WENCK File #1305-0028
December 2017

Lebanon Hills Regional Park Subwatershed Assessment Report

Prepared for:

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List of Acronyms

AIS	Aquatic invasive species
BMP	Best Management Practice
C	Coefficient of Conservatism
CLP	Curly-leaf pondweed
CN	Curve Number
EWM	Eurasian water milfoil
FIN	Fishing in the Neighborhood Program
FQI	Floristic quality index
GIS	Geographic Information System
LHRP	Lebanon Hills Regional Park
LiDAR	Light Detection and Ranging
MIDS	Minimal Impact Design Standards
MnDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
NCHF	North Central Hardwood Forest
NRCS	National Resource Conservation Service
NURP	Nationwide Urban Runoff Program
P8	Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds
RFQA	Rapid Floristic Quality Assessment
SAV	Submerged aquatic vegetation
SCS	Soil Conservation Service
SPI	Stream Power Index
SWCD	Soil and Water Conservation District
TP	Total Phosphorus
TSS	Total Suspended Solids
WHEP	Wetland Health Evaluation Program

1.0 Executive Summary

Located in Dakota County, Minnesota, Lebanon Hills Regional Park (LHRP) covers almost 2,000 acres and is the largest park in the Dakota County Park system. LHRP offers a variety of recreational activities including hiking, horseback riding, canoeing, fishing, swimming, as well as various educational programs and opportunities. LHRP is a highly valued resource and improving and protecting water quality and other water features throughout the park is extremely important to park patrons, local citizens, Dakota County, and the surrounding cities.

The purpose of this subwatershed assessment is to identify and prioritize watershed management solutions for LHRP, focusing on protecting and improving the water quality and ecological communities of the of the lakes within the park. The targeted outcome of this study is a list of potential stormwater best management practices (BMPs) that reduce nutrient loading and improve water quality of the lakes throughout the park. While this study included the entire LHRP boundary, the final BMP list focused primarily on five priority lakes within the park: Jensen, O'Brien, Schulze, McDonough, and Holland.

Several models and tools were used to evaluate current conditions, set goals, and identify BMPs to protect and improve the priority lakes within LHRP. A watershed model (P8) was developed to determine existing watershed pollutant loading from LHRP and the surrounding cities that drain to the park. BATHTUB lake response models were developed for several lakes throughout the park to determine watershed load reductions needed for the priority lakes to meet water quality goals/targets. Output from the P8 and BATHTUB models were used to identify several potential locations for stormwater BMPs throughout LHRP and surrounding areas. Each BMP was then evaluated to determine appropriate size along with estimated cost and phosphorus load reductions. Thus, this report provides a cost benefit analysis which will help the County prioritize future stormwater BMP implementation.

2.0 Background

2.1 PURPOSE

Lebanon Hills Regional Park (LHRP) is located in Dakota County, Minnesota. LHRP covers almost 2,000 acres and is the largest park in the Dakota County Park system. There are a variety of recreation resources available within the park for park users as well as several different forest, prairie, wetland, and lake natural resources. A subwatershed assessment study of LHRP was initiated by Dakota County in Spring 2017 to identify and prioritize target watershed management solutions for the park, focusing on protecting and improving the water quality and ecological communities of the lakes within LHRP. There have been a number of studies, assessments and plans developed and completed for LHRP, however, this subwatershed assessment study is the first major effort focused on water quality improvements and protection within the park. The identified elements of the subwatershed assessment include:

- identification of data gaps related to water quality, stormwater flow pathways, and potential pollutant loading;
- preparation of a work plan to collect lake water quality and sediment chemistry data to support watershed and in-lake water quality modeling efforts;
- examination of internal and external pollutant loading on each waterbody within the park using appropriate modeling methodology;
- identification of targeted Best Management Practices (BMPs) necessary to achieve recommended pollutant load and volume reductions that will protect or improve the park’s water resource designated uses and goals;
- evaluation of feasibility, costs (including maintenance), and effects of potential BMPs on recreational opportunities, natural resources, water resources and wetlands, and fish and wildlife populations within the park.

This report summarizes the results of the tasks completed during the subwatershed assessment study including collected water quality data, completed field assessments, developed watershed and lake models, areas evaluated for improvement projects, identified BMP projects, and preliminary design for prioritized improvement projects.

2.2 STUDY AREA

LHRP is located in north-central Dakota County with the boundary of the park located within the southern portion of the City of Eagan and the northern portion of the City of Apple Valley (Figure 2-1). The park boundary is 1,962 acres and has an extensive trail network as well as seven visitor areas. The LHRP Master Plan (Dakota County, 2015) indicates that trails are the main attraction for park users however there are a number of popular features associated with the lakes in the park including several lakeside picnic areas and the Schulze Lake beach. The study area for LHRP subwatershed assessment includes the park boundary as well as the areas that drain to the park, which combined together comprise the overall park subwatershed. The total drainage area for the LHRP is 3,870 acres which includes the park and an additional 1,908 acres of contributing watershed area. The study area includes the cities of Eagan and Apple Valley as well as portions of Rosemount in the southeast corner of the study area.

There are 13 named lakes within LHRP including: Gerhardt; Portage; Jensen; O'Brien; Marsh; McDonough; Holland; Schulze; Cattail; Beaver; Bridge; Dakota; and Wheaton. The priority lakes for the subwatershed assessment as identified in the RFP include: O'Brien; McDonough; Holland; Schulze; and Jensen. Approximately 10% of the LHRP is managed by stormwater infrastructure (i.e. storm sewer). Stormwater flow across the remainder of the park is via overland flow. For the contributing areas outside of the park, approximately 40% is managed via storm sewer infrastructure. Across the study area for the LHRP there are 58 stormwater ponds as well as 172 wetlands. There are also 48 wooded depressions (not classified as wetlands) and 11 drainage swales. All of the features contribute to stormwater flow pathways, storage, and overall management within the study area.

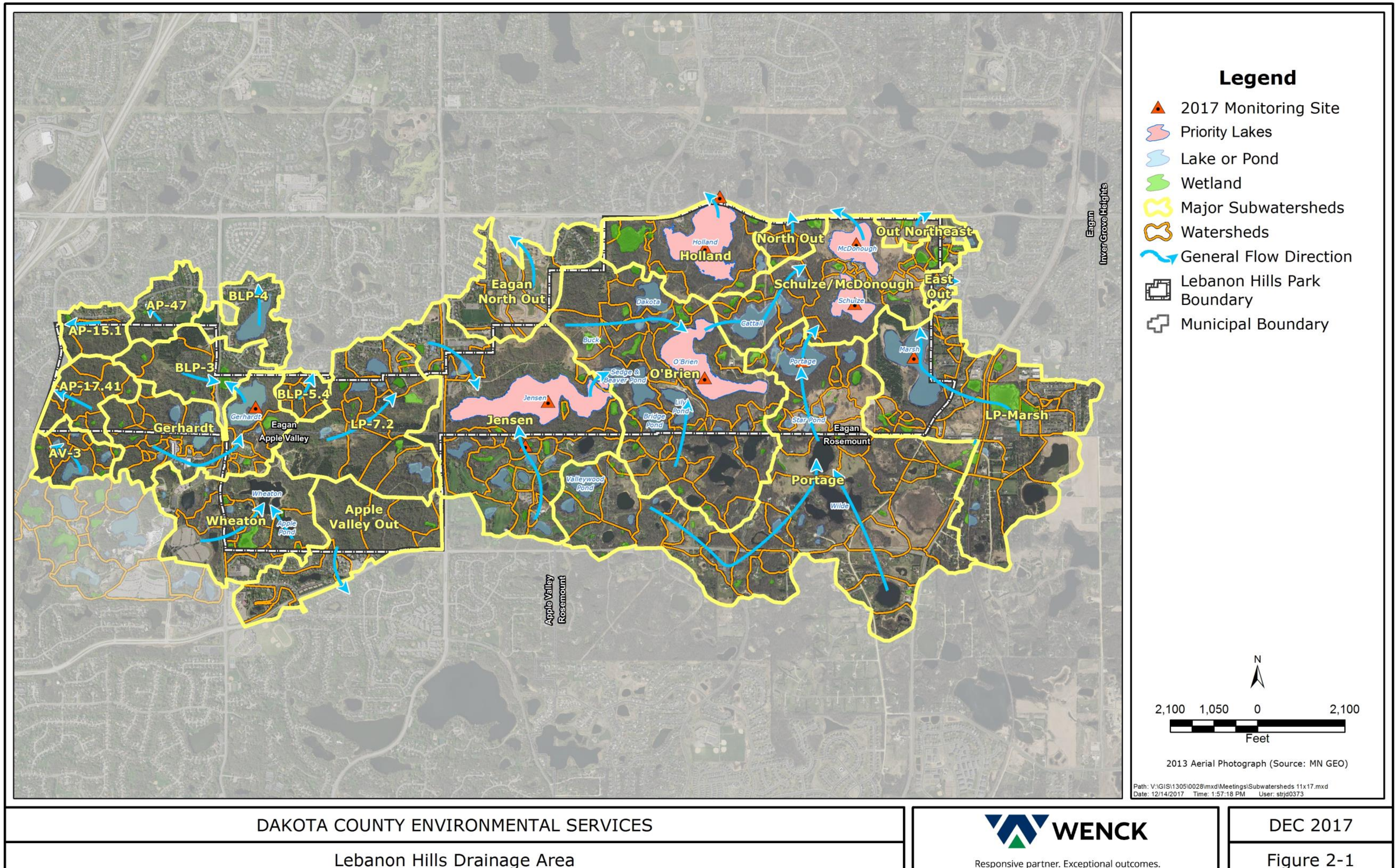


Figure 2-1. LHRP Subwatershed Assessment Study Area.

2.3 LAND USE

The total study area includes the LHRP as well as the surrounding areas that drain to LHRP (Figure 2-1). There is approximately 3,970 acres in the study area that includes 1,962 acres within the park boundary and an additional 1,908 acres that are outside the park boundary but drain to the park. Within the LHRP study area, land use is a mixture of low density residential, forested parkland, and wetlands/open water basins based on the 2010 Metropolitan Council Land Use GIS files. Land use in the study area also includes impervious areas which were delineated from recent aerial images. The urban area outside the LHRP boundary that drains into the park is predominantly large lot residential (Table 2-1).

