Water Resource Services Inc.
144 Crane Hill Road
Wilbraham, MA 01095
kjwagner@charter.net
413-219-8071

March 11, 2024

To: Ms. Erica Kidd
Lake Auburn Watershed Protection Commission
Via email at ekidd@awsd.org

From: Ken Wagner, WRS, Inc.

Re: Evaluation of improvement potential for Lake Auburn

Dear Ms. Kidd and interested parties from the LAWPC:

WRS, Inc. with its partner Ecological Instincts, has completed a review of the potential to reduce phosphorus (P) loading to Lake Auburn and minimize the potential for harmful algal blooms. The actual field assessment and resulting estimation of loading reductions conducted by Ecological Instincts is described in an accompanying memorandum attached as an addendum. For purposes of assessing overall impact of non-point source (NPS) load reductions and other possible management actions (including dredging the Basin, installing a P inactivation dosing station, or treating the lake with aluminum a second time), we used the Lake Loading Response Model (LLRM). I will concisely describe its use here but have prepared a much larger document on how to apply this model in the past and can supply that to anyone with a more technical interest.

With the model set up and calibrated to pre-2019 conditions (before the lake aluminum treatment, using data from 2014-2018), LLRM was used to predict the outcome of the aluminum treatment and compare that to actual data from 2020-2023. The result was accurate, suggesting the model was verified for use in testing further scenarios for managing P inputs to Lake Auburn. The results of those scenarios are expressed as a steady state average P concentration in the lake and the probability of observing chlorophyll-a (a common algal pigment indicative of algal biomass) in excess of 4, 6 or 8 ug/L. Results can be compared with each other and both the theoretical best possible condition attainable with current land use or the expected original condition of the lake without any human uses in the watershed. This analysis sheds light on what actions would be most effective for improving and protecting Lake Auburn.

LLRM Set Up

LLRM is a spreadsheet model with cells linked to provide calculations of contaminant load generation, attenuation on the way to a lake, and final concentration in the lake based on water and contaminant loading using a series of empirical models. It is a fairly simple model, requiring limited data to use effectively, but it works best when water quality data are sufficient to test assumptions and adjust coefficients properly. LLRM is applied here to evaluate water and P loading to Lake Auburn.

The watershed of Lake Auburn was divided into 10 drainage areas, each with a land use breakdown and total area (Table 1, Figure 1).

Table 1. Drainage basins and land use in the Lake Auburn watershed

	1-Mud Pond	2-L Wilson Pond	3-The Basin	4-Townsend Bk	5-Rt 4	6-WAR-YC-GL	7-Spring Rd	8-N Auburn	9-Lake Shore Drive (W)	10-Lake Shore Drive (E)	TOTAL
LAND USE	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)
Low-Density Mixed Urban	15.8	13.2	17.9	20.5	13.2	10.6	18.9	5.5	3.3	4.7	123.6
Medium-Density Mixed Urban	0.0	0.0	0.0	4.3	1.2	0.0	0.0	0.0	0.0	0.9	6.3
High-Density Mixed Urban	0.0	0.0	0.0	0.0	2.2	1.9	0.0	0.0	0.0	0.0	4.1
Low-Density Residential	30.7	37.6	21.8	17.0	10.2	12.1	28.1	10.3	2.3	14.5	184.5
Medium-Density Residential	0.0	0.0	0.0	3.6	1.5	0.0	0.0	0.0	0.0	0.0	5.1
High-Density Residential	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0	3.1
Hay/Pasture	76.1	6.7	39.7	20.3	2.8	34.1	11.7	1.9	0.0	3.5	196.9
Cropland	16.1	0.0	2.0	7.0	0.2	12.7	4.8	0.0	0.0	1.1	44.0
Forest	689.1	320.5	506.4	435.5	86.0	207.9	221.6	121.1	91.2	130.9	2810.1
Water	44.5	52.9	49.6	14.2	4.4	10.8	0.2	4.0	1.8	2.2	184.7
Disturbed	2.2	0.5	2.5	24.7	0.0	3.1	0.0	0.0	0.0	0.0	33.0
Turf/Golf	0.0	0.0	0.0	14.7	0.0	0.9	0.0	0.0	0.0	0.0	15.6
Open Land	28.6	10.9	34.6	32.3	13.2	20.6	37.2	10.1	2.2	22.7	212.4
TOTAL	903.1	442.3	674.5	594.1	138.0	314.6	322.5	152.9	100.7	180.6	3823.3

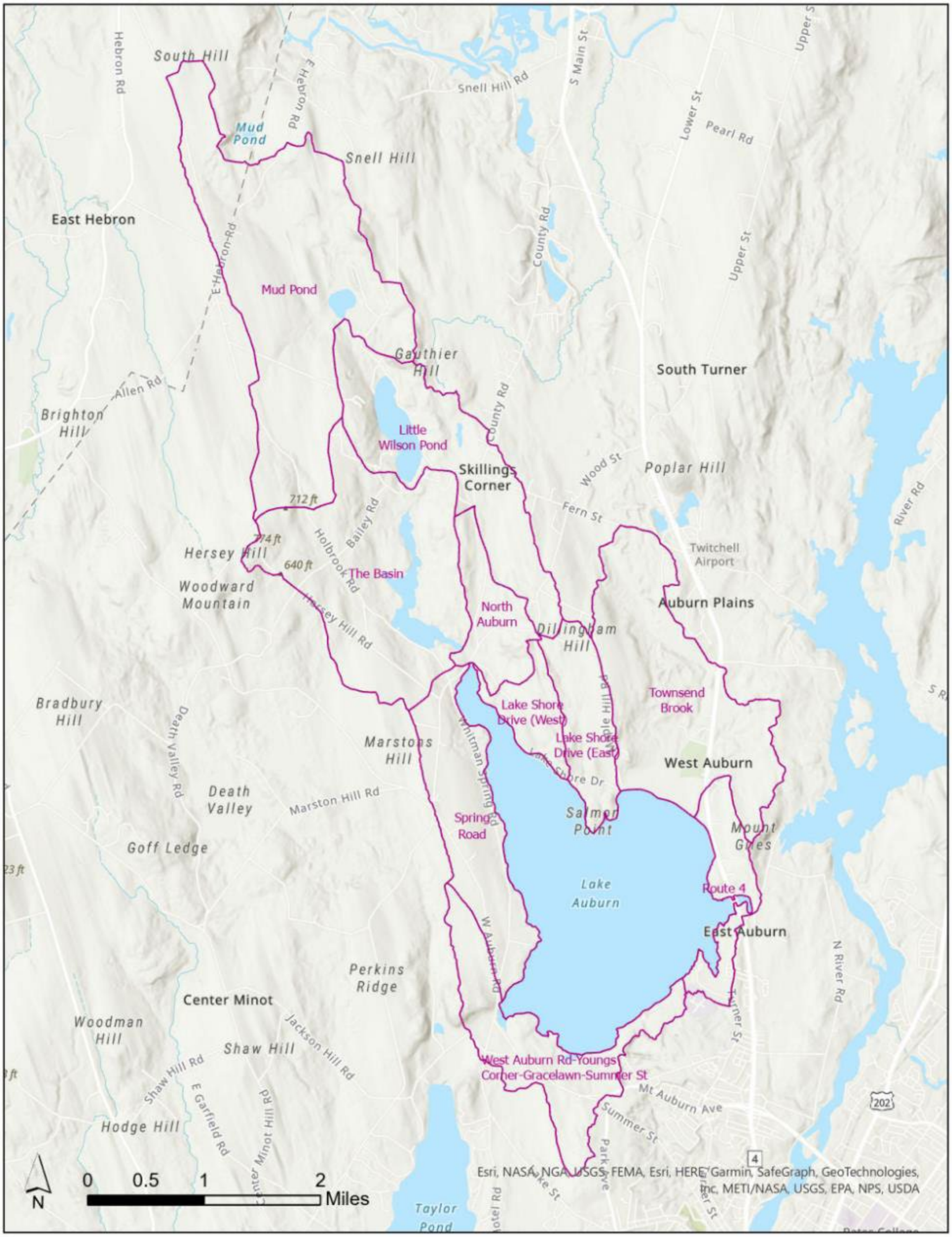
Water and P export coefficients are assigned based on a known range for the area, usually using the mean or median to start with and adjusting to get the model to match actual data. For example, the range of P export for forested land is 0.02 to 0.83 kg/ha/yr with a mean of 0.24 and median of 0.20 kg/ha/yr. Yet forested land in Maine falls near the low end of this scale from past experience and a value of 0.10 kg/ha/yr was applied based on that knowledge. Export coefficients apply to all land of a given type within the watershed; one cannot assign parcels in one drainage basin a different export coefficient than in the other basins.

Attenuation coefficients are also assigned, but on a basin by basin basis, depending on features or management actions that affect the transport of water and P to the lake. For example, a lake will typically remove at least half the P unless it is filled with sediment, and evaporation will cause greater loss of water from a lake than from a stream. Again, there is a known range for attenuation for each drainage basin feature (e.g., lake, wetland, buffer zone, detention or infiltration basin, etc.) and values are applied based on knowledge of the specific basin. A basin with a stream passing through with steep slopes will provide minimal loss of water or attenuation of P, while a flat basin with extensive wetlands will cause greater loss of water and P on the way to the lake. This is where having data for flow and P at the downstream end of the drainage area is important to verify proper selection of attenuation coefficients.

There are also modules within LLRM for addressing direct atmospheric inputs (regional values from other studies are fairly reliable), point source inputs (none for Lake Auburn), on-site wastewater disposal (some but not a large influence in this system), wildlife inputs (less known for this system but estimates can be made), and internal loading (release from sediment, calculable from lake data).

The loads of water and P from different sources are summed up and act as inputs to the predictions part of the model, where the steady state average concentration of P in the lake is calculated and other water quality features such as clarity and the probability of chlorophyll-a occurring above chosen thresholds are estimated.

Figure 1. Drainage basins in the Lake Auburn watershed



Once the model is initially set up, data from the downstream end of any drainage area and from the lake itself can be used to evaluate the accuracy of the model results and coefficients can be adjusted to get better matches. While the ultimate goal is to match predicted in-lake P concentration to real data, having data to evaluate accuracy for each drainage basin is also important and is often a weak point of LLRM use. In the case of Lake Auburn, monitoring efforts by LAWPC staff has resulted in a valuable database of flows and water quality measures, typically with 50 to 100 values for each point of interest in the watershed over the last decade. Confidence in the model is greatly enhanced when the results for each basin match real data.

