East Goose, West Goose and Wilkinson Lakes Feasibility Study

Prepared for
Vadnais Lake Area Water Management Organization (VLAWMO)
In partnership with Young Environmental Consulting Group

May, 2017

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Contents

List of Tables

List of Figures

1.0 Project Background and Goal-Setting

The Vadnais Lake Area Water Management Organization (VLAWMO), the Minnesota Pollution Control Agency (MPCA) and other stakeholders have collected a significant amount of monitoring data and completed Total Maximum Daily Loads (TMDLs) and numerous additional studies to better understand and address excess phosphorus loading to East and West Goose Lakes and Wilkinson Lake. In addition, nearly 19,000 pounds of bullheads were removed from Goose Lake between 2012 and 2015. Barr Engineering Company (Barr) and Young Environmental Consulting Group were retained by VLAWMO to revisit whether the current lake water quality standards are realistic or attainable and complete a feasibility study that will determine the best options for achieving significant nutrient reductions in all three lake basins, with a priority to work towards delisting the impaired waters within the next five years.

Figure 1-1 shows the topography, watershed divides and drainage patterns for East and West Goose Lakes while the same information, including subcatchments and monitoring stations, is depicted for Wilkinson Lake in Figure 1-2.

1.1 Summary of Lake TMDLs and Recent Studies

In preparing for the stakeholder charrette, the Barr/Young Environmental team systematically reviewed reports and data collected on Goose Lake and Wilkinson Lake, including the total maximum daily load (TMDL) report and implementation plan, sustainable lake management plans, storm sewer and treatment practice plans, proposed redevelopment plans, fish and aquatic plant survey reports, bathymetric surveys and internal loading analyses. Through the stakeholder participation process and personal communications we also became more aware of the potential for boating impacts on water quality changes in the Goose Lake basins and the conservation planning efforts to limit significant land use changes in the Wilkinson Lake watershed.

The TMDL report (Wenck, 2013) and implementation plan (VLAWMO, 2014) called for the following total phosphorus load reductions for the respective lakes:

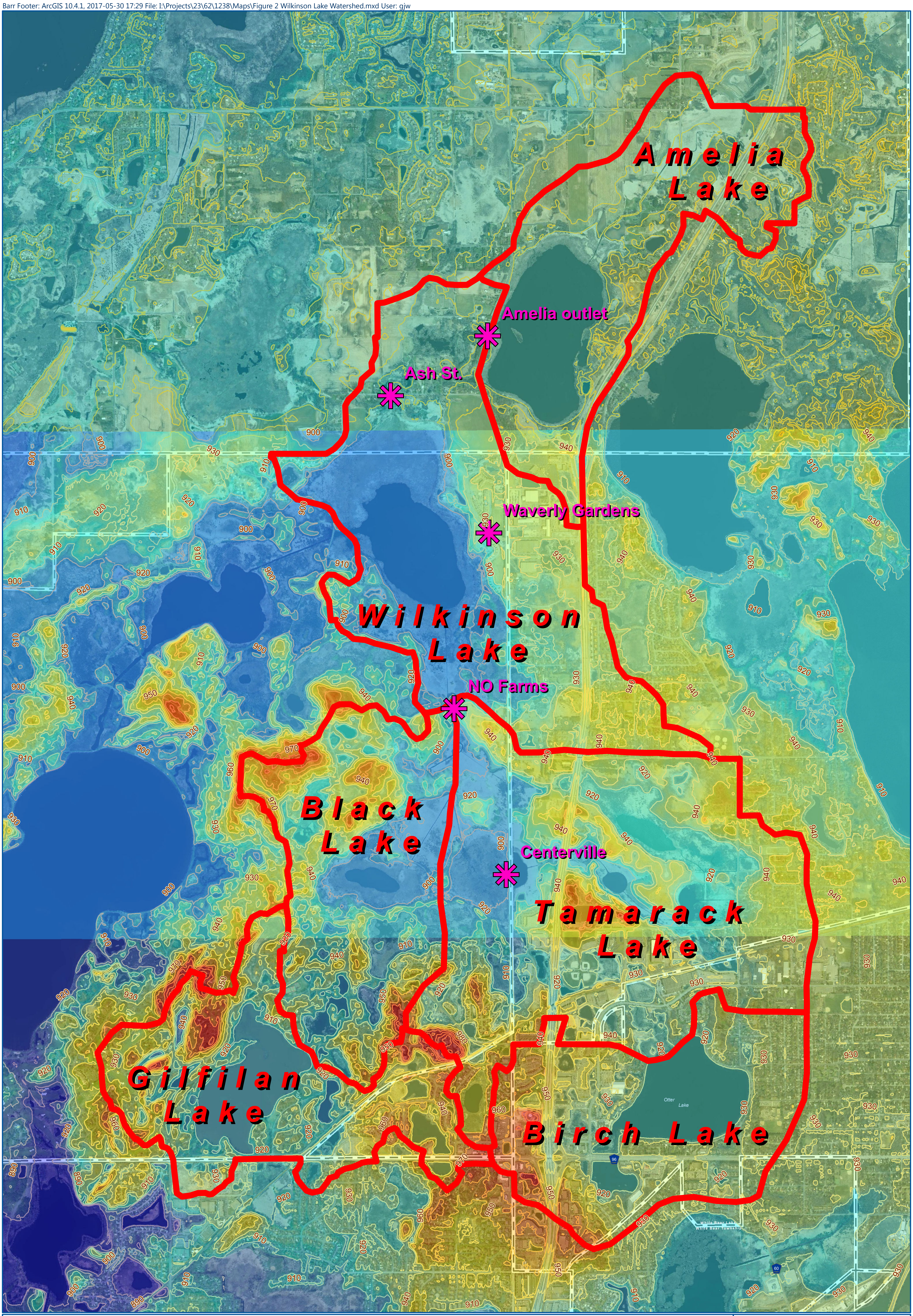
- 91% reduction for East Goose Lake—corresponds to 96% reduction of internal load and 63% reduction from stormwater runoff
- 70% reduction for West Goose Lake—corresponds to 71% reduction of internal load, 77% reduction from East Goose Lake and 86% reduction from stormwater runoff
- 63% reduction for Wilkinson Lake—corresponds to 76% reduction from stormwater runoff

Anoxic sediment phosphorus release rates determined from laboratory experiments on Goose Lake cores (James, 2010 and Wenck, 2014) were approximately an order of magnitude lower than the release rates used for the lake water quality modeling in the TMDL study. The difference in internal load was attributed to resuspension associated with motor boat activity (Wenck, 2013). A subsequent study (UW Stout and Wenck, 2015) of sediment resuspension as a potential phosphorus source indicated that Goose Lake sediment has a high potential for resuspension, but does not release or desorb phosphorus and plays a minor role in contributing bioavailable phosphorus to the lake.

