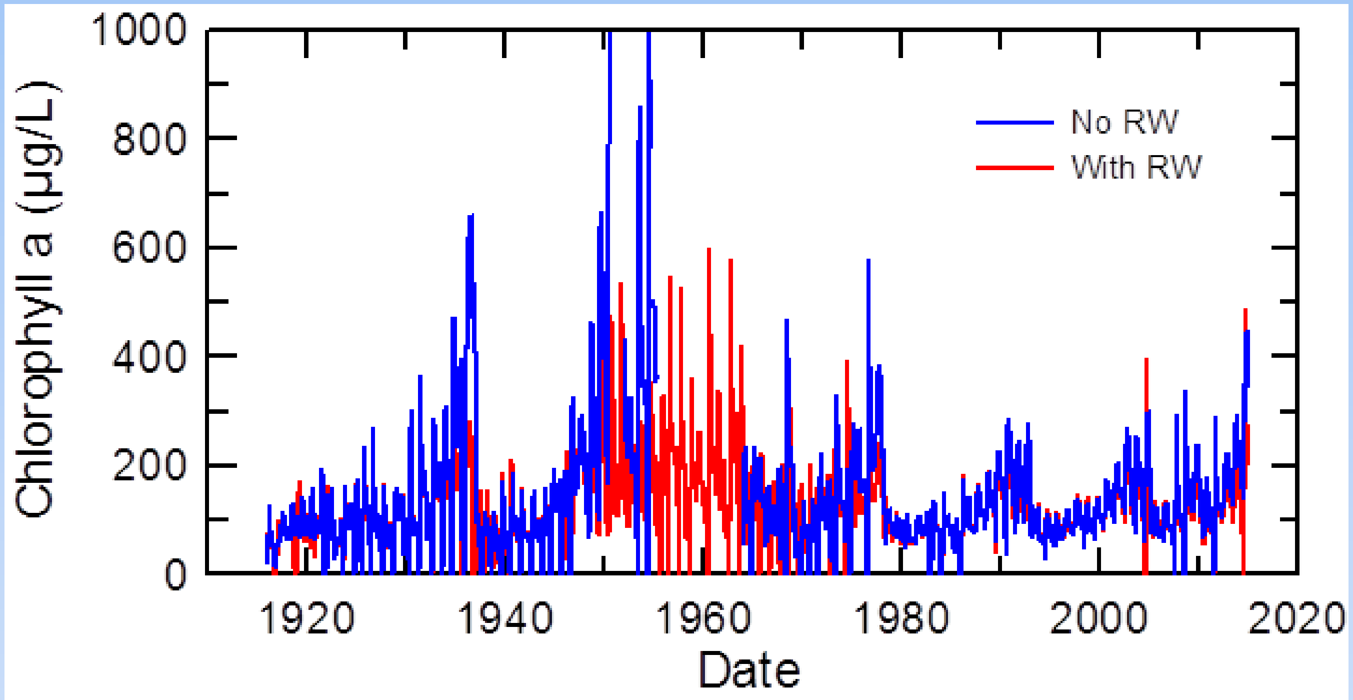
- Total N concentrations without RW inputs varied in response to watershed inputs and evapoconcentration
- Inputs of RW not predicted to markedly increase total N concentration in the lake, and in fact lowered concentration when lake level very low (and evapoconcentration high)

Total P



- Similar to total N, recycled water supplementation did not substantially alter predicted concentrations, and was predicted to *decrease* P concentrations relative to no RW inputs at low lake levels due to:
  - Dilution during periods of otherwise strong evapoconcentration
  - Evidence for incorporation into food web and subsequent settling
  - System predicted to return to values of 0.2-0.25 mg/L

