Table E-1. CNRP Implementation Plan

CNRP Activity	CNRP Element	Milestones	Metrics	Lead	Complete by	Status
Watershed-based BMPs	Ordinances Development	Evaluate need to revise existing or establish new ordinances to reduce sources of nutrients in the watershed	Complete ordinance evaluation	Permittees	31-Mar-13	
			Establish revised or new ordinances	Permittees	31-Dec-13	
	Street Sweeping & Debris Removal	Street Sweeping & Debris Removal	Evaluate existing street sweeping and debris removal programs to identify opportunities to enhance program	Permittees	31-Mar-13	
			Implement program enhancements, where identified, and as approved in local jurisdiction	Permittees	31-Dec-13	
			Annual reporting of regular street sweeping and debris removal outcomes in Annual Report, with emphasis on TMDL benefits	Permittees/MS4 Program	November 30, each year	
	Inspection & Enforcement	Continued implementation of inspection and enforcement program	Update inspection and enforcement program if needed based on outcome of ordinance evaluation	Permittees	31-Mar-14	
			Annual reporting of regular inspection and enforcement activities in Annual Report, with emphasis on TMDL benefits	Permittees/MS4 Program	November 30, each year	
	Septic System Management	Continued implementation of Septic System Management Plan for the watershed; modify implementation as needed to comply with State OWTS Policy	Annual reporting of septic system management activities in Annual Report, with emphasis on TMDL benefits	Permittees	November 30, each year	
	Public Education & Outreach	Continued implementation of PEO program	As part of Annual Report preparation evaluate PEO program to determine need to modify or expand PEO activities that target nutrient sources	Permittees/MS4 Program	November 30, each year	
			Update PEO materials, as needed; implement PEO program	Permittees/MS4 Program	Annually, as needed	
	WQMP Implementation	Implement approved LID-based WQMP following Regional Board approval	Prepare final WQMP, obtain Regional Board approval, and implement in watershed	Permittees/MS4 Program	Within 6 months of Regional Board approval of WQMP	
	Lake Elsinore	Support implementation of existing lake aeration system	Establish necessary agreements among aeration system participants	MS4 Program in collaboration with stakeholders	31-Dec-12	
		Complete alternatives analysis of in-lake remediation project(s) for Canyon Lake	Select in-lake remediation project(s) for Canyon Lake	MS4 Program in collaboration with stakeholders	30-Jun-14	

In-Lake Remediation Projects	Canyon Lake	Prepare preliminary design for HOS	Preliminary HOS design to support CEQA process	MS4 Program in collaboration with stakeholders	30-Jun-14	
		Implement CEQA process	Obtain CEQA approval of HOS	MS4 Program in collaboration with stakeholders	31-Dec-14	
		Prepare final design for HOS	Finalize HOS design; complete bid and award process	MS4 Program in collaboration with stakeholders	31-Dec-14	
		Implement process to obtain all permits and approvals	Secure permits and approvals to operate HOS	MS4 Program in collaboration with stakeholders	31-Dec-14	
		Implement HOS construction	Complete construct and testing of HOS	MS4 Program in collaboration with stakeholders	31-Dec-15	
		Establish operation and maintenance agreement	Operation of properly maintained HOS	MS4 Program in collaboration with stakeholders	January 1, 2016 and following	
		Implement reduced monitoring program	Completion of annual monitoring as required by current approved monitoring program	MS4 Program in collaboration with stakeholders	30-Jun-15	
		Prepare revised comprehensive monitoring program	Submit revised comprehensive monitoring program to the Regional Board for approval	MS4 Program in collaboration with stakeholders	31-Dec-14	

Monitoring Program	In-Lake Monitoring	Implement Regional Board-approved revised comprehensive monitoring program	Completion of annual monitoring as required by revised program	MS4 Program in collaboration with stakeholders	31-Dec-20	
	Watershed-based Monitoring	Continue implementation of Phase I watershed monitoring program	Completion of annual monitoring as required by current approved monitoring program	MS4 Program in collaboration with stakeholders	30-Jun-15	
		Prepare revised comprehensive monitoring program	Submit revised comprehensive monitoring program to the Regional Board for approval	MS4 Program in collaboration with stakeholders	31-Dec-14	
		Implement Regional Board-approved revised comprehensive monitoring program	Completion of annual monitoring as required by revised program	MS4 Program in collaboration with stakeholders	31-Dec-20	
	Annual Reports	Complete annual reports to assess effectiveness of CNRP	Submittal of annual reports to Regional Board by August 15	MS4 Program in collaboration with stakeholders	November 30, annually	
	Interim Compliance Assessment	Demonstrate compliance with interim TMDL requirements	Submittal of assessment of compliance with interim TMDL requirements	MS4 Program in collaboration with stakeholders	31-Dec-15	
	Final Compliance Assessment	Demonstrate compliance with WLAs	Submittal of assessment of expected compliance with final TMDL requirements including any recommended supplemental actions.	MS4 Program in collaboration with stakeholders	30-Nov-19	
Special Studies	Use of Chemical Additives	Evaluate potential to use chemical additives, e.g., alum, Zeolite or Phoslock, as an in-lake remediation strategy alternative	Complete studies, as appropriate, to evaluate potential for use of chemical additives	MS4 Program in collaboration with stakeholders	30-Jun-13	

(Optional)	Land Use Updates	Update watershed urban land use based on 2010 data	Submit land use revision to the Regional Board	MS4 Program in collaboration with stakeholders	30-Jun-18	
	TMDL Model Update	Revise/update TMDL models for Canyon Lake/ Lake Elsinore based on new data (e.g., land use, water quality)	Submit TMDL models to the Regional Board	MS4 Program in collaboration with stakeholders	31-Dec-18	
Adaptive Implementation	Task Force	Participate in Task Force process	Regular attendance at Task Force meetings	MS4 Program in collaboration with stakeholders	Ongoing	
	Pollutant Trading Plan (PTP)	Provide input to the development of the PTP	Final PTP submitted to the Regional Board	MS4 Program in collaboration with stakeholders	Prior to December 31, 2012 (in coordination with CNRP)	
	CNRP Revisions	Review progress towards achieving TMDL requirements based on compliance assessments; modify CNRP as needed	Prepare compliance assessment; if needed, submit revised CNRP to the Regional Board	MS4 Program/Permittees	30-Nov-15	
		Review progress towards achieving final TMDL requirements based on compliance assessments; modify CNRP as needed	Prepare compliance assessment; if needed, submit revised CNRP to the Regional Board	MS4 Program/Permittees	30-Nov-19	
	TMDL Revision	Based on degree of Regional Board support, prepare materials to support revision to the TMDL as part of the Triennial Review process, if revision is appropriate	Submit recommendations and supporting material for revisions to the TMDL to the Regional Board	MS4 Program in collaboration with stakeholders	Prior to potential triennial review dates in 2015 and 2019	

Technical Memorandum

Task 6: Predicted Water Quality in Canyon Lake with In-Lake Alum Treatments and Watershed BMPs

Objective

The objective of this task was to evaluate the predicted water quality in Canyon Lake that would result from implementation of watershed BMPs, in-lake alum treatments, and watershed BMPs in conjunction with alum treatments.