Barr Footer: ArcGIS 10.4.1, 2017-05-29 17:29 File: I:\Projects\23\62\1238\Maps\Figure 1 East and West Goose Lake Watershed_BMPs.mxd User: gjw

EAST AND WEST GOOSE LAKE WATERSHED
Vadnais Lakes Area Watershed Management Organization

FIGURE 1-1



BARR

Wilkinson Watershed Sampling Sites

Wilkinson Lake Subcatchments

10-Foot Elevation Contour

Municipal Boundary

0 1,000 2,000

Feet

WILKINSON LAKE WATERSHED

Vadnais Lake Area Watershed Management Organization

FIGURE 1-2

1.2 Lake Water Quality Goal Setting

MPCA uses MNLEAP modeling to estimate background phosphorus levels for lakes, which provides one basis for goal setting and evaluating how a lake is doing given its ecoregion and morphology. Table 1-1 shows how the MNLEAP predicted phosphorus concentration, which represents an ecoregion-based estimate of water quality for “minimally-impacted” lakes, compares to the ten-year summer average total phosphorus concentrations observed for the respective lakes. The results indicate that the shallow lake standard should be appropriate for East Goose Lake, but is expected to be more difficult to attain for West Goose and Wilkinson Lakes.

Table 1-1 Comparison of MNLEAP Modeling to Observed Lake Water Quality

Lake	Average Summer Total Phosphorus Concentration (µg/L), 2007-2016	MNLEAP Predicted Phosphorus Concentration (µg/L)
East Goose	257	47
West Goose	174	62—83
Wilkinson	140	100

Figures 1-3, 1-4 and 1-5 show how the last ten years of average summer total phosphorus, chlorophyll-a and Secchi disc transparency, respectively, have varied for each of the three lake basins. The first four years of the records shown in each figure represent the data used for the TMDL analyses of the respective lakes. The monitoring data shows that all three lakes are not meeting any of the three shallow lake criteria during the period of record. Figure 1-3 shows that average total phosphorus concentrations were generally better for all three lakes in 2011 and significantly worse in 2016. As a result, these two years became the focus of the updated lake and watershed modeling discussed in Section 3.

Figure 1-3 Summer Average (June-Sept.) Total Phosphorus Concentrations (µg/L) since 2007

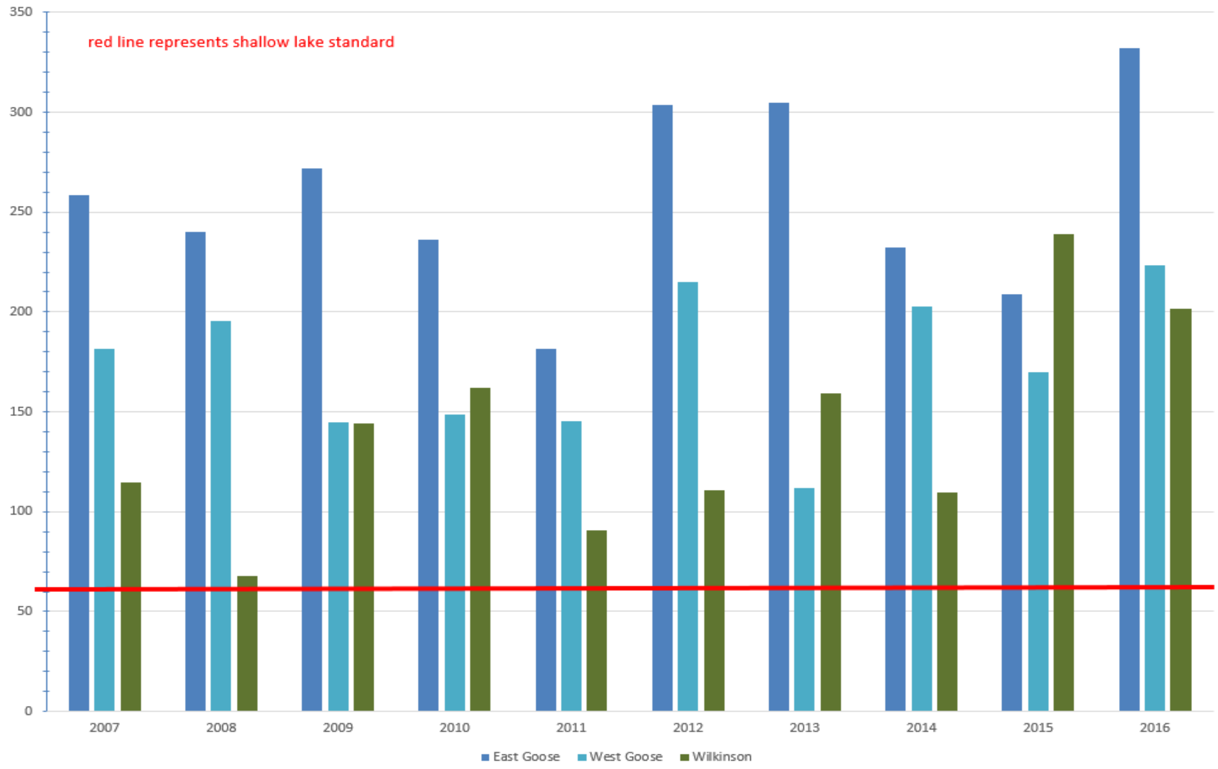


Figure 1-4 Summer Average (June-Sept.) Chlorophyll-a Concentrations (µg/L) since 2007

