

Long-Term Water Quality Simulations  
for Lake Elsinore: Effects of Supplementation  
with Recycled Water (v.2)

*Michael Anderson*  
*UC Riverside*

## Objectives

Evaluate impacts of recycled water inputs on key water quality measures (chlorophyll a, DO, total N and total P concentrations) relative to no recycled water supplementation

## Approach

Extend previously developed DYRESM (Dynamic Reservoir Simulation Model) that quantified water budget and provides 1-D hydrodynamic/thermodynamic/salinity predictions

CAEDYM (Computational Aquatic Ecosystem Dynamics Model) was linked to DYRESM model to predict water quality and ecological properties of lake

Period from 1916-2014 simulated using LEMP basin and meteorological and runoff data for this interval as described in Tech Memo 1.1

Water quality model was calibrated against available 2000-2014 data

Influent concentration data were taken from a range of sources

Source	TDS (mg/L)	PO4-P (mg/L)	Total P (mg/L)	NH4-N (mg/L)	NO3-N (mg/L)	Total N (mg/L)
San Jacinto R	310	0.28	0.50	0.22	0.57	1.62
Local Runoff	150	0.20	0.48	0.22	0.80	1.82
Recycled H <sub>2</sub> O	705	0.32	0.41	0.36	1.62	2.87

Default values were used for nearly all model parameters; a few parameters were adjusted to reflect observed conditions in lake

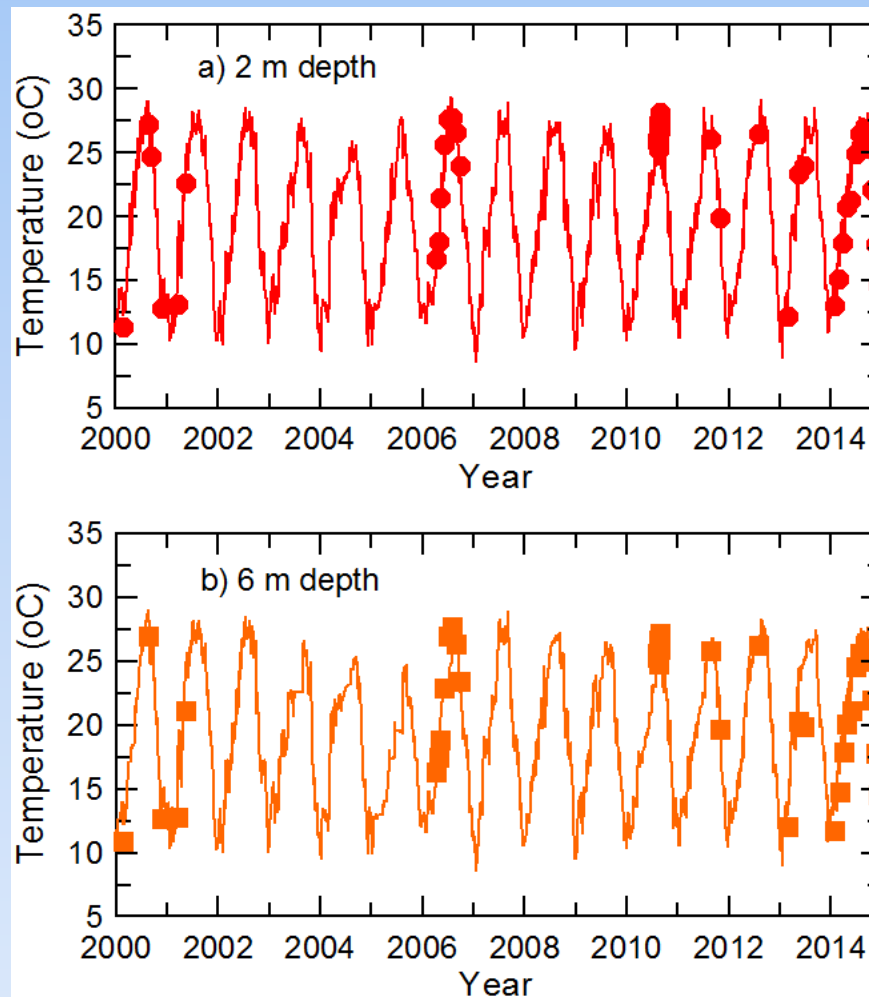
## Model Calibration

### *Temperature*

Model reasonably reproduced representative measured temperature values at 2 m and 6 m depth

