Technical Memorandum

To: Stephanie McNamara, Vadnais Lake Area Water Management Organization (VLAWMO)
From: Greg Wilson, Barr Engineering Co. (Barr)
Subject: Reevaluation of Goose Lake Alum Treatment Effectiveness
Date: March 10, 2020
Project: 23621353.00

Minnesota Board of Water and Soil Resources (BWSR) awarded $190,000 in grant funds to VLAWMO this past January for the East Goose Lake alum treatment which ranked as the highest scoring submittal in the FY2020 Projects and Practices category. Two potential issues with the alum treatment have been raised since the project award—the resurgence of the bullhead population in the lake and potential impact on alum floc given the high likelihood that boating restrictions will not be in-effect following the alum treatment. The purpose of this memorandum is to reevaluate the timing and potential effectiveness of alum treatment for East Goose Lake given the aforementioned concerns. As a part of this evaluation, information from past shallow lake alum treatments were compiled/consulted, the applicability of alternative stable states was considered, watershed BMP cost-benefit material was updated and project assurances were reconsidered to make recommendations about whether alum treatment still makes sense for East Goose Lake at this time.

Examples of Successful Alum Treatments for Shallow Lakes

The long-term efficacy of alum treatment for deeper lakes is well documented, but some studies have raised concerns about the longevity of alum treatment for shallow lakes. As a result, the available monitoring data was compiled and reviewed for four shallow lakes in the region that have had alum treatments between eight and 23 years ago, which Barr staff either designed and/or had firsthand experience with the lake and watershed management. In general, alum treatment represented the final management measure that converted each one of these lakes from turbid, eutrophic systems to a clear-water state.

The following table summarizes the in-lake total phosphorus (TP) changes that resulted from alum treatment in each of the four shallow lakes that were evaluated. In all four cases, the alum treatment has remained effective at controlling internal phosphorus load and there are indications or anecdotal evidence for the three oldest that the treatment longevity has been supported by positive feedback from changes to the lake ecology.

Lake	10-yr Ave Pre-Alum Treatment TP (mg/L)	1-yr Post-Alum Treatment TP (mg/L)	% Δ	1-yr to 3-yr Post-Alum Treatment TP (mg/L)	% Δ	1-yr to 5-yr Post-Alum Treatment TP (mg/L)	% Δ	1-yr to 10-yr Post-Alum Treatment TP (mg/L)	% Δ
Isles	0.061	0.022	*-64%*	0.029	*-52%*	0.034	*-44%*	0.040	*-33%*
Half Moon, WI	0.064	0.035	*-45%*	0.035	*-46%*	0.036	*-44%*		
SW Anderson	0.100							0.021	*-79%*
Kohlman	0.088	0.050	*-43%*	0.043	*-51%*	0.046	*-48%*	0.046	*-48%*

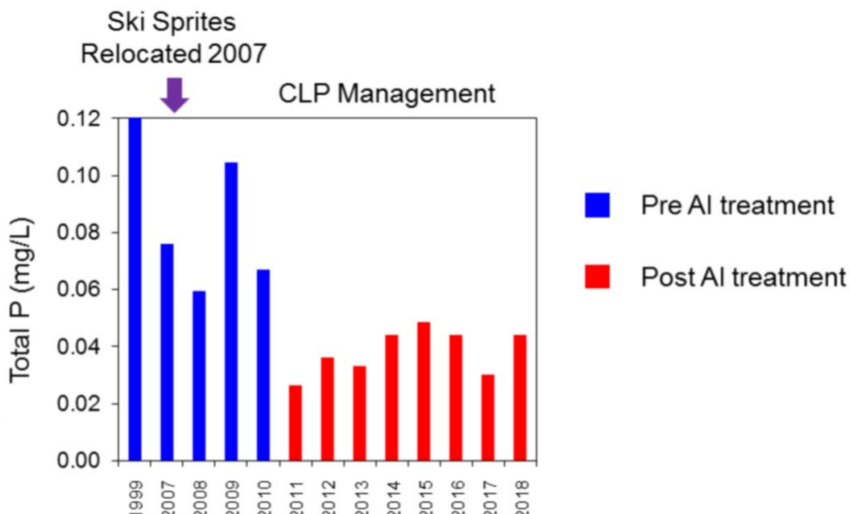
Notes
% Δ - Percent reduction in total phosphorus compared to 10-yr pretreatent average.