Pre-2019 Lake Condition

Very good agreement was obtained between actual data and either drainage basin or lake predictions in what is identified as scenario #1 (Table 2) with limited adjustment of model parameters. Data for Lake Auburn from 2014-2018 were used. The average volume weighted P concentration and average from epilimnetic cores provided a range of 10.8 to 11.2 ug/L while the prediction from LLRM was 10.9 ug/L. Tributary inputs were a reasonable match for actual flow data and P concentrations. Predicted and measured flows for drainage areas deviated by no more than 17% and averaged 6% difference. Predicted P concentrations for tributaries deviated from measured averages by <14%. A few drainage areas had limited data and larger deviations for understandable reasons (e.g., only one of several tributaries measured, data skewed by dominant wet weather values), but the overall agreement was acceptable. Chlorophyll-a is predicted to exceed 4 ug/L 27% of the time and did exceed that level 25% of the time. Thresholds of 6 and 8 ug/L had predicted occurrences of 7.7 and 2.3% with actual exceedances of 8 and 2%.

Current Lake Condition

LLRM was altered to represent current lake conditions by changing the internal loading in what is identified as scenario #2 (Table 2). The 2019 treatment of about half the lake area with aluminum stripped some P from the water column and inactivated surficial sediment P that could be released back into the water column. Based on the 2020-2023 data for the lake, a decrease in internal loading of 115 kg/yr was achieved. The treatment was expected to inactivate about half the available P in the contributing layer of sediment, but these data suggest that the reduction was closer to one third of the pre-treatment internal load. There will be year to year variation based on weather pattern (e.g., temperature and incoming organic load), but the model only considers a long-term steady state condition.

The predicted post-aluminum treatment TP was 9.7 ug/L while the range from actual data was 9.6 to 10.5 ug/L. Chlorophyll-a >4 ug/L was predicted at 17.6% vs actual data at 15.3%. Chlorophyll-a in excess of either 6 or 8 ug/L was predicted at 4.1 and 1.0% respectively, compared with 6.1 and 1.4% from actual data. The LLRM, as set up, appears to properly represent Lake Auburn and the result of P loading to it.

Potential Future Lake Condition with Management

LLRM was used to evaluate the likely results of various management options (Table 2). Changes were made to reflect the anticipated effect of chosen management actions, usually by altering the attenuation coefficient for any drainage area in which the action was planned. Choosing the new attenuation coefficient is the challenge, and being as rational and realistic as possible was the goal. The accompanying memorandum from Ecological Instincts provides the justification for the

Table 2. Results of LLRM for tested scenarios

Scenario #	1	2	3	4	5	6	7	8	9
SUMMARY TABLE FOR SCENARIO TESTING	2014-2018 pre-Al trtmnt	2020-2023 post-Al trtmnt	Pre-development Conditions	Maximum feasible P reduction	Identified NPS sites remediated (expected results)	Identiifed NPS sites maximum reduction	2nd Al trtmnt in lake	Basin dredged	Al dosing at Basin
Phosphorus (ppb)	10.9	9.7	4.6	6.8	9.4	9.2	8.5	9.1	8.7
Bloom Probability									
Probability of Chl >4 ug/L	27.0%	17.6%	0.0%	2.5%	15.6%	14.1%	9.6%	13.4%	10.6%
Probability of Chl >6 ug/L	7.7%	4.1%	0.0%	0.3%	3.4%	2.9%	1.7%	2.8%	2.0%
Probability of Chl >8 ug/L	2.3%	1.0%	0.0%	0.0%	0.8%	0.7%	0.4%	0.6%	0.4%

	10	11	12	13	14	15	16	17
SUMMARY TABLE FOR SCENARIO TESTING	Al dosing and dredging at Basin	Al dosing and dredging at Basin + 2nd lake Al trtmt	NPS sites remediated + 2nd lake Al trtmnt	NPS sites remediated + dredging at Basin	NPS sites remediated + dredging at Basin + 2nd lake Al trtmnt	NPS sites remediated + Al dosing and dredging at Basin	NPS sites remediated + Al dosing and dredging at Basin + 2nd lake Al trtmnt	NPS sites remediated to max + Al dosing and dredging at Basin + 2nd lake Al trtmnt
Phosphorus (ppb)	8.3	7.2	8.3	9.0	7.8	8.3	7.1	7.0
Bloom Probability								
Probability of Chl >4 ug/L	8.6%	3.5%	8.1%	12.5%	6.0%	8.5%	3.4%	2.9%
Probability of Chl >6 ug/L	1.5%	0.4%	1.4%	2.5%	0.9%	1.5%	0.4%	0.3%
Probability of Chl >8 ug/L	0.3%	0.1%	0.3%	0.6%	0.2%	0.3%	0.1%	0.1%

amount of P load that could be reduced by work on NPS sites, including developed and agricultural sites listed by CDM Smith in its evaluation as adjusted by Ecological Instincts through its 2023 assessment. For management of NPS sources, attenuation coefficients that resulted in the expected P load reductions were chosen. In some cases, actions also affect water load, as with dredging the Basin, which would provide more detention time and evaporation as well as greater P retention. Adjustments were made on a drainage area by drainage area basis. Once individual actions like dredging or NPS control were evaluated, combinations of management actions were modeled.

Management Options

Considered management options included remediating identified NPS sites at two levels of success, a second in-lake aluminum treatment, dredging the Basin, and installing an aluminum dosing station to treat water in or leaving the Basin. To provide comparison of results beyond the pre-aluminum treatment period (2014-2018) and the current condition (2020-2023, post-aluminum treatment), LLRM was run to simulate pre-development conditions (all land altered by human use restored to forest) and maximum feasible P reduction conditions (watershed loading decreased by 20% or to an attenuation minimum of 50%, Basin dredged, internal load reduced by 75%). Combinations of management options were also simulated by LLRM for comparison.

LLRM Results from Management

The model suggests that prior to human development (including agriculture) in the Lake Auburn watershed, average P concentration in the lake was slightly less than 5 ug/L, consistent with values for the more pristine lakes in Maine (scenario #3, Table 2). Chlorophyll-a >4 ug/L would not be expected. With current land use but every practical management method applied throughout the watershed and in the lake, the average P concentration would be expected to be slightly less than 7 ug/L, chlorophyll-a would exceed 4 ug/L 2.5% of the time and very rarely go above 6 ug/L (scenario #4, Table 2). Scenario 4 sets the maximum expectation for improvement through management. While doing better is not impossible, it is very unlikely based on considerable experience elsewhere. An increase of about 2 ug/L from pre-development to current land use conditions is therefore suggested as unavoidable, rising from 4.6 ug/L to 6.8 ug/L. Fortunately, P at around 7 ug/L would minimize algae issues and provide conditions that support the filtration waiver. The central question is how close to this expected maximum improvement can various management actions move the lake?

Scenarios 5 through 9 examine the individual management methods listed above, each applied independently and singly. These result in average P concentrations between 8.5 and 9.4 ug/L, slight decreases from the current average P concentration of 9.7 ug/L (scenario #2). Chlorophyll-a concentration would exceed 4 ug/L between 9.6 and 15.6% of the time, compared to 17.6% now by LLRM prediction. Chlorophyll-a concentration would exceed 6 ug/L between 1.7 and 3.4% of the time, compared to 4.1% now by LLRM prediction. Chlorophyll-a >8 ug/L would still be rare, <1%, compared to about 1% now. These are significant improvements, but do not approach the maximum feasible improvement (scenario #4).

The best improvement from an individual management action comes from a second lake treatment with aluminum (scenario #7), but that improvement would diminish substantially after no more than 8 years. Remediating NPS sites (scenarios #5 and 6) provides the least improvement, either at a management level expected to be achievable by normal effort or a higher level that will require more effort than is typical. Benefits might be provided for a longer duration, however, with watershed management. Dredging the Basin to provide enhanced detention of water and retention of P and installation of a dosing station to inactivate P leaving the Basin provide improvement intermediate to NPS site remediation and lake treatment to inactivate P. All may be worthwhile and will improve conditions over the current situation, but none is sufficient by itself to eliminate algae issues. One additional important benefit of dredging the Basin is that it would reduce organic loading to Lake Auburn, likely a major factor in oxygen loss during summer. NPS site remediation will also provide benefits in organic input control, but the Basin serves the largest drainage area by far and covers some of the NPS sites.

The second part of Table 2 includes scenarios involving combinations of the individual management actions assessed in the first part of Table 2. Dredging the Basin to improve its performance in sequestering P from this largest of drainage areas and installing a dosing station to inactivate P passing through that waterbody (scenario #10) would decrease average P concentration to 8.3 ug/L, reducing the probability of chlorophyll-a >4 ug/L to 8.6%, >6 ug/L to 1.5%, and >8 ug/L to 0.3%. This combination action would greatly reduce P entering Lake Auburn from 53% of the watershed but has no effect on other inputs. Adding a second lake treatment to inactivate P to the Basin dredging and a P inactivation dosing station (scenario #11) decreases the average P concentration to 7.2 ug/L and moves the probabilities for exceeding chlorophyll-a thresholds much closer to the expected maximum feasible improvement level. How long the in-lake treatment will last will depend on continued loading from the watershed, but the dredging of the Basin and inactivation of P passing through it could extend the duration of benefits from in-lake treatment considerably.

The remainder of the scenarios in the second part of Table 2 include NPS site remediation with various combinations of the other management options. Where NPS remediation is coupled with dredging the Basin or inactivating P at the Basin outlet or a second in-lake P inactivation treatment (scenarios #12 through #15), predicted average P is no greater than 9 ug/L, but does not approach the level achieved by scenario #11. Combining the lower level of NPS site remediation with Basin dredging and P inactivation at the Basin and in the lake (scenario #16) reduces the average P concentration to 7.1 ug/L, while combining the higher level of NPS site remediation with the other actions (scenario #17) decreases P concentration to 7.0 ug/L. These combination management scenarios achieve the greatest P load reduction and maximum improvement of in-lake conditions.