Approach

The DYRESM-CAEDYM model developed in earlier studies was used to assess water quality following in-lake alum treatments and with watershed BMPs. A total of 12 different scenarios were evaluated (Table 1). The existing scenario ("Existing") represents the model-predicted water quality in Canyon Lake over 2002-2011, while the BMPs scenario represents the predicted water quality that would result from a 15% reduction in total N and total P (assumed here to be a uniform reduction in both dissolved and particulate forms of N and P). This scenario thus differs from that evaluated in Task 4a that considered the TMDL-prescribed reductions of total N of 31% and that for total P of 73% (Anderson, 2012).

Table 1. Summary of the 12 simulations conducted evaluating BMPs, alum treatments, and BMPs in conjunction with alum treatments for Canyon Lake.

Scenario	**BMP**	**PO_4 Stripping**	**Int Load Red**
Existing	-	-	-
BMPs	√	-	-
Alum H	-	√	-
Alum W	-	√	-
Alum H + W	-	√	-
Alum H + IL	-	√	√
Alum H + W + IL	-	√	√
BMP + Alum H	√	√	-
BMP + Alum W	√	√	-
BMP + Alum H+ W	√	√	-
BMP + Alum H + IL	√	√	√
BMP + Alum H + W + IL	√	√	√

The effects of annual alum applications to the lake were also evaluated (with and without implementation of watershed BMPs) (Table 1). Whereas we previously considered microfloc alum injection into the San Jacinto River and Salt Creek to lower bioavailable PO_4-P (Task 3), these scenarios evaluated in-lake treatments. The "Alum H" scenario considered annual additions of alum on October 1 of each year at a dose sufficient to strip the hypolimnion (H) of almost all of the PO_4-P that had accumulated to that point, but assumed it would achieve no reductions in internal loading. Similarly, the "Alum W" scenario considered that which alum was also added annually at a lower effective dose to the entire water column during the winter (W) (potentially 60,000 kg yr^{-1}, on February 1). The winter treatment thus served as an alternative to inflow treatment and would strip much of the PO_4-P that had been delivered to the lake with inflows through the end of January (and remained in the basin, that is, not spilled to Lake Elsinore). The "Alum H + W" scenario considered both of these annual alum additions designed to strip PO_4-P out of the water column. These treatments were assumed to not substantively influence internal loading of PO_4-P from bottom sediments, however.

Larger doses during the hypolimnetic treatment (potentially 140,000 kg yr^{-1}) would be expected to also reduce internal loading rates. The effectiveness of such treatments would be strongly dependent upon external loading events, and such events would potentially yield short-lived benefits. For the purposes of these simulations, such reductions in internal loading ("IL") were assumed to achieve an annual average reduction of 50%. The "Alum H + IL" scenario thus allowed for both hypolimnetic stripping of PO_4-P <u>and</u> a 50% reduction in the annual average internal PO_4-P loading rate. Similarly, the "Alum H + W +IL" scenario involved alum treatment and stripping of PO_4-P out of the water column on February 1 and hypolimnetic treatment on October 1 combined with a 50% reduction in annual average internal loading. The whole water column winter treatment (Alum W) was not assumed to substantively alter internal PO_4-P loading due to the lower dose and lower corresponding Al concentration in the lake (during a time when potentially large external inputs may yet still arrive with storms in February and March). These alum scenarios were also evaluated in combination with the 15% external load reductions achieved through BMPs in the watershed (designated with "BMP) (Table 1).

Results

A large volume of data was generated in these 12 different sets of simulations. Volume-weighted annual average and 10-yr average concentrations were calculated for total P, total N, and DO while surface concentrations for chlorophyll a were determined. Volume-weighted DO concentrations were calculated only for the lowermost 7 m of the water column. Volume-weighted nutrient concentrations are presented to reflect the total inventory of nutrients in the water column of Canyon Lake as was reported in Task 3. Annual average concentrations of total P, total N, chlorophyll a and DO are provided in Figs. 1-4 for (i) the existing condition, (ii) with BMPs implemented in the watershed (15% reductions in nutrient loading), and (iii) with annual alum treatments of the hypolimnion that stripped PO_4-P out of the lower water column and also lowered internal loading rates by 50%. Reduction of external loading of nutrients by 15% through implementation of watershed BMPs lowered annual average total P concentrations in the lake by an average of 0.05 mg/L, while alum treatment of the hypolimnion was predicted to lower volume-weighted concentrations by an average of 0.22 mg/L (Fig. 1). Hypolimnetic alum treatment was predicted to bring volume-weighted annual concentrations below the 0.1 mg/L total P target in 2 of 10 years (Fig. 1).

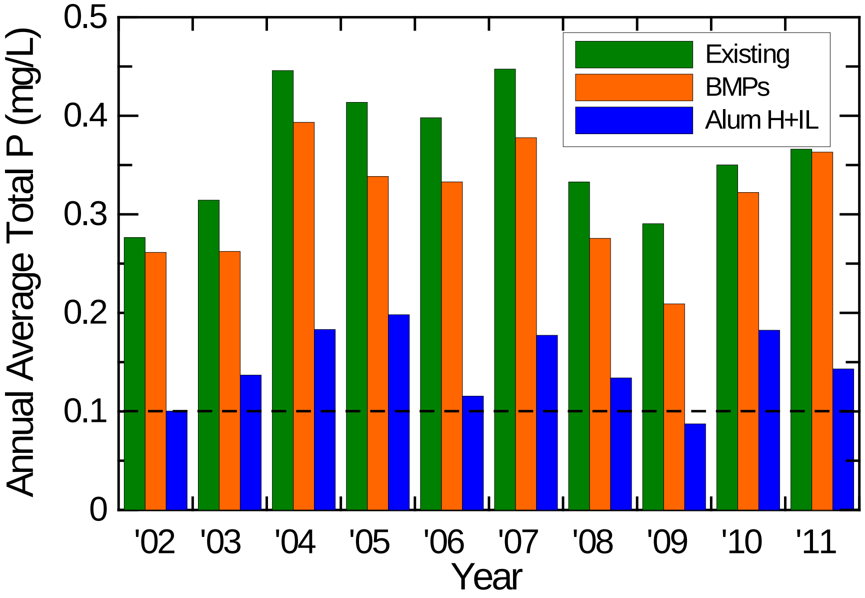

Fig. 1. Volume-weighted annual average total P concentrations in Canyon Lake under (i) model-simulated existing conditions, (ii) with implementation of watershed BMPs achieving 15% external load reductions, and (iii) with alum treatment of hypolimnion with internal PO_4 load reductions.