Table 2-1. Land Use within the LHRP study area.

Land Use	*Within LHRP Boundary*		*Outside LHRP Boundary*	
	Acres	Percent	Acres	Percent
Agricultural	0	*0.0%*	61	*3.2%*
Farmstead	0	*0.0%*	6	*0.3%*
Park, Recreational, or Preserve	1,568	*79.9%*	389	*20.4%*
Open Water	371	*18.9%*	231	*12.1%*
Developed/Low Intensity	12	*0.6%*	1,096	*57.5%*
Developed/Medium Intensity	0	*0.0%*	34	*1.8%*
Developed/High Intensity	11	*0.6%*	90	*4.7%*
Total	*1,962*	*100%*	*1,908*	*100%*

2.4 SOIL TYPE

Hydrologic soil group classifications are based on Natural Resources Conservation Service (NRCS) Web Soil Survey. Group A soils are comprised of sandy soils that promote infiltration and reduce the risk for runoff. Group B soils are silty loams or loam soils that tend to have a well-drained profile. Group C soils are sandy clay loams with an increase in runoff potential and smaller grain size. Group D soils are heavy clay soils with limited infiltration potential and have the highest risk of runoff. Soil data for the LHRP study area is predominantly groups A, B, and C soils both within and outside the park boundary. (Table 2-2). Some soils within the study area are dual hydrologic soil groups; this designation is given when the soils can be reclassified from D soils to an A, B, or C with drainage modifications. Such modifications include engineered soil or installing a tile drainage network.

Table 2-2. Hydrologic soil groups within the LHRP Study Area

Hydrologic Soil Type	*Within LHRP Boundary*		*Outside LHRP Boundary*	
	Acres	Percent	Acres	Percent
A	223	11.4%	190	*9.9%*
A/D	2	0.1%	13	*0.7%*
B	146	7.4%	93	*4.9%*
B/D	3	0.2%	3	*0.2%*
C	1,191	60.7%	1,331	*69.8%*
C/D	34	1.7%	55	*2.9%*
D	166	8.5%	5	*0.3%*
Unclassified/ Open Water	198	10.1%	219	*11.5%*
Total	*1,962*	*100.0%*	*1,908*	*100.0%*

3.0 Data and Assessments

3.1 LAKE DESCRIPTION AND CHARACTERISTICS

The eastern LHRP chain of lakes, which includes all five of the priority lakes covered in this study, generally flow from the south/west to the north/east through the park system. Jensen, Portage, and Marsh Lakes are located on the periphery of LHRP and receive runoff from land outside the park boundary. Outflow from these lakes flows to other lakes within the LHRP boundary through a series of streams, culverts, pipes and overland flow channels. Below is a detailed description of the five priority lakes located within the eastern LHRP chain of lakes. General flow pathways for the park and lakes in the study area are shown in Figure 2-1.

Jensen Lake

Jensen Lake is the western-most lake in the LHRP eastern chain of lakes. With a surface area of approximately 56 acres, Jensen Lake is the largest lake in LHRP (Table 3-1). The lake has a relatively small watershed compared to its surface area, which results in it having one of the smallest watershed to lake area ratios of any lake in this study. Jensen Lake is shallow (maximum depth of 8 feet) but has a long residence time (~2 years), which is primarily a function of its watershed to lake area ratio. The watershed draining to Jensen Lake includes approximately 40 acres of residential development in the City of Eagan that enters the lake from the west/northwest through a series of stormwater pipes/ponds. The Valleywood Golf Course, which is located south of Jensen Lake in the City of Apple Valley, also flows to Jensen Lake and accounts for approximately 40% (~170 acres) of its watershed. Runoff from the golf course is routed to a series of ponds prior to entering the park via small surface flow channels along the southern LHRP boundary. Jensen outlets to Sedge and Beaver Pond through a small channel on the northeast corner of the lake.

O'Brien Lake

O'Brien Lake is a moderately sized (37 acres) shallow lake with a maximum depth of 10 feet located in the central portion of the eastern LHRP. The lake is located approximately one mile downstream of Jensen Lake and receives flow from Buck, Sedge, Beaver, Bridge, and Lily Ponds, Dakota Lake, and a series of other small ponds and wetlands surrounding the lake. These upstream waterbodies account for approximately 85% (756 acres) of the drainage area to O'Brien Lake, and therefore the lake's direct watershed represents only 15% (133 acres) of its watershed. The direct watershed to O'Brien Lake is completely within LHRP and is comprised mostly of forested parkland, however there are some buildings and other structures on the Camp Butwin property just east of the lake.

Schulze Lake

Schulze Lake is the smallest (15 acres) of the LHRP priority lakes, however with a maximum depth of 15 feet, it is one of the deeper shallow lakes in LHRP. Schulze Lake is located in the northeast corner of the eastern portion of LHRP. Schulze is the only lake in LHRP with a public swimming beach and, with the LHRP Visitor Center located along the northeastern shoreline of the lake, it is the most heavily trafficked lake in LHRP. The drainage area to Schulze Lake includes outflow from Portage Lake and its 607-acre watershed, and a 59 acre direct watershed. The direct watershed to Schulze Lake includes several hiking trails directly around the lake. Only a small portion of the buildings and parking lots in the LHRP visitor center drain directly to Schulze Lake as a majority of this area flows to McDonough Lake.

McDonough Lake

McDonough Lake is located approximately 500 feet north of Schulze Lake. McDonough Lake is similar in size (19 acres) to Schulze Lake, however it is shallower (maximum depth of 8 feet) and has a significantly bigger drainage area (2,163 acres). As a result, McDonough Lake has the largest watershed to lake area ratio (114:1) and shortest residence time (0.2 years, or ~73 days) of the LHRP priority lakes. The watershed draining to McDonough Lake includes outflow from Schulze Lake, Marsh Lake, and Cattail Lake, which is located downstream of O'Brien Lake. The direct watershed to McDonough is approximately 7% (153 acres) of its total drainage area and includes a small residential development (~10 acres) within the City of Eagan directly east of the lake. Most of the LHRP visitor center and other trails and parkland downstream of the previously mentioned upstream lakes also drain to McDonough Lake.

Holland Lake

Holland Lake is the deepest lake (max depth of 55 feet) within LHRP and has a relatively small drainage area. Due to these characteristics, Holland Lake has the smallest watershed to lake area ratio (4:1) and longest average residence time (~16 years) of any lake in this study. The watershed draining to Holland Lake is located completely within the LHRP boundary and consists of steep sloped forested park land. Although Holland Lake is a deep lake, it does demonstrate some shallow lake characteristics with a moderately large littoral area (73%) capable of support submerged aquatic vegetation (SAV) and therefore likely sensitive to biological influences such as aquatic invasive species (AIS).

Table 3-1. Watershed and lake characteristics for the LHRP priority lakes

Characteristic	Jensen	O'Brien	Schulze	McDonough	Holland
Size [acres]	56	37	15	19	43
Max Depth [ft]	8	10	15	8	55
Mean Depth [ft]	3.6	5.9	8.1	4.3	12.4
Littoral Area [percent]	100%	100%	100%	100%	73%
Lake Classification	Shallow	Shallow	Shallow	Shallow	Deep
Upstream Lake(s)	None	Jensen, Sedge & Beaver, Lily, Dakota	Portage	O'Brien, Cattail, Schulze, Marsh	None
Total Watershed [acres]	416	889	666	2,163	157
Watershed: Lake Area Ratio	7:1	24:1	44:1	114:1	4:1
Residence Time [years]	2.2	1.2	0.8	0.2	16.0

3.2 LAKE WATER QUALITY DATA

Water quality in Minnesota lakes is often evaluated using three associated parameters: total phosphorus (TP), chlorophyll-a, and Secchi depth. TP is typically the limiting nutrient in Minnesota's lakes, meaning that algal growth will increase with increases in phosphorus. However, there are cases where phosphorus is widely abundant and the lake becomes limited by nitrogen or light availability. Chlorophyll-a is the primary pigment in aquatic algae and has been shown to have a direct correlation with algal biomass. Since chlorophyll-a is a simple measurement, it is often used to evaluate algal abundance rather than expensive cell counts of specific algal species. Secchi depth is a physical measurement of water clarity made by lowering a black and white disk until it can no longer be seen from the surface. Higher Secchi depths indicate less light-refracting particulates in the water column and better water quality. Conversely, high TP and chlorophyll-a concentrations point to poorer water quality and thus lower water clarity. Measurements of these three parameters are interrelated and can be combined into an index that describes water quality.

Intensive water quality sampling was conducted by Dakota County staff on each of the LHRP priority lakes in 2017. For each lake, surface samples were collected bi-weekly from June to late September and analyzed for TP, chlorophyll-a, Secchi depth, chloride, total suspended solids (TSS), nitrogen, temperature, and dissolved oxygen. In addition to the priority lakes, Portage, Marsh and Gerhardt Lakes were also sampled approximately one time per month from June through September in 2017 (Appendix A). Prior to 2017, water quality sampling data for the lakes within LHRP is rather limited over the past 15 years. Water quality, including TP, chlorophyll-a and Secchi depth, was monitored on four lakes (Jensen, O'Brien, McDonough, and Holland) in 2007 and 2008. Additionally, Secchi depth measurements have been recorded periodically in Jensen, Schulze, McDonough, Holland, and Gerhardt Lakes since 2000. Results of the 2017 intensive water quality monitoring efforts for the priority lakes are summarized in Figure 3-1. Appendix A and Table 3-2 show long-term historic average summer growing season TP and chlorophyll-a concentrations and Secchi depths for the LHRP priority lakes.