However, remediation of identified NPS sites, while beneficial, does not provide a large enough P load reduction in scenarios #16 and #17 to be very different from scenario #11 (dredging, P inactivation in Basin and Lake Auburn). Much greater watershed NPS load control is needed and is very challenging in this (and many other) watersheds. The identified sites are mostly small and diffuse, necessitating a lot of separate efforts and considerable expense. Going beyond the identified problem sites will require more assessment and work on private property, much of it not under any jurisdiction that provides a means to force action. The higher level of NPS management applied in scenarios #6 and #17 assumes a level of cooperation that may not be achievable and only reduces P in Lake Auburn by 0.1 ug/L over the lower level of NPS management.

The results from scenario testing can be visualized in comparative bar charts for P (Figure 2), chlorophyll-a >4 ug/L (Figure 3), chlorophyll-a >6 ug/L (Figure 4), and chlorophyll-a >8 ug/L (Figure 5). The maximum achievable P reduction from management results in the minimum achievable P or Chl-a concentration in the lake, shown as horizontal lines on the graphs. All of the solutions that approach the minimum achievable P or Chl-a concentration through management actions involve both dredging the Basin and adding a P inactivation dosing station near the Basin. The changes in average P concentration may not seem all that large when viewed on the graph, but they translate into substantial shifts in Chl-a concentration that are important to raw water quality at the water supply intake.

Average P concentration represents a distribution, and actually visualizing that distribution may be helpful in understanding the results of management. Considering the pre-treatment period of 2014-2018 vs the post-treatment period of 2020-2023, the two leftmost bars in Figure 2, the distribution of P (Figure 6) demonstrates how the aluminum treatment has moved P concentrations toward lower values. There are still elevated values in the righthand tail, but overall, the post-treatment distribution has been compressed to the left, toward lower values, resulting in the observed decrease in average TP (Figure 2). There are values in the 2020-2023 distribution that are lower than any in the 2014-2018 distribution. The spread of the distributions (standard deviation) is similar, but the post-treatment distribution is skewed toward lower P concentrations. This translates into a lower probability for any given Chl-a threshold value (Figures 3-5) and improved raw water quality at the intake. Additional management will continue to move the P distribution to the left.

Figure 2. Average predicted phosphorus concentration in Lake Auburn in response to management actions

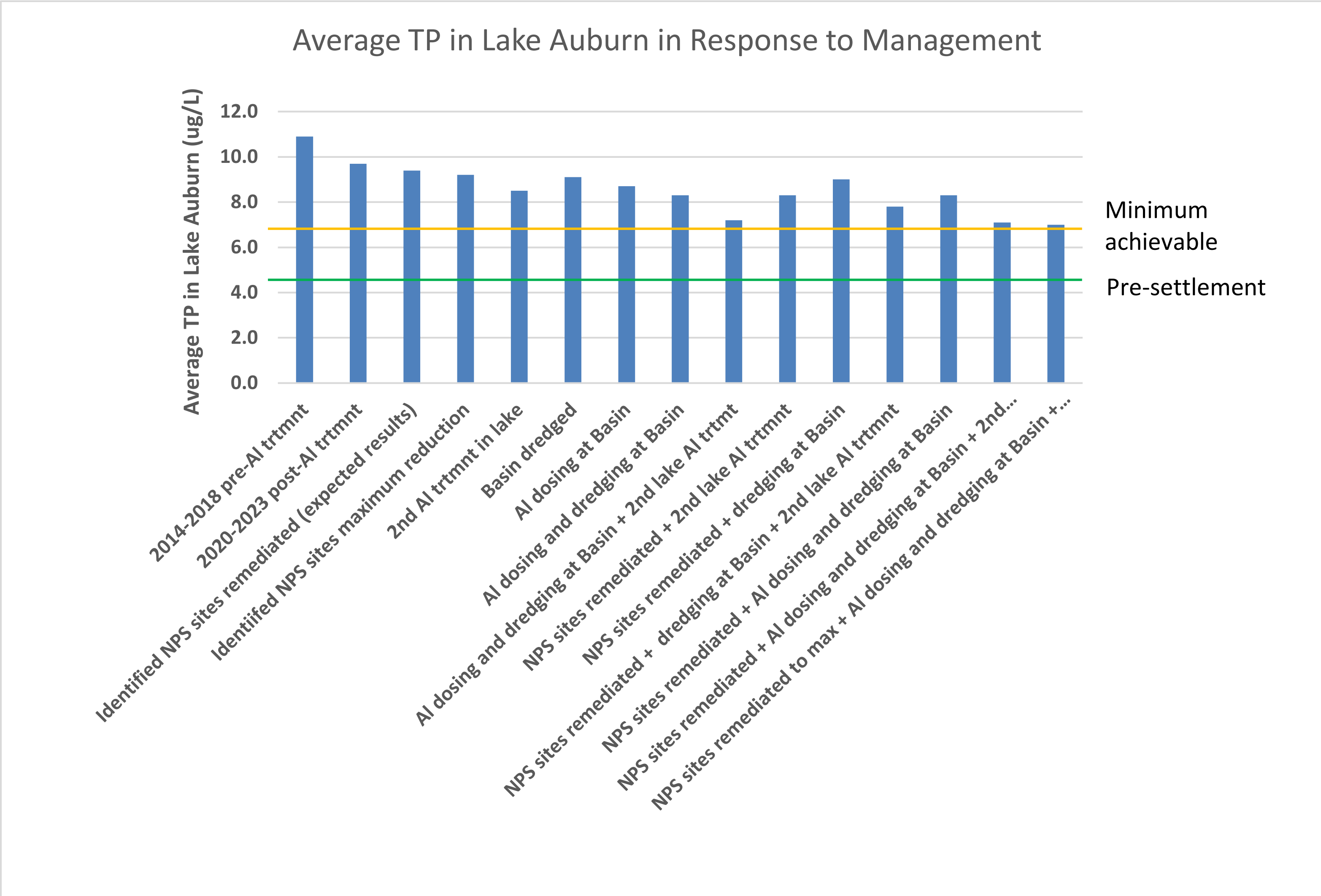


Figure 3. Probability of experiencing a chlorophyll-a concentration greater than 4 ug/L in Lake Auburn in response to management actions

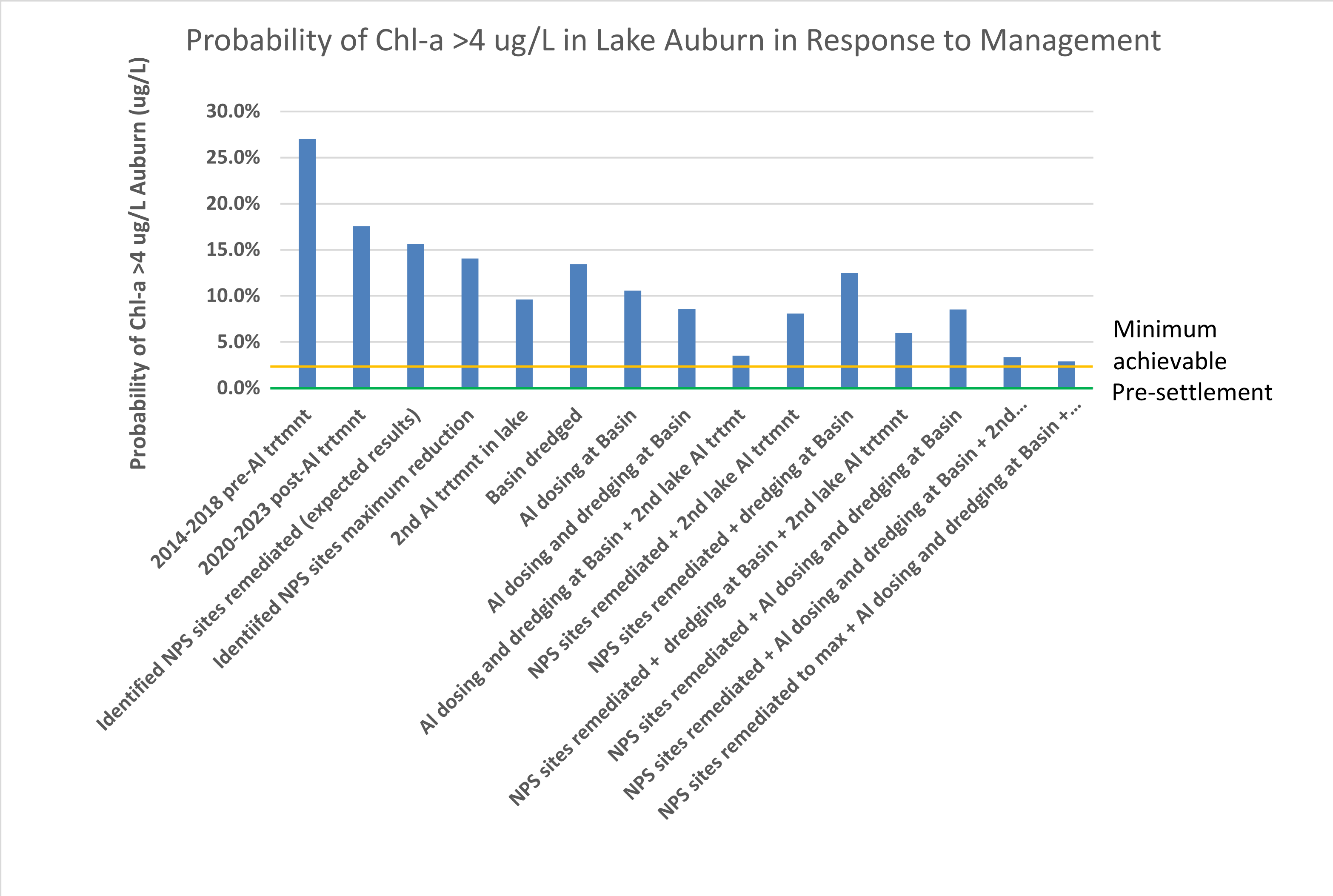


Figure 4. Probability of experiencing a chlorophyll-a concentration greater than 6 ug/L in Lake Auburn in response to management actions