Total N concentrations were less strongly affected by BMPs or alum treatment (Fig. 2), with BMPs and hypolimnetic alum treatment with internal P load reductions predicted to yield an average reductions of 0.11 and 0.15 mg/L, respectively. While alum was not assumed to directly alter the rate of internal loading of N, it does appear that some relatively modest indirect reductions in total N were predicted.

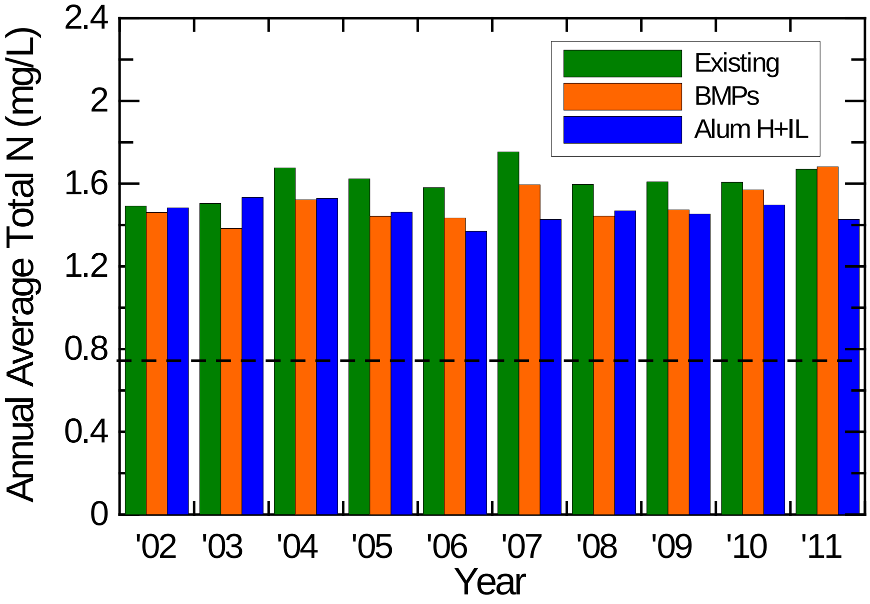

Fig. 2. Volume-weighted annual average total N concentrations in Canyon Lake under (i) model-simulated existing conditions, (ii) with implementation of watershed BMPs achieving 15% external load reductions, and (iii) with alum treatment of hypolimnion with internal PO_4 load reductions.

Alum treatment of the hypolimnion had a surprisingly dramatic effect on predicted annual average chlorophyll a levels in the lake, however (Fig. 3). Based upon these simulation results, such a treatment is sufficient to drive the lake to P-limitation and dramatically reduce chlorophyll concentrations. Detailed inspection of simulation results indicate that some diffusion-dispersion of alum across the thermocline and into the epilimnion occurred as a result of the large concentration gradient; these results are thus thought to reflect water quality from some limited surface treatment as well. (That is, a true hypolimnetic treatment would presumably yield somewhat higher predicted concentrations, although no additional simulations were conducted to assess the influence of depth of alum injection.) Implementation of BMPs also achieved some reductions in annual average chlorophyll a concentrations (Fig. 3), although reductions were much lower than for alum (0.7 - 5.8 μg/L, or 2.2 - 15.8%).

The annual average concentration of DO in the lower portion of the water column exhibited relatively modest interannual variation, ranging from 4-5 mg/L, with no meaningful difference between the existing condition and that when watershed BMPs were in place (Fig. 4). Annual treatment of the hypolimnion with alum was predicted to increase slightly annual average DO concentrations (Fig. 4).

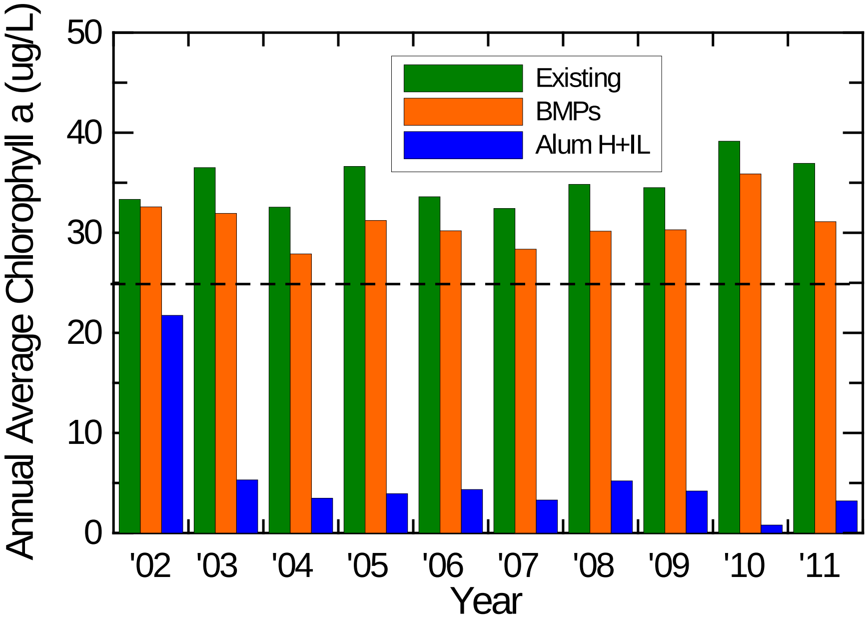

Fig. 3. Epilimnetic annual average chlorophyll a concentrations in Canyon Lake under (i) model-simulated existing conditions, (ii) with implementation of watershed BMPs achieving 15% external load reductions, and (iii) with alum treatment of hypolimnion with internal PO_4 load reductions.