The 2017 water quality sampling for the priority lakes indicate average summer growing season TP concentrations in Jensen, O'Brien, Schulze and McDonough were well below the 60 µg/L State standard for shallow lakes in the North Central Hardwood Forest (NCHF) Ecoregion. Similarly, Holland Lake average summer growing season TP was below the 40 µg/L State standard for deep lakes in the NCHF Ecoregion. While seasonal averages for all lakes were below State TP standards, individual TP measurements exceeded State standards on one occasions for Jensen Lake, and on two occasions for Schulze and McDonough Lakes. Most of the TP exceedances occurred during mid-summer (July and August) and coincided with elevated algae growth.

The 2017 monitoring results also suggest that Jensen, O'Brien, McDonough, and Holland are currently meeting State chlorophyll-a standards for shallow lakes (20 µg/L) and deep lakes (14 µg/L) in the NCHF ecoregion. O'Brien and Holland Lakes had extremely low chlorophyll-a concentrations throughout the entire summer growing season which suggests algae growth was low and the lakes exhibited very good water quality. While the 2017 average growing season chlorophyll-a concentrations for Jensen and McDonough were below the State standard, these lakes did have a few individual exceedances of the 20 µg/L standard. These exceedances (two for McDonough and one for Jensen) occurred during the July sampling events which suggest these lakes are susceptible to occasional nuisance algae blooms. Schulze Lake, with an average growing season chlorophyll-a concentration of 47 µg/L, was the only LHRP priority lake that did not meet State water quality standards in 2017. Schulze lake chlorophyll-a concentrations exceeded the 20 µg/L standard on 5 of 8 sampling events in 2017. Chlorophyll-a in Schulze increased steadily throughout May and July and reached a maximum concentration of 110 µg/L in mid-August (Appendix A). The high 2017 chlorophyll-a concentrations in Schulze coincided with poor water clarity as Secchi depth measurements did not meet State water quality samples from June through September. These data indicate nuisance algae blooms are a common occurrence in Schulze Lake throughout the summer growing season.

In order for a lake to be assessed for impairment, Minnesota State Water Quality Assessment protocol (MPCA, 2014) requires monitoring data be collected over a minimum of 2 years with at least 8 total sample points, and the data must be collected from June to September. Once these requirements are met, a lake is considered impaired if TP and at least one of the response variables (chlorophyll-a or Secchi) exceed State water quality standards. Since the State TP standard is currently being met throughout LHRP, it does not appear that any of the lakes within the park would be considered impaired at this time. As discussed above, Schulze Lake does not currently meet State standards for chlorophyll-a and transparency. Only one year (2017) of monitoring data has been collected for Schulze Lake and therefore at least one more year of monitoring data would be needed for assessment. If future monitoring in Schulze are similar to the 2017 results, the lake would likely receive a designation of "insufficient data". This designation is given to lakes in which only one of the thresholds is exceeded (i.e. TP or chlorophyll-a or Secchi), while the other two are in compliance with the standards.

Chloride samples for each priority lake were collected by Dakota County staff in 2017 in conjunction with the TP, chlorophyll-a, and Secchi depth measurements discussed above.

Results of the chloride sampling indicate concentrations are low in each of the priority lakes and well below the 230 mg/L chloride standard for Minnesota Lakes. Results of the chloride sampling are summarized in Table 3-2 and Appendix A. Dakota County and the individual Cities surrounding LHRP currently implement road salt BMPs in and around the LHRP drainage area. It is recommended that the County continue monitoring chloride within the LHRP priority lakes to ensure chloride concentrations remain low and, if chloride concentrations begin to increase, implement additional road salt BMPs as necessary so that chloride does not become an issue.

Table 3-2. Summary of WQ for LHRP priority lakes.

Parameter		Jensen	O'Brien	Schulze	McDonough	Holland
TP [µg/L]	2017 Average	28	10	48	41	10
	Historic Average	34	22	**	44	18
	State Standard	60				40
Chl-a [µg/L]	2017 Average	14	4	47	16	4
	Historic Average	12	17	**	10	4
	State Standard	20				14
Secchi [m]	2017 Average	0.9*	1.7*	0.7	1.3*	3.9
	Historic Average	1.3	1.7	1.9	1.9	3.7
	State Standard	1.0				1.4
Chloride [mg/L]	2017 Average	26	17	46	41	32
	Historic Average	**	**	**	**	33
	State Standard	230				
WQ Trends	Historic Average	< Secchi	None	< Secchi	None	< TP < Chl-a > Secchi

* Measurements are inconclusive due to obstruction by SAV
** 2017 was the only year sampled for this parameter
Note: Historic WQ averages are based on available data from 2000 through 2017

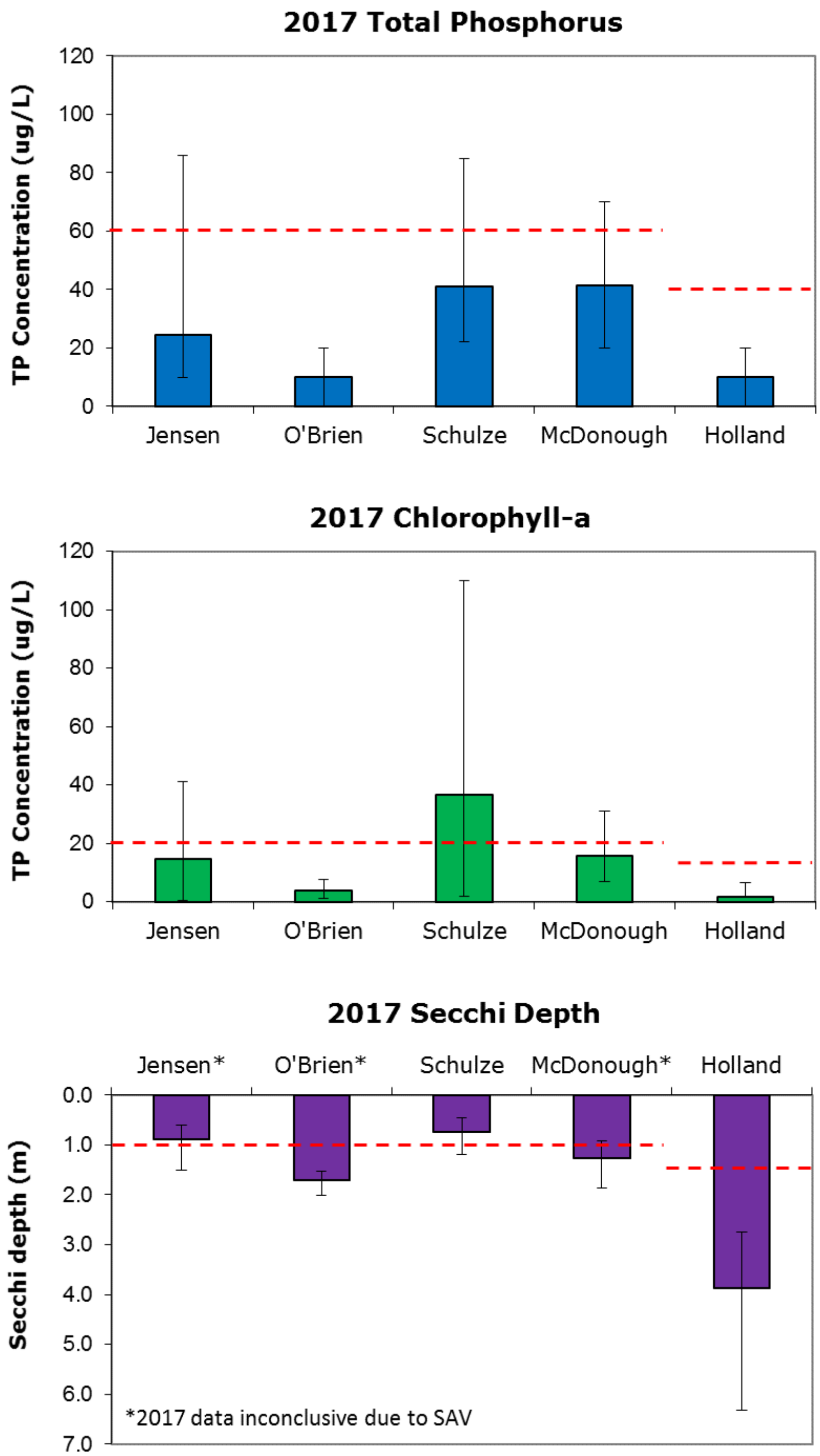


Figure 3-1. Summary of 2017 WQ monitoring results for LHRP priority lakes.
Notes on these figures: solid bars represent average summer growing season values, error bars represent the total range in 2017 data, and the dotted red lines show State water quality standards for each parameter.

3.3 LAKE SEDIMENT ASSESSMENT

Internal phosphorus loading from lake sediments has been demonstrated to be an important aspect of the phosphorus budgets of both shallow and deep lakes. However, measuring or estimating internal loads can be difficult, especially in shallow lakes that may mix many times throughout the year. To estimate internal loading in LHRP, sediment cores were collected from the deepest portion of six lakes throughout the park. Phosphorus release rates were then measured in the lab under anoxic (without oxygen) conditions (UW-Stout 2017; Appendix B). Sediment chemistry was also analyzed for two of the lakes, Jensen and Gerhardt, to characterize the type of phosphorus within the lake sediments. This information is useful in evaluating potential management options and chemical dosing rates if it is determined internal load treatment project(s) are feasible options.

Results of the sediment analysis shows that the rate of phosphorus release from the sediment ranged from 0.4 to 1.9 mg/m2/day for the six assessed lakes within LHRP (Figure 3-2). Schulze Lake (1.9 $mg/m^2/day$) and Gerhardt Lake (1.6 $mg/m^2/day$) displayed the highest release rates, while McDonough (0.6 $mg/m^2/day$) and O'Brien (0.4 $mg/m^2/day$) exhibited the lowest. Sediment release rates for the six lakes were relatively low compared to other lakes throughout the state of Minnesota, as they all fell below the 75th and 25th percentile. Despite relatively low release rates, sediment phosphorus release was measurable in all six lakes and has the potential to represent a significant portion of these lake's phosphorus budget. Average annual phosphorus loading estimates for each major source, including sediment, for the LHRP priority lakes is presented in Section 4.5.