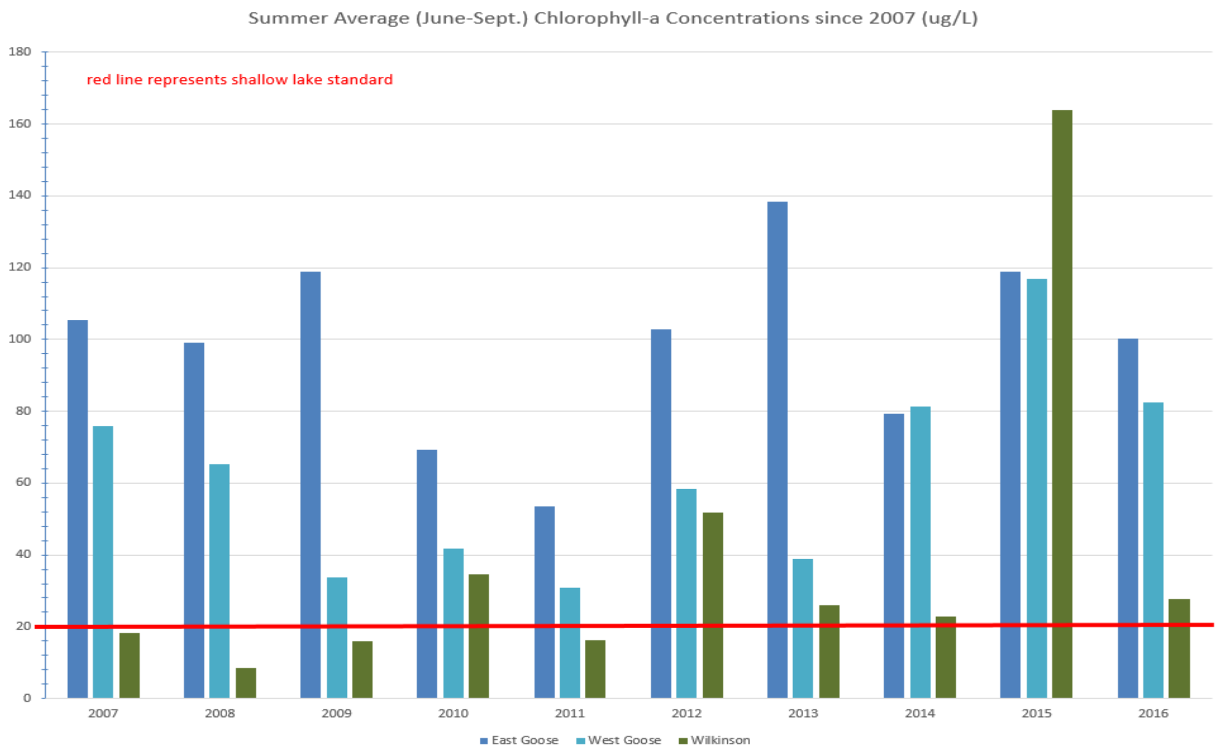
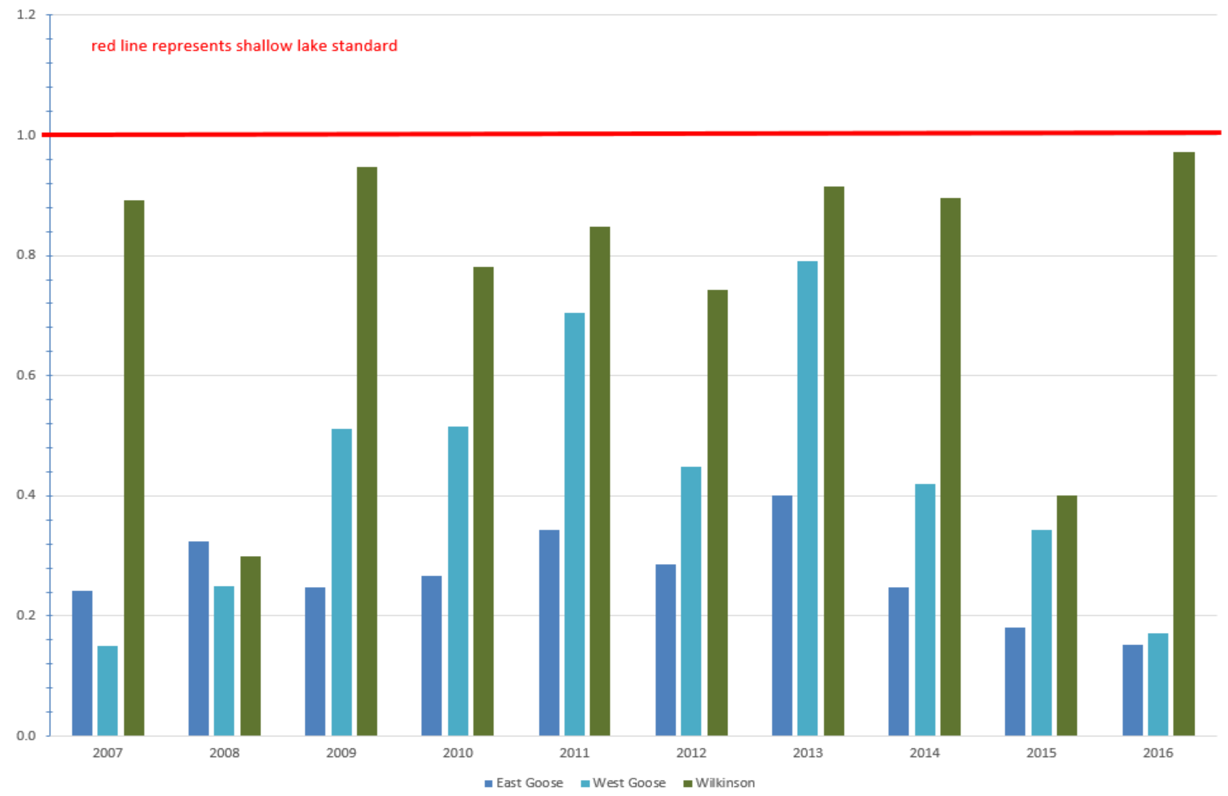


Figure 1-5 Summer Average (June-Sept.) Secchi Disc Transparency (meters) since 2007



2.0 Stakeholder Charrette and Regulatory Summary

Understanding the inner working and prescribing management strategies of lake systems requires use of complex mathematical watershed and lake models. However, the resultant management strategies, although technically supported, are often difficult to convey to the public. To address the issue, a stakeholder engagement process was incorporated into the project. The goal of the stakeholder engagement process was to involve the public, regulatory agencies and VLAWMO staff in the process of identifying and vetting management solutions for Goose Lake and Wilkinson Lake.

On January 10, 2017, the team hosted the Goose Lake and Wilkinson Lake Stakeholder Charrette. The Charrette was attended by members of the public, non-governmental organizations (Midwest Ski Otter Ski Club and North Oaks Homeowners Association), municipal agencies (Cities of North Oaks and White Bear Lake and Ramsey Conservation District), state government (Minnesota Department of Natural Resources and Minnesota Pollution Control Agency) and VLAWMO staff. The attendees convened for a state of the lake presentation for each lake followed by collaborative group discussions.

Collaborative discussions were facilitated around three questions. The questions and information generated are summarized below.