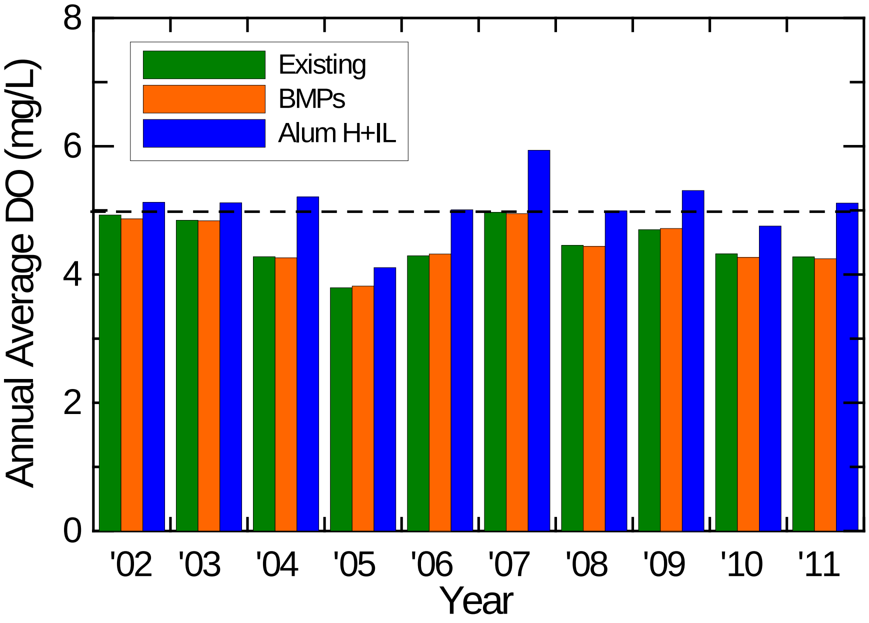

Fig. 4. Volume-weighted annual average dissolved oxygen (DO) concentrations in hypolimnion of Canyon Lake under (i) model-simulated existing conditions, (ii) with implementation of watershed BMPs achieving 15% external load reductions, and (iii) with alum treatment of hypolimnion with internal PO_4 load reductions.

Simulation results were also used to calculate the 10-year average concentrations of total N, total P, chlorophyll a and DO (Table 2). It is useful to compare these values with the TMDL numeric targets of 0.1 mg/L for total P, 0.75 mg/L for total N, and 25 μg/l for chlorophyll a. Here we consider the full range of simulations conducted, including winter alum treatments, BMPs and all combinations of scenarios. We note that, on a 10-yr average, no scenario met either the total P or total N targets, while all alum treatments successfully met the chlorophyll a target.

Table 2. 10-yr average volume-weighted total P and total N concentrations, surface chlorophyll a concentrations, and volume-weighted hypolimnetic DO concentrations.

Scenario	**Total P (mg/L)**	**Total N (mg/L)**	**Chlorophyll a (μg/L)**	**DO (mg/L)**
Existing	0.364±0.061	1.611±0.078	35.0±2.2	4.49±0.37
BMPs	0.314±0.059	1.501±0.091	31.0±2.3	4.47±0.36
Alum H	0.197±0.059	1.468±0.069	9.6±6.3	4.94±0.50
Alum W	0.250±0.087	1.481±0.075	12.2±6.7	4.88±0.42
Alum H + W	0.200±0.065	1.469±0.062	9.1±5.8	4.97±0.50
Alum H + IL	0.146±0.038	1.465±0.048	5.6±5.8	5.07±0.46
Alum H + W + IL	0.151±0.058	1.454±0.045	5.3±5.3	5.08±0.46
BMP + Alum H	0.191±0.045	1.343±0.080	8.6±6.4	4.96±0.49
BMP + Alum W	0.245±0.078	1.343±0.080	11.6±6.7	4.88±0.44
BMP + Alum H + W	0.190±0.045	1.348±0.083	8.6±6.0	4.96±0.45
BMP + Alum H + IL	0.138±0.036	1.336±0.080	4.9±5.5	5.11±0.47
BMP + Alum H+W+ IL	0.152±0.071	1.336±0.081	4.9±5.4	5.09±0.47

These results can also be considered in a probabilistic way through use of cumulative distribution functions (cdf) that describe the frequency of occurrence or exceedance (e.g., Fig. 5a). Here one sees that a 100% probability exists that volume-weighted total P concentrations in Canyon Lake will exceed 0.1 mg/L, with the predicted exceedance frequency decreasing with increasing total P concentrations (Fig 5a). For the existing condition, we see a very high (90%) frequency of exceeding 0.2 mg/L, a 50% probability of exceeding the median value of 0.35 mg/L, and about a 10% frequency in which total P concentrations exceed 0.5 mg/L (Fig. 5a, orange line). Implementation of BMPs shifted the concentrations to slightly lower values, e.g., lowering the median concentration from 0.35 to 0.29 mg/L (Fig. 5a). Total P concentrations nonetheless were predicted to remain quite high with implementation of watershed BMPs.

Treatment of the lake with alum further shifted the cdfs to lower concentrations, e.g., lowering the median total P concentration for hypolimnetic alum treatment (Alum+H) to 0.137 mg/L, and to 0.081 mg/L with winter and hypolimnetic treatments with internal loading control (Alum H+W+IL) (Fig. 5b). Alum treatment in combination with BMPs had a small effect (e.g., reducing the median total P concentration from 0.081 mg/L to 0.075 mg/L for the Alum H+W+IL scenario with BMPs) (Fig. 5c).

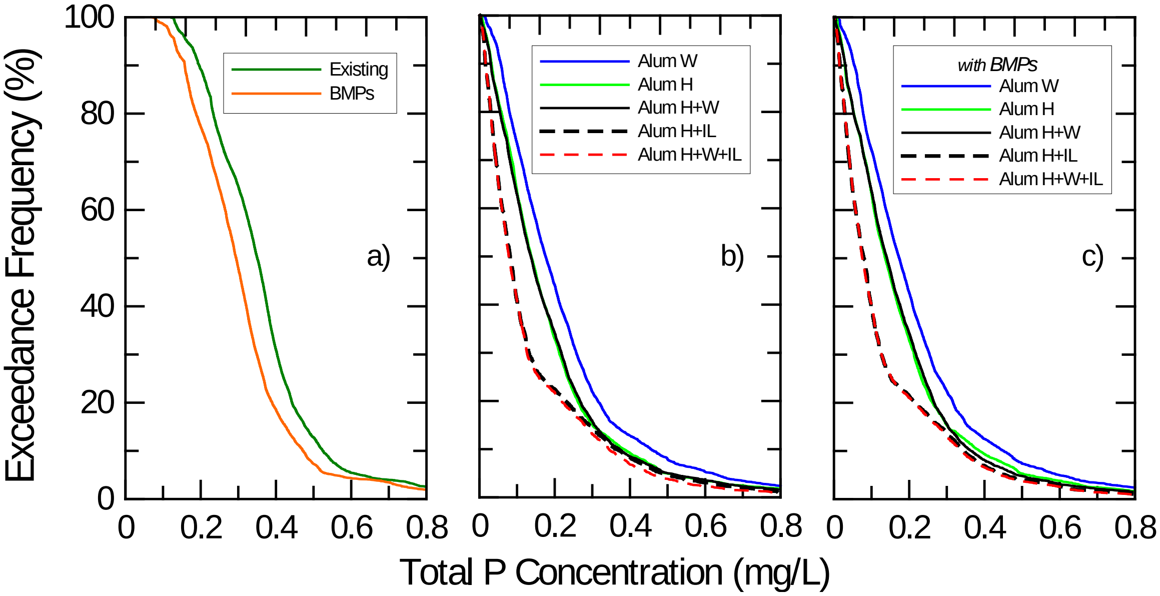

Fig. 5. Cumulative distribution functions showing exceedance frequency as function of simulated total P concentrations in Canyon Lake under (a) existing and BMP scenarios, (b) alum treatments, and (c) BMPs with alum treatments.