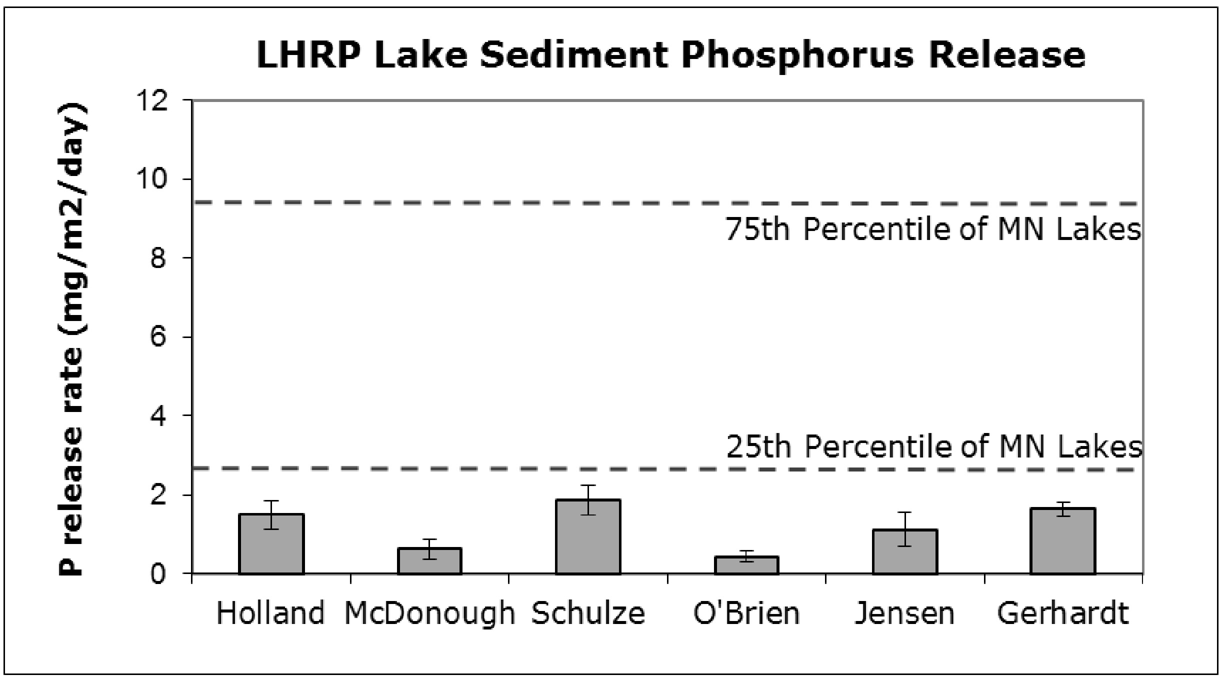


Figure 3-2. Laboratory-measured sediment phosphorus release rates for six lakes within LHRP.

3.4 LAKE VEGETATION SURVEYS

Submerged aquatic vegetation (SAV) perform numerous water quality and ecosystem services in lakes. Healthy SAV communities are especially important for shallow lakes as they can act as a barrier or blanket between the sediment and the water column, reducing the amount of nutrient interactions and exchanges. SAV also provide critical habitat for many aquatic biota, especially large bodied Cladocerans (an aquatic invertebrate). Having protection from predation allows large bodied Cladocerans the ability to help maintain water quality in shallow lakes by consuming algae from the water column.

Declines in the diversity and abundance of native SAV can be an indication of a shifting water quality state. As disturbances increase, sensitive vegetation species are lost from the system and often replaced with less desirable and sometimes aquatic invasive species (AIS). AIS pose an additional threat to water quality as they often outcompete native vegetation further reducing habitat and in some cases, may contribute to nutrient loading and algal blooms.

Curly-leaf Pondweed (CLP) is one SAV species that has the ability to grow under the ice and reaches its maximum growth in May and June, when most native plant growth is still hindered by cool water temperatures. Since it has little competition from native species early in the year, CLP can form dense stands that incorporate nutrients from the lake sediments. When the plants begin to die back (senesce) in early summer the nutrients stored in the stems and leaves of the plants are released back into the lake. If other SAV species do not grow back in place of the senescing CLP, the vacant areas left behind lack a barrier between sediment and water column nutrient exchange furthering decreasing water quality. Eurasian water milfoil (EWM) is another prominent AIS found in many lakes (including LHRP) that can outcompete native vegetation species. This species can also hybridize with native milfoils making it difficult to manage.

Point-intercept vegetation surveys were performed in mid-June and early/mid August 2016 on the five priority lakes in LHRP, as well as 13 other lakes in LHRP (Blue Water Science, 2017). The primary purpose of the early summer (June) surveys were to target and estimate the distribution and abundance of CLP, which senesces by early summer and is typically missed and/or under-represented during late summer surveys. The late summer (August) surveys were conducted to assess EWM as well as each lake's overall plant community and diversity during the peak of the summer growing season. Results of each survey are summarized in Table 3-3.

Total SAV coverage for the five priority lakes was generally good and covered 76%-100% of the survey points. EWM was found in four of the five priority lakes (O'Brien, Schulze, McDonough, and Holland), while CLP was observed in three of the lakes (Schulze, McDonough and Holland). For the four EWM infested lakes, EWM was observed at 2%-52% of the sample points and average growth densities ranged from 1.0 to 2.3 (1=low density; 4=high density). For the CLP infested lakes, CLP was observed at 24%-39% of the sample points and average growth densities ranged from 1.0 to 1.8.

One tool that can be used to evaluate the overall health of the SAV community in lakes is the floristic quality index (FQI). The FQI is based on a metric of species richness and a Coefficient of Conservatism (C), which is a score (0 -10) that relates a species site fidelity and tolerance to disturbance. Therefore, species that have narrow habitat ranges and/or low tolerance to stress have high C-values. Therefore, the more species observed in a lake and the greater the C-values the greater the system health. Due to natural differences in species composition between deep and shallow lakes as well as the differences across ecoregions, the Minnesota Department of Natural Resources (MnDNR) has developed both deep and shallow lake FQI impairment thresholds to rate and evaluate SAV community health.

FQI was evaluated for each of the LHRP priority lakes using results of the 2016 vegetation surveys discussed above. Results indicate Jensen Lake was the only priority lake that exceeded the FQI impairment threshold. O'Brien, Schulze, McDonough and Holland were all below the FQI threshold, suggesting these lakes could benefit from improvements to the SAV community, particularly growth and proliferation of native plant species. Management techniques to improve native plant species could include AIS treatments/control, fish management, and water quality, particularly water clarity, through nutrient control and/or other measures. These techniques are discussed in more detail in Section 5.

Table 3-3. Summary of 2016 SAV surveys for LHRP priority lakes.

Parameter	Jensen	O'Brien	Schulze	McDonough	Holland
SAV Coverage [percent]	100%	98%	78%	97%	76%
CLP Coverage [percent]	0%	0%	26%	39%	24%
CLP Density [average]	NA	NA	1.0	1.1	1.8
EWM Coverage [percent]	0%	2%	52%	32%	48%
EWM Density [average]	NA	1.0	2.3	1.6	1.9
FQI Score	19.4	17.7	14.4	11.4	15.2
FQI Threshold	17.8	17.8	17.8	17.8	18.6
FQI Status	Above Threshold	Below Threshold	Below Threshold	Below Threshold	Below Threshold

3.5 LAKE FISH SURVEYS

The MnDNR is the agency that has the responsibility of fisheries surveys and management (including stocking) for lakes in Minnesota. The MnDNR typically concentrates their survey efforts on lakes with public boat accesses as these waterbodies get the most attention from anglers and most of the fisheries management efforts. There are fish communities in the lakes within LHRP and fishing is one of the available recreational activities for park visitors. However, to date there have been limited fish surveys or fisheries management completed by the MnDNR for the lakes within LHRP. This is likely due to the lack of dedicated motor boat access points for these lakes. There have been some stocking efforts completed by the MnDNR for the lakes in LHRP as part of the Fishing in the Neighborhood Program (FIN). Under the FIN program catchable size fish are stocked into lakes within the Twin Cities metropolitan region to encourage fishing in urban areas.

Fish community information was gathered from review of MnDNR Lakefinder online records (http://www.dnr.state.mn.us/lakefind/index.html). The fish community can be an important contributing factor when trying to understand water quality in a lake. This can be especially true for shallow lakes where the absence of important native species (i.e. top predators) or the presence of undesirable species (i.e. common carp) can have significant impact of the overall ecology of the lake and the associated water quality. A summary of the fish community assessments and fish stocking information available for the priority lakes in LHRP is provided in Table 3-4.

Table 3-4. Summary of DNR fish survey and stocking reports for LHRP priority lakes.

Lake	DNR Fish Surveys	DNR Stocking Information
Jensen	Not Available	Not Available
O'Brien	Not Available	Not Available
Schulze	Not Available	Black Crappies: 2008
McDonough	2015	Black Crappies: 2008, 2010 – 2012; Bluegill: 2008; 2010 - 2014
Holland	2013, 2007, six surveys prior to 2000	Brown Trout: 2007; 2009; 2013; 2014 Rainbow Trout: 2011 - 2016

Based on the MnDNR Lakefinder records, there have been no fish community surveys or fish stocking efforts in Jensen or O'Brien Lakes. There is no fish community information available for Schulze Lake but there was one stocking effort where black crappies were stocked in the lake in 2008. The lake likely has similar fish community to McDonough Lake. The fish community in McDonough Lake was surveyed in 2015 for the first time since 1965. MnDNR fish community surveys in lakes typically include two survey methods that target different components of the fish community, which are trap nets and gill nets. For McDonough Lake the 2015 survey only included trap nets which focus on species utilizing nearshore habitats. McDonough Lake mainly contains panfish species including bluegills and black crappies as well as green sunfish and black bullheads. The survey noted that all of the fish were found in low abundance and were below average in size. The stocking records for McDonough Lake indicate catchable size bluegills and black crappies have been stocked in the lake over the last ten years, however the 2015 survey indicates these fish may not survive as the lake has previously experienced winter kill. There were no top predators collected during the trap net surveys in 2015 even though the narrative from the MnDNR indicates that McDonough Lake was previously used as a walleye rearing pond.