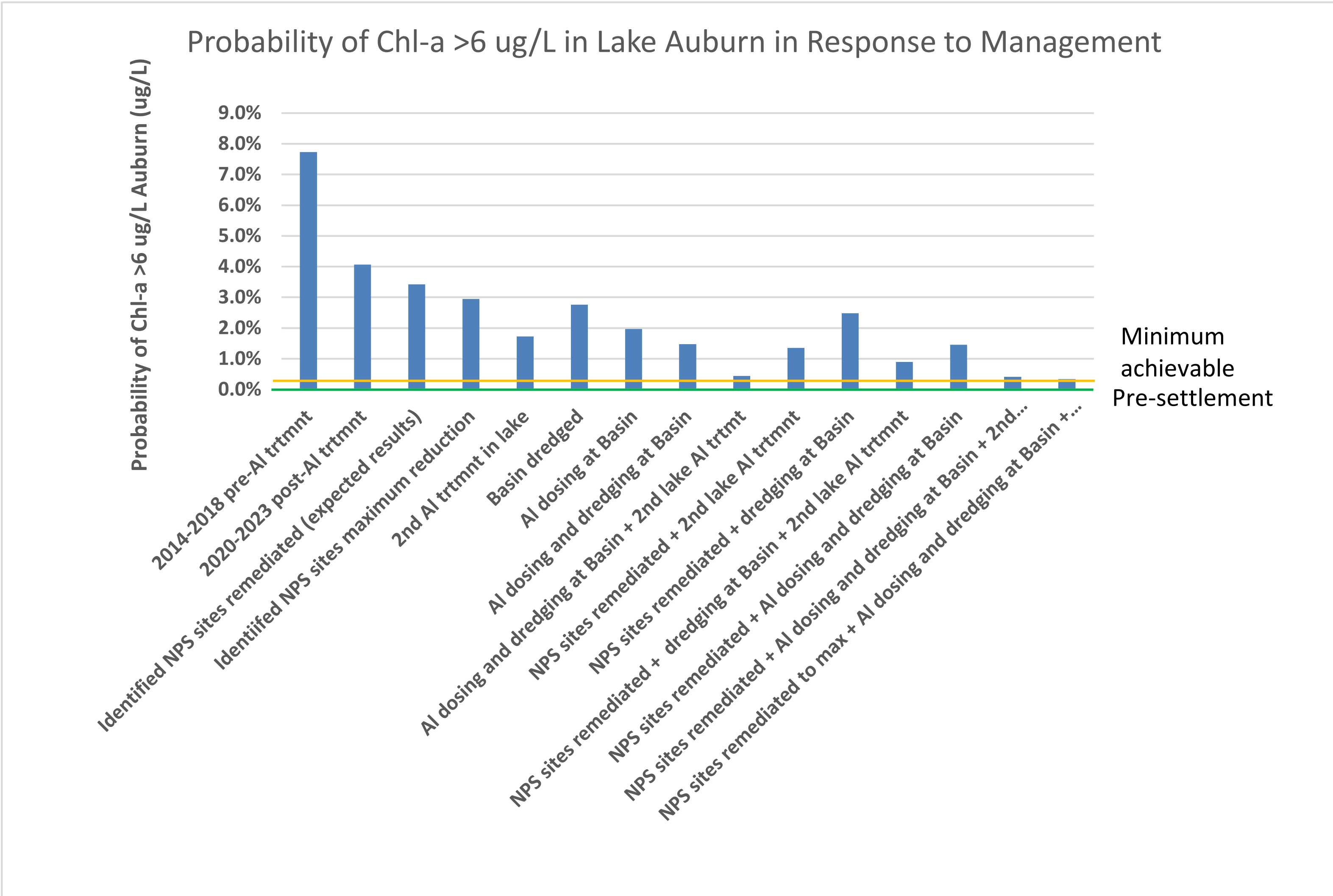


Figure 5. Probability of experiencing a chlorophyll-a concentration greater than 8 ug/L in Lake Auburn in response to management actions

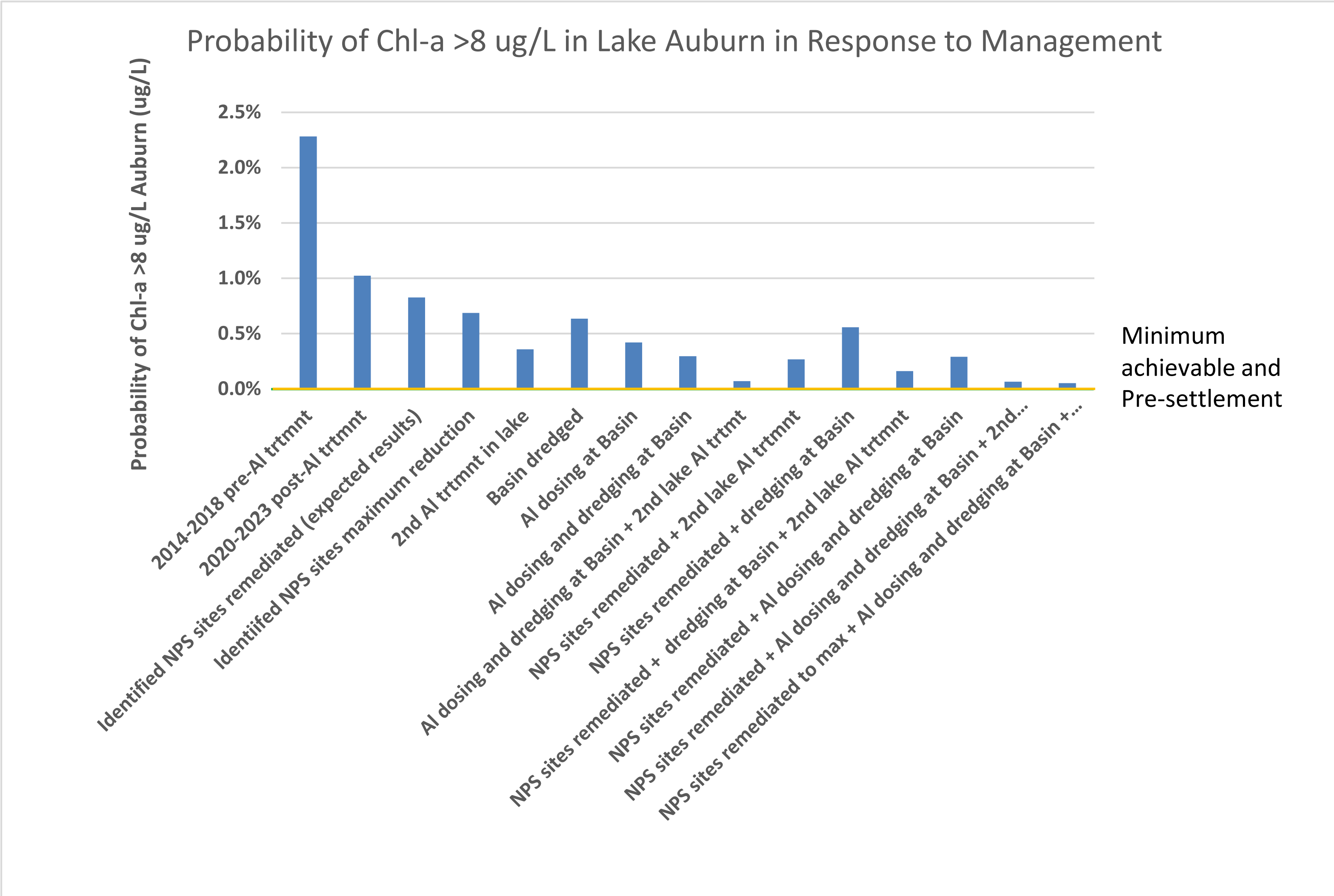
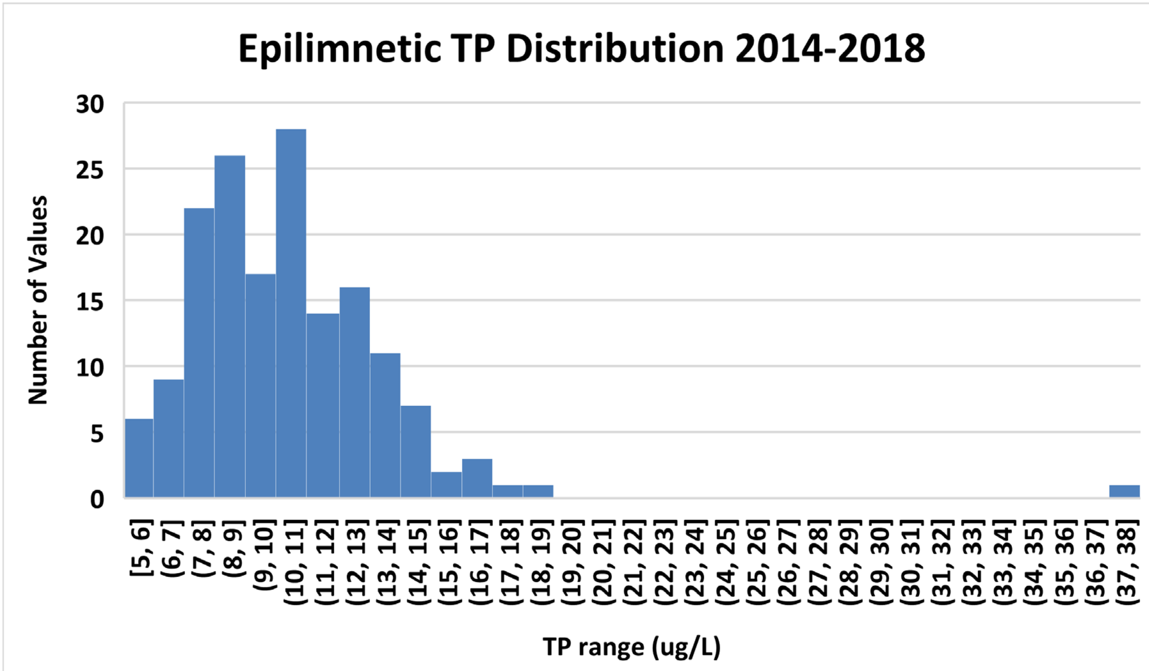
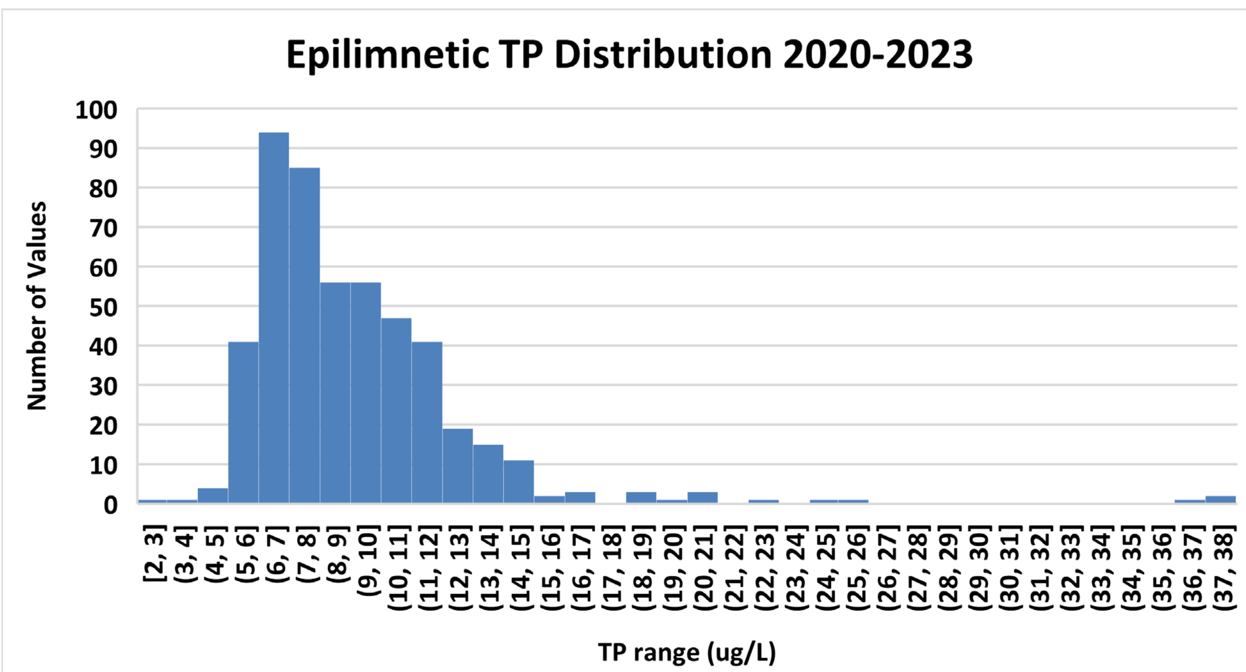