Volume-weighted total N concentrations for the different scenarios are also presented using cumulative distribution functions (Fig. 6). As inferred from the annual average (Fig. 2) and the 10-yr average data (Table 2), the different scenarios resulted in generally similar cdfs (Fig. 6). The BMPs shifted the cdfs to slightly (about 0.10 mg/L) lower concentrations relative to existing conditions, with median (50%) exceedance frequency reducing the concentration from 1.56 to 1.45 mg/L (Fig. 6). Alum treatments yielded very little differences in the distribution of predicted total N concentrations and slightly (about 0.03 mg/L) lower than levels predicted for BMPs. Implementation of BMPs in conjunction with alum treatments further shifted the cdfs to lower concentrations; the median concentration dropped to 1.29 mg/L for essentially all combinations of treatment (Fig. 6c).

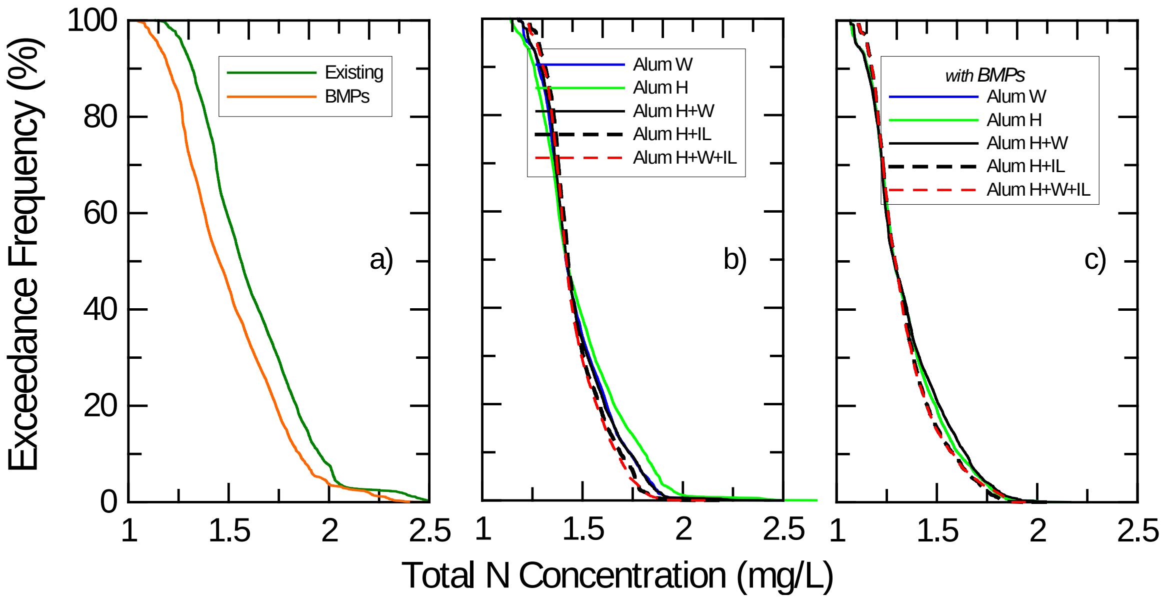

Fig. 6. Cumulative distribution functions showing exceedance frequency as function of simulated total N concentrations in Canyon Lake under (a) existing and BMP scenarios, (b) alum treatments, and (c) BMPs with alum treatments.

The cumulative distribution functions for predicted chlorophyll a concentrations are provided in Fig. 7. For the existing condition (Fig. 7a, green line), we see a very high (95.9%) frequency of exceeding 10 μg/L, although exceedance frequency drops rapidly at higher concentrations. The 50% exceedance frequency for the existing condition corresponds to a median chlorophyll a concentration of 23.5 μg/L. There is a finite probability/frequency of daily chlorophyll a concentrations exceeding 100 μg/L (4.3%). Implementation of BMPs had a small effect on the cdf for chlorophyll a concentration (Fig. 7a, orange line), e.g., shifting the median concentration from 23.5 μg/L to 21.5 μg/L and lowering the predicted frequency of exceeding 100 μg/L from 4.3% to 2.7%.

As indicated in Fig. 3 and Table 2, alum treatments had a dramatic effect on predicted chlorophyll a concentrations relative to existing conditions and with BMPs. This can also be seen clearly in the cdfs (Fig. 7b,c). Whereas chlorophyll a levels exceeded 10 μg/L 95.9% of the time in the simulated existing conditions, the frequency in which chlorophyll a concentrations exceeded 10 μg/L dropped to 37.8% when alum was added at moderate doses to strip PO_4 from the hypolimnion, and to only 16.5% when larger doses sufficient to also help control internal PO_4-P loading (Fig. 7b). Thus, only a small portion of time, generally during fall, did chlorophyll a levels exceed 10 μg/L. Concentrations exceeding 25 μg/L occurred only 12.5% with moderate doses of alum and 4.1% of the time at higher doses that also helped control internal recycling.