Strong seasonal trends evident, with summer temperatures 26-28°C and winter values typically near 11-12°C

Strong stratification was not predicted within water column, consistent with generally well-mixed conditions in lake



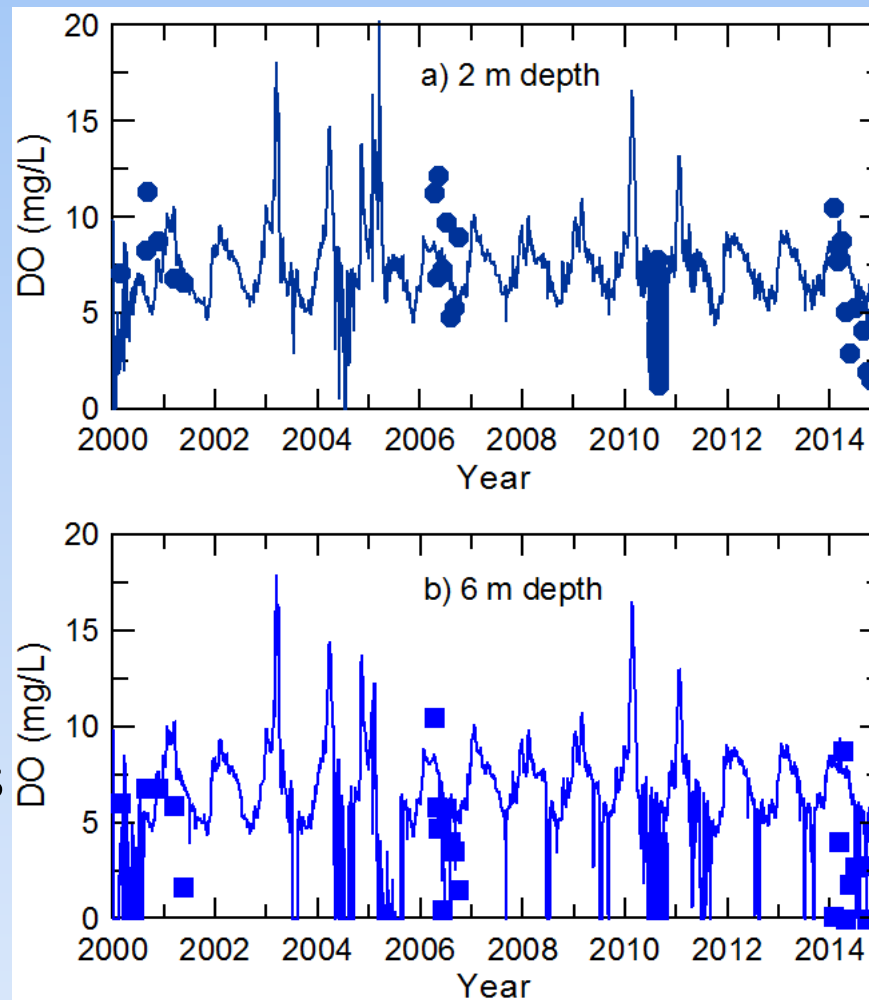
## *Dissolved Oxygen*

The model also predicted some seasonal trends in DO, with higher values during the winter cooler months when  $O_2$  solubility is greater

Evidence of both supersaturation and undersaturation was present

Model did predict some low surface DO episodes (e.g., in 2000, 2003 and 2010), but over-predicted concentrations in 2014

