Report 3

LAKE ELSINORE NUTRIENT TMDL MONITORING PROGRAM ANNUAL REPORT FOR YEAR 2001/2002

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Lake Elsinore Nutrient TMDL Monitoring Program
Annual Report for the Year 2001/2002

Submitted to
Lake Elsinore San Jacinto Watershed Authority

Submitted By
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California Regional Water Quality Control Board – Santa Ana Region

Santa Ana Regional Water Quality Control Board (Regional Board) staff continued water quality monitoring in Lake Elsinore and Canyon Lake through 2001/2002 water year. The field monitoring parameters include temperature, dissolved oxygen (DO), conductivity, pH, Secchi depth, and depending on the instrument, oxidation-reduction potential (ORP) and salinity. The lab analyses include total dissolved solids (TDS), hardness as CaCO3, chlorophyll a, total phosphate as P, soluble phosphate as P, total nitrogen, nitrate, nitrite, ammonium, organic nitrogen, Kjedahl nitrogen, biological oxygen demand (BOD), chemical oxygen demand (COD), turbidity, and total suspended solid. Three stations on Lake Elsinore and four stations on Canyon Lake were monitored (Figure 1). At each sampling station, water samples were collected from top (0-6 ft depth) and bottom (one foot above sediment). When water depth is over 20 feet, a sample from the mid-depth was taken. Water samples were collected biweekly in the summer and monthly in other seasons.

On June 28, 2002, Elsinore Valley Municipal Water District started the discharge of tertiary treated wastewater to Lake Elsinore. As one of the requirements of the permit by the Regional Board, an intensive monitoring program was implemented two weeks before the discharge. The new monitoring program encompasses all the elements of the Lake Elsinore nutrient TMDL monitoring. Therefore, the TMDL monitoring program was terminated as of June 28. This report will summarize the data collected for Lake Elsinore during May 2001 through June 2002. Data from the previous year will be included for discussion as well. Canyon Lake nutrient TMDL monitoring program will continue for another year till June 2003. A separate report will be prepared at the end of this year.

It is important to note that during the entire time frame of the Lake Elsinore nutrient TMDL monitoring program, the area is in a draught cycle and there were insignificant external nutrient loadings to the lake. Therefore, the monitoring data collected represents the internal nutrient cycling processes and their impact on algal growth and water clarity.

Conservative Constituents (TDS and Hardness)

Total dissolved solids (TDS) increased significantly from 2001 to 2002, from 1500 mg/L to near 2000 mg/L. The monitoring data from the previous year, 2000-2001, showed a increase in TDS from 1200 to 1500 mg/L (Figure 2). Such increase in TDS is caused by the evaporation loss of water and concentration of salts in Lake Elsinore. The Basin plan has a numerical water quality objective for Lake Elsinore of 2000 mg/L. It appears that if there is no fresh water flowing into Lake Elsinore, the lake will violate the TDS objective soon.

As shown in Figure 3, total hardness of Lake Elsinore increased from 200 mg/L in 2001 to 250 mg/L in 2002. A smaller increase also occurred from 175 mg/L in 2000 to 200 mg/L in 2001. Similar to TDS, the increase in hardness can be attributed to lake level decline and concentration due to evaporation.