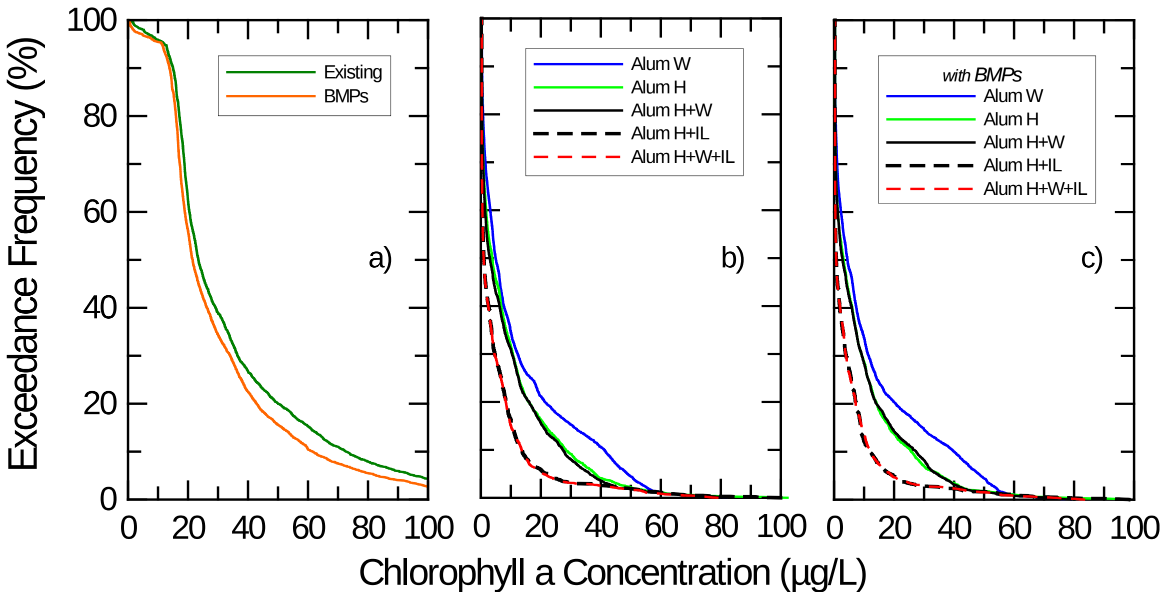

Fig. 7. Cumulative distribution functions showing exceedance frequency as function of simulated chlorophyll a concentrations in Canyon Lake under (a) existing and BMP scenarios, (b) alum treatments, and (c) BMPs with alum treatments.

Exceedance frequencies were also calculated for volume-weighted hypolimnetic DO concentrations (lowermost 7 m of the water column) (Fig. 8). Volume-weighted hypolimnetic DO concentrations were in all cases >2.8 mg/L (i.e., 100% frequency of exceeding this value), with identical median DO concentrations of 3.66 mg/L for both the existing condition and with implementation of BMPs (Fig. 8a). Volume-weighted hypolimnetic DO concentrations ≥5 mg/L were predicted 18.9% of the time under existing conditions and 18.4% with BMPs. Alum treatments were predicted to shift to somewhat higher frequencies the occurrence of DO concentrations ≥5 mg/L (27.6 - 33.2% of the time (Fig. 8b,c). Alum treatments sufficient to provide some control over internal PO_4 recycling in combination with BMPs provided the highest DO levels in the hypolimnion (median value of 3.63 mg/L, 33.2% frequency exceeding 5 mg/L).

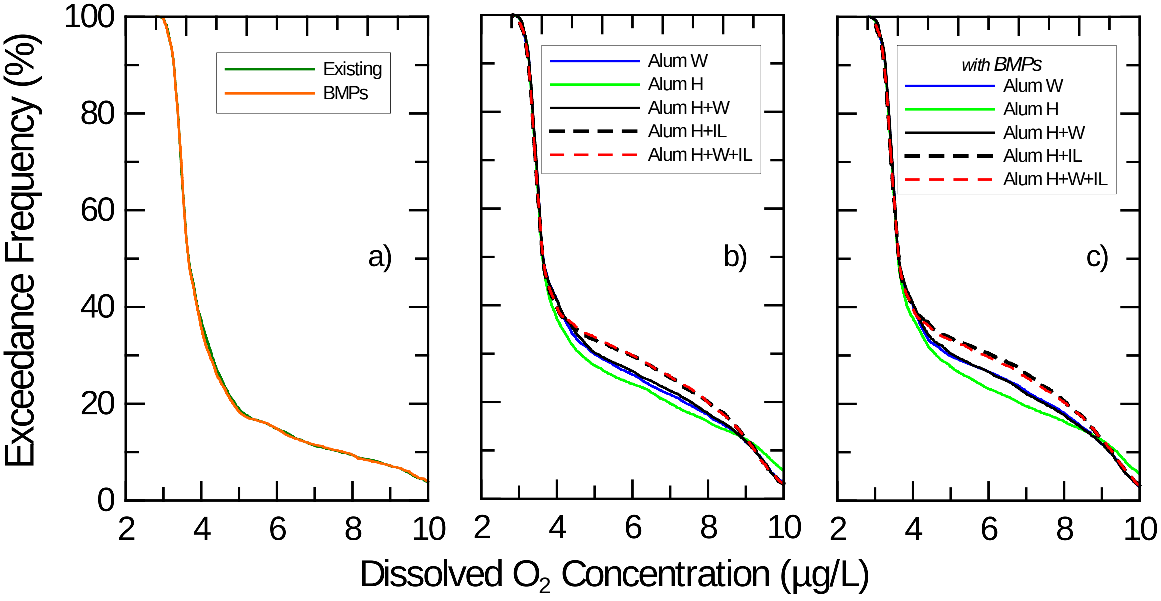

Fig. 8. Cumulative distribution functions showing exceedance frequency as function of simulated total P concentrations in Canyon Lake under (a) existing and BMP scenarios, (b) alum treatments, and (c) BMPs with alum treatments.

<u>Alum Treatment Considerations</u>

Due to the proton production associated with hydrolysis when alum is added to water, and the strong pH dependence of Al solubility, there are some constraints on alum treatment of natural waters. Specifically, the water has to have sufficient alkalinity to maintain circumneutral pH and yet not be too high to favor formation of aluminate ($Al(OH)_4^-$) and thereby diminish efficient formation of $Al(OH)_3$ floc and inhibit PO_4 retention.

Dr. Noblet recently completed jar tests that demonstrated efficient removal of PO_4 from hypolimnetic water from Canyon Lake, with >90% removal at an alum dose between 50-75 mg/L (or 2-3 mg/L Al) (Fig. 9). Such a dose would be expected to consume about 0.3 meq/L of alkalinity, so the lake would be well buffered against strong pH changes at this relatively modest alum dose (Canyon Lake in years past has had alkalinities >3 meq/L, or about 10x that value) (Anderson et al, 2007). The pH of hypolimnetic water decreased only modestly with alum doses up to 100 mg/L (by 0.4-0.7 units, to pH~7.3) (Noblet, 2012), Larger pH reductions were found for waters from East Bay, although outgassing of CO_2 resulted in an increase in pH over time, consistent with other studies (Berkowitz et al., 2005; Anderson et al., 2007).

Dissolved Al concentrations in hypolimnetic waters were found to be increased above background (72-83 µg/L) by a factor of 4-5x (to 236-389 µg/L) with alum addition however (Noblet, 2012). The dissolved Al concentrations following alum addition thus did exceed the chronic toxicity threshold of 87 µg/L, but was well below the acute toxicity threshold of 750 µg/L. It is nonetheless worth noting that the background concentrations were quite close to the chronic threshold. It is also worth noting that the very low DO concentrations and high levels of H_2S in the summer hypolimnion preclude use of this portion of the water column by essentially all aquatic invertebrates, zooplankton and fish. Elevated concentrations of dissolved Al for a moderate period of time in this part of the lake are thus not expected to have any negative ecological consequences. Moreover, dissolved Al concentrations have been found to decrease over time in both laboratory and field settings, including the alum treatment of Big Bear Lake in 2004 (Berkowitz, 2005).