2.1 What kind of recreational support can Goose Lake use?

According to the groups, Goose Lake can support non-motorized activities, waterskiing, pontooning, and fishing for crappies and bass. The groups also acknowledged concerns about the absence of waterfowl and bald eagles, and the presence of curlyleaf pondweed. In addition to the concerns acknowledged, they also thought plant herbicides or harvesting warranted further investigation, as well as the correlation between bullhead removal and improvements in water quality and clarity, and whether water skiing and aquatic plants can coexist in Goose Lake.

2.2 What part do fish and aquatic plants play?

When attendees rotated into this group, they were interested in discerning the difference between invasive and non-invasive plants. It was noted that the lakes have curlyleaf pondweed and Eurasian water milfoil (both invasive plant species) edging into East Goose Lake from the southwest corner. Also, there was concern about the lack of species diversity and how that would affect the ecological functions of the lakes. They were also interested in an evaluation of the following:

- Investigating how fish and plants interact within the lake system and the possibility of using alum treatment on all or part of East Goose Lake;
- Conducting a fish study in Wilkinson Lake; and
- Encouraging recreational use in one of the Goose Lake basins.

2.3 Does the lake's classification appear accurate for attaining water quality standards?

After the state of the lake presentation, the attendees wondered why Wilkinson Lake is considered a shallow lake and not a wetland. The group discussions generated questions for regulatory agencies to address and VLAWMO staff to consider. The questions were:

a. If Wilkinson Lake is a wetland, are the activities planned to address water quality reflective of a wetland or shallow lake?

b. The Department of Natural Resources (DNR) and Minnesota Pollution Control Agency (MPCA) have classifications for public wetlands and public waters. What do these agencies take into consideration when determining the classification of a lake?

c. If the classification for Wilkinson is wrong and it should be a wetland instead of a shallow lake, are the resources (both financial and manpower) being wasted on non-attainable standards?

d. How will modifying the classification affect Wilkinson Lake's eligibility for clean water funding, and other grants?

e. How do climate change and the standard operating procedures of the St. Paul Regional Water Service affect Wilkinson Lake and other lakes?

The questions related to lake classifications (a, b, c and d from above) were discussed with the Board of Water and Soil Resources, the DNR and the MPCA at a follow-up meeting with the state agency staff on February 6, 2017. The remaining question is addressed as part of this study.

During the agency meeting, the DNR stated that the public water/wetland designation is assigned through the legislative process and is a part of Minnesota state law. The public water/wetland designation is not easily modified. The MPCA detailed their role as the agency responsible for assessing a lake's quality and its ability to meet designated standards. Modifying the classification to assign a shallow lake or wetland designation to the public water/wetland through the MPCA is a relatively straightforward process requiring data (maximum depth, littoral area, shoreline vegetation, uses, etc.) supporting the change. After considerable discussion and a qualitative review of the available data on Wilkinson Lake, is was concluded that maintaining the shallow lake classification is best for this system. Wilkinson Lake is in the upper watershed and discharge from it must be relatively clean so as not to adversely affect the water quality of downstream lakes that ultimately feed the water supply. Maintaining the shallow lake classification for Wilkinson Lake will also ensure that eligibility for grant funds will not be affected.

3.0 Water Quality Modeling and Analysis

A key component to performing diagnoses is selecting a rigorous approach to evaluating potential water quality benefits. While the simplified lake and watershed modeling approach used in the 2014 TMDL project was adequate for state and federal agency requirements, it did not account for intra-annual variations in lake water quality was not considered for use in this feasibility analysis as it lumps parameters at an annual time scale, treats lakes as fully mixed in a steady-state with uniform residence time, and does not adequately distinguish internal phosphorus loading sources from watershed sources during the critical conditions for water quality impairment. Based on our review of the available monitoring data and understanding of the purpose of the feasibility study, our approach for evaluating the primary drivers of water quality impairment in each lake adds further clarity, because it is based on updated monitoring data and accounts for intra-annual variations and recent management actions. Differentiating the individual drivers of lake water quality is based on the observed dynamics of each lake to set realistic expectations for future management actions.

The approach for this analysis used existing monitoring data, professional judgment, and modeling to identify the best approach to cost-effectively improve lake water quality. Specific subtasks included:

- Review current and historic water chemistry and biological data. Evaluate long- and short-term water quality trends.
- Review sediment phosphorus data and use it to estimate the internal phosphorus loading potential.
- Using existing watershed modeling, develop an updated lake phosphorus balance that includes phosphorus loads from watershed and in-lake sources and evaluate results to better understand the effect of varying climatic and sensitivity to management changes.
- Analyze fish data to evaluate potential impacts of carp and black bullhead on lake water quality and to determine the impact of water quality dynamics on the fish community.
- Consider the effects that recreational boating are expected to have on lake water quality.
- Integrate data analyses from above to diagnose causes of lake water quality problems, including feedback loops and dynamics between biological measurements and lake water quality observations.
- Evaluate water quality improvement options to identify feasible and cost-effective water quality improvement options for each lake basin.
- Complete an evaluation of feasible water quality improvement options to estimate expected lake water quality changes that could be attained.

3.1 Data Gaps and Limitations of Past Analyses

Lake and watershed modeling, along with the associated GIS mapping, from the TMDL study were obtained and reviewed for use in this study. In addition to the aforementioned limitations of the temporal scale of the lake water quality modeling, it was determined that the following data gaps and limitations of the past analyses would also need to be addressed to better evaluate the sources of phosphorus during the critical condition and potential improvement options for the respective study lakes:

- The P8 watershed modeling from the TMDL study did not simulate the existing Best Management Practices (BMPs) in the West and East Goose Lake watersheds or natural ponds and wetlands in the Wilkinson Lake watershed. As discussed in the following section, this may have led to overestimated phosphorus loadings for each watershed in the TMDL study.
- The GIS mapping (and associated P8 watershed modeling) from the TMDL study included a significant landlocked area from Gem Lake in the West Goose Lake watershed. This may have also led to overestimated phosphorus loading for this watershed in the TMDL study.
- Figure 1-1 also reflects other small changes that were made to the East Goose Lake watershed divides to better plan for and recommend additional BMPs for future implementation.
- Stormwater monitoring data collected in the Wilkinson Lake watershed since 2011 was obtained and evaluated to better distinguish priority phosphorus source areas that would not otherwise have been determined from the P8 modeling developed for the TMDL study.

3.2 Existing Best Management Practices (BMPs)

Figure 1-1 shows the locations in the East and West Goose Lake watersheds where the city of White Bear Lake and Ramsey County have previously implemented BMPs for stormwater treatment. These existing BMPs include seven ponds, seven rainwater gardens, three swirl separators and five infiltration pipes.