Of the lakes within LHRP, Holland Lake has the most available fish community information as well as previous records of fish stocking. Holland is the only deep lake for the priority lakes in the park. There have been two fish community surveys in the last ten years in Holland Lake (2013 and 2007) as well as six prior surveys from 1975 through 2000. The fish community surveys on Holland Lake included standard trap nets (which focus on near shore species) and gill nets (which focus on open water species). The 2013 survey indicates that Holland Lake has a community dominated by bluegills, other sunfish, and northern pike. The lake also includes largemouth bass and black crappies. The MnDNR narrative describing the fish community indicates there is a good number of northern pike in the lake which is an important native top predator species. MnDNR also noted that the bluegill and other sunfish population is very high for Holland Lake but is rather undersized with slow growth rates (when compared to other lakes similar to Holland in Minnesota). The MnDNR has stocked stream trout species, including both brown trout and rainbow trout, multiple times over the last ten years. The trout species have mainly been added as a "put and take" fishery and there were no brown trout sampled the most recent fish survey. Trout species can be an important predator species in lakes and streams however the stocked trout in Holland Lake do not appear to be persisting in the lake long enough to be an important consideration on the overall lake management.

3.6 EROSION ASSESSMENT

There are several areas throughout LHRP that have significant elevation changes and in these areas there are many dry channels and gullies meandering through the park system, often along dedicated trails. Some of these channels are experiencing various levels of erosion during runoff events. Severe erosion in gullies and along trails can oftentimes deliver potentially significant sediment and nutrient loads to downstream receiving waters. To assess the amount and severity of channel erosion, a combination desktop analysis and field assessment were completed for LHRP. The desktop analysis used a Stream Power Index (SPI), which is a GIS exercise that calculates the erosive power of overland flow which can be used to help identify potential gully flow erosion "hot spots". SPI takes into account local slope geometry and site location in the landscape and is calculated in GIS according to the following equation:

$$SPI = \ln (A * Slope)$$

Where A is catchment area (flow accumulation). As catchment area and slope gradient increase, flow velocities and the amount of water contributed by upslope areas also increase leading to higher erosion potential and SPI values.

Available Light Detection and Ranging (Lidar) data was used to calculate SPI throughout the entire LHRP system, however SPI analysis focused on areas near the five priority lakes since erosion from these areas are more likely to effectively deliver sediment to the lakes. Priority areas were determined based on overlaying the SPI layer and Lidar contours to identify gully features with high SPI values. The identified sites for field assessment based on the SPI index were previously provided within the Water Resources Sample Plan for the LHRP (see Appendix C).

The results of the desktop analysis were utilized by County staff to conduct a field assessment within the park. The field assessment utilized the Natural Resource Conservation Service (NRCS) field office technical guide methodology. A summary of the field methods developed for this effort is provided as Appendix C. Over the course of several field visits, County staff conducted assessments at over 30 sites throughout the park. Specific features of note were photographed during each site assessment along with measurements and general field notes following the erosion assessment methodology. The results of the field assessment determined that many areas of erosion within the park can be addressed through routine park maintenance along trails. Several areas for target improvement projects were also identified. Specific improvement projects that will target channel and trail erosion are described in Chapter 5.

3.7 WETLAND MONITORING

The MPCA developed the Wetland Health Evaluation Program (WHEP) which is a citizen based monitoring program that allows a rudimentary assessment and quantification of a wetland's vegetation and macroinvertebrate community. Dakota County began sponsoring the WHEP in 1997. Since then, approximately 181 wetlands have been monitored throughout the County, seven of which are located within LHRP and its watershed. In general, wetlands within the park have shown a wide range of scores and none of the sites have sufficient data to evaluate long-term trends. A summary of the WHEP monitoring results for the wetlands within the LHRP study area was provided in the Water Resources Sample Plan (see Appendix C). The Sample Plan also provided recommendations for additional wetland monitoring and assessment within the park, including consideration of conducting the MPCA Rapid Floristic Quality Assessment (RFQA) as a tool to measure and quantify the health of a wetland (MPCA 2014). The RFQA provides more quantitative scoring of the wetland's vegetation community and therefore could be used to assess high priority wetlands in the park. The RFQA could also provide a useful tool for evaluating effectiveness of wetland restoration projects as they are completed throughout the park.

4.0 Modeling and Analyses

4.1 P8 MODELING METHODOLOGY

Wenck evaluated stormwater runoff volume and water quality in the LHRP study area by reviewing GIS information, subwatershed boundaries, existing BMPs, stormwater models, and other data provided by County, SWCD and City staff. Wenck modeled the existing area hydrology and water quality using the computer program P8 (Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds). P8 is a computer model originally developed for the United States Environmental Protection Agency (USEPA) for simulating the generation and transport of stormwater runoff pollutants in watersheds. P8 is a useful diagnostic tool for evaluating and designing watershed improvements and BMPs. The model requires user input on watershed characteristics, basin attributes, local precipitation and temperature, and other parameters relating to water quality and basin removal performances. Due to annual variability in historical precipitation records and subsequent model results, the P8 model was executed for a 10-year precipitation record to obtain average loading estimates that were used in the analysis.

The watershed characteristics used for the P8 model includes the Soil Conservation Services (SCS) hydrologic soil group, land use classification, and the impervious fraction of the land in the watershed. The land use classification was obtained from the 2010 Metropolitan Council Land Use layer as described in Section 2.3. Soil data was obtained from the NRCS Web Soil Survey as described in Section 2.4. The hydrologic soil group characterizes infiltration capacity of the soils and runoff characteristics. Arcview GIS software was used extensively in assessing watershed characteristics.

In P8, pervious and impervious areas are modeled separately. Runoff volumes from pervious areas are computed using the SCS Curve Number (CN) method. Runoff from impervious areas begins once the cumulative storm rainfall volume exceeds the specified depression storage, with the runoff rate equal to the rainfall intensity.

Because P8 calculates runoff separately from pervious and impervious areas, it was necessary to determine the impervious fraction of each watershed. For the P8 model, the impervious areas for portions of the watershed with City stormsewer systems were assumed to be 100% directly connected. An impervious area is considered directly connected if runoff flows directly from it into the conveyance system via continuous paved areas. Impervious areas for portions of the watershed that do not have stormsewer conveyance systems were considered to be 50% directly connected, and 50% indirectly connected. The impervious fraction was calculated for each subwatershed based on the land use(s), with each land use having an assumed impervious percent. The assumed percent impervious associated with each land use is listed in Appendix D.

As discussed previously, watershed runoff volumes from pervious areas were computed for P8 using the SCS CN method. Within each watershed a pervious CN was calculated based on the soil type and land use. The pervious CN was area weighted in each subwatershed using the values described in Appendix D.

The P8 model requires an hourly precipitation record (rain and snowfall) and daily temperature record. Precipitation and temperature data were obtained from the Minneapolis/St. Paul Airport Weather Station.

The treatment devices utilized in P8 provide collection, storage, and/or treatment of watershed discharges. A variety of treatment devices can be modeled in P8, including detention basins (wet or dry), infiltration basins, swales, buffers, aquifers, and pipes.

Detention basin (stormwater ponds) volume information was obtained from previously built models that detail the storage capacities with data gaps filled in using LiDAR data. For vegetated wetland areas, it was assumed that the permanent pool depth was 0.5 feet. For open water wetland areas, it was assumed that the permanent pool depth was 1 foot. For areas within the City of Eagan, the City's PondNet model was used to determine the average depth of the storage device. A HydroCAD model (Barr Engineering, 2006) was also available for areas within the City of Rosemont and was used to define storage and outflow information for this portion of the study area.

Basin outlet information was obtained from PondNet and the HydroCAD (where available). If data was not available, the outlet was assumed to be the hydraulic equivalent of a 12-inch diameter culvert. LiDAR and aerial photography were used to approximate overland outlets where identified from a LiDAR derived 2ft contour dataset.

The NURP50 sediment particle distribution and concentration file was selected for the P8 models. The component concentrations in the NURP 50 file represent the 50th percentile (median) values compiled in the Environmental Protection Agency's (EPA's) Nationwide Urban Runoff Program (NURP).

Lift station water volume pumping rates were available at one lift station location, the Holland Lift Station, within the LHRP study area. The Holland Lift station is located near Holland Lake and pumps water from LHRP to the City of Eagan stormsewer system. The watershed draining to the Holland Lift Station includes most of the eastern portion of the LHRP study area, including Holland and McDonough Lakes and upstream contributing areas. For model calibration, the method that produced the best results was to compare the annual pumping volumes for the Holland Lift Station (years 2010 through 2016) to the P8 predicted outflow volumes for the eastern LHRP study area. Slight adjustments were made to the pervious CNs and impervious fraction inputs for each subwatershed to better match the Holland Lift Station pumping volumes and P8 modeled flow volumes (Appendix D). Pervious CNs were reduced by 10% and impervious fractions were reduced by 50% from initially assumed values.

4.2 EXISTING CONDITIONS P8 MODEL

Wenck created an existing conditions P8 model for the entire study area to mimic the watershed as it is today by routing runoff through the city stormsewer system, stormwater ponds, and surface channels/streams. The study area was broken into 304 individual subwatersheds as shown in Appendix D. An average annual breakdown of the watershed TP load delivered to each of the priority lakes is summarized in Section 4.5. It is important to point out that these estimates include the expected removals due to upstream lakes, wetlands and stormwater ponds throughout the study area. Appendix D shows the locations of the existing stormwater practices throughout the study area and also includes maps showing outflow TP loads and concentrations for each subwatershed in the LHRP study area.