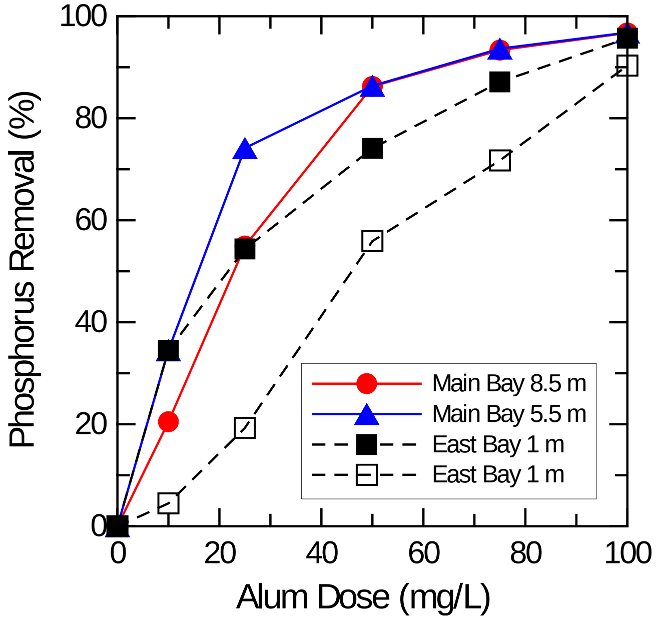

Fig. 9. Phosphorus removal from Canyon Lake water as function of alum dose.

The chemistry of Canyon Lake is not vastly different from that of Big Bear Lake (e.g., pH 8.2, alkalinity 3-4 meq/L), so it is useful to consider that case study further. Specifically, pH and alkalinities in the lake returned to pre-treatment levels within a couple months of treatment, and dissolved Al concentrations, while often near 200 µg/L (0.2 mg/L) during application, quickly decreased to <50 µg/L following the end of the application (due to the large size of the lake and scale of the treatment, application occurred over several weeks). Importantly, no significant short-term or longer-term negative ecological impacts were noted (e.g., no fish mortality was observed).

A small pilot treatment in Papoose Bay with a large (~400-500 mg/L alum) dose was conducted prior to that full-scale treatment; a small logger deployed there found pH to recover to pre-treatment levels within 14 days (dissolved Al measurements were not made, however).

Removal of phosphorus from water collected from East Bay water at about 1 m depth generally demonstrated somewhat lower total P removal efficiencies when compared with the hypolimnetic water; this presumably results from a much larger fraction of P in particulate forms and the higher initial pH that could result in less floc formation. Nonetheless, alum treatment of East Bay waters significantly reduced total P concentrations and lowered turbidity while yielding dissolved Al concentrations below the acute toxicity threshold.

These findings suggest that, with some care, an alum treatment of Canyon Lake should be an effective way to remove phosphorus from the water column and, for surface treatments, should also improve water clarity for at least a short period following application.

Conclusions

This set of simulations indicate:

(i) Implementation of watershed BMPs that achieve a 15% reduction in external loading of N and P was found to yield modest improvements in water quality in Canyon Lake.

(ii) Annual hypolimnetic alum treatment, especially with a sufficient dose to reduce internal PO_4 recycling, provided strong predicted reductions in total P and dramatic reductions in chlorophyll a concentrations.

(iii) Modest alum doses in early winter also yielded significant reductions in total P and chlorophyll levels, although the extent of improvements were lower than predicted with larger hypolimnetic doses.

(iv) BMPs and alum treatments had limited effects on total N and DO concentrations.

(v) Recent jar test results and past experience at Big Bear Lake suggest that, with some care, treatment of Canyon Lake with alum should shift the lake to P-limitation and provide significant reductions in chlorophyll a concentrations.

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Canyon Lake Alum Jar Testing Study

Conducted by the Water Quality Laboratory –California State University San Bernardino

Supervised by Dr. Jim Noblet

Summary of Results

Four field samples were collected from Canyon Lake, two locations in the Main Body, and two locations in the East Bay. Samples in the main lake (8 L) were collected from below the thermocline, i.e., in the hypolimnion. Samples were collected at CSUSB monitoring stations 7 (near the damn) and 8 (middle of main channel). Samples from the east bay (10 L) were collected at monitoring stations 9 and 10, from the middle of the channel adjacent to Road Runner beach and Indian beach, respectively. Samples from the east bay were taken at approximately one meter depth as the lake at these locations was not stratified.

Jar tests were performed on the collected samples using 1.0 L samples, using a 10,000 ppm alum stock solution. Jar test were performed as follows: The appropriate amount of alum stock was added to each sample, and flash mixed at 220 rpm for 1.25 minutes, then followed by flocculation at 25 rpm for 30 minutes. The samples were then allowed to settle for 2-3 hours until all of the floc had fully settled. Before and after treatment samples were measured for pH, temp, turbidity, conductivity, dissolved aluminum concentration, total nitrogen and total phosphorus. Alkalinity and TOC samples are still being analyzed and the data are forthcoming. The goal of the testing was to identify the dose of alum required to achieve a turbidity of less than 1.0 NTU. The tests were performed at doses of 0 (control, before), 10, 25, 50, 75, and 100 mg/L Alum.

The results of the testing are presented in the attached spreadsheet. For the hypolimnion samples from stations 7 and 8, a dose of 25-50 ppm alum is sufficient to achieve a turbidity of$\leq$1.0 NTU. However, doses of 100 ppm are required to achieve the lowest dissolved Al concentrations, and maximum phosphorus removal. For the east bay water samples, it appears that a dose of 100 ppm alum is required to achieve both turbidity reduction and the lowest dissolved Al concentrations, and maximum phosphorus removal. It is noteworthy that the pH of the sample from station 10 (farthest into the east bay) dropped almost two pH units with a 100 ppm alum dose. However, pH and turbidity measurements taken after 24 hrs showed that pH had gone back up by 0.6 pH units while turbidity dropped slightly.

These initial results show that alum may be effective in reducing the turbidity and phosphorus content of the waters from throughout the lake, but the residual aluminum concentrations exceed the EPA ambient water quality criterion for protection of aquatic biota, which is 87 µg/L for chronic toxicity (the acute toxicity criterion is 750 µg/L). It is possible that even higher alum doses my decrease the residual dissolved Al, but dose is limited by the alkalinity of the lake water.