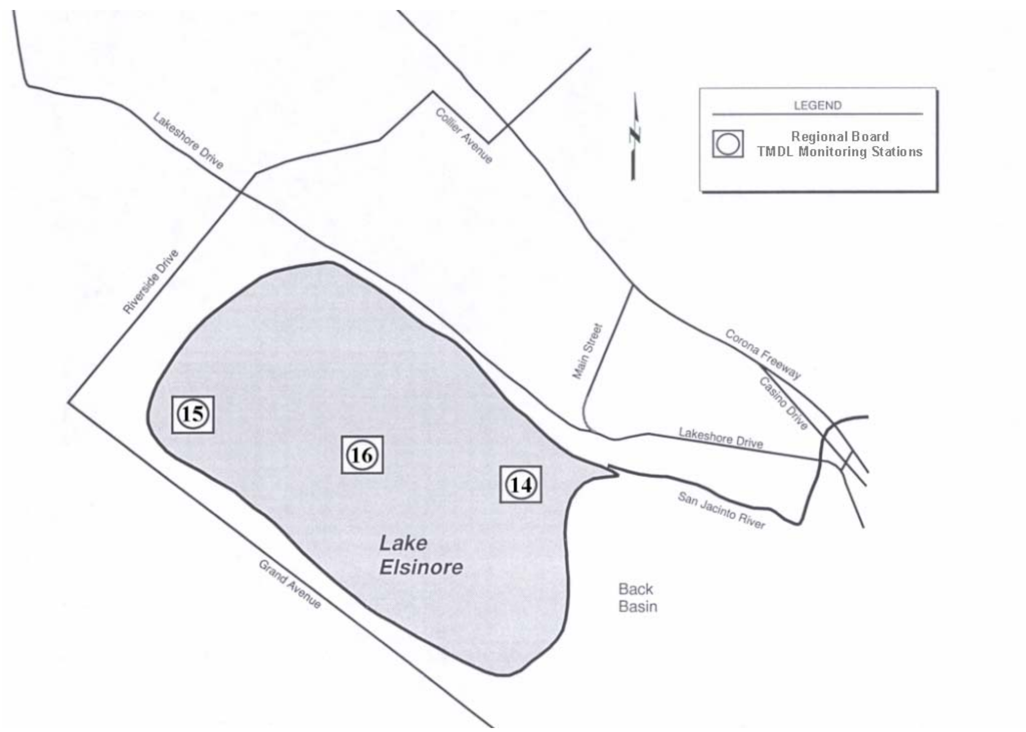


Figure 1. Lake Elsinore Nutrient TMDL monitoring stations.

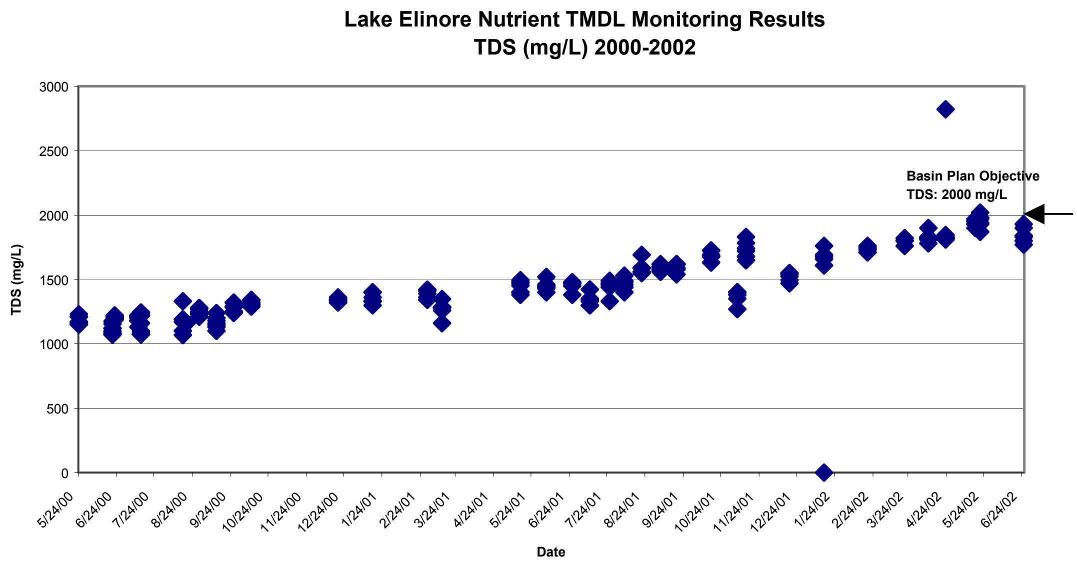


Figure 2. Lake Elsinore total dissolved solid from 2000 to 2002.