4.3 LAKE RESPONSE MODELS

A lake response model for each priority lake was setup to help establish TP budgets and necessary load reductions needed for each lake to meet the in-lake water quality goals (See Section 4.5). The lake response model selected for this exercise was the Canfield-Bachman lake equation (Canfield and Bachman, 1981). This equation estimates the lake phosphorus sedimentation rate, which is needed to predict the relationship between in-lake phosphorus concentrations and phosphorus load inputs. The phosphorus sedimentation rate is an estimate of net phosphorus loss from the water column through sedimentation to the lake bottom, and is used in concert with user supplied lake-specific characteristics such as annual phosphorus loading, mean depth, and hydraulic flushing rate to predict in-lake phosphorus concentrations. Model predictions are then compared to measured data to evaluate how well the model describes the lake system. If necessary, the model parameters are adjusted appropriately to achieve an approximate match to monitored data. Once adjustments are made, the resulting relationship between phosphorus load and in-lake water quality is used to determine the assimilative capacity.

To setup the lake response model for each lake, Wenck used methodology similar to the lake TMDLs in the Vermillion River Watershed TMDL Study (MPCA, 2015). The four major phosphorus sources defined in the lake response models include atmospheric load, watershed load, upstream lake load (if necessary), and internal load. Atmospheric phosphorus loading to each lake was estimated using literature rates for dry (<25 inches of rainfall), average (25-38 inches), and wet (>38 inches) precipitation years (Barr Engineering, 2004). Watershed loading was estimated using P8 model output described in the previous section. Contributions from upstream lakes was estimated using monitored or modeled in-lake TP concentrations and hydraulic information from the P8 model. Internal loading from the lake sediments was calculated using the sediment core information discussed in Section 3.3.

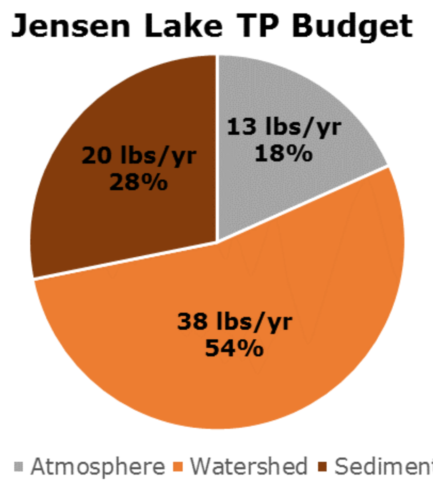
With the atmospheric, upstream lake, watershed, and sediment loads defined, the lake response model predicted average annual TP concentrations were compared to available monitored TP concentrations for each lake. In general, the modeled in-lake TP concentrations for Jensen, O'Brien, and Holland Lakes were close to monitored concentrations and no adjustments were needed. For Schulze and McDonough Lakes, however, initial modeled in-lake TP concentrations were 16-23% below observed TP concentrations. For these lakes, the lake response required an additional TP load of approximately 11 and 14 pounds per year for Schulze and McDonough, respectively. These additional loads, referred to as model residual loads, could be the result of one (or more) of the defined loading sources being under-represented, or one or more loading source(s) that is not currently accounted for in the TP source assessment. Other potential sources could include inputs from rough fish or an imbalanced fishery, CLP senescence, geese and/or other wildlife, and human inputs such as septic systems and public swimming beaches.

4.4 LAKE TP BUDGETS

Detailed TP source budgets for each priority lake were developed using output from the P8 and lake response models discussed previously. Results of this modeling exercise suggest phosphorus loading to the priority lakes is primarily dominated by watershed sources and, in the case of McDonough and Schulze, loading from upstream lakes and/or sediment release. Below is a brief discussion of each lake's average annual TP budget (model years 2007 through 2016).

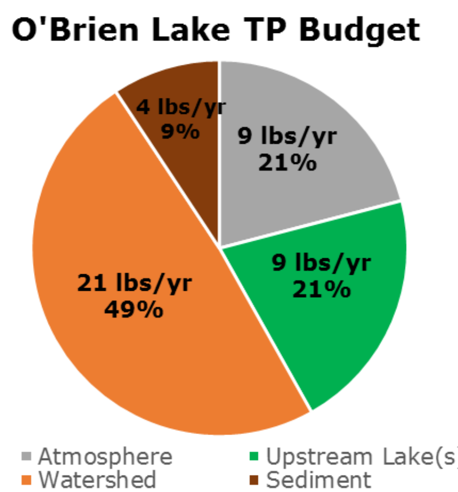
Jensen Lake

TP loading from Jensen Lake's drainage area represents a majority (54%) of the annual TP load to the lake. Internal load from Jensen Lake sediments (28%) represents the second largest source of TP. Internal load can play a significant role during the warm summer months when TP load from the watershed is low and primary production is high. As discussed in Section 3.2, Jensen Lake did exhibit one exceedance of the chlorophyll-a standard in late July, which suggests algae blooms do occassionally occur in mid-summer. Due to Jensen's large surface area, atmospheric inputs account for approximately 18% of the lakes TP budget, which is one of the highest of all the lakes included in this study.

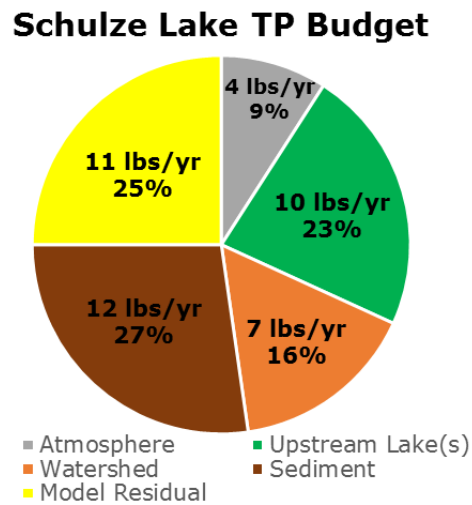


O'Brien Lake

Compared to Jensen Lake, TP loading to O'Brien Lake is split more evenly between direct watershed runoff, upstream lakes, sediment release, and atmospheric inputs. Watershed loading to O'Brien Lake represents approximately 49% of the lakes TP budget and includes inputs from several ponds and wetlands surrounding the lake, including Buck and Dakota ponds. Loading from the major upstream lakes (Lily Lake, Sedge & Beaver Pond, and Jensen Lake) account for approximately 21% of the lake's TP budget. TP loading from the atmosphere (21%) also respresents a sizeable portion of the lake's TP budget while sediment inputs (9%) is a relatively small portion of the overall budget. It should be noted that current water quality in O'Brien Lake is very good and meets State water quality standards throughout the summer growing season.

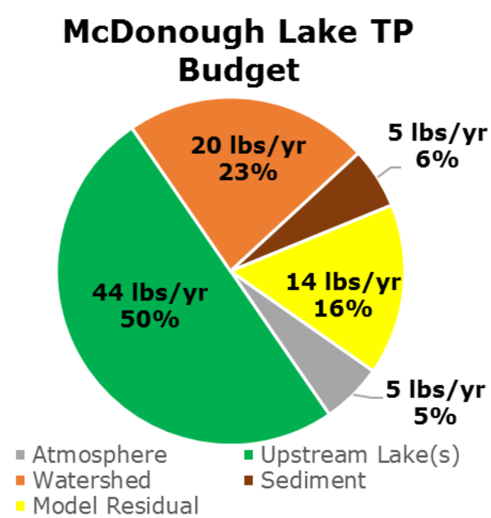


Schulze Lake



TP loading sources for Schulze Lake (perhaps more than any other lake within LHRP) are split relatively evenly between watershed, upstream lake, sediment and the model residual load. Watershed sources (16%) include inflow from the direct watershed and surrounding ponds and park land downstream of O'Brien and Portage Lakes. Upstream Lakes account for approximately 23% of the lakes total budget and include outflow from Portage, O'Brien, Lily, Sedge & Beaver, and Jensen Lakes. It is estimated that TP release from the sediment is approximately 12 pounds per year (27%) which is the 2nd highest of the priority lakes within LHRP. As discussed in Section 3.2, nuisance algae blooms in Schulze Lake are common throughout the entire summer growing season which is another line of evidence that loading from the lake's sediment may be a significant source of phosphorus to the lake's water column. The model residual load, or additional load needed to calibrate the lake response model, represents approximately 25% (11 lbs/yr) of Schulze lake's TP budget. This load could include TP inputs from one or several unknown sources such as rough fish and/or an imbalanced fishery, CLP senescence, or inputs from the public swimming beach.

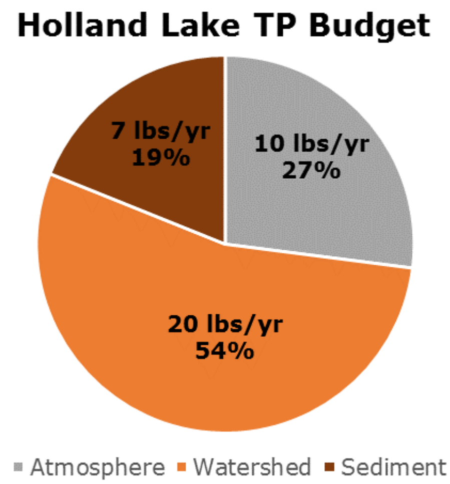
McDonough Lake



Due to its position within LHRP and its watershed, the largest source of TP loading to McDonough Lake is inflow from upstream lakes (50%). Major upstream lakes in the McDonough drainage area include, Marsh, Schulze, O'Brien, and Jensen Lakes. Inputs from the watershed downstream of the major upstream lakes accounts for the next largest source (23%) of TP to McDonough Lake. The model residual load required to calibrate the McDonough Lake response model was 14 pounds per year which is a sizeable portion (16%) of the lake's annual phosphorus budget. Similar to Shulze Lake, the model residual could include inputs from an unbalanced fish community, CLP, or a another loading source not accounted for in this modeling exercise. Inputs from the lake sediments and atmospheric deposition represent relatively small portions of the McDonough Lake TP budget.

Holland Lake

Despite having a relatively small drainage area compared to other lakes in this study, the largest source of TP to Holland Lake is its watershed (54%). The watershed draining to Holland Lake is entiriely comprised of parkland and there are no upstream contributing lakes. Other TP sources to Holland Lake include atmospheric deposition (27%) and TP release from the lake's sediment (19%). As discussed in Section 3.2, Holland Lake currently displays very good water quality and has demonstrated an improving trend in all three water quality parameters since the mid-1980's.