Figure 6. Comparison of phosphorus concentration distribution before and after aluminum treatment of Lake Auburn in 2019.





Conclusions from LLRM

The current condition of Lake Auburn is acceptable for most uses, but the risk of algae problems is higher than desirable for a water supply, especially one with a filtration waiver. The expected condition of the lake prior to settlement and increased human uses would be characterized as pristine, while the feasibly achievable condition with current land uses includes P that is higher by 2 ug/L (26% increase from background). The P concentration prior to the in-lake aluminum treatment in 2019 was more than 6 ug/L (137%) higher than the predicted background level, while the current concentration based on 4 years of data since the aluminum treatment is about twice the predicted background level (100% increase). Reducing the current P concentration and probability of algae issues to the minimum achievable level for existing land use requires a reduction of about 3 ug/L. This will require multiple management measures over an extended period of time, but some approaches yield faster improvement than others.

A much larger watershed management program, involving legislation to gain jurisdiction, particularly outside the Auburn city limits, and a high level of funding to bring it to fruition, would be needed to achieve desired in-lake conditions by that approach. Such an effort, if possible, would take several decades to achieve appropriate goals. Watershed management is needed and should be pursued in the Lake Auburn watershed, but if improved conditions are desired within the next few years, management will have to include options other than remediation of NPS sites and protection from additional land use changes that induce greater P and organic loading. This will undoubtedly be disappointing to people or organizations devoted to controlling pollution at the source, but it is a reality of historic land use change and regulatory and funding limitations.

Dredging the Basin to improve its retention capacity for a range of contaminants, including both P and organic matter, and installing a P inactivation dosing station in or just downstream of the Basin would address the largest delineated drainage area to Lake Auburn (53% of watershed area) and reduce average P concentration in Lake Auburn to 8.3 ug/L. Combined with a second in-lake P inactivation treatment, the P concentration could be reduced to 7.2 ug/L, only 6% higher than the expected maximum improvement achievable.

Any decision on how to approach the improvement of Lake Auburn will involve more than just estimation of achievable reductions. Cost, permitting, implementation timeframe, and jurisdiction must all be considered. Yet this analysis suggests that relatively rapid improvement could be achieved through P inactivation, especially if coupled with dredging the Basin to restore its retention capacity.

Cost of Management

There are capital costs associated with all management options, and for at least the dosing station there is ongoing operational cost. CDM Smith estimated a cost of $180,000 for remediation of 11 sites, mostly erosion control efforts, an average of over $16,000 per site. Additional non-structural measures were proposed without cost estimation, but most costs related to such efforts are internalized within organizations and difficult to quantify. In some cases, the real cost is an opportunity cost, for example income not generated when an agricultural area is taken out of service.

The CDM Smith watershed-based protection plan also included possible dredging of Blanchard Pond, updating the Tighe and Bond cost estimate to $67,600-84,500 as of the end of 2022. CDM Smith also updated the Tighe and Bond cost estimate for removing an impoundment off Turner Road to $5,600-7,900.

In this review, we attempted to cost out the management for all known problem watershed sites, including erosion areas along roadways or on public lands, private properties near water that are believed to contribute at elevated levels, and agricultural lands that have a higher inherent P export. A more detailed analysis is provided as an appendix. From the CDM Smith list of 64 possible problem sites, we were able to evaluate inputs and remediation costs for 51 sites. Known agricultural areas in the watershed were also addressed, and properties around Little Wilson Pond were included in the P input reduction program.

The cost summary (Table 3) divides the costs among the known problem NPS sites, agriculture, and Little Wilson Pond residences and provides high- and low-end estimates based on the level of P load reduction achieved. The attainable P load reductions have been discussed previously, but here the expected cost for those reductions is presented. There are many more watershed sites involved than in the cost estimate from CDM Smith, which addressed 11 identified NPS sites. A more detailed breakdown and discussion is included in the appendix, but from Table 3 one can see that it will be an expensive endeavor to address all currently known sites. Depending on the level of P load reduction sought, the cost will range from slightly more than $840,000 to over $1 million in today's dollars. With inflation and the likelihood that such a program would be spread over the next decade, the cost will likely be higher.

Table 3. Cost summary for watershed management projects

	P (kg/yr) (Low Estimate)	P (kg/yr) (High Estimate)	Low Estimated Cost	High Estimated Cost
PLET NPS Sites	14	25	$635,500	$762,600
Agriculture	23	29	$143,852	$186,255
Residential	3	5	$63,000	$94,500
Total:	**40**	**59**	**$842,352**	**$1,043,355**

Based on the total number of sites on which some form of P control would be exercised, the cost per site is somewhere between $9,500 and $11,600, lower than projected by CDM Smith for its shorter list of larger NPS sites, but consistent with expectations for the range of actions contemplated. The range of costs per site could be substantial, given differences in size, severity, and remediation needs.

Another way to look at the cost for P control is the expense per unit of P removed or made unavailable. For the projected watershed NPS management program, the average cost is between $17,700 and $21,000 per kg P. While seemingly very high, this is consistent with estimates from many other watershed management projects compiled by the USEPA. It is expected that with limited maintenance that reduction would be valid for many years, so the initial capital investment would provide ongoing P load reduction. If we assumed that the reduction held for 10 years, the cost per kg P/yr would be $1,770-2,100. Unit costs for agricultural improvements are lower, while those for PLET NPS sites are higher, but overall, a cost of around $2,000/kg P removed is to be expected.

Dredging the Basin will be an expensive endeavor if approved. The pre-dredging studies necessary to plan a dredging project were projected to cost $80,000 by CDM Smith and that is a reasonable estimate. Making assumptions about the quantity and quality of material to be dredged, CDM Smith suggested a dredging cost range of $2.8-8.5 million. If we assume that half the 110-acre Basin area is dredged and that an average of 3 feet of organic material is removed, that would be about 266,000 cubic yards of sediment. At a cost of $30/cy, the lowest cost envisioned, that would be an $8 million project. Sediment quality and disposal restrictions are a major determinant of cost for which we have no data at this time. Environmental impacts regulated under state and federal law are major determinants of whether such a project can even move forward, but without dredging the Basin, the detention capacity for the largest portion of the Lake Auburn watershed will remain severely compromised. Evaluating Basin bathymetry, sediment accumulation, and sediment quality should therefore have a high priority in management planning. Some partial dredging option should be workable and could greatly benefit reduction of organic matter entering Lake Auburn as well as P control.

While the details of a dredging project cannot be worked out at this time, the LLRM model was used to estimate the amount of P that could be detained in the Basin if it was dredged. That estimate was 70 kg/yr. If a dredging project cost $8 million, that would equate to $114,300 per kg P, although that P load reduction would continue annually for many years. Amortized over a 50-year period, the cost would be $2,286/kg P.

Re-treatment of Lake Auburn with aluminum as was performed in 2019 would be more expensive now or in the near future as a consequence of increased cost for aluminum products. The same dose would be recommended, but the 2019 cost of about $800,000 can be expected to increase to at least $1 million. The 2019 treatment appears to have reduced the P load to the lake by 115 kg, based on actual data, not just the model, so the cost per kg inactivated in 2019 was $7,000/kg and for any near future treatment it is expected to be about $8,700/kg. The target P is permanently removed from the system, so the reduction would hold for years after treatment. Assuming 10-20 years of benefit, the cost per kg of P removed would be $435-870, consistent with P inactivation projects elsewhere.

CDM Smith updated previous estimates from WRS (Wagner) for a dosing station, projecting a capital cost of $120,000 and an annual operational cost of $47,000. The capital cost appears valid, but a more detailed evaluation of operational costs is needed. With the modeling work for the watershed completed, we can now estimate that 10.7 million cubic meters of water flows through the Basin and into Lake Auburn each year. With storm flows averaging at least 5 times dry weather flows but occurring only 20% of the time, the split between storm and dry weather flows would be about even. Storm flow may represent as much as 80% of the total flow. With much higher P concentrations in storm flows, the portion of the P load delivered by storms will be much higher than during dry weather, making storm water the logical target of treatment.