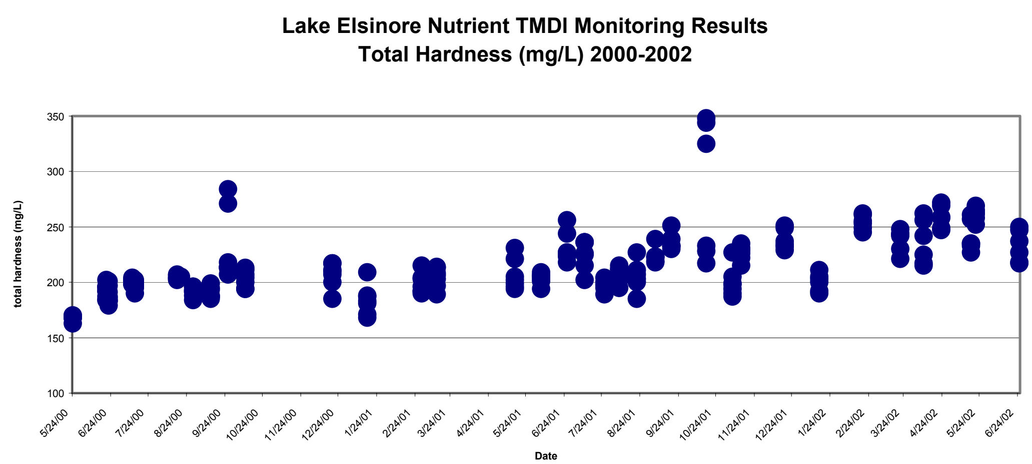


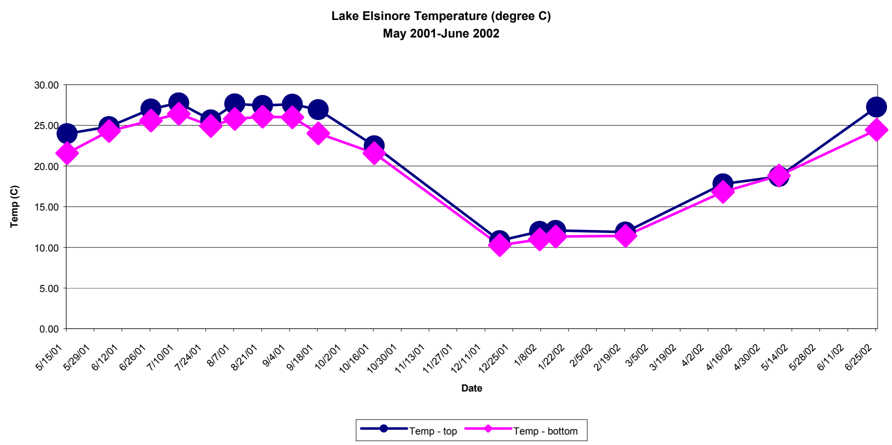
Figure 3. Lake Elsinore total hardness from 2000 to 2002.

Temperature and Dissolved Oxygen

The temperature and dissolved oxygen (DO) for Lake Elsinore were measured at the three monitoring stations. Since the mid-lake station (LE 16) has a greater water depth than the other stations, the discussion will focus on LE 16. Table 1 shows the summary of temperature and DO at LE 16. Figure 4 shows the temperature and DO trend over the time period of May 2001 through June 2002.

Table 1. Lake Elsinore temperature and dissolved oxygen at monitoring station LE 16.

	Temperature(C)	DO (mg/L)
Average	21.47	6.97
Min	10.27	0.28
Max	28.13	15.77
Count	208.00	208.00



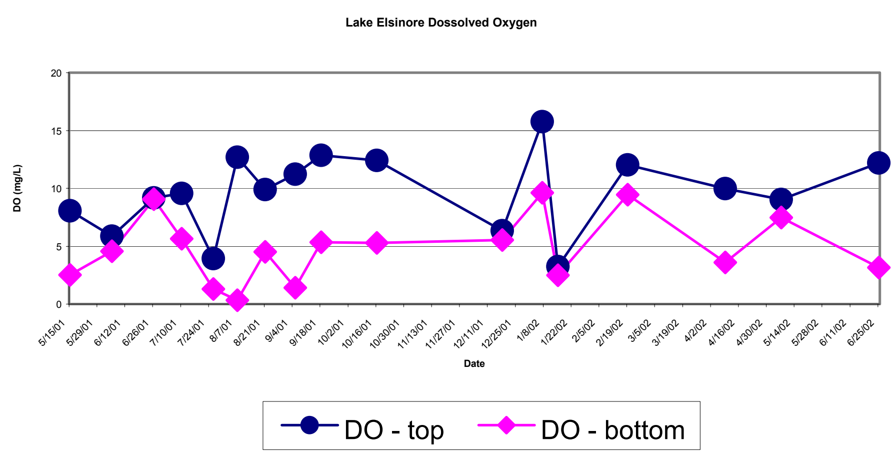


Figure 4. Lake Elsinore temperature and dissolved oxygen during May 2001 through June 2002.

As shown in Figure 4, the lake surface temperature and bottom temperature are mostly the same, indicating an efficient thermal mixing of Lake Elsinore throughout the year. However, DO graph shows that the Lake does become anoxic at the bottom during summer time.

To better illustrate the anoxic condition in Lake Elsinore, DO profiles in the summer of 2001 are shown in Figure 5. In the summer of 2001, the anoxic conditions (DO < 5 mg/L) were generally developed at depth of 8 feet. The anoxic conditions seem to be randomly developed over time, not having a progressive seasonal trend in the summer of 2001. Since the monitoring stopped in late June, the DO profiles developed by Dr. Anderson at UC Riverside were used here for comparison purpose (Figure 6).