Since it wasn’t clear how well these BMPs have been maintained and the watershed mapping did not delineate the direct drainage areas tributary to each practice, the updated P8 watershed modeling did not account for treatment for these BMPs. However, a sensitivity analysis was performed with the lake water quality modeling to evaluate how much a 50 percent reduction in total phosphorus loading would influence the respective lake concentrations.

3.3 East Goose Lake

Updated lake and watershed modeling was developed for this study and optimized to reproduce the observed water quality for each lake during the summer periods of interest. Figure 3-1 shows how the predicted and measured total phosphorus concentrations compare during the summer of 2016 for East Goose Lake. Approximately 85 percent of the phosphorus load was attributed to sediment phosphorus release during this time period. As a result, Figure 3-1 also shows that the predicted phosphorus concentration in East Goose Lake would be much more sensitive to an 80 percent reduction in internal load (similar to what would be expected following an in-lake alum treatment) than it would have been in response to a 50 percent reduction in stormwater loading (similar to what would be expected with widespread BMP implementation) during 2016. It should also be noted that the results of these analyses are based on the same starting phosphorus concentration at the beginning of the summer. Over time, following full-scale BMP implementation or in-lake alum treatment, it is expected that the starting concentrations would be closer to the shallow lake standard at the beginning of each summer season. Based on the results shown in Figure 3-1, this in turn, should ensure that an in-lake alum treatment would maintain lake water quality at levels that would be consistent with the shallow lake standards.

Figure 3-1 2016 Water Quality Modeling Results for East Goose Lake

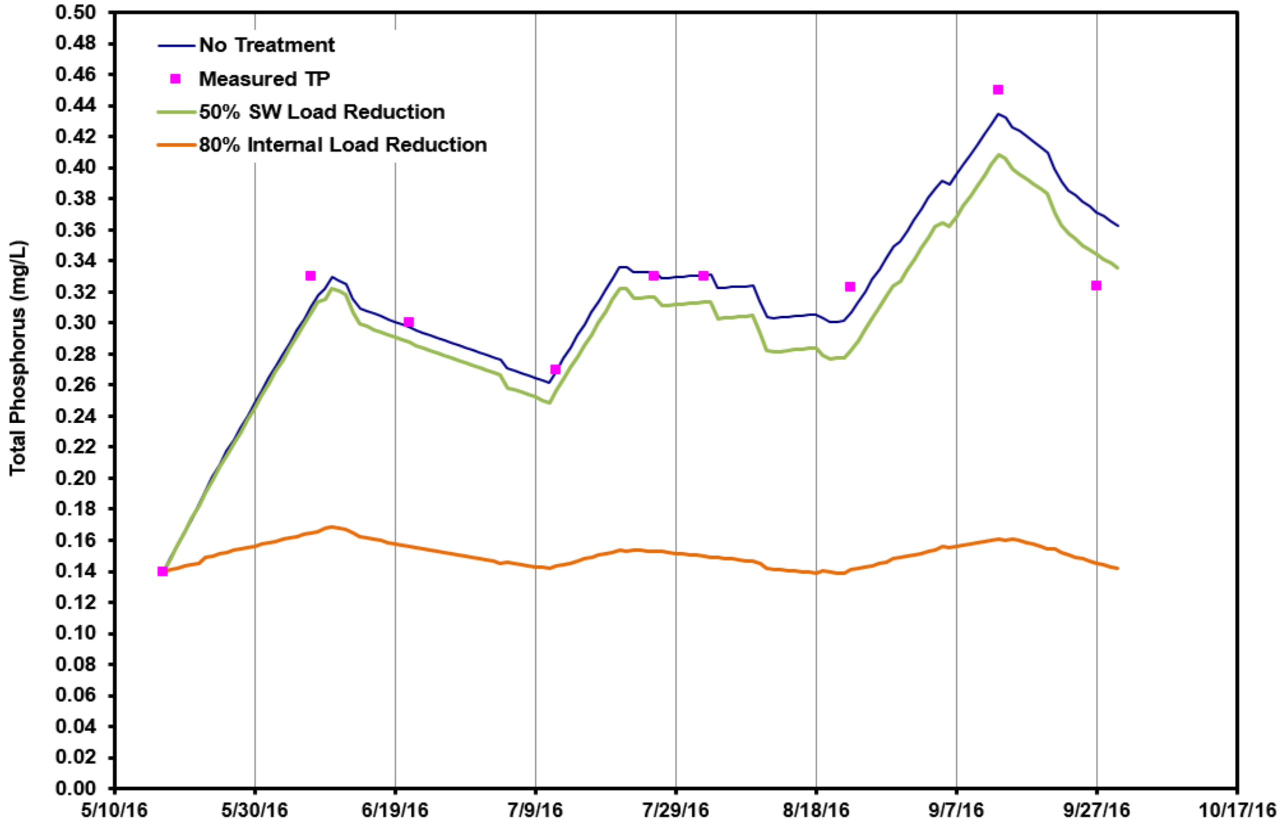
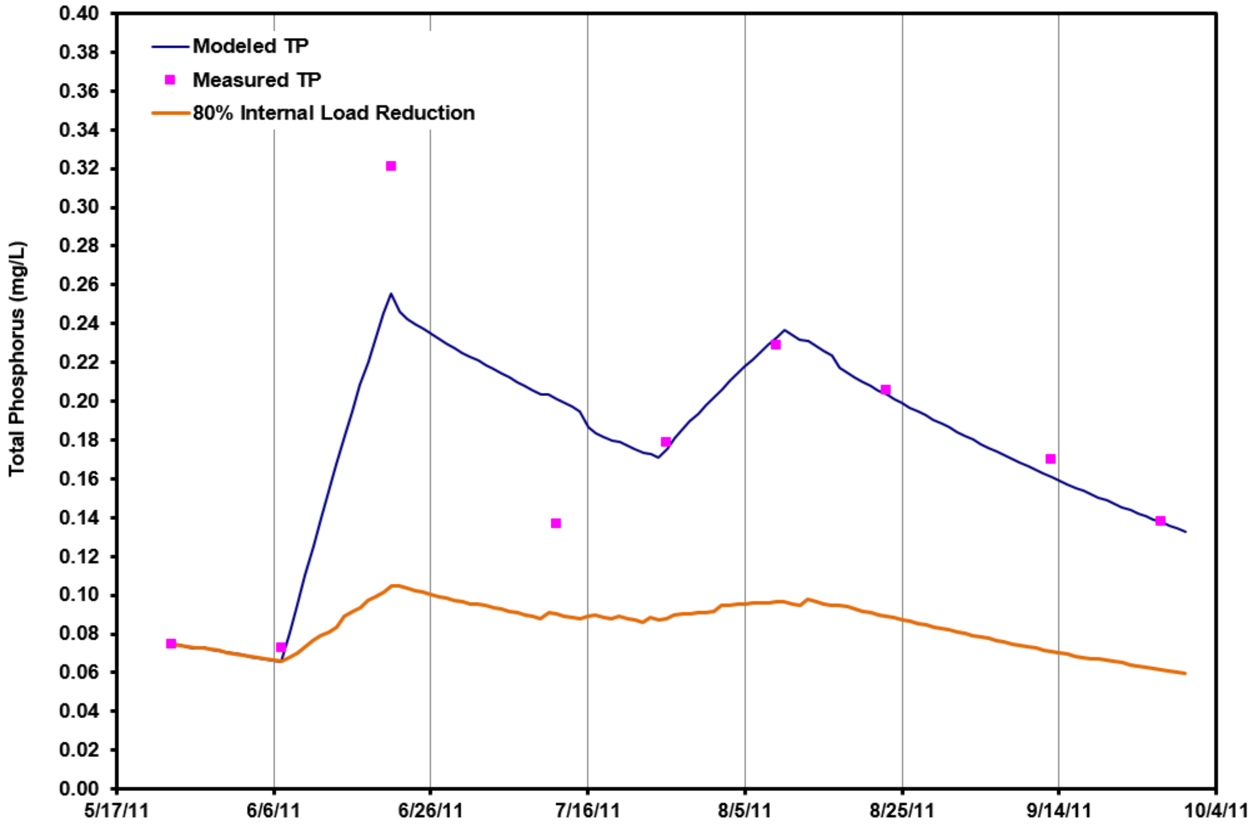