Chlorophyll a



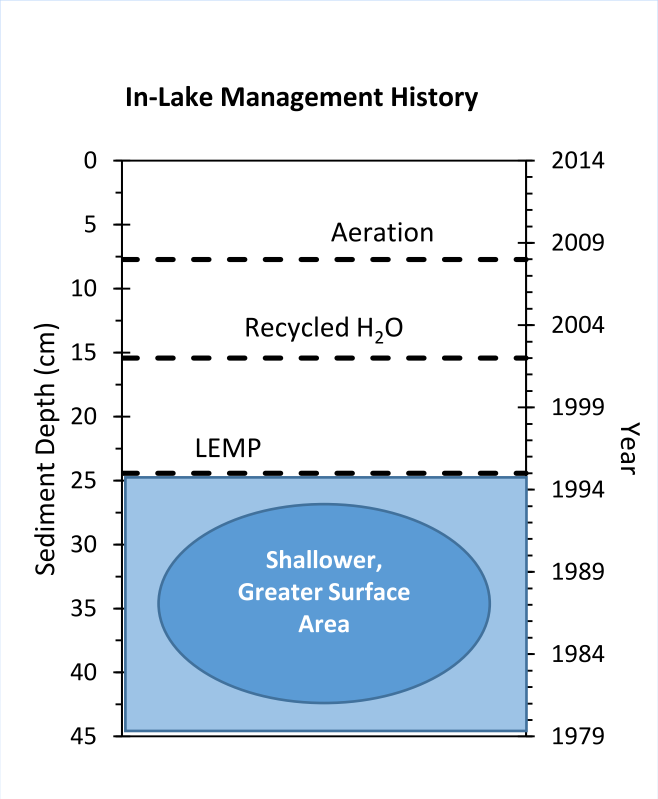
- Predicted daily chlorophyll a concentrations varied dramatically over simulation period, with levels reaching 1000 µg/L during periods of very low lake levels
- Recycled water additions had little effect on chlorophyll a concentrations owing to similar nutrient levels as natural runoff

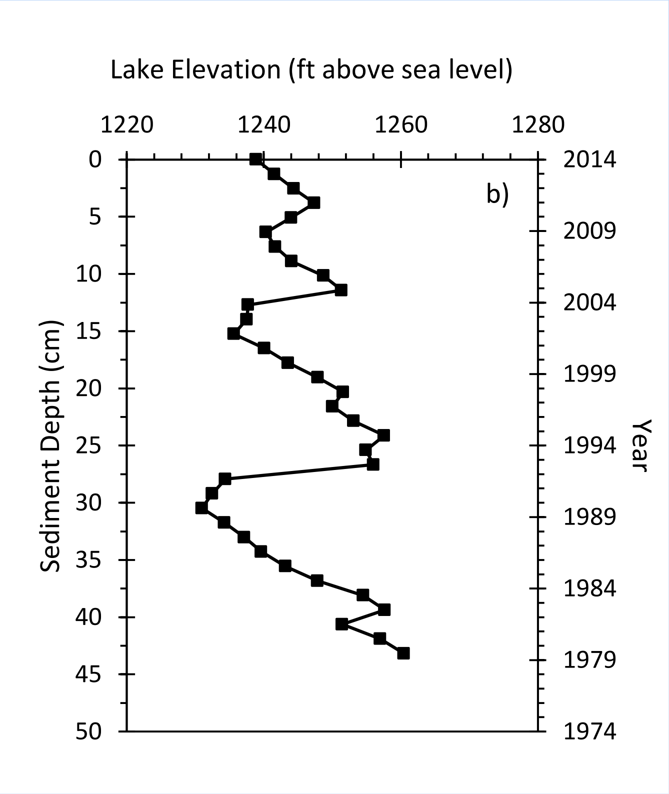
Mean Predicted Values: 1916-2014				
	Mean Concentration (mg/L or µg/L)			
	DO	Total N	Total P	Chl a
No RW	8.85	4.27	0.27	140
With RW	8.30	4.20	0.26	125
With RW+Aeration	9.03	4.01	0.24	125
With RW(0.1 PO_4)+Aer	9.02	4.01	0.23	125

- Recycled water inputs *lowered* slightly the average DO, TN, TP and chlorophyll a concentrations in lake relative to no recycled water inputs
- Supplementation with recycled water coupled with aeration
  - increased mean DO level
  - decreased slightly TN and TP concentrations
  - did not affect average chlorophyll a levels
- Reduction of PO_4-P in recycled water to 0.1 mg/L was not predicted to alter (99-yr) average values; median and shorter intervals differ more