Assuming treatment of 6 million cubic meters of water (6 billion liters) per year at a dose of 1 mg/L as aluminum, 6000 kg of aluminum would be needed. The most common formulation of polyaluminum chloride, a likely product for use in this application, contains 0.264 kg of aluminum per gallon, suggesting a need for 22,700 gallons of product each year. The cost of polyaluminum chloride (and all other aluminum products) has risen in the last couple of years due to several market factors and is currently about $3.50/gallon. This suggests a chemical supply cost of about $80,000 per year. Power costs and some system maintenance will apply, but the chemical cost is the main expense. An annual operational cost of up to $100,000 is currently projected for treating 6 billion liters of water.

However, there are factors that are likely to alter this estimate. The cost would rise if a higher dose of aluminum was found to be necessary or more water had to be treated. The cost would decline if treatment occurred only part of the year, and it is likely that treatment would cease for the winter, as the chemical cannot be allowed to freeze in the tanks. Unless a heated storage area was provided, a treatment season of April through November should be assumed, cutting treatment costs by 33%. Use of aluminum sulfate may be possible, reducing operational costs by about 30%, as aluminum sulfate is less expensive. The reason to use polyaluminum chloride is its lesser impact on pH, but at a dose of only 1 mg/L there should be little pH impact from any aluminum product. Testing the inactivation of storm water leaving the Basin would be appropriate for choosing a product and setting the most appropriate aluminum dose.

From the modeling work, P inactivation of water leaving the Basin could lower the P load to Lake Auburn by just under 100 kg/yr. At a first-year cost of $220,000 ($120,000 capital, $100,000 operational), the cost per kg P removed would be $2,234, but in subsequent years only the operational cost applies, and the reduction would cost $1,015/kg P. This is actually on the high end of cost per kg for P inactivation with aluminum but is appropriate for planning purposes.

The total cost for a program to reduce P loading to Lake Auburn to a level that minimizes the probability of high algal biomass in general and cyanobacteria abundance more specifically is estimated at about $11 million (Table 4), to be applied over a decade. Dredging the Basin and installing a P inactivation dosing station associated with that waterbody will provide most of the achievable benefit with regard to watershed P load reduction. Dredging costs cannot be reliably estimated with the information in hand at this time, and the projected $8 million is a reasonable placeholder, but a smaller dredging project at lower cost seems likely, addressing just the downstream area of the Basin. The installation of a P inactivation dosing station is among the least expensive items in the program but has an ongoing annual operational cost that is significant. Yet P inactivation represents the most flexible and cost-effective option for reducing P inputs to Lake Auburn. Re-treating the lake itself is also cost effective, but does not address ongoing inputs from the watershed, a problem that will continue and is likely to become more severe without attention.

An analysis of the cost of P control vs. building a treatment facility for potable supply may be in order, but the value of Lake Auburn extends beyond its use as a source of potable water. Preservation of all uses of the lake will require watershed and in-lake actions to reverse the eutrophication trend documented over the last couple of decades. Management should extend beyond P control to nitrogen and organic matter as well, and to various other contaminants being generated in the watershed by human uses and potentially detrimental to Lake Auburn.

Duration of Benefits

The level of P load reduction achievable with each management action and the duration of benefits from any load reduction will vary with management action. For the most part, watershed improvements such as erosion control are taken as permanent, although problem conditions will continue to arise, either in the same areas due to use patterns or new areas, so ongoing watershed management is to be expected if full benefits are to be maintained. It would be reasonable to expect about 10 years of benefit from any structural watershed management action and the cost for that benefit has been considered on a 10-year timeframe (Table 4). Whether a specific structure requires maintenance, or a new area requires a similar structural approach, it would be appropriate to assume that whatever costs are devoted to watershed management could need to be repeated every 10 years to maintain the same level of water quality benefit.

Table 4. Cost summary and benefit duration for phosphorus input reduction to Lake Auburn

Management Action	P Reduction (kg)	Duration of Benefits (yr)	Capital Cost ($)	Operational Cost ($/yr)	Cost per Kg P Removed per Year ($)
Watershed Management					
PLET NPS Sites	14 to 25	10	640,000 to 765,000	0	3,100 to 4,600
Agriculture	23 to 29	10	144,000 to 187,000	0	630 to 650
Residential (Little Wilson Pd)	3 to 5	10	63,000 to 94,500	0	1,900 to 2,100
Dredging the Basin	70	50	8,000,000	0	2,300
Lake Auburn P inactivation	115	10 to 20	1,000,000	0	440 to 870
Basin P inactivation dosing	99	1	120,000	100,000	1,150*
Total for 10-year program	**324 to 443**		**9,967,000 to 10,200,000**	**1,000,000***	

* Calculated on the basis of capital cost and operational costs over a 10-year period

Non-structural controls carry less explicit cost and would be expected to provide ongoing benefits indefinitely. Taking agricultural areas adjacent to streams out of service in favor of buffer zones would be one example, as would education to minimize the use of lawn fertilizer and exposed soils on private properties. Agreements with landowners may need to be renewed and education is an ongoing need, but the benefits can be assumed to be permanent with continued participation. Most of the actions proposed for the Lake Auburn watershed are structural, however, so the 10-year time frame for benefits remains applicable.

Dredging is usually considered to provide improvement for more than 50 years, although storm water detention areas in urban environments often need cleaning once per decade and some smaller lakes with large watersheds that have been dredged have refilled in 20-30 years. For the Basin, we do not know how long it took to reach its current condition, but at 110 acres with a 5,050-acre watershed and two upstream waterbodies, infilling should be gradual and about 50 years of benefit should accrue. Watershed management around and upstream of the basin would also help prolong the benefits of dredging.

In-lake P inactivation addresses P in the water column at the time of treatment and P released from surficial sediment exposed to anoxia. Aluminum binding of P in the water column at low P concentrations is not especially efficient; a reduction of 10-20% was realized from the first lake treatment. Yet with a long detention time, the water column inactivation lasts several years. Inactivation of P in the surficial sediment tends to be more efficient, and the prevention of P release under anoxic conditions is a major benefit. Stratified lakes that are treated with aluminum for sediment P inactivation at a dose targeting all P in the upper 10 cm of sediment have exhibited reduced P release for an average of 21 years. Benefits last until the P is replaced, from the watershed either as new dissolved P inputs or as particulate matter that settles to the bottom and fuels later internal loading, or from upward migration of P from deeper sediments where there has been no inactivation. Assuming 10-20 years of benefit from re-treatment of Lake Auburn is reasonable.

The dose of aluminum applied to Lake Auburn would have to be much higher to remove more P from the water column; the lower the P concentration, the higher the necessary Al:P ratio. The applied dose was estimated to be enough to inactivate about half the P in the upper few centimeters of targeted sediment, and the post-treatment data suggest that about a third of that P was actually inactivated. Other sediment constituents can bind with aluminum, so the process is not ideal. A second treatment of Lake Auburn would likely involve the same dose of aluminum and similar results could be expected. The results within the water column would have similar duration of benefits, on the order of 8 years but highly dependent on the weather and watershed inputs. The results in the sediment would be additive, and a second treatment might provide more than an additional decade of reduced P release from sediment. There is little evidence of major P release since treatment, but oxygen has remained adequate over most of the lake bottom since the treatment and that limits P release independent of the treatment.

The benefits from a P inactivation dosing station will be proportional to the level at which dosing is applied, but the benefits are lasting as long as the treatment continues. Aluminum-bound P is not subject to easy dissociation and renewed availability. P inactivated by aluminum can be assumed to have been functionally removed from the system. This process occurs naturally where aluminum is abundant, at least relative to iron, and the dosing station is mimicking a natural process where aluminum is less available for P binding. However, as P loading from the watershed is an ongoing process, elevated by many human uses of the watershed, there will be a need to continue P inactivation until such time as watershed influences can be adequately controlled to reduce P inputs to an acceptable level. Any P reduction from a dosing station should be considered to provide benefits on an annual basis, as each year brings new inputs that require inactivation by this approach.

The combination of cost, P removed, and duration of benefits allows an assessment of the overall cost-effectiveness of various program components (Table 4). Actions to reduce agricultural inputs and direct treatment of the lake for P inactivation provide the greatest P load reduction per dollar spent over a projected 10-year program. P inactivation by a dosing station is next most cost-effective, while other actions are at least twice as expensive per kg P removed per year over a 10-year period. Yet all of these program elements are necessary to reach the lowest possible P concentration in Lake Auburn and the more expensive options tend to address the problems at their sources, a preferable approach where affordable.

Management Timeframe

The rate at which management can proceed is a function of funding, jurisdiction over a property or land use or permission to take action on non-jurisdictional properties, and any necessary permits. Necessary funds are described in previous sections on the cost of management and duration of benefits. Jurisdiction will depend largely on whether or not the property is in Auburn and is public or private; this is a potentially complicated issue into which we have no special insights other than to note that where funding is available, cooperation will be easier to get. Most watershed actions require no permits, although precautions to avoid erosion or other impacts must often be taken. The treatment of the lake requires a discharge permit granted by Maine DEP, and although no P inactivation dosing station has yet been constructed and operated in Maine, such a station would undoubtedly require a discharge permit as well. Dredging requires permitting under multiple programs, including under federal statutes including Sections 401 and 404 of the Clean Water Act. It is difficult to provide any precise estimate of how long it would take to prepare for and conduct a complete management program for P control in Lake Auburn and its watershed, but the timeframe associated with specific elements can be suggested.

For watershed management actions, erosion controls are a central focus of most actions and include regrading, vegetating, armoring, and flow diversions. Each individual action would probably only take a week or two to complete. The planning phase could be much longer, with potentially protracted negotiations with landowners and arrangements with contractors. The CDM Smith report set a schedule for watershed work and projected 10 years to address its list of problem sites, a list which initially guided this review. CDM Smith included possible dredging of Blanchard Pond and removal of an impoundment off Turner Road, actions that require more time to plan and permit, so it is possible that all watershed work could be completed within 5 years with adequate funding, estimated at $180,000 for 11 sites by CDM Smith. With the list generated in this report, a timeframe closer to 10 years is probably a better estimate, although much more time will be spent planning and negotiating actions than actually remediating problem sites.

It took about 5 months to permit the original aluminum treatment of Lake Auburn that was conducted in 2019. A similar timeframe would be expected for any subsequent treatment. Although experience with such treatments has accumulated, the process is the same in terms of filings, stakeholder notifications, receipt of comments, responses, and presumptive permit issuance.