Correctly timing such episodes can be challenging



## Nutrients

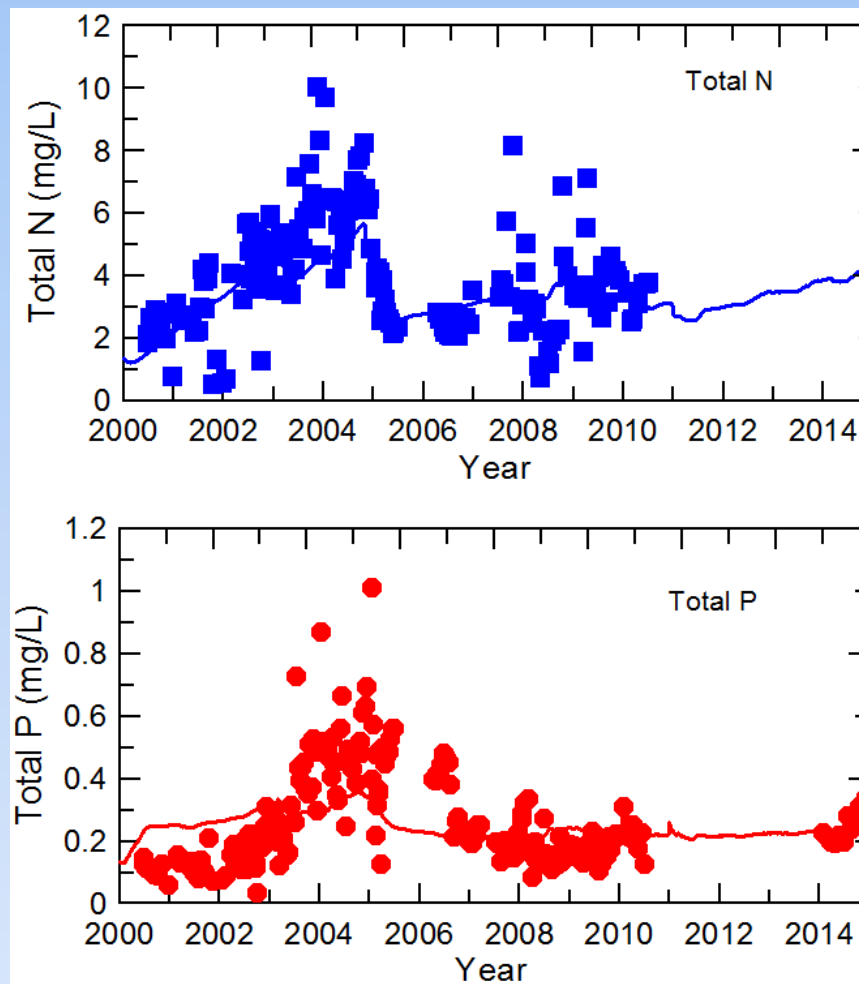
The model predicted general observed trends in total N concentrations

- Increased concentration from 2000-2004
- Marked reduction in 2005
- Subsequent increase in 2008-2010

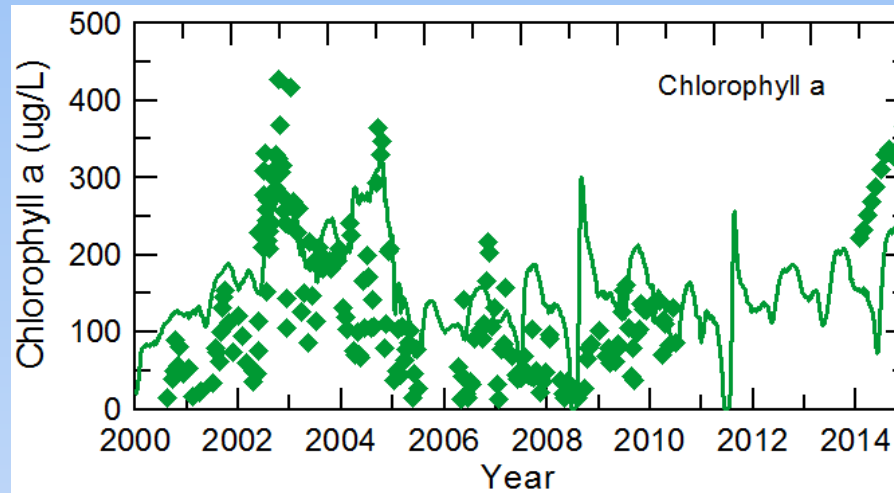
Model underpredicted total N concentrations in 2003-04

Total P baseline values reasonably described, but missed marked increase in 2003-04

- some of this increase attributed to sediment resuspension that was not adequately represented by model
- model not able to quantify resuspension due to benthivorous fish



- Chlorophyll a concentrations exhibited strong annual periodicity in both measured and predicted values
- Model reproduced high values in 2002-04 but overpredicted levels in late 2008



- It proved to be very difficult to capture the unique characteristics of *Oscillatoria*, which dominates the lake in especially in extreme algal events
- A simple comparison was conducted using the 2000-2010 period (when regular monitoring data available)