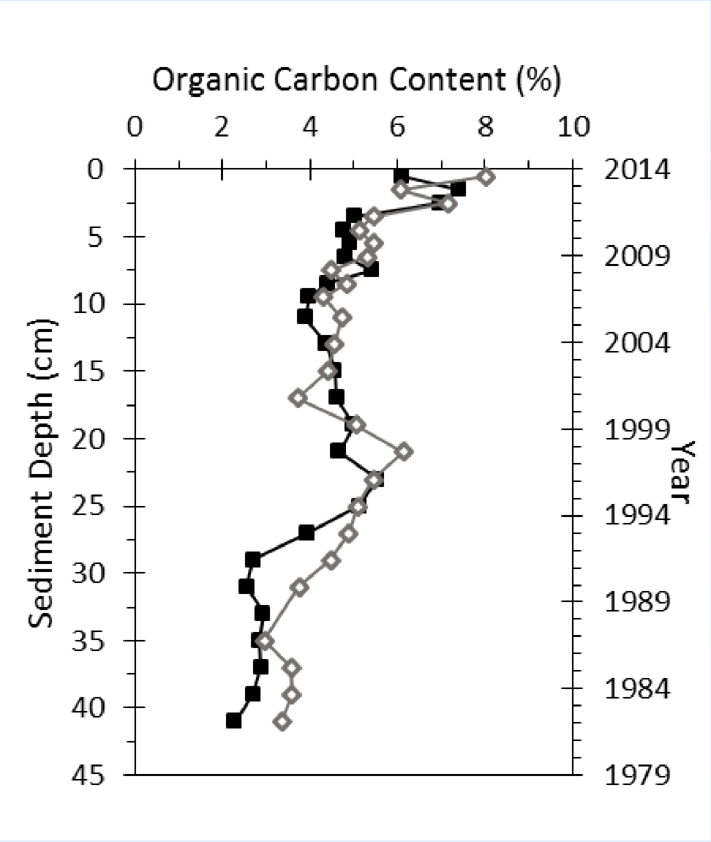
Sediment Record of Conditions in Lake Elsinore

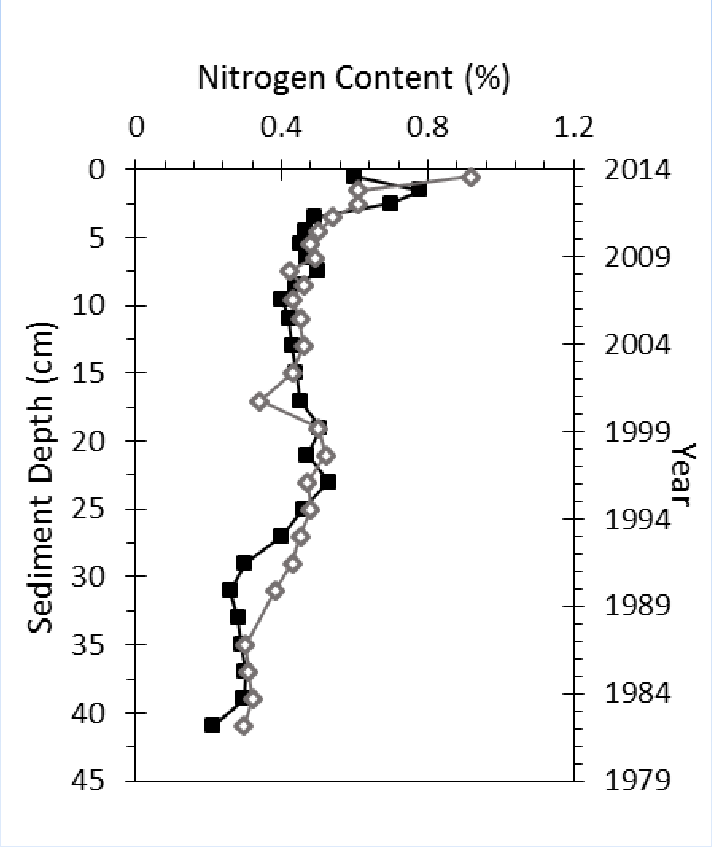
- While we have some recorded events for Lake Elsinore, including dry lake bed from mid-late 1950's – 1964, the lake itself has also provided a record
- Sediment cores provide a record of conditions in the lake