Lake of the Isles, Minneapolis

Lake of the Isles received an alum treatment in 1996. As shown in the above table, the TP concentration immediately dropped by two-thirds from the 10-year average TP concentration observed over the ten years prior to the treatment. Between the last five to fifteen years, the TP concentration has remained between 30 and 40 percent lower than the pretreatment TP average, and is significantly lower than the shallow lake standard of 0.060 mg/L. The Lake of the Isles watershed has not undergone significant change either before or after the alum treatment.

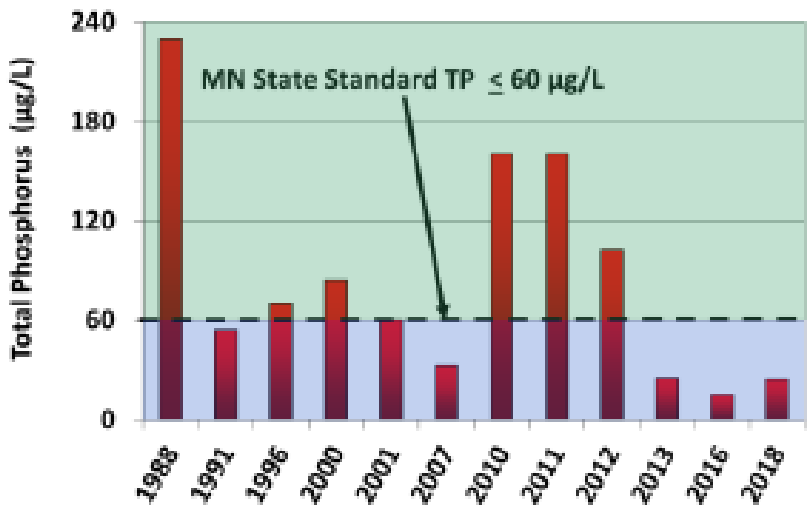
Half Moon Lake, Eau Claire, Wisconsin

Half Moon Lake received an alum treatment in 2011, as well as another, smaller maintenance treatment for one arm of the lake in 2017. As shown in the above table, the TP concentration has remained approximately 45 percent lower than the 10-year average TP concentration observed over the ten years prior to the treatment, and is significantly lower than Minnesota's shallow lake standard. While the Half Moon Lake watershed has not undergone significant change since the alum treatment, it should be noted that water-skiing was moved off the lake in 2007, boating restrictions were put in-place and private lakeshore residences have been systematically purchased and converted to public ownership. The following figure shows TP changes over time, which also reflects annual curlyleaf pondweed treatments.



Southwest Anderson Lake, Eden Prairie

Southwest Anderson Lake received an alum treatment in the fall of 2012. As shown in the above table, the TP concentration has remained approximately 80 percent lower than the 10-year average TP concentration observed over the ten years prior to the treatment, and is significantly lower than the shallow lake standard. The lake watershed has not undergone significant change since the alum treatment. The following figure shows TP changes over time, which also reflects a lake drawdown and aquatic plant treatment to control curlyleaf pondweed.



Kohlman Lake, Maplewood

Kohlman Lake received an alum treatment in 2010. As shown in the above table, the TP concentration has remained between 45 and 50 percent lower than the 10-year average TP concentration observed over the ten years prior to the treatment, and remains lower than Minnesota's shallow lake standard. While the Kohlman Lake watershed had not undergone significant change since the alum treatment, it should be noted that significant efforts were taken to remove carp from the lake and watershed, while water-skiing and boating have continued as lake uses. Aquatic plant growth increased significantly following the alum treatment, but plant harvesting has been used to balance recreational and ecological use and Ramsey-Washington Metro Watershed District has maintained monitoring records and quantified the TP removed through plant harvesting.