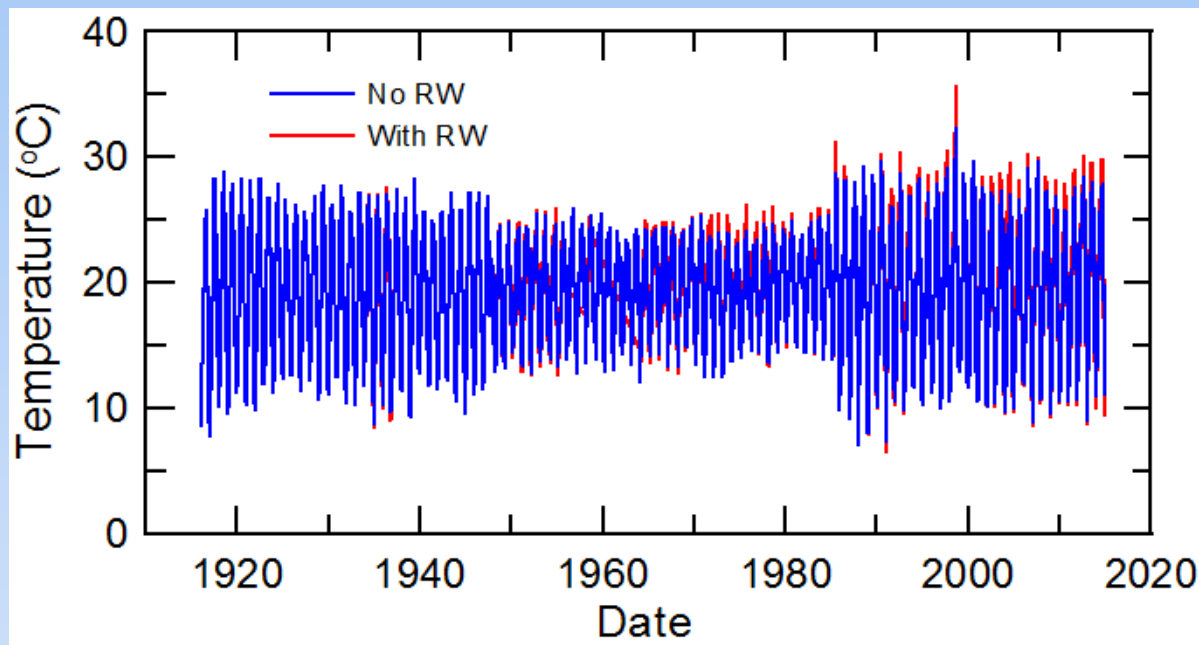
Mean predicted and observed values: 2000-2010				
	Observed	Predicted	% Error	<i>Prior Calibr</i>
Total N	3.98	3.39	-14.8	-18.1
Total P	0.265	0.246	-7.2	49.1
Chlorophyll a	130	157	20.8	-34.0

- Overall, model calibration for this dynamic period of time was improved relative to earlier calibration
- Model calibration included:
  - use improved data for recycled water
  - daytime diffused aeration operation
  - food web effects through incorporation of:
    - 2 zooplankton groups (Cladocerans, copepods)
    - 2 fish groups (shad, piscivores)
- Model is most useful for *relative (semi-quantitative)* comparison of water quality with/without recycled water inputs, food web alterations, etc. rather than rigorous quantitation