The installation of a dosing station would require selection of a site, any permitting associated with that site (e.g., if in a wetland or some other location within the jurisdiction of any agency with approval power), and a discharge permit for the actual dosing. Once fully permitted, construction of the site would be followed by actual dosing and associated monitoring. The logical site for a dosing station would be near the Basin, although exactly where depends on whether or not the Basin is dredged. If not dredged, the dosing station should be close to the outlet, allowing treatment of outflow that appears to currently supply a lot of P and organic matter. If dredged, the station could be located further upstream, near the inlet or with a discharge point within the Basin and slightly upstream of any dredged area, allowing for settling within the Basin. Waiting for dredging to occur would lengthen the timeline, but from the time a location for the station and its discharge is selected, a permit could be in place within 6 months. Station construction could be rapid but could take up to 6 months, so assuming a year as the timeline for putting a dosing station into operational mode seems reasonable.

Planning and permitting a dredging operation is complex and normally takes at least a year and could require a lead time of two years. Multiple agencies have jurisdiction and there will be many questions and likely constraints on dredging the Basin. We do not at this time have even the most basic information on sediment quality and quantity, and the CDM Smith report suggested that a dredging feasibility assessment be conducted for about $80,000. Such an assessment would take 4-6 months to complete. The actual time to perform the dredging is mostly a function of how much sediment is removed, but it appears that appropriate dredging of the Basin could be accomplished in about half a year. So a rational timeframe for dredging would be about 3 years from the time a decision was made to pursue such dredging, assuming all permit are granted.

The various management actions can run concurrently, although some have partial dependence on others (e.g., determining dosing station location is partly a function of whether or not the Basin will be dredged). If the Basin was dredged before a dosing station was installed, it would be at least 3 years before that dosing system was operational. However, the dosing station could be installed within a year near the outlet of the Basin and its discharge location changed with any later dredging of the Basin. The whole dosing station could even be moved, not requiring a lot of permanent construction.

We usually think of watershed management as a decade-long process, moving slowly with many small projects running sequentially, not concurrently, but more could be done faster with adequate funding and effort. Yet the nature of the work to be done in the Lake Auburn watershed is consistent with a 10-year timeframe.

Based on the above considerations, a dosing station could be in operation and a second treatment of Lake Auburn could occur within a year, the Basin could be dredged in 3 years, and the watershed work envisioned in this and the CDM Smith report could be completed in about 10 years. Availability of funding and regulatory approvals could lengthen these timelines.

Dosing Station Construction

There are three basic elements of a dosing station: tanks in which P inactivation products are stored, a delivery pipeline leading to the discharge point, possibly with some mixing system at the discharge end, and a controlled pump system to move the product from the tanks to the discharge location. There are multiple designs and configurations for dosing stations, but the elements are the same and the footprint is rarely large (Figure 7). The primary considerations are the amount of P inactivation product to be stored at any one time (and by extension the replacement frequency for product) and power to operate the control system and pumps.

For treatment of water flowing through the Basin, depending on how much stormwater is treated over what portion of the year, a maximum need of about 20,000-25,000 gallons of aluminum product is projected. The Indian Lake system (Figure 7, bottom) has twin 6000-gallon tanks, an appropriate quantity for the Lake Auburn application, with tanks being filled twice per year and

Figure 7. Example phosphorus inactivation dosing stations

Morses Pond dosing station, in operation since 2008, with two tanks and two pumps serving two tributaries.

Indian Lake dosing station, in operation as of 2023, with two pumps and two tanks serving a single tributary.

left empty over the winter. The discharge pipe can be simple PVC tubing with 1/8" holes bored in a small section at the end. Experimentation with various nozzles and aperture sizes has indicated that this simple arrangement is sufficient when the product is added to moving water (Figure 8, upper panel). If the discharge is to the middle of the Basin rather than the inlet or outlet, some mixing system may be needed for best results. Mechanical or air driven mixing has been employed for this purpose in other systems (Figure 8, lower panel).

There are other designs and configurations that could be applied; P inactivation dosing stations offer flexibility in design and operation. Some systems have been constructed in underground bunkers with no visible parts above ground other than a filling aperture for delivering the aluminum product and an access manhole. A system can be made portable, with most parts on a flatbed trailer, although full tanks are best placed on the ground in an area with secondary containment. Various pumps have been used, with peristaltic pumps generally preferred as there is minimal contact between pump parts and the chemical; annual replacement of the short section of tubing subject to compression to move the chemical is the only significant maintenance required and pumps tend to last 5-10 years. Building some redundancy into the system is highly desirable. Have two tanks, two pumps, and two possible delivery lines. Only one set may be needed at any time, but any failure can be quickly overcome with minimal loss of treatment capacity.

One add-on feature that has proven extremely worthwhile for dosing stations is automation. A flow or precipitation trigger, set to go off if flow or precipitation exceeds a pre-determined amount, turns on the pump(s), with settings that deliver chemical at a pre-determined rate for a pre-determined time. The system can be run online, accessed by computer or cell phone, with overrides to shut the system off, continue operation longer than the pre-determined setting, change the trigger value for flow or precipitation, or alter the rate of chemical addition. This allows automatic response to storms with remote capability for adjustment.

Next Steps

This analysis has applied a large amount of data and experience with other lake systems, but there remain a number of assumptions that need to be verified. Most critical is the condition of the Basin: its current bathymetry, the amount of sediment accumulated in it, the quality of that sediment, and biological resources that have bearing on whether or not permits can be issued to allow dredging of this waterbody. CDM Smith called for such a study and that need is emphasized here.

The potential to establish a P inactivation dosing station needs to be further investigated. The elements of such stations are well understood, but the ability to site and permit a dosing station that addresses water passing through the Basin remains to be ascertained. There are many such stations in Florida, two in Massachusetts, and others scattered across the USA, but no such dosing station has been installed and operated in Maine. A dosing station will undoubtedly require a discharge permit, but the viability of this concept should be discussed with the Maine DEP and stakeholders in general.

The long-term health of Lake Auburn is likely to depend on appropriate watershed management. P inactivation is an effective interim approach, but ultimately watershed inputs should be reduced, and this will require watershed management. The commitment to such management needs to be made and the LAWPC should organize for action in the watershed. Some improvements have already occurred, but the intensity and pace of action is currently insufficient to maintain desirable conditions in Lake Auburn. Funding and jurisdiction are significant issues, so this is not an easy process, but the condition of Lake Auburn in the future will depend on the level of action taken soon.

Figure 8. Discharge from dosing station

Discharge of polyaluminum chloride (above) to an inlet on a calm day for visibility, with air-driven mixing (below) in the same area to mix the aluminum product when turbulence is low.

Appendix

Cost Estimates For Watershed NPS Control

TECHNICAL MEMORANDUM

TO: Ken Wagner, Water Resource Services

FROM: Jen Jespersen, Ecological Instincts

SUBJECT: **Cost Estimates- Lake Auburn Watershed**

DATE: March 7, 2024

INTRODUCTION

In October 2023, Ecological Instincts assessed NPS pollution sources in the Lake Auburn watershed. The assessment involved revisiting 64 sites identified by CDM Smith in 2022 and resulted in estimated pollutant load reductions that can be achieved by remediating the NPS Sites, as well as potential pollutant load reductions from addressing pollution from agricultural lands in the watershed. Maps of sites surveyed by type and by estimated P load reduction are provided in Attachment A. A follow-up request was made by the Auburn Water District to estimate the costs associated with achieving these pollutant reductions.

METHODS

Pollutant load reductions were calculated three different ways based on the land use and survey methods for different areas of the watershed. High-end and low-end pollutant load reduction estimates were also calculated for each category. Based on these methods, cost estimates were similarly made using different methods for the different types of sites and areas surveyed.

Pollutant Load Estimation Tool (PLET) Sites

For a majority (51) of the sites visited in the 2023 watershed assessment, the US EPA Pollutant Load Estimation Tool (PLET) was used to calculate pollutant load reductions that are possible through addressing the sites. A map of PLET sites by estimated P load reduction is presented in Attachment A (based on low-end P load reduction estimates). The estimated cost of materials and labor to install the recommended BMPs for these sites are based on detailed field measurements, cost of materials from local retailers and best professional judgement based on experience installing BMPs through watershed restoration projects across the state.

Two sets of load reduction estimates were calculated to develop a range of load reductions, presented as low and high. Low-end estimates reflect the most realistic values for each site based on field observations while high estimates utilized slightly higher lateral recession rates. Because of this, high and low-end pollutant load reduction estimates represent a range of possible reductions from installing the same BMPs rather than potential reductions for different levels of remediation efforts. Therefore, each site's cost was increased by 20% to calculate high end cost estimates for each site. Higher cost estimates for PLET sites do not necessarily reflect an increased reduction in the P load, but are meant to account for variations in costs based on factors such as inflation, availability of materials, and contractor rates and availability. A list of the PLET sites and their associated P load reduction estimates and cost estimates is provided in Attachment B.

Agriculture

Because access to agricultural land was not available during the surveys, and limited information was provided beyond the 2022 CDM survey related to agriculture in the watershed, the Maine DEP's Relational Method[1] was used to estimate phosphorus loading reductions by addressing NPS pollution on agricultural land in the watershed. In this application, the Total P reduced was calculated for cropland and hay/pasture by calculating the fraction of the total watershed P load these land use types represent, the fraction of the load addressed, and the expected BMP efficiency for each land cover type. To get low-end P reduction estimates, the fraction of the load addressed was set at 72% for cropland and 68% for hay/pasture based on BMPs being installed on all farms in the City of Auburn and 25% of all farms in towns outside of the City of Auburn. For high-end agriculture estimates, farms outside of Auburn installing BMPs was increased from 25% to 75%, for a total fraction addressed for all agriculture in the watershed of 91% for cropland and 89% for hay/pasture.

In order to estimate costs for addressing P loading from each fraction of agricultural land in the watershed, average costs per acre for commonly used NRCS EQIP practices were calculated based on USDA's FY24 payment rates for the EQIP program.[2] These average costs per acre were applied to the entire area of each agriculture type in the watershed to get the total cost for addressing all agricultural land in the watershed ($45,731 for cropland and $161,725 for hay/pasture). The total costs were then multiplied by the proportions of the agricultural land area assumed to be addressed in both the high and low-end P load reduction scenarios to get a high and low-cost estimate for reducing P loading from agriculture in the watershed.