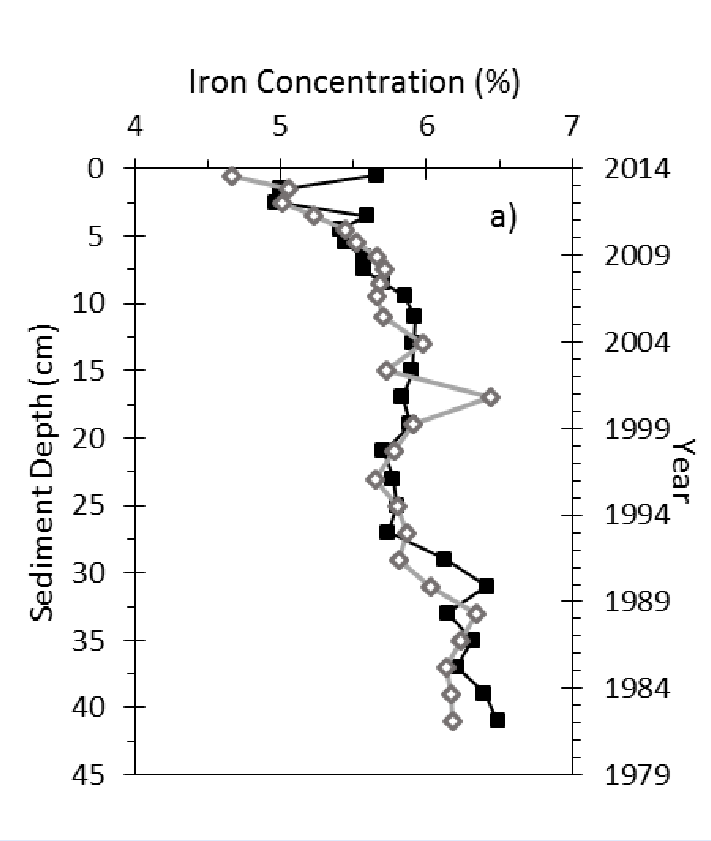


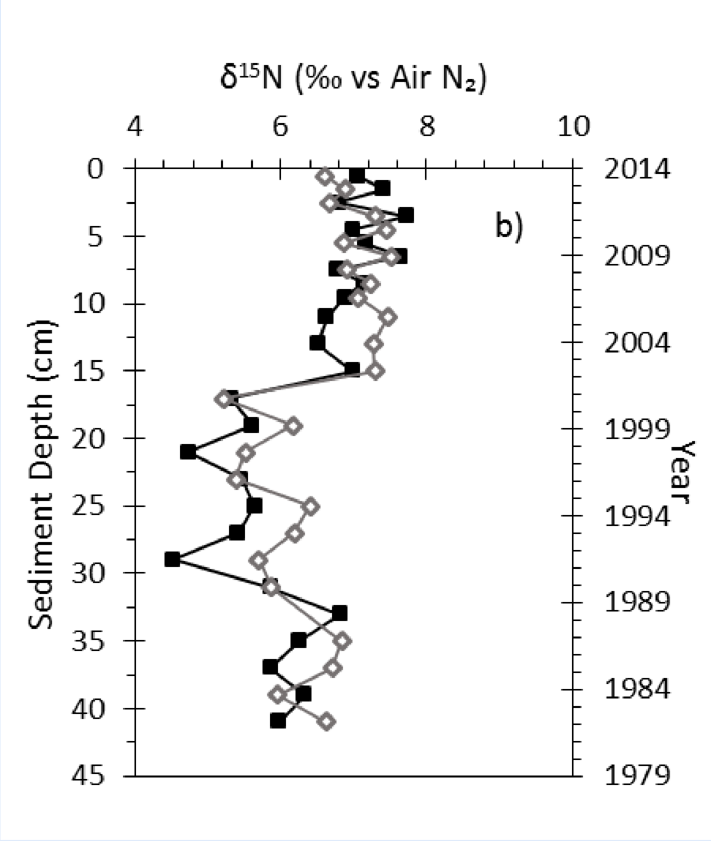
- Organic C and total N have both varied with depth and time
- Reductions in concentrations in top 5-10 cm (4-8 yrs) due to microbial processing and diagenesis
- A notable shift happened around 1990-1995 coincident with the completion of LEMP; smaller deeper lake may have enhanced organic matter preservation within the sediments