Alum Treatment and Watershed BMP Cost Effectiveness

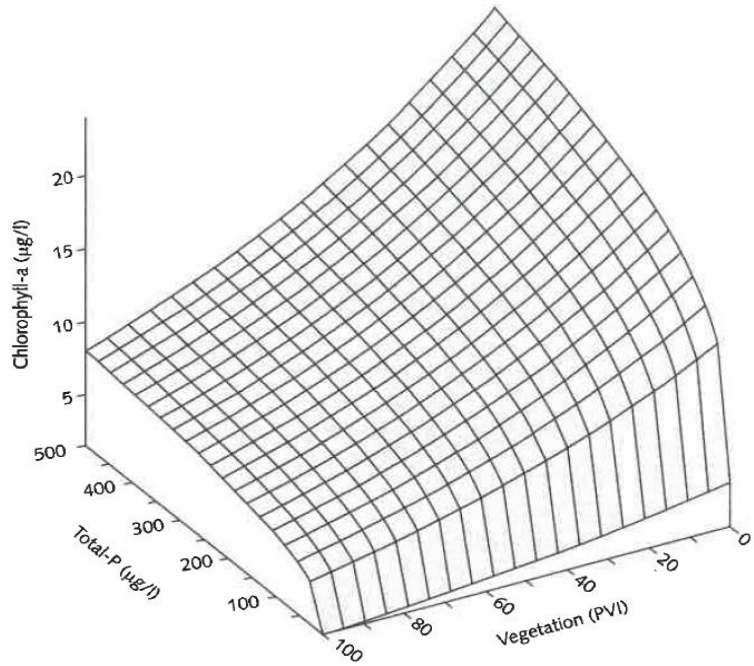
Over the last year and a half Barr has assisted VLAWMO in an effort to further clarify watershed loading into both Goose Lake basins and identify the most cost-effective BMPs that could utilize watershed based grant funding. Hydrologic and hydraulic modeling was developed, along with updates to the P8 water quality modeling, to identify and complete concept designs for three sets of BMPs that could feasibly be implemented in the East Goose Lake watershed. The results of this analysis showed that the combined costs of implementing all three BMP options would approach $2.3 million and could drop the average annual watershed TP load by approximately 70 pounds. The cost-benefit associated with implementation of any of the watershed BMP options ranges from $1,000 to $3,000 per pound of TP reduced per year.

In addition, the lake water quality modeling cited in the In-Lake Treatment Feasibility Study was revisited to put the updated watershed TP loading and BMP load reduction estimates into perspective with the expected benefit and cost of an in-lake alum treatment ($190,000). Depending on which year was used from the in-lake water quality modeling, it was confirmed that the internal TP load in East Goose Lake would range from 550 to 1,000 pounds per year. Assuming that an in-lake alum treatment would reduce the internal TP load by 80 percent, the cost benefit associated with implementation of the alum treatment of East Goose Lake translates to a range of $240 to $430 per pound of TP reduced per year.

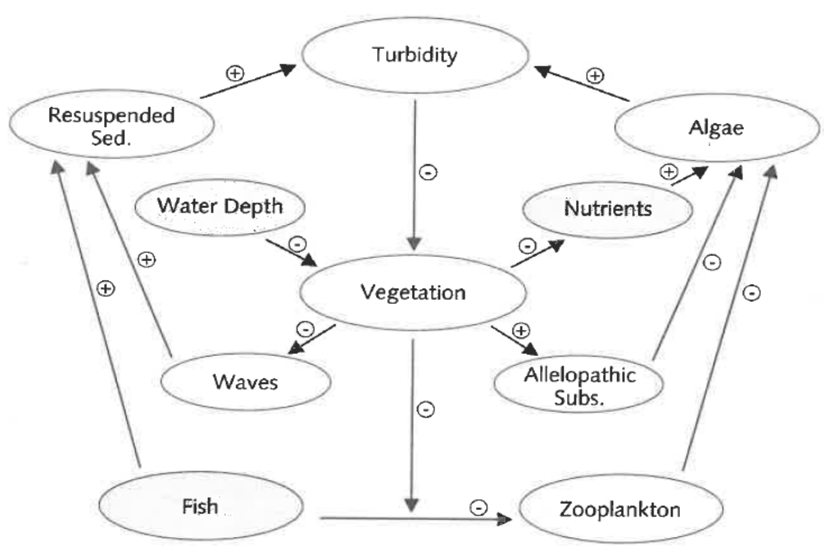
A comparison of the annualized cost-benefit analysis between watershed BMPs and alum treatment indicates that it is between 2.3 to 12.5 times more cost-effective to complete an alum treatment on East Goose Lake, compared to implementation of any of the other watershed BMP options. It is further noted that all of the internal TP load represents bioavailable phosphorus that is immediately available for uptake by algae, whereas no more than half of the TP load reduced by watershed BMPs would come from bioavailable TP loss. In addition, TP load reductions estimated for the watershed BMPs apply to the whole year, while the TP load reductions associated with in-lake alum treatment apply to the same summer months used in determining compliance with the State water quality standards.