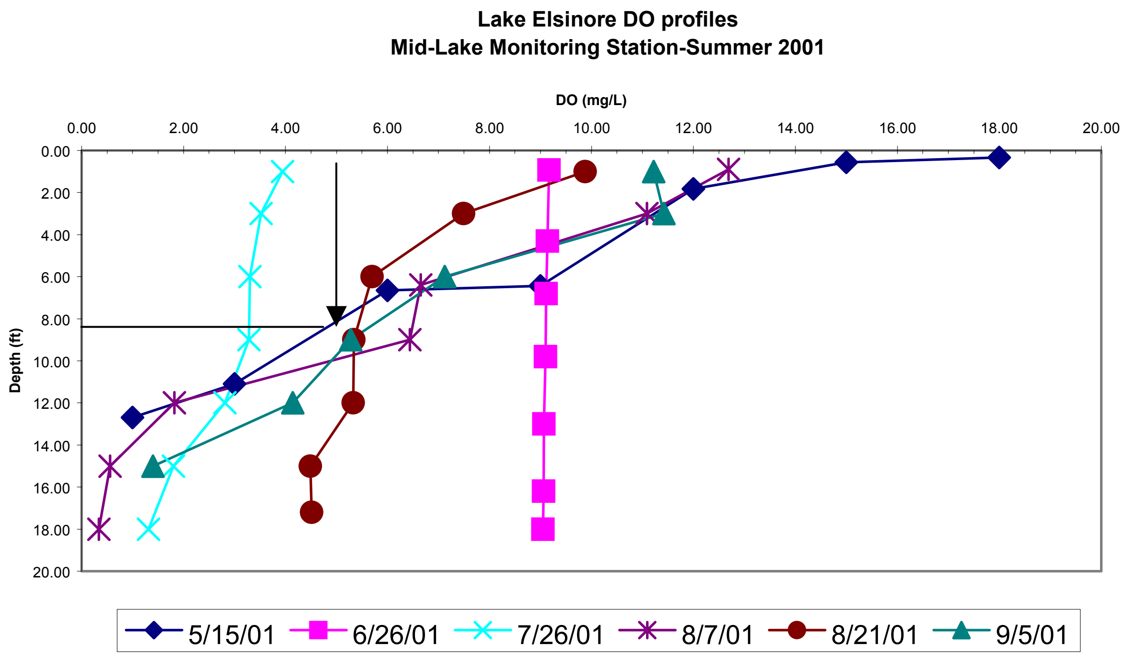


Figure 5. Lake Elsinore DO profiles during summers of 2001.

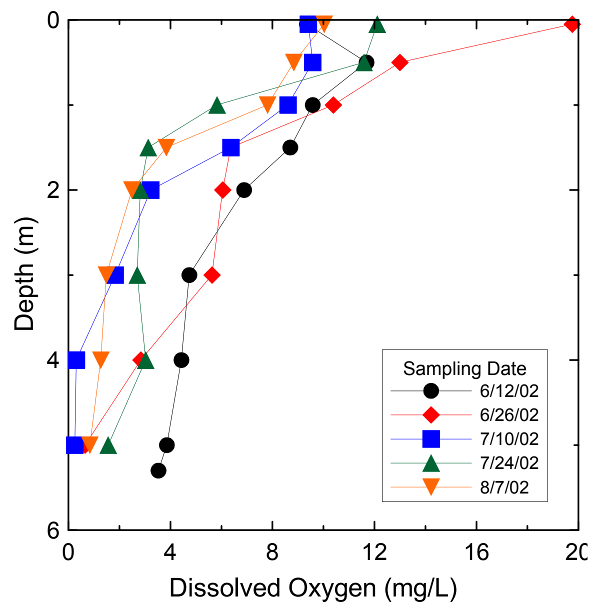


Figure 6. Lake Elsinore DO profiles in the summer of 2002 (from Lake Elsinore Recycled Water Project – Report #1, M. Anderson, 2002.)

As shown in Figure 6, the anoxic condition developed at depth less than 2 meters (6 feet) in the summer 2002. Further more, the anoxic conditions progressed towards shallower water as the summer advanced to August. Fish kill occurred on August 22 and 23 of 2002. The progression of anoxic condition in the summer of 2002 also correlate to the high algal biomass in the same time period, as will discussed in the next section.

Algal Biomass (Chlorophyll a) and Water Clarity (Secchi Depth)

Chlorophyll *a* concentration has been used as an algal biomass indicator in lake eutrophication studies. Normally a lake with chlorophyll *a* concentration greater than 20 µg/L is considered eutrophic. Secchi depth indicates water clarity. US EPA is recommending Secchi Depth of less than 2m as one criteria for eutrophic status. The summaries of Lake Elsinore nutrient data for year 2000 through 2002 are shown in Table 2.