Canyon Lake Alum Study Results

Station 7 (hypolimnion, 8.5 m)

Alum Dose (mg/L)	pH	Temp (^{o}C)	Turbidity* (NTU)	Cond. (μS/cm	Diss. Al (μg/L)	Tot N (mg/L)	Tot P (mg/L)
0	7.57	22.1	90.25	1032	72	2.290	1.010
10	7.45	21.3	1.51	1030	289	2.310	0.803
25	7.50	21.6	0.91	1032	366	2.210	0.455
50	7.44	21.5	0.54	1036	321	2.160	0.139
75	7.30	21.7	0.43	1037	298	2.060	0.067
100	7.29	21.3	0.89	1042	258	1.770	0.033

* High Turbidity was due to a precipitation reaction that occurred during storage at 4^{o}C.
Field turbidity was around 6.0 NTU

Station 8 (hypolimnion, 5.5 m)

Alum Dose (mg/L)	pH	Temp (^{o}C)	Turbidity (NTU)	Cond. (μS/cm	Diss. Al (μg/L)	Tot N (mg/L)	Tot P (mg/L)
0	7.97	22.10	5.89	1100	83	1.100	0.313
10	8.06	22.20	2.00	1117	374	0.960	0.205
25	7.91	21.60	1.03	1124	389	0.809	0.081
50	7.66	22.00	0.71	1118	355	0.705	0.043
75	7.41	21.60	0.62	1118	276	0.676	0.020
100	7.31	22.00	0.18	1127	236	0.688	0.010

Station 9 (East Bay, Road Runner Beach)

Alum Dose (mg/L)	pH	Temp (^{o}C)	Turbidity ** (NTU)	Cond. (μS/cm	Diss. Al (μg/L)	Tot N (mg/L)	Tot P (mg/L)
0	8.55	21.8	2.17	1270	134	1.348	0.098
10	8.01	21.3	1.96	1299	287	1.460	0.064
25	7.81	21.6	1.37	1290	331	1.210	0.045
50	7.64	21.3	0.95	1290	285	0.971	0.025
75	7.52	21.8	0.52	1305	231	0.813	0.013
100	7.33	21.3	0.69	1299	146	0.647	0.004

** Turbidity changed during storge at 4^{o} C. Field turbidity was 12.7

Station 10 (East Bay, Indian Beach)

Alum Dose (mg/L)	pH	Temp (^{o}C)	Turbidity*** (NTU)	Cond. (μS/cm	Diss. Al (μg/L)	Tot N (mg/L)	Tot P (mg/L)
0	8.56	22.1	7.84	1277	17	1.635	1.056
10	8.06	22.1	4.60	1286	607	1.480	0.094
25	7.66	21.8	3.55	1287	511	1.310	0.079
50	7.17	21.9	1.77	1294	456	0.994	0.043
75	6.95	22.0	1.47	1296	441	0.801	0.028
100	6.69	22.0	0.71	1297	280	0.585	0.009

*** Turbidity changed during storge at 4^{o} C. Field turbidity was 20.0

Station 10 After 24hrs	pH	Turbidity*** (NTU)
	8.56	7.84
	8.10	4.04
	7.88	2.70
	7.63	1.85
	7.46	1.46
	7.30	0.53

I want to make you aware of a couple of comments from Hope Smythe on the FY 2011-12 LE&CL Annual TMDL report, that I believe we should be diligent in how we address .

Hope has noted the following:

1. Now that the watershed sampling has occurred for a few years, it would be useful to include a summary table of the annual loads as measured each year in order to begin to evaluate and track the 10-year average TMDL.

2. Now that a large database of water quality data has been generated for both Canyon Lake and Lake Elsinore, it would be useful to perform statistical analyses to evaluate how chlorophyll a levels and dissolved oxygen are related to TP and TN concentrations, lake level or other factors. I would be interested to know if the Task Force believes this would an appropriate next step for data analysis or if other evaluation techniques are preferred (modeling).

How do you want to proceed on these tasks?

Hope's entire email follows, if you wanted to read the comments in their greater context.

I appreciate your feedback.

Thank you,

Rick Whetsel
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From: Smythe, Hope@Waterboards [mailto:Hope.Smythe@waterboards.ca.gov]
Sent: Tuesday, August 28, 2012 10:14 AM
To: Rick Whetsel
Cc: Smythe, Hope@Waterboards
Subject: Lake Elsinore/Canyon Lake TMDL Annual Report

Rick – I have reviewed the draft annual report. In general, I find the report and presentation of data to be thorough and well organized. I do have a couple of questions/comments.

<u>San Jacinto River Watershed Monitoring:</u>

3. As indicated in the report, the USGS flow data is provisional. Will there be a follow-up addendum or memo to the annual report that will report the final USGS flow data? This may also include a recalculation of the nitrogen and phosphorus loads.
4. Now that the watershed sampling has occurred for a few years, it would be useful to include a summary table of the annual loads as measured each year in order to begin to evaluate and track the 10-year average TMDL.

Lake Elsinore Monitoring

1. Table 3-1 indicates that the WLA for EVMWD supplemental water is specified as an annual load. Both the TMDL and the EVMWD permit specify the supplemental water WLA as a 5-year running average. Therefore, I would recommend an additional table be added to this section that summarizes the annual nitrogen and phosphorus load for each year of supplemental water addition. That will allow tracking and evaluation of the 5-year WLA compliance.
2. We note that there was a fish kill reported on April 27, 2012. Was any water quality data collected in Lake Elsinore during this time period? I do note that, as reported in Table 3-2, there were no exceedances of the ammonia acute and/or chronic criteria during April. However, it is unclear if the April sampling period occurred when the fish kill was reported. Further, from Figures 3-3 and 3-4, it appears that dissolved oxygen levels in April 2012 were suppressed. It would be useful to have some discussion of the fish kills in relationship to the reported data.

Canyon Lake Monitoring

1. I note that there are several exceedances of both the acute and chronic ammonia criteria in both the Main Basin and East Bay. In reviewing the annual report from last year (July 2010-June 2011), there were only exceedances of the chronic criterion in the Main Basin. I am unclear why this year's ammonia exceedances are greater than last year. However, I do note that there were no reported fish kills in Canyon Lake during the sampling period.

Finally, I'd like to reiterate a comment that I made upon review of last year's annual report. Now that a large database of water quality data has been generated for both Canyon Lake and Lake Elsinore, it would be useful to perform statistical analyses to evaluate how chlorophyll a levels and dissolved oxygen are related to TP and TN concentrations, lake level or other factors. I would be interested to know if the Task Force believes this would an appropriate next step for data analysis or if other evaluation techniques are preferred (modeling).

Please let me know if you wish to discuss these comments or need further information.

Hope

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Hope Smythe
Chief, Inland Waters Planning Section
951-782-4493