Alternative Stable States of Shallow Lakes

Scheffer and van Nes (2007) revisited the original stable states theory for shallow lakes, which was inspired by observations that lakes tended to shift rather abruptly between clear and turbid states, and that once lakes turned turbid, they resisted restoration efforts. This theory applied to East Goose Lake in its turbid state would imply that fish (along with sediment phosphorus release) promote algae growth by recycling nutrients and/or stir up sediments (along with wind mixing and boating) and control development of zooplankton that would otherwise help clear the water of algae. The turbidity, in turn, makes it difficult to establish submerged plants. In contrast, once submerged plants become established they can greatly reduce turbidity by reducing wave resuspension and supporting other mechanisms (zooplankton, etc.) that control excessive algae without requiring additional reductions in phosphorus concentrations. As Sheffer (1998) shows in the following figure, an increasing extent of aquatic vegetation coverage can greatly reduce chlorophyll-a (or algae growth) for the same TP concentration. The positive and negative effects of plant growth are most pronounced on either end of the spectrum.



Scheffer and van Nes (2007) concluded that while the original theory remains quite valid to explain major patterns of change, less conspicuous shifts between alternative states also seem to occur in reality, whereby the change of biological communities along a gradient of eutrophication can be seen as a continuum in which gradual species replacements are interrupted at critical points by moderate or more dramatic shifts in communities. The most optimistic expectations are that implementation of watershed BMPs will provide a gradual shift in lake water quality for East Goose Lake, which realistically, may be imperceptible for lake use given the extremely high TP concentrations that currently exist. It will take an alum treatment on East Goose Lake before aquatic plants can become established, which in turn, can establish a positive feedback loop as shown in the following figure (Sheffer, 1998).



Project Assurances for In-Lake Alum Treatment

Two potential issues with the alum treatment have been raised since the project award—the resurgence of the bullhead population in the lake and potential impact on alum floc given the high likelihood that boating restrictions will not be in-effect following the alum treatment.

Bottom-feeding fish tend to stir up a deeper layer of sediment than other biological life in lake systems. For example, adult carp might be expected to stir up 10 to 20 cm of sediment, or two to three times the sediment thickness that is typically used to estimate the alum dose required for alum treatment. Given the current condition is East Goose Lake, it is possible that doubling the alum dose could mitigate the impact of the bullhead population. The less costly and better alternative for long-term water quality benefit involves bullhead removal and ongoing monitoring to control the rough fish population of the lake.

Barr recently became aware of a paper that helps address the potential impact that boating could have on alum floc following an alum treatment. Egemose et al. (2009) conducted a laboratory resuspension experiment using a calibrated erosion chamber with intact sediment cores from a shallow lake that had previously been treated with aluminum. They found that newly applied aluminum reduced sediment stability (initially), but ageing led to the same stability as untreated sediment within two months with an intact biofilm or within four months with a disturbed biofilm. Egemose et al. (2009) also concluded that aluminum application to shallow lakes prone to resuspension, and with high production, must be done in periods with less resuspension risk to allow for two to four months for floc stabilization. As a result, it is expected that a late-summer/early-fall alum treatment of East Goose Lake would provide adequate ageing and/or biofilm development to mitigate the increased potential for sediment resuspension before the following summer.

Recommendations

After accounting for the bioavailable fraction of TP load reduced during the summer months, an in-lake alum treatment is between ten and fifty times more cost-effective at perceptively improving lake water quality in East Goose Lake. As a result, it is recommended that VLAWMO submit the aforementioned project assurances and cost-benefit information to BWSR and proceed with work plan approval for Phase I of the alum treatment. Lake water quality response should then be monitored following the Phase I alum application for two summers to ensure that the desired effect is attained before proceeding with the second phase of alum application (which may require a request for BWSR to extend the project schedule by one year).

References

Egemose, S., G. Wauer and A. Kleeberg. 2009. Resuspension behaviour of aluminum treated lake sediments: effects of ageing and pH. Hydrobiologia 636: 203-217.

Scheffer, M. 1998. Ecology of Shallow Lakes. Chapman & Hall. London.

Scheffer, M. and E.H. van Nes. 2007. Shallow lake theory revisited: various alternative regimes driven by climate, nutrients, depth and lake size. Hydrobiologia 584: 455-466.