Table 1. Estimated costs for achieving high and low-end estimated P reductions from agricultural land.

	% Addressed (Low End)	Cost (Low)	% Addressed (High End)	Cost (High)
Cropland:	72%	$33,153.53	90%	$41,538.31
Hay/Pasture:	68%	$110,699.41	89%	$144,716.18
Total:		**$143,852.94**		**$186,254.49**

Little Wilson Pond

The third pollutant load reduction modeling method focused on P reductions for shoreline residential development on Little Wilson Pond. Load reductions were estimated by averaging pollutant reduction estimates calculated using the PLET for two of the 2023 NPS sites on the shoreline of Little Wilson Pond (UB-20 & UB-21) and previously used load reduction estimates for low-impact residential NPS sites from a recent Ecological Instincts project at North Pond in Smithfield, ME to calculate an average pollutant load reduction for a single site. The number of developed shoreline properties on the pond was estimated using parcel data and aerial imagery. Low-end pollutant load

[1] Jeff Dennis, Division of Watershed Management, Maine DEP, n.d.

[2] https://www.nrcs.usda.gov/sites/default/files/2023-12/fy24-maine-eqip.pdf

reductions assume that BMPs will be installed on 50% of all shoreline properties on Little Wilson Pond, while high-end estimates assume BMPs will be installed on 75% of shoreline properties.

To get cost estimates for installing BMPs on residential sites on Little Wilson Pond, $3,000 was used as an estimated average cost for each site. This number was multiplied by 21 sites (50% of lots installing BMPs) to get the low-end cost estimate, and by 32 (75% of lots installing BMPs) to get high and low-end cost estimates.

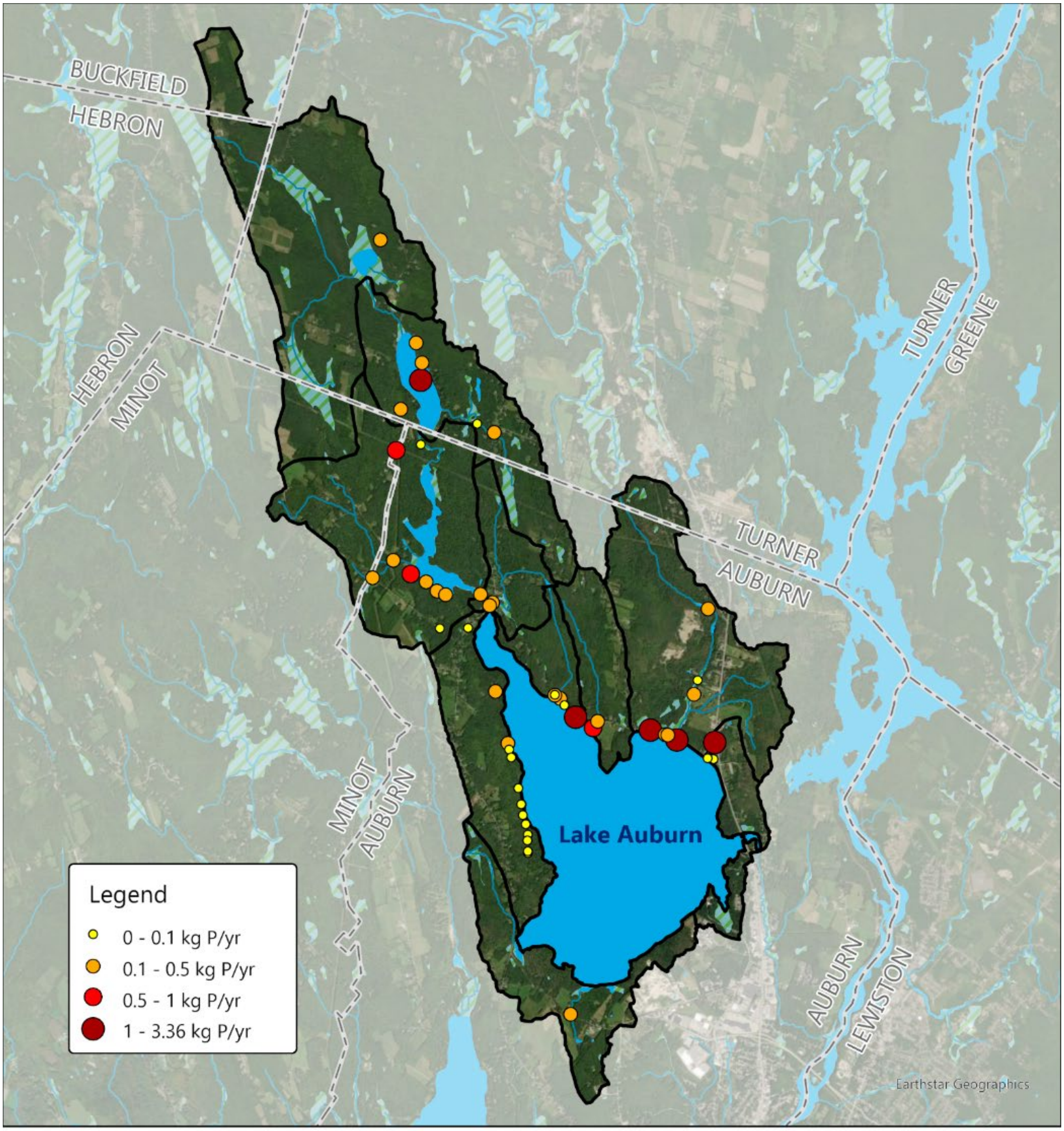
RESULTS

Results of the cost estimates provide two potential scenarios for costs associated with addressing NPS pollution in the Lake Auburn watershed. The lower cost scenario estimates a total cost of $842,352 to achieve load reductions of 14-25 kg P/yr from PLET NPS sites, 23 kg P/yr from agricultural land, and 3 kg P/yr from residential sites around Little Wilson Pond. The higher-cost scenario estimates a total cost of $1,043,355 to achieve load reductions of 14-25 kg P/yr from PLET NPS sites, 29 kg P/yr from agricultural land, and 5 kg P/yr from residential sites around Little Wilson Pond. These cost scenarios are meant to represent a range of potential costs for addressing NPS pollution. Actual costs will vary widely based on factors including landowner participation, inflation, availability of materials, and contractor rates and availability.

Table 2. Estimated high-end and low-end P load reductions and costs for each site type.

	P (kg/yr) (Low Estimate)	P (kg/yr) (High Estimate)	Low Estimated Cost	High Estimated Cost
PLET NPS Sites	14	25	$635,500	$762,600
Agriculture	23	29	$143,852	$186,255
Residential	3	5	$63,000	$94,500
Total:	**40**	**59**	**$842,352**	**$1,043,355**

ATTACHMENT A: MAP OF PLET SITES BY P LOAD REDUCTION



Lake Auburn NPS Assessment

Sites by Estimated P Reduction

0 0.5 1 2 3 4 Miles

Data Source: FB Environmental, USDA (NHD), Maine Geolibrary, EcoInstincts, Maxar
Projection: NAD 1983 UTM Zone 19N
Map Created By: K. Goodwin, Ecological Instincts, February 2024

ATTACHMENT B: P LOAD REDUCTION AND COST ESTIMATES FOR PLET SITES

PLET Sites	Low P Load Reduction (kg/yr)	High P Load Reduction (kg/yr)	Low Estimated Cost	High Estimated Cost
L-3	0.42	0.42	$100,000	$120,000
LS-1a	0.40	1.25	$3,000	$3,600
LS-1b	0.29	1.58	$3,000	$3,600
LS-5	0.18	0.23	$3,000	$3,600
LS-6	0.63	0.73	$150,000	$180,000
LS-7	0.03	0.09	$3,000	$3,600
LS-9	0.33	1.32	$5,000	$6,000
LS-10	0.00	0.00	$1,000	$1,200
LS-11	1.78	2.32	$4,500	$5,400
LS-12	0.13	0.13	$4,000	$4,800
SR-1	0.05	0.05	$1,500	$1,800
SR-3	0.38	0.47	$2,500	$3,000
SR-4	0.03	0.03	$500	$600
SR-5	0.04	0.07	$3,500	$4,200
SR-6	0.02	0.02	$2,500	$3,000
SR-8	0.03	0.08	$1,000	$1,200
SR-9	0.03	0.18	$5,500	$6,600
SR-10	0.03	0.03	$1,200	$1,440
SR-11	0.02	0.07	$1,000	$1,200
SR-12	0.01	0.01	$8,500	$10,200
SR-13	0.04	0.11	$1,200	$1,440
SR-15	0.04	0.12	$10,000	$12,000
SR-16	0.17	1.04	$2,100	$2,520
TB-1	0.16	0.35	$650	$780
TB-3	0.17	0.17	$12,500	$15,000
TB-4	0.06	0.17	$3,000	$3,600
TB-8	1.28	1.28	$100,000	$120,000
TB-10	0.03	0.04	$10,000	$12,000
TB-11 & (TB-9)	0.04	0.04	$3,000	$3,600
TB-12	0.01	0.01	$0	$0
TB-13	1.81	3.93	$1,000	$1,200
TB-14	1.07	1.35	$3,500	$4,200
TB-15	0.17	0.44	$5,500	$6,600
TB-16	0.23	0.71	$650	$780
UB-1	0.15	0.32	$2,500	$3,000
UB-2	0.14	0.57	$2,500	$3,000
UB-3	0.31	0.63	$2,500	$3,000

PLET Sites	Low P Load Reduction (kg/yr)	High P Load Reduction (kg/yr)	Low Estimated Cost	High Estimated Cost
UB-4	0.26	0.26	$6,000	$7,200
UB-5	0.62	0.62	$5,000	$6,000
UB-6	0.11	0.11	$2,000	$2,400
UB-7	0.39	1.28	$3,500	$4,200
UB-8	0.02	0.02	$1,500	$1,800
UB-9	0.03	0.03	$2,500	$3,000
UB-10	0.57	0.69	$50,000	$60,000
UB-11	0.05	0.05	$6,200	$7,440
UB-12	0.17	0.17	$80,000	$96,000
UB-14	0.29	0.40	$2,500	$3,000
UB-17	0.38	0.38	$7,500	$9,000
UB-20	0.24	0.24	$2,000	$2,400
UB-21	0.22	0.22	$2,000	$2,400
Totals:	**14.07**	**24.83**	**$635,500**	**$762,600**