Table 2. Lake Elsinore nutrient data summer for May 2001 through June 2002 compared to the previous year.

	TP (mg/L)	TKN (mg/L)	Chlorophyll a (ug/L)	DO (mg/L)	Secchi Depth (in)	NH4-N (mg/L)	TKN/TP	TP (ug/L)
2000-2001								
Minimum	0.04	0.60	4.90	0.28	6.00	ND	13.33	40.00
Maximum	0.90	6.60	124.00	14.67	45.00	1.90	32.74	900.00
Median	0.12	2.50	38.05	6.59	24.00	0.20	20.81	115.00
Mean	**0.13**	**2.50**	**43.48**	**6.91**	**24.63**	**0.24**	**21.10**	**125.25**
Standard Deviation	0.08	0.83	27.65	3.01	8.62	0.25	6.33	77.11
	TP (mg/L)	**TKN (mg/L)**	**Chlorophyll *a* (ug/L)**	**DO (mg/L)**	**Secchi Depth (inches)**	**NH4-N (mg/L)**	**TKN/TP**	**TP (ug/L)**
2001-2002								
Minimum	0.07	0.55	23.57	0.34	11.33	ND	2.62	73.33
Maximum	0.21	4.40	228.33	15.77	31.33	0.70	52.71	210.00
Median	0.12	2.98	78.07	6.78	18.67	ND	23.71	123.33
Mean	**0.12**	**2.69**	**103.30**	**6.97**	**18.48**	**NA**	**26.48**	**124.12**
Standard Deviation	0.04	1.31	70.19	3.30	6.66	NA	13.67	36.57

Compared to the data from previous year, the mean chlorophyll *a* concentration has more than doubled, from 43 ug/L to 103 ug/L; and the Secchi depth reading has decreased by 23%, from 25 inches to 18 inches. Water quality in Lake Elsinore has deteriorated for recreational uses, especially during the summer of 2002. Such a trend is documented in Figure 6, which includes the monitoring data from the Lake Elsinore users survey data. The lake users survey was conducted in Lake Elsinore to solicit public opinion of Lake Elsinore conditions and to correlate that with water quality parameters, i.e., chlorophyll a and Secchi depth. The survey results showed that the majority of the lake users considered Lake Elsinore having "poor clarity" and "severe algae" as well as lake use being "substantially limited" to "impossible to use" when chlorophyll concentration exceeded 130 ug/L (Cindy Li, 2002). However, only 30% of the lake users considered Lake Elsinore as "not quite clear, a little algae visible, green color of water barely perceptible", the best condition during the survey when chlorophyll *a* concentration is at 40 ug/L.

Figure 7 also suggests a reverse relationship between chlorophyll *a* and Secchi depth. A linear regression of the chlorophyll a and Secchi depth data yields the following expression:

$$\text{chlorophyll } (\mu g/L) = 67.16 * (1/\text{Secchi}(m^{-1})) - 55.96 \quad (1)$$

$R^2=0.82$ (Anderson 2002)

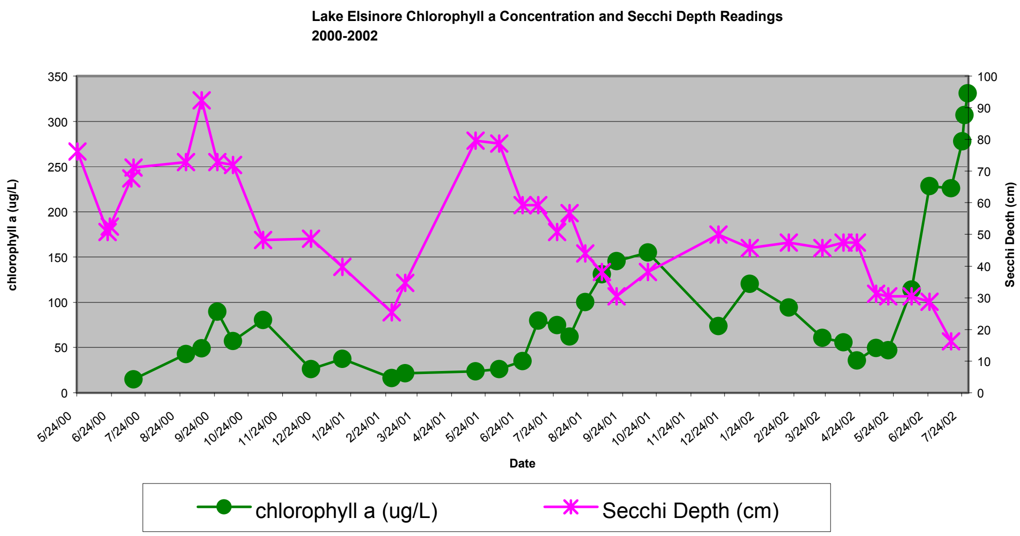


Figure 7. Lake Elsinore chlorophyll *a* concentration and Secchi depth reading from May 2000 through August 2002.