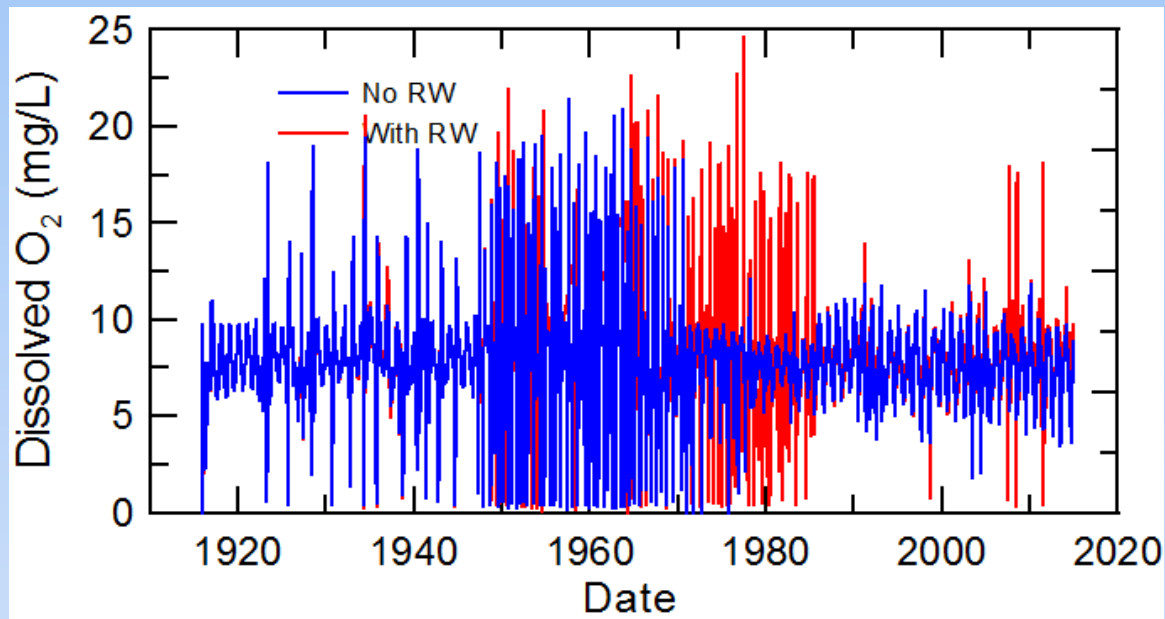
## Results

### *Daily Average Water Column Temperature*



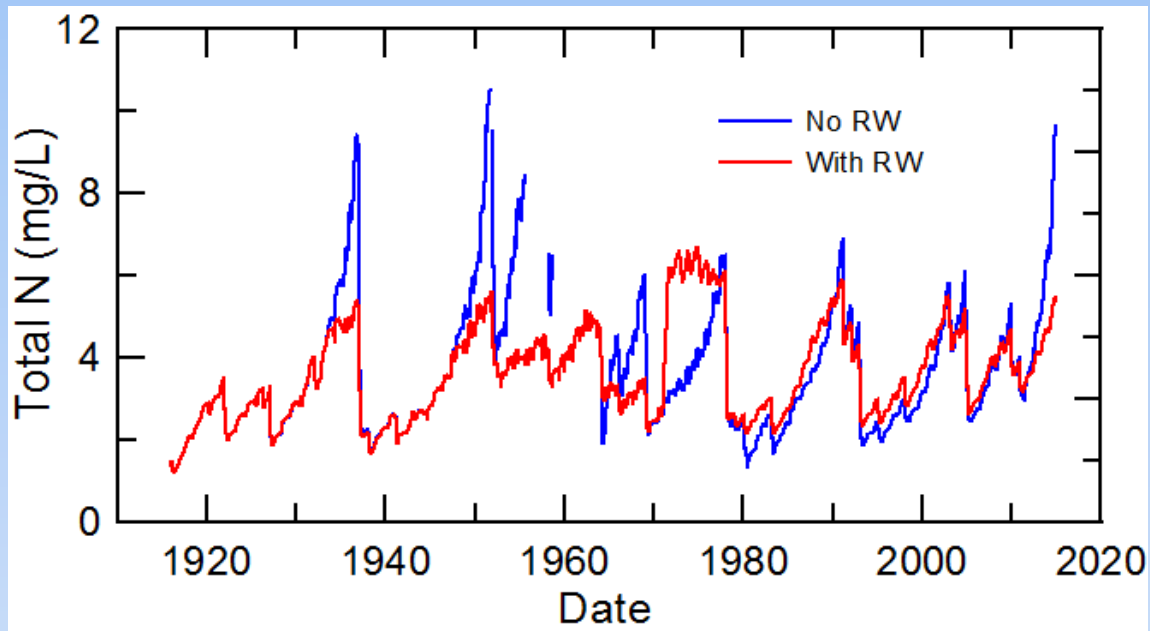
- Model predicted strong seasonal variation in average water column temperature
- Greater interannual temperature ranges in 1916-1945 and 1995-2014
- Recycled water inputs were not predicted to alter the heat budget or temperature of the lake