Figure 3-2 shows how the predicted and measured total phosphorus concentrations compare during the summer of 2011 for East Goose Lake. Approximately 80 percent of the phosphorus load was attributed to sediment phosphorus release during this time period. As a result, Figure 3-2 shows that the predicted phosphorus concentration in East Goose Lake would respond well to an 80 percent reduction in internal load (similar to what would be expected following an in-lake alum treatment) during 2011. Again, based on the results shown in Figure 3-2, an in-lake alum treatment would maintain lake water quality at levels that would be consistent with the shallow lake standards.

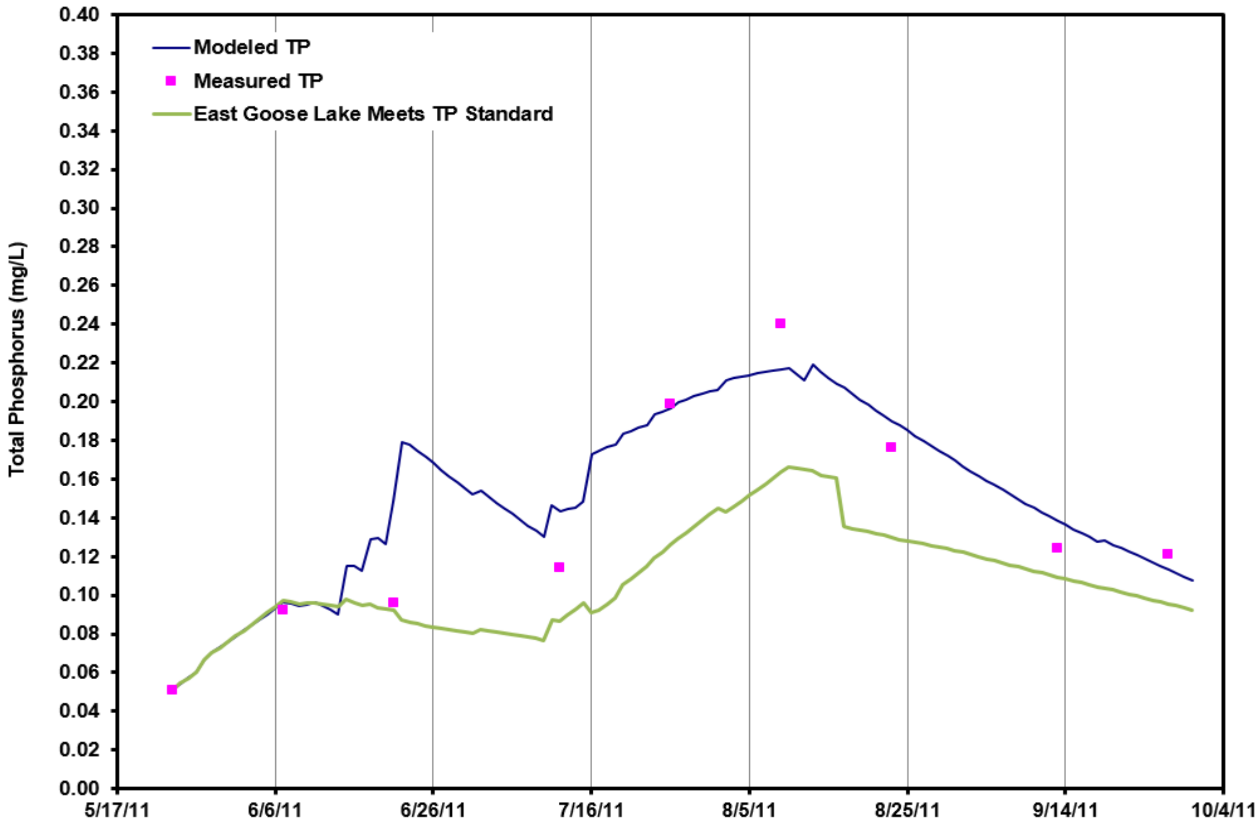
Figure 3-2 2011 Water Quality Modeling Results for East Goose Lake



3.4 West Goose Lake

Figure 3-3 shows how the predicted and measured total phosphorus concentrations compare during the summer of 2011 for West Goose Lake. Approximately 26 percent of the phosphorus load was attributed to sediment phosphorus release, 34 percent can be attributed to stormwater runoff and 39 percent to upstream contributions from East Goose Lake during this time period. As a result, Figure 3-3 also shows that the predicted phosphorus concentration in West Goose Lake is more sensitive to a reduction in incoming phosphorus concentration from East Goose Lake (similar to what would be expected if East Goose Lake had a phosphorus concentration that met the 60 µg/L standard) during 2011. Over time, following an in-lake alum treatment (and to a lesser extent, full-scale BMP implementation), it is expected that the concentrations would be maintained closer to the shallow lake standard throughout the summer season.