Such a relation is similar to the empirical relationship developed by Walker (1996):

$$\text{Chlorophyll (ug/L)} = (1/Z_{SD} - F)/0.025 \qquad (2)$$

Where F is the non-algal turbidity (generally <0.4m^{-1}), and Z_{SD} is Secchi depth expressed in meters. This relationship holds when the primary source of turbidity is due to algal biomass. Therefore, expression (1) suggests that 82% of the variance in chlorophyll *a* concentration can be explained by Secchi depth. In another word, turbidity of Lake Elsinore can be attributed mostly to the algal cells in the water column.

Nutrients (Phosphorus and Nitrogen)

Phosphorus and nitrogen are essential nutrients for algal growth, as well as carbon, light and other minerals. Algal blooms in many lakes are caused by enrichment of these two nutrients. In year 2001 through 2002, the mean concentrations of phosphorus and total Kjeldahl nitrogen (TKN) are similar to the previous year (Table 2), with a mean TP of 0.12 ± 0.04 mg/L and mean TKN of 2.69 ± 1.3 mg/L. The ratio of TP over TKN has a mean of 26.48, suggesting phosphorus being the limiting nutrient for algal growth, similar to the previous year.

The plot of total phosphorus, total Kjeldahl (TKN), and chlorophyll *a* concentration is shown in Figure 8. The figure shows that TP concentration peaks in the spring and then decreases as algal biomass increase. The algae cells probably uptake nutrients from water column and fix them in the biomass. TP concentration seems to increase from 2000 to 2002.

Figure 8 also show that TKN concentration increase from 2000 to 2002. There is an apparent decrease in TKN concentration in the winter seasons, which might be caused by mineralization of organic matter and denitrification processes.

Compared to chlorophyll *a* concentration increase, the increase in both TP and TKN concentration is very small. The relative constant TP and TKN concentrations and clear increase of chlorophyll a concentration in Lake Elsinore indicates the complex nutrient cycling processes in Lake Elsinore. To keep the nutrient concentrations constant, there must be a constant supply to offset the uptake by algae cells. This supply is probably the lake sediment that releases nutrients to water column since there were no significant external sources of nutrients to Lake Elsinore in the last two years. The drastic increase in chlorophyll *a* concentration may suggest that other factors contributed to the algal growth. One such factor might be lake elevation, as will be discussed in the next section.

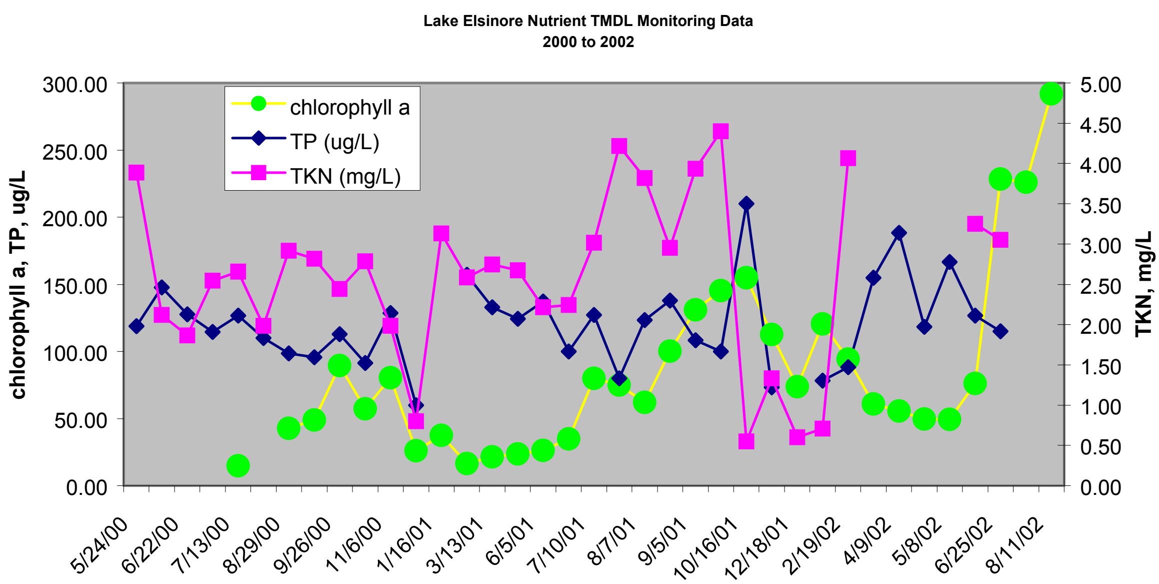


Figure 8. Lake Elsinore total phosphorus (TP), total kjeldahl nitrogen (TKN) and chlorophyll *a* concentrations from 2000 to 2002.