## *Daily Average Water Column DO*



- Predicted daily average water column DO levels varied modestly from 1920-1950 without RW
- Extreme oscillations predicted during low lake levels 1950-1970
- Periodic inputs of RW yielded even greater variance, often with DO supersaturation and anoxia

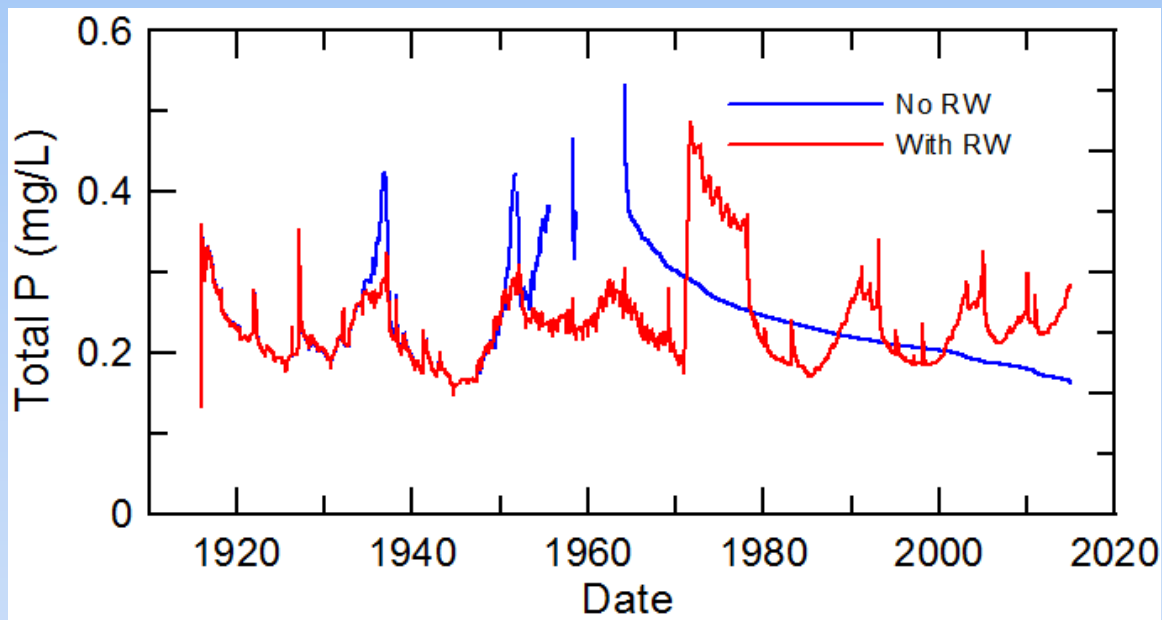
## Daily Average Water Column Total N



Total N concentrations without RW inputs varied in response to watershed inputs and evapoconcentration

Inputs of RW predicted to markedly increase total N concentration in the lake, beyond that due to evapoconcentration