- We also see changes in other sediment properties, including total Fe and $\delta^{15}N$, indicating fundamental changes resulting from management actions at lake
- $\delta^{15}N$ informs us about N uptake and transformations
  - <1980 – 1989: Natural lake signature for N
  - 1989 – 2002: Construction of LEMP and smaller deeper lake
  - 2002 – 2014: Recycled water additions to lake



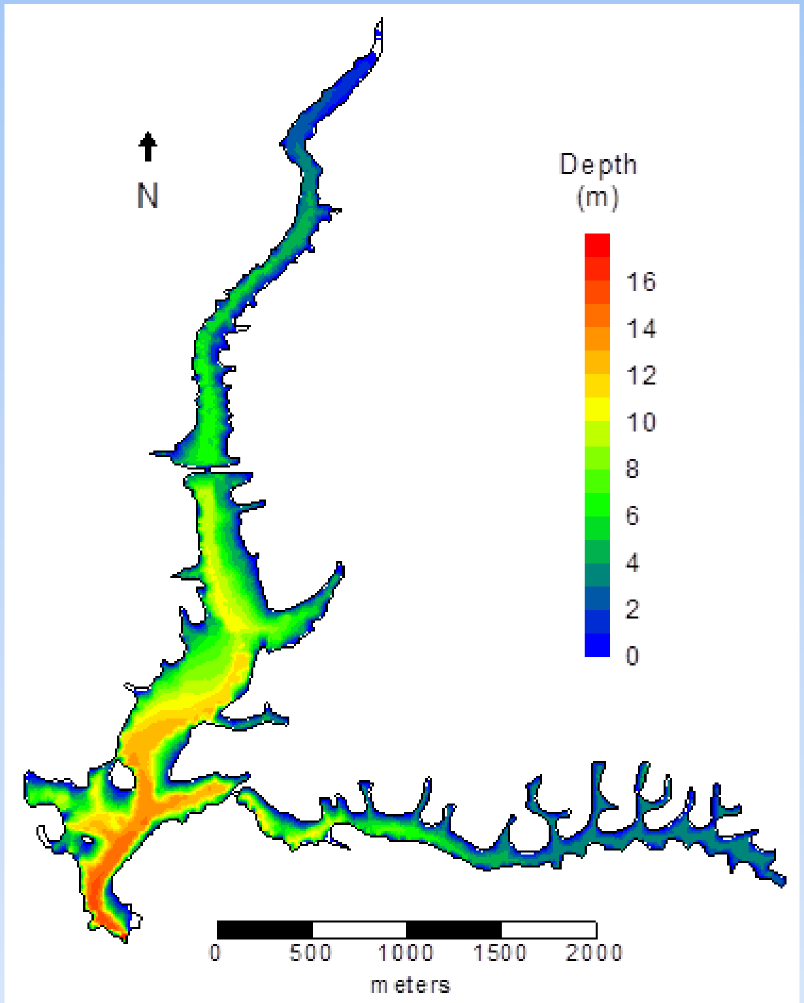


Comparison of concentrations of P in different forms within sediments of selected lakes in Southern California.				
Lake (n=# sites)	Mean Phosphorus Fractionation in Sediments (µg g^{-1} dw)			
	NH_4Cl-P	Fe-P	Mobile-P	NaOH (Al)-P
Big Bear L. (n=15)	1 (1%)	129 (99%)	130	191
Canyon L. (n=5)	59 (13%)	386 (87%)	459	890
L. Elsinore (n=2)	120 (63%)	70 (37%)	190	150
Diamond Valley L. (n=20)	1 (1%)	91 (99%)	92	268

- Canyon Lake has much higher levels of mobile-P (P that can be released from sediment) than other lakes
- Lake Elsinore has a much lower mobile-P content, with little Fe-P
- These observations result from Canyon Lake serving as a sediment trap and limiting downstream transport of sediment
  - Low Fe-P accounts for limited effectiveness of aeration at controlling P in Lake Elsinore; aeration would be more effective in Canyon Lake
  - Reducing water column and sediment mobile-P is target for alum