Lake Water Quality and Lake Elevation

Lake elevation can affect water quality. When the lake level is low, the water temperature can increase, nutrients in sediment can be rapidly released to photic zone for algal uptake. Temporary thermal stratification, rapid development of anoxia and sediment P release, followed by wind mixing, provided a series of internal lading events over a summer (Cook *et al*., 1993).

Figure 9 shows the relationship between lake elevation and total phosphorus and chlorophyll *a* concentrations. Lake elevation data were available from October 2000 through September 2002. The lake elevation decreased from 1242 feet above sea level in the spring of 2001 to near 1236 feet in the summer of 2002. The figure also shows that as lake elevation dropped, both TP and chlorophyll *a* concentration increased.

Figure 10 shows the correlation between lake elevation and log of chlorophyll *a,* TP concentration, and Secchi depth. As lake elevation decreased, chlorophyll *a* concentration increased, TP concentration increase, and Secchi depth reading decreased. The decrease of lake elevation has also caused the increase in nutrient release rate from sediment. Recent core flux data from UC Riverside does indicates that SRP release rate has 40-100% since 2000 (M. Anderson, 2002, personal communication).

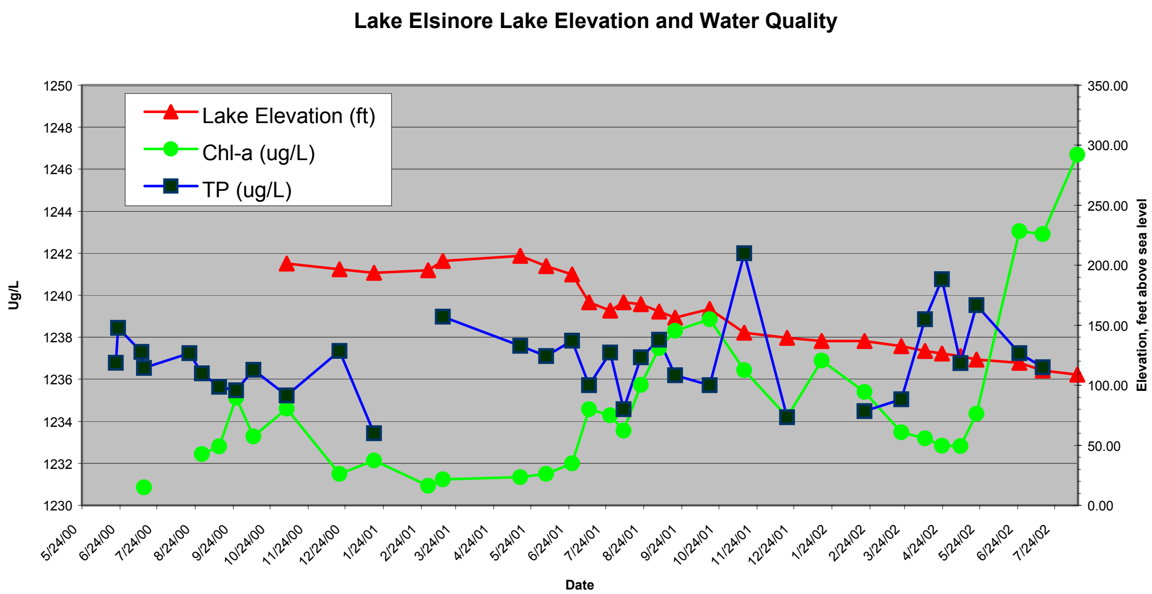


Figure 9. Lake Elsinore elevation and water quality.