Figure 3-3 2011 Water Quality Modeling Results for West Goose Lake



3.5 Wilkinson Lake

Figure 3-4 shows how the predicted and measured total phosphorus concentrations compare during the summer of 2011 for Wilkinson Lake. A majority, if not most, of the phosphorus load can be attributed to watershed runoff during this time period, especially when the results of the average phosphorus concentrations observed during the 2011 watershed monitoring (depicted in Figure 3-5) show that there were a couple of areas contributing high phosphorus concentrations. The priority phosphorus source area north of the lake appears to develop between the Amelia Lake outlet and the Ash St. monitoring station, while the priority phosphorus source area south of the lake can be attributed to flow that originates upstream of the NO Farms monitoring station, but downstream of Birch Lake, Black Lake and the Centerville monitoring station (see Figure 1-2). In both areas, there are ponds/wetlands that may be releasing sediment phosphorus during the summer months. Over time, following full-scale BMP implementation, it is expected that the phosphorus concentrations would be maintained closer to the shallow lake standard throughout the summer season.

Figure 3-4 2011 Water Quality Modeling Results for Wilkinson Lake

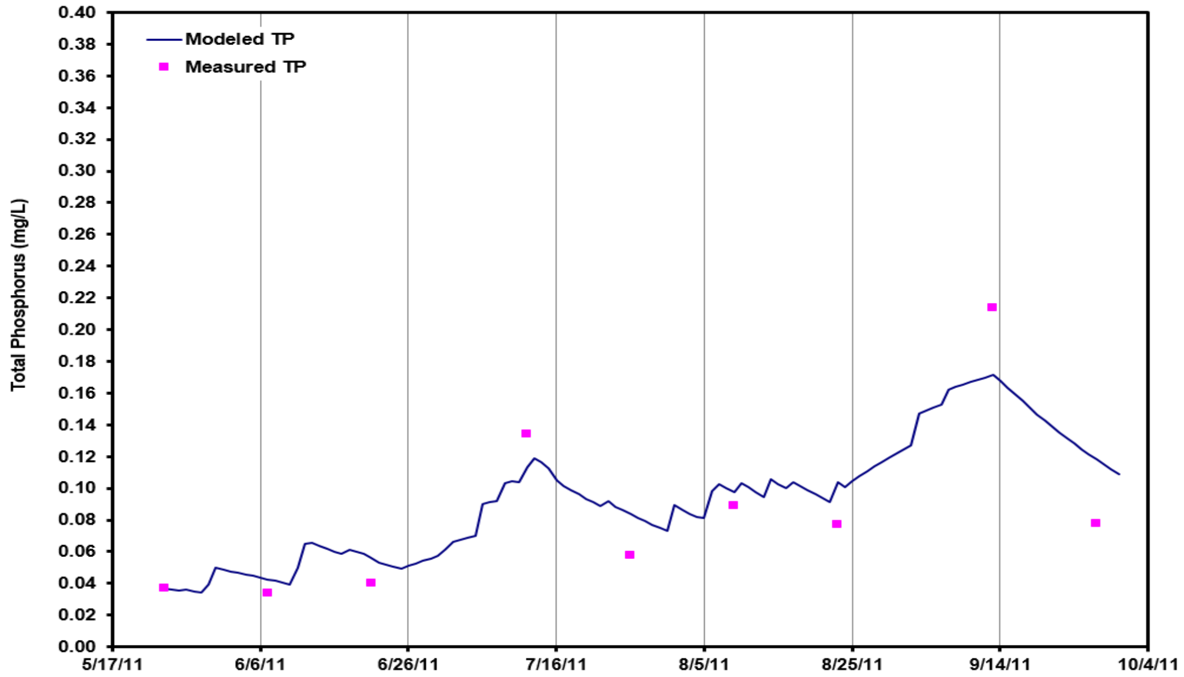
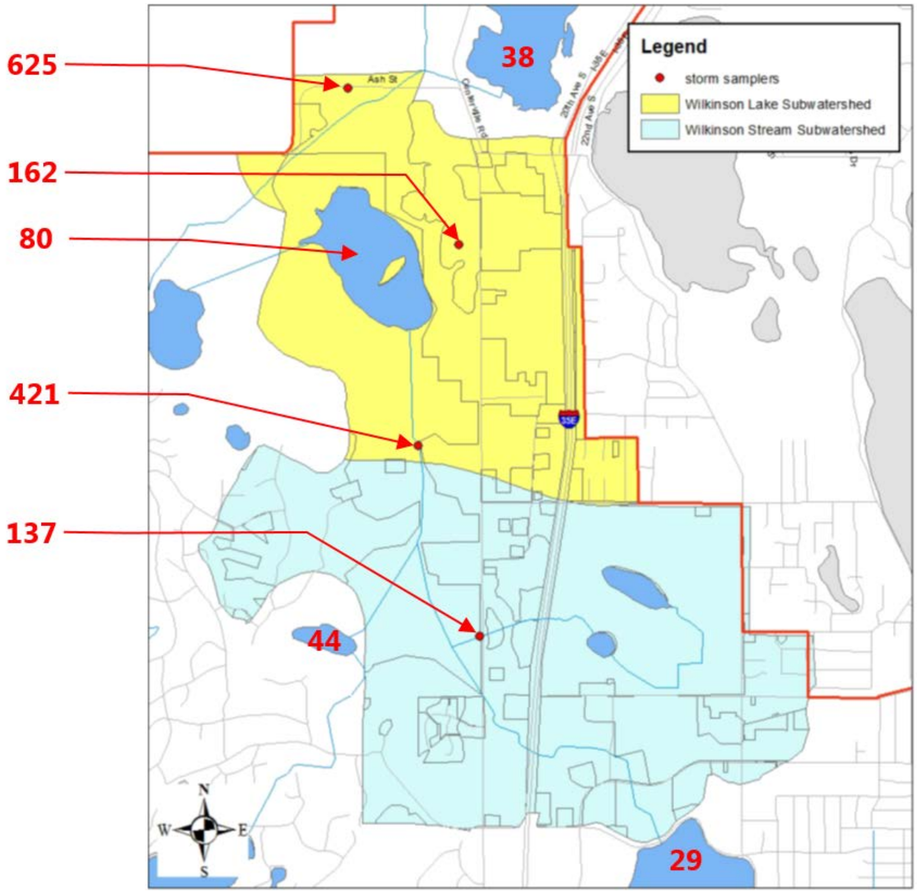


Figure 3-5 Average 2011 Total Phosphorus Concentrations (µg/L)—Wilkinson Lake Watershed



4.0 Recommendations

4.1 East and West Goose Lakes

4.1.1 Potential Improvement Options

As discussed in Section 3.2, and shown in Figure 1-1, there are several existing BMPs in the East and West Goose Lake watershed. An evaluation of the storm sewer conveyances that did not have any existing stormwater treatment revealed that there are approximately five high-priority watershed locations where BMPs should be considered for implementation.