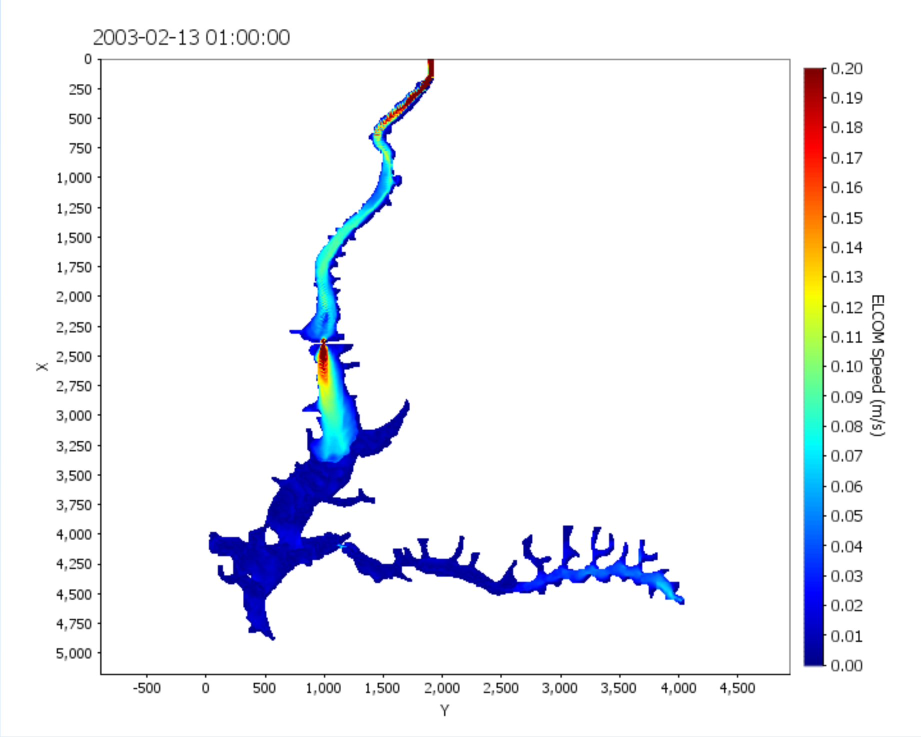
Canyon Lake

- A detailed bathymetric map was developed for Canyon Lake from a 2-day hydroacoustic survey conducted in December 2014
- This survey provided an up-to-date assessment of lake capacity
- Substantial sedimentation has lowered capacity relative to 1993 storage curve
- Sub-bottom profiling with 38-kHz transducer further indicates that >5 m of sediment has been deposited in many regions of the lake since its construction about 100 years ago



Canyon Lake

- A 3-D model for Canyon Lake has recently been developed
- While simulations are ongoing, a detailed model will better capture the complex hydrodynamics and water quality observed across the lake



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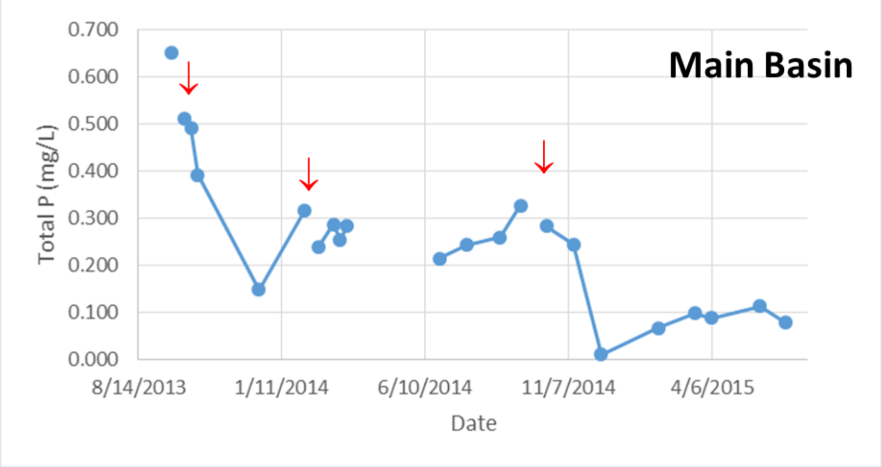
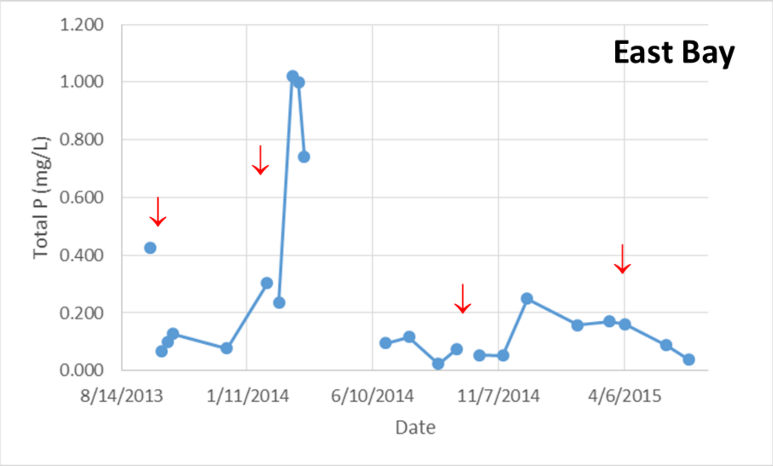
Present