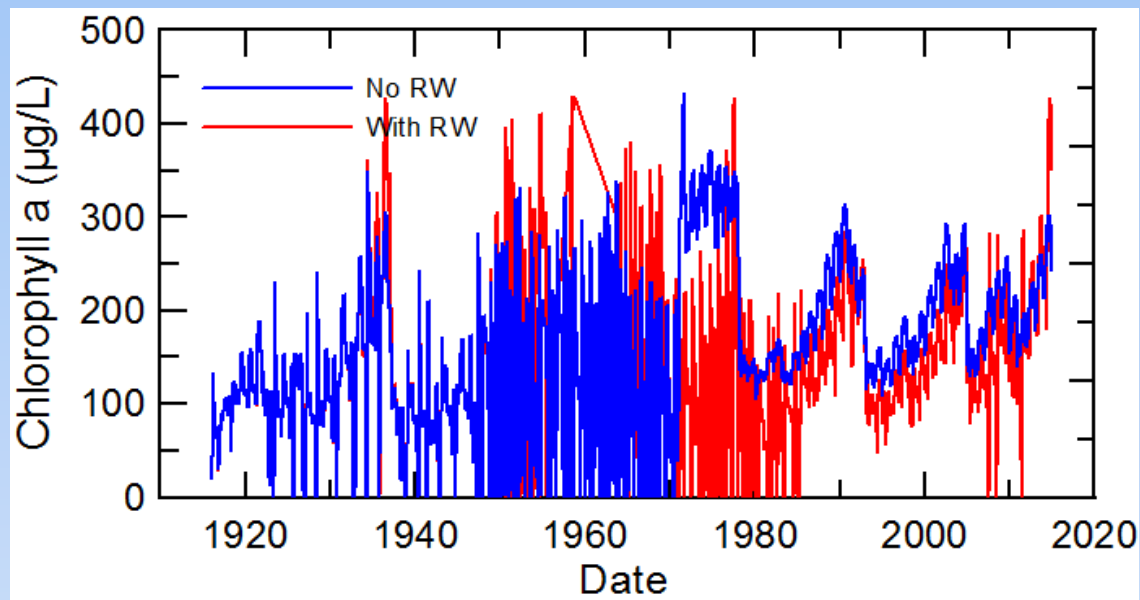
## Daily Average Water Column Total P



Recycled water supplementation was predicted to actually *decrease* P concentrations relative to no RW inputs, due to:

- Dilution during periods of strong evapoconcentration
- Evidence for incorporation into food web and subsequent settling
- System predicted to return to values of 0.2-0.25 mg/L

## Daily Average Water Column Chlorophyll a



- Recycled water inputs tended to exacerbate extreme swings in chlorophyll a values
- Initial inputs in late 1930's triggered a slight increase in predicted chlorophyll a
- Inputs during drought in 1970's predicted to have a positive impact on chlorophyll a

### Mean Predicted Values: 1916-2014

	Temp	DO	Total N	Total P	Chl a
No RW	19.58	7.92	3.65	0.23	138
With RW	19.51	7.82	3.64	0.24	161
Rel Change	-0.36%	-1.26%	0.02%	4.3%	16.7%

- Addition of recycled water had no effect on mean temperature
- Recycled water inputs also had little effect on mean DO concentration although did increase variability in DO
- Supplementation with recycled water *increased* mean total N content by 57.9% and *increased*, with this model parameterization, mean total P concentration by 4.3%
- Mean chlorophyll a concentration was increased by 16.7% as a result of recycled water addition in this model parameterization

## Conclusions

Simulations provide improved insights into response of lake to long-term recycled water inputs

Supplementation with recycled water was predicted to:

- No affect temperature and heat budget of lake
- Had negligible effect on mean DO concentration in lake, but increased range of average water column DO concentrations, with both increased supersaturation and greater episodes of anoxia
- Had negligible effects on average total N and total P concentrations
- Did increase chlorophyll a concentrations slightly

Overall, model predictions do not indicate marked effects on water quality resulting from periodic inputs of recycled water to help maintain lake level

## Questions Previously Outlined

- ) How do nutrient concentrations, salinity concentrations, dissolved oxygen (DO) concentrations and algae concentrations vary with lake level under pre-development and modern land use conditions?
- ) How does the addition of recycled water change the natural variations in lake level that would otherwise occur and what is the net effect on nutrient, salinity and algae concentrations over time?
- ) What is the estimated effect on water quality (nutrients, algae, DO) of limiting the carp population? (Note: similar to the question previously addressed in Dr. Anderson's 2006 sensitivity study).
- ) What is the estimated effect on water quality (nutrients, algae, DO) of stocking hybrid game fish to reduce the shad population and protect the zooplankton population?



) What is the net effect of using recycled water to stabilize water levels in Lake Elsinore over a long period of time? Specifically, how do all of the following change with and without the presence of recycled water? And, what is the net effect on each of adding more/less recycled water?

- a) Acre-feet of aquatic habitat; surface acres of recreational reservoir
- b) Algae and DO concentrations
- c) Nutrient and salinity concentrations

) What is the estimated effect on water quality in Lake Elsinore if additional measures are implemented to further reduce the average phosphorus concentration in recycled water (e.g. from the current 0.5 mg/L down to as low as 0.1 mg/L in 0.1 mg/L increments)?

) To what extent, if any, will reducing algae populations in Lake Elsinore affect ammonia concentrations in the lake?

) Based on our best understanding of dynamic lake levels, asymmetric precipitation/runoff/loading patterns and nutrient cycling in Lake Elsinore, how much reduction in new external nutrient loads and/or existing sediment loads would be required to achieve compliance with the TMDL response targets for chlorophyll-a and DO?