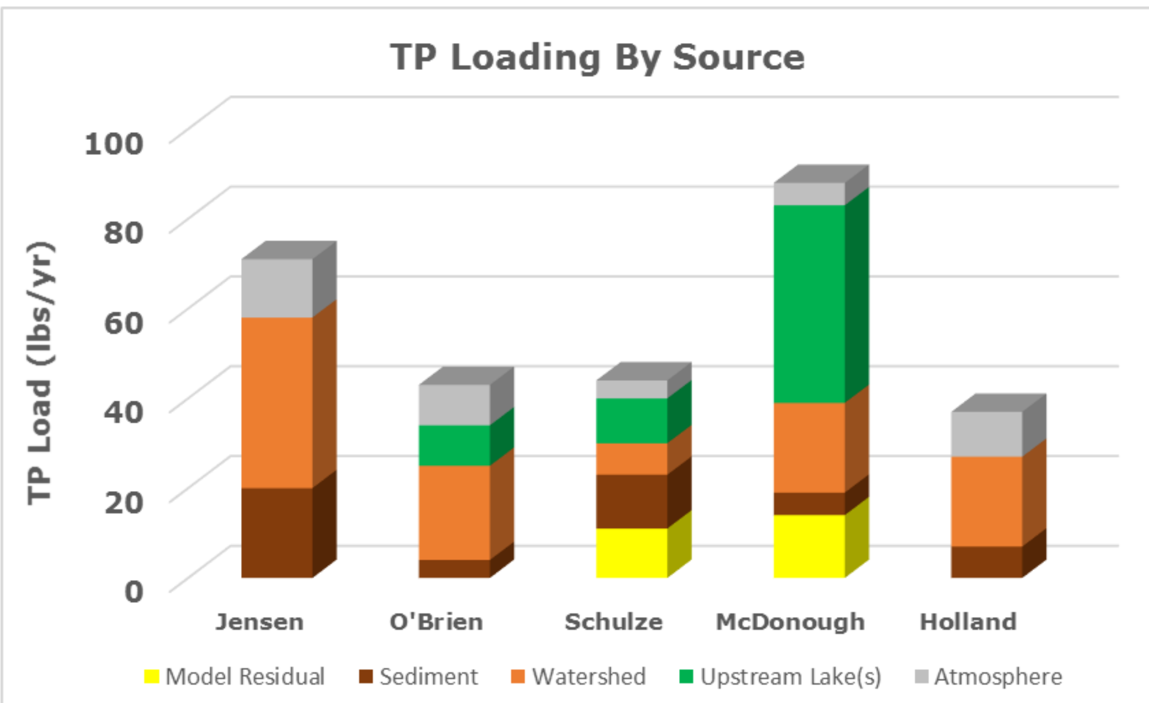


Figure 4-1. TP loading by source for LHRP priority lakes.

4.5 PRIORITY LAKE TARGETS AND LOAD REDUCTION GOALS

As discussed in Section 3.2, all of the LHRP priority lakes included in this study currently meet State water quality standards for TP. One of the priority lakes, Schulze Lake, is not currently meeting the shallow lake chlorophyll-a State standard based on the 2017 monitoring data collected by Dakota County. Two other priority lakes, Jensen and McDonough Lakes, were close to exceeding the chlorophyll-a standard in 2017. These three lakes also had Secchi depth measurements that were at or below State standards in 2017, likely due to elevated algae levels present during the summer growing season. Since all three of these lakes currently meet State water quality standards for TP, an alternative TP concentration target/goal below the 60 µg/L State standard will need to be developed in order to reduce algae levels, improve water clarity, and ensure that they will not become impaired in the near future.

Upon review of the historic TP and chlorophyll-a data for all lakes in LHRP (Appendix A), it appears that elevated chlorophyll-a levels (i.e. at or above the 20 µg/L standard) generally begin to occur in lakes when they display average growing season TP concentrations higher than 35 µg/L. Lakes that have maintained average growing season TP levels below 35 µg/L have, for the most part, displayed good water clarity and have kept chlorophyll-a levels in-check and below the 20 µg/L standard. Therefore, for the purposes of this study, a TP concentration target/goal of 35 µg/L was established for shallow lakes and 20 µg/L for deep lakes within LHRP. Three of the priority lakes, O'Brien, Holland and Jensen, currently meet these TP concentration goals, while Schulze and McDonough Lakes do not (Table 4-1).

To meet the 35 µg/L target/goal, TP loading to Schulze and McDonough will need to be reduced by approximately 14 and 22 pounds per year, respectively. Since O'Brien and Holland currently meet the 35 µg/L target/goal, a TP load reduction goal of 5% was set for these lakes in order to maintain current TP concentrations and to ensure TP levels do not increase in the future. A 5% load reduction goal for lakes currently meeting State water quality standards is consistent with MPCA's guidelines for addressing protection lakes in WRAPS reports throughout the State of Minnesota (MPCA, 2017). Recent monitoring data indicate average TP concentrations for Jensen Lake fall just below the 35 µg/L target/goal, and chlorophyll-a concentrations occasionally exceed State water quality standards. Therefore, it is proposed that Jensen Lake's TP load reduction goal be set to 10%, rather than 5%, to provide additional margin of safety in meeting the LHRP 35 µg/L TP target/goal. To meet the 10% and 5% TP load reduction goals, TP loading would need to be reduced by approximately 7 pounds per year for Jensen, and 2 pounds per year each for O'Brien and Holland (Table 4-1).

Table 4-1. TP targets and load reduction goals for LHRP priority lakes.

Description	Jensen	O'Brien	Schulze	McDonough	Holland
Current TP [µg/L]	34	22	48	44	18
Target TP [µg/L]	35	35	35	35	20
Current Status	Meeting Target	Meeting Target	Not Meeting Target	Not Meeting Target	Meeting Target
Current TP Load	71 lbs/yr	43 lbs/yr	44 lbs/yr	88 lbs/yr	37 lbs/yr
TP Load Goal	64 lbs/yr	41 lbs/yr	30 lbs/yr	66 lbs/yr	35 lbs/yr
TP Load Reduction Goal [percent]	10%	5%	32%	25%	5%
TP Load Reduction Goal	7 lbs/yr	2 lbs/yr	14 lbs/yr	22 lbs/yr	2 lbs/yr

5.0 Projects and Practices

5.1 OVERVIEW

The primary purpose of this study is to identify a variety of BMP options to reduce watershed and in-lake pollutant loads, particularly TP, to help meet the goals and target reductions discussed in Section 4.5. This section provides general descriptions of the proposed BMPs that could be implemented within the study area to reduce TP loading, sediment, peak discharge, and, in some cases, improve the biologic community. The following sections provide a description of the proposed BMPs, pollutant load reductions (if applicable), and cost benefit analysis. The proposed BMPs were separated into three categories: regional stormwater BMPs, erosion BMPs, and in-lake management BMPs. General descriptions and examples of each BMP type is included in Appendix E.

5.2 REGIONAL STORMWATER BMPS

Wenck used the existing conditions P8 model described in Section 4.2 to identify regional BMPs to reduce phosphorus loading from certain subwatersheds throughout the study area. The regional projects were selected at locations with high annual phosphorus loads determined from the existing conditions P8 model (Appendix D).

It is important to note that all the proposed projects have potential design challenges and cost considerations that need to be fully investigated prior to their implementation. During final design and monitoring, a proposed project may not meet estimated pollutant removal effectiveness and/or the cost estimates presented in this report due to design challenges that may be identified during the design process. BMP performance can also vary from year to year based on climatic conditions and other environmental factors. In addition, ongoing and consistent maintenance activities are required to maintain performance. This includes sediment removal, vegetation maintenance, filter maintenance and monitoring. A summary of specific maintenance activities and associated maintenance costs for the regional stormwater BMPs is provided in Appendix F.

5.2.1 BMP Sizing, Design, and Pollutant Reduction Considerations

Wenck used methodology and research presented in MPCA's Minnesota Stormwater Manual (link) to evaluate sizing, design, and pollutant reductions for the BMPs identified in this study. In general, the filtration practices identified in this report were sized to filter the runoff from the 1.1-inch event (consistent with MPCA's Minimal Impact Design Standards) and to meet a drawdown time of 48 hours or less. In some cases, the filtration area footprint would not allow for BMP sizing to the 1.1-inch event and instead was sized to a smaller event of 0.75-inches. Total phosphorus reductions for the regional filtration practices were calculated based on the estimated water quality treatment volume, estimated phosphorus loads, and the recommended pollutant removal efficiency from the Minnesota Stormwater Manual.

5.2.2 Planning Level Cost Estimates

Planning level cost estimates were developed and a cost benefit analysis was performed to aid in prioritization of proposed BMPs. The cost estimates are based on past experience with BMP retrofit projects and regional treatment projects. The cost estimates include:

- Construction costs for the proposed BMP, such as: mobilization, site preparation, outlet modification, minor storm sewer or structural work, and erosion control
- Level 2 sediment disposal costs (if any) according to MPCA guidance
- Engineering costs (typically 20% of BMP cost)
- Construction administration costs (Typically 10% of BMP cost)
- 30% contingency cost
- Annual maintenance estimated cost (included in the 30-year cost) which includes general site inspection and minor housekeeping
- Larger maintenance project estimated cost every 10 years (included in the 30-year cost) which includes mobilization, site preparation, complete replacement of iron-enhanced sand filter media, partial replacement/repairs to draintile/stormsewer, and erosion control
- The 30-year life cycle cost is the total future estimated cost and therefore takes into account a 3% annual inflation rate

These costs do not include wetland mitigation, major structural work, and/or land/easement acquisition. All costs were rounded to reflect planning level estimates. Therefore, it is recommended that a more detailed feasibility assessment and cost estimate be prepared for specific projects the County may wish to pursue.