Canyon Lake

- A series of alum applications to the main bay and east bay of Canyon Lake have been conducted
- Alum binds PO4-P and reduces its availability for algae





- The total P levels were consistently lower in the main basin following alum treatment than in 2009-2012 when total P was 0.4-0.8 mg/L
- Concentrations were also lower in East Bay, although the storm on February 27, 2014 introduced additional P into East Bay that have since declined to ~0.1 mg/L

Lake Elsinore

- A diffused aeration was installed in 2008 to improve mixing and reduce frequency and severity of low dissolved oxygen (DO) events and resulting fish kills
- Since that time, no large fish kills have been observed, although a couple of smaller fish kills have nonetheless occurred
- High salinities and low lake level have dominated the lake over the past several years as region gripped by prolonged drought
- These unfavorable conditions have affected the water quality and ecology of the lake
  - Transparency was <10-15 cm throughout spring-summer of 2015
  - Phytoplankton community dominated by *Pseudanabaena* →
  - Zooplankton community dominated by copepods (~no *Daphnia*)

↲

Future

- Simulations provide improved insights into past, present and future water quality and ecology of lakes
- Supplementation of Lake Elsinore with recycled water:
  - Prevents the complete dessication of lake witnessed in 1950s-60s
  - Predicted to maintain minimum level of 1232-1234’
  - Has limited effect on mean DO concentration in lake, but increased range of water column DO concentrations
  - Has negligible effects on average total N and total P concentrations
  - Predicted to lower slightly chlorophyll a concentrations
- Overall, model predictions do not indicate marked effects on water quality resulting from periodic inputs of recycled water to help maintain lake level
- Salinity in Lake Elsinore is a concern; high salinity:
  - Impairs sport fish and beneficial zooplankton reproduction
  - Negatively alters food web and water quality
  - Outflows needed to remove salts from lake and maintain conditions

- Canyon Lake is less severely affected by drought relative to Lake Elsinore owing to its position in the watershed and relatively small size
- Notwithstanding, it to is subject to declines in lake level, although salinity accumulation is not a concern since it frequently spills to Lake Elsinore
- Soils and sediment eroded from the watershed are deposited in Canyon Lake resulting in rapid sedimentation and infilling
- These sediments are enriched in mobile-P, especially in a reducible Fe-P phase
- Control of PO4-P via alum has shown meaningful progress, although continued in-lake controls along with watershed BMPs are needed to further improve water quality
- New 3-D modeling for Canyon Lake will provide greater understanding of relationships and unique water qualities of the distinct north, main and east basins

Conclusions

- The complex hydrology of the region presents unique challenges in managing Lake Elsinore and Canyon Lake
- These challenges will increase in the face of climate change that will raise temperatures, increase evaporative losses, and further increase climate variability in the coming decades
- Application of numerical models offer valuable insights in their past, present and future
- Continued and creative efforts will be needed within the lakes and their watersheds to manage and help them meet their beneficial uses