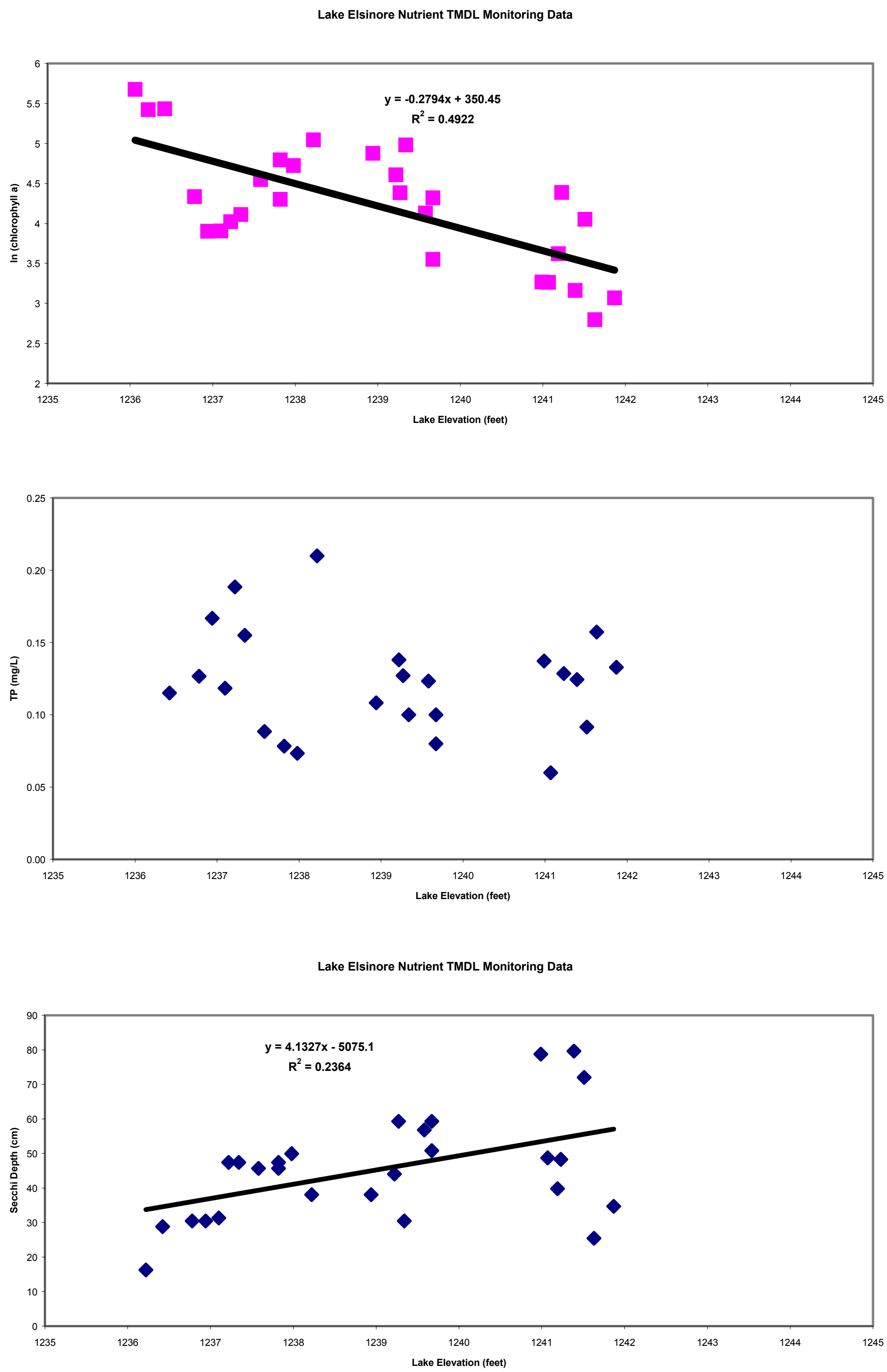


Figure 10. Correlation between lake elevation and water quality parameters in Lake Elsinore.

Conclusion

The monitoring results for year 2001 through 2002 have shown deterioration of water quality in Lake Elsinore as reflected by chlorophyll a and Secchi depth. Dissolved oxygen has also dropped to a degree that fish kill occurred in August 2002. A regression between chlorophyll a and Secchi depth suggest that algal cells cause turbidity of Lake Elsinore. Phosphorus and nitrogen concentrations increased slightly. Correlation exists between lake elevation and water quality. The lake elevation decrease may have caused the increase of nutrient release rate from sediment.

References

Anderson, M. (2002). Lake Elsinore recycled water project – report #1.

Cook, G.D. *et al*. (1993). Restoration and management of lakes and reservoirs (2nd edition). CRC Press LLC.

Li, C. (2002). Lake Elsinore user survey results for September 8, 2002.

US EPA, (1999). Protocol for developing nutrient TMDLs.

Walker, W.W. (1996). Simplified procedures for eutrophication assessment and prediction: user manual. Instruction Report W-96-2-2 (updated April 1999), U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.