Table 4-1 provides rough estimates of planning level construction costs for the respective BMPs at the recommended BMP locations, based on experience with similar practices in Metro lake watersheds. It is expected that wider-scale implementation of rainwater gardens throughout the watershed would be more cost-effective than the other watershed BMPs shown in Table 4-1, but they may not be feasible and would likely need to be implemented as a part of street reconstruction projects to realize significant cost savings. It is also expected that the alum treatment costs for Options 6 and 7 will be closer to the range shown, which will need to include collection and analysis of additional sediment cores across each lake surface for phosphorus fractionations and dose determinations.

Table 4-1 Summary of Water Quality Improvement Options

Water Quality Improvement Option	Estimated Annual TP Reduction (lbs/yr)	Planning Level Opinion of Potential Costs	Annual Cost per Pound TP Removed ($/lb)
Option 1—Retrofit Lake Bay for Improved Stormwater Treatment	10	$100,000	$10,000
Option 2—Construct Off-Line Filtration System for Low Flows	25	$300,000	$12,000
Option 3—Construct Pond On-Line With 36"-dia. Storm Sewer	25	$300,000	$12,000
Option 4—Infiltration Pipe Upstream of Storm Sewer Outfall to East Goose Lake	5	$50,000	$10,000
Option 5—Infiltration Pipe on School Property	25	$100,000	$4,000
Option 6—Alum Treatment of West Goose Lake	100	$100,000—$130,000	$1,000—$1,300
Option 7—Alum Treatment of East Goose Lake	800	$400,000—$500,000	$500—$625

4.1.2 Recommended BMP Maintenance

In discussing the existing watershed BMPs (see Section 3.2 and Figure 1-1) with White Bear Lake staff it was understood that some of the practices may not have been inspected and/or maintained on a regular basis, or were in-need of more documentation for maintenance activities. For example, the rainwater gardens along County Road F have not been regularly maintained in the past, but it is expected that the County will contract with CCM crews for annual maintenance that should include weeding, trash removal, addition of mulch and supplemental plantings where necessary. Similarly, it is recommended that MS4 and VLAWMO staff coordinate to document inspections and maintenance of all existing watershed BMPs. Depending on existing BMP performance, it can be used to adapt future maintenance activities and inform or change the priority for implementing some of the BMPs identified in Table 4-1. Additionally, depending on the maximum depth, it is suggested that Oak Knoll Pond should be sampled for phosphorus in the pond water during a range of summer flows, as well as phosphorus fractionations from a sediment core sample.

4.1.3 Recommendations for Further Study

4.1.3.1 Spent Lime for Internal Load Control

Barr (Barr Engineering Company, 1992) previously demonstrated the potential use of spent lime sludge from water treatment operations as a bottom sealer to prevent phosphorus release from anoxic sediments collected from Goose Lake. The study used a sediment/water microcosm approach that showed that various small doses of spent lime were capable of completely controlling sediment phosphorus release under anoxic conditions. Since these experiments were conducted, Barr has demonstrated the efficacy of using spent lime to treat phosphorus and solids in stormwater runoff, but in-lake treatment for sediment phosphorus control has not been attempted outside of the lab setting. Since a significant portion of the cost of in-lake alum treatment is associated with the chemical costs, it is worth considering alternatives such as spent lime, which is a byproduct of water treatment operations that currently incurs significant expense for disposal by local utilities.

It is recommended that VLAWMO initiate a study, in cooperation with Barr, to evaluate pilot-scale implementation of this treatment approach as well as development of the conceptual design and potential cost-effectiveness for full-scale implementation of in-lake treatment for the Goose Lake basins (and/or any other watershed basins that are currently experiencing high levels of sediment phosphorus release). The recommended study objectives would include assessments of spent lime availability and transportation costs, savings in comparison with current disposal methods, the equipment needs and costs for surface water applications including both filter cake and slurry forms of spent lime, and assessments of sediment and surface water quality improvements as well as the overall life-cycle cost-effectiveness for comparison with other in-lake treatment options. It is expected that the cost for this pilot-scale study could range from $15,000 to $30,000, depending on the treatment extent and monitoring requirements.

4.1.3.2 Lake Vegetation Management Plan (LVMP)

A lake vegetation management plan (LVMP) is a document the Minnesota Department of Natural Resources (DNR) develops with public input to address aquatic plant issues on a lake. The LVMP is intended to balance riparian property owner's interest in the use of shoreland and access to the lake with preservation of aquatic plants, which is important to the lake's ecological health. It is recommended that VLAWMO work with the DNR and the public to develop a LVMP for both East and West Goose Lakes that will prescribe the permitted aquatic plant management actions (mechanical and/or herbicides) for a five-year period, including controls for invasive plants and restoration of lake shore habitat. VLAWMO should also pass along Ramsey Conservation District's plant survey and inquire with DNR about whether the survey information can be used as the control for future plant management actions.

4.2 Wilkinson Lake

As discussed in Section 3.5, there are two separate areas (upstream of both the Ash St. and NO Farms monitoring stations) in the Wilkinson Lake watershed that are contributing significantly higher total phosphorus concentrations/loadings to the lake. In both areas, there are ponds/wetlands that may be releasing sediment phosphorus during the summer months. As a result, it is recommended that VLAWMO conduct longitudinal monitoring over a range of flows during the summer months that would include collection of grab samples analyzed for total phosphorus, soluble reactive phosphorus, nitrate, ammonia and total suspended solids, along with dissolved oxygen, temperature and flow measurements during each sampling event.

If the next fishery survey indicates that Wilkinson Lake contains a significant rough fish population, then the efficacy of the carp barrier at the lake outlet and/or passage from upstream lakes should be re-evaluated for recruitment.

5.0 References

Barr Engineering Company. 1992. The Effects of Spent-Lime Sludge Additions on the Anoxic Sediment Phosphorus Release Rates of Goose Lake, Ramsey County, Minnesota. Prepared for St. Paul Water Utility.