5.2.3 Proposed Regional Stormwater BMPs

Eight regional BMPs were identified throughout the LHRP Study Area (See Figure 5-1). In siting and developing the list of proposed BMPs, Wenck focused primarily on public owned property such as easements, parks, and/or City/County right of way as they are usually easier to implement, maintain, and manage over the life of the practice. If all the proposed regional BMPs were implemented, the LHRP Study Area would see reduced watershed TP loads of approximately 60 pounds per year. Table 5-1 provides a summary of the estimated TP reductions, construction cost estimates, 30-year life cycle costs, and cost-benefit analysis for the eight proposed regional BMPs. Detailed cost estimates for each proposed practice is provided in Appendix F. Below is a general description of each proposed regional stormwater BMP.

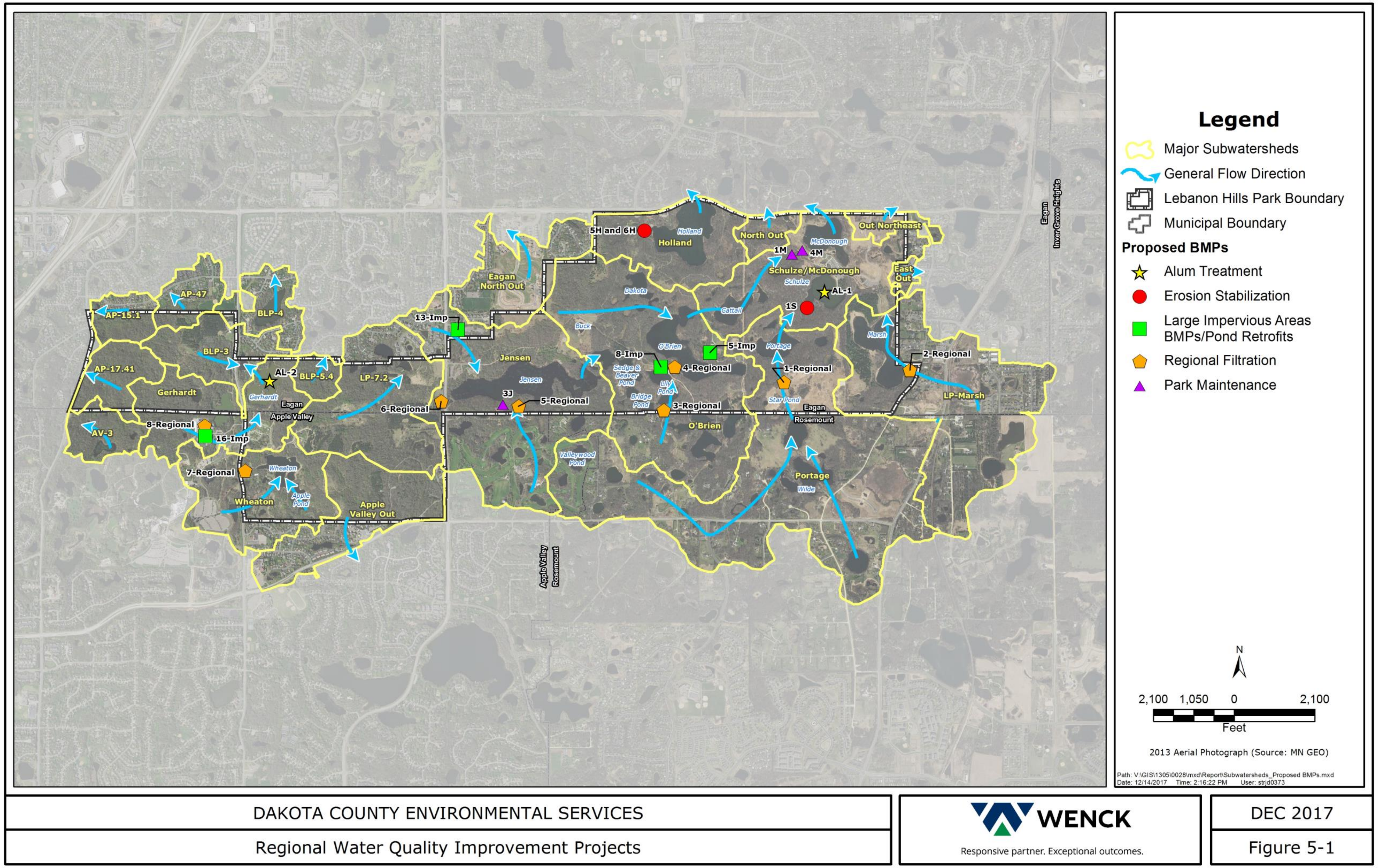


Figure 5-1. Proposed projects and practices in the LHRP Study Area

REG-1 (Schulze/Portage Lake)

The REG-1 BMP is a surface filtration basin located adjacent to the outlet channel of Star Pond (Watershed ID LP-66) which is upstream of Schulze and Portage Lakes. The contributing watershed is approximately 619 acres with primarily undeveloped and low density residential land use. P8 modeling results indicate the estimated annual TP load is 28.9 lbs with a high dissolved phosphorus fraction. Due to the high dissolved phosphorus fraction, it is proposed that the filtration basin media be iron enhanced sand which can remove the dissolved phosphorus. The iron enhanced sand filtration (IESF) area was sized to treat runoff from the 1.1-inch storm event and is estimated to reduce TP loads by approximately 16.1 lbs per year. The project includes earthwork, IESF basin (approximately 9,300 sf), berm and outlet structure, and site restoration. The estimated construction cost is approximately $425,000. The 30-year life cycle cost estimate is approximately $1,245,000. The 30-year cost-benefit is $2,578/lb TP removed.

Concept overview of proposed filtration basin location and approximate sizes.

Photo of project site looking downstream. The channel is located between the trees in the middle of photo. The filtration basin is proposed where the grassy area is on the right side of the photo.

REG-2 (McDonough/Marsh Lake)

The REG-2 BMP includes two surface filtration benches retrofitted to an existing pond (Watershed ID LP-22.2) at the shoreline of Marsh Lake. The contributing watershed is approximately 303 acres with residential and commercial land use. The P8 model indicates the annual TP load out of this pond is 27.9 lbs with a high dissolved phosphorus fraction. Due to the high dissolved phosphorus fraction, it is proposed that the filtration bench media be iron enhanced sand. The IESF benches were sized to treat runoff from the 1.1-inch storm event and is estimated to reduce TP loads by 16.4 lbs per year. The project includes rerouting storm sewer from LP-22.1 to the pond, two IESF benches (approximately 9,100 sf total), pond cleanout and expansion, berm and outlet structure, and site restoration. The estimated construction cost is approximately $645,000. The 30-year life cycle cost estimate is approximately $1,585,000. The 30-year cost-benefit is $3,222/lb TP removed.

Concept overview of proposed filter bench locations (tan rectangle) and approximate sizes. Blue lines indicate existing storm sewer infrastructure.

Photo from the southeast corner of the existing pond. Filter benches are proposed on both sides of the pond.

REG-3 (O'Brien Lake/Lily Pond)

The REG-3 BMP includes two surface filtration basins located adjacent to the outlet channel of LP-15.1 at the shoreline of Lily Pond which is upstream of O'Brien lake. The contributing watershed is approximately 144 acres of primarily undeveloped and low density residential land use. The P8 model estimates that this channel delivers approximately 7.3 pounds of TP/year to Lily Pond with a high dissolved phosphorus fraction. Therefore, it is proposed that the sand filtration areas be enhanced with iron and sized to treat runoff from the 1.1-inch storm event and is estimated to reduce TP loads by 4.1 lbs per year. The project includes earthwork, two IESF areas (approximately 2,700 sf total), berm and outlet structure, and site restoration. There is not a significant amount of elevation difference at this location which will be a challenge in the design and implementation of the proposed filter. The estimated construction cost is approximately $190,000. The 30-year life cycle cost estimate is approximately $530,000. The 30-year cost-benefit is $4,309/lb TP removed.

Concept overview of proposed filtration basin locations and approximate sizes.

The existing channel looking upstream. Filtration basins are proposed on both the east and west side of the channel.

Photo of project site looking east. The existing culvert/channel is located along the foreground of photo. Filtration benches are proposed on both the east and west side of the existing channel.

REG-4 (O'Brien Lake)

The REG-4 BMP is a surface filtration basin located adjacent to the outlet channel of Lily Pond directly upstream of O'Brien Lake. The contributing watershed is approximately 649 acres which includes a mixture of land use. The in-lake response modeling for Lily Pond estimates an annual TP outflow load of 9.0 lbs with a low dissolved phosphorus fraction. Due to the low dissolved phosphorus fraction, a sand filter without iron is proposed. The sand filter was sized to treat runoff from the 0.75-inch storm event and is estimated to reduce TP loads by 5.5 lbs per year. The project includes earthwork, a sand filtration basin (approximately 13,700 sf), berm and outlet structure, and site restoration. The estimated construction cost is approximately $415,000. The 30-year life cycle cost estimate is approximately $760,000. The 30-year cost-benefit is $4,606/lb TP removed.

Concept overview of proposed filtration basin location and approximate size.


Photo of project site looking downstream. The channel is located within the trees along the left side of the photo. The filtration basin is proposed to the right of the channel in the open area to where the hill is located.

REG-5 (Jensen Lake)

The REG-5 BMP is a surface filtration basin located in a wooded area downstream of LP-11 prior to discharging to Jensen Lake. The contributing watershed is approximately 77 acres consisting of residential land use and a golf course. The P8 estimated annual TP load for this site is 3.2 lbs with a high dissolved phosphorus fraction. Due to the high dissolved phosphorus fraction, an IESF is proposed and sized to treat runoff from the 1.1-inch storm event. This project would reduce TP loads to Jensen Lake by approximately 1.8 lbs per year. The project includes earthwork, IESF basin (approximately 1,000 sf), berm and outlet structure, and site restoration. At the proposed location, stormwater is conveyed in a pipe which would need to be intercepted and diverted to the surface for the proposed surface filtration basin. A below grade filter could be installed, however, the cost would increase and monitoring and maintenance may be more challenging. The estimated construction cost is approximately $165,000. The 30-year life cycle cost estimate is approximately $360,000. The 30-year cost-benefit is $6,667/lb TP removed.

Concept overview of proposed filtration basin location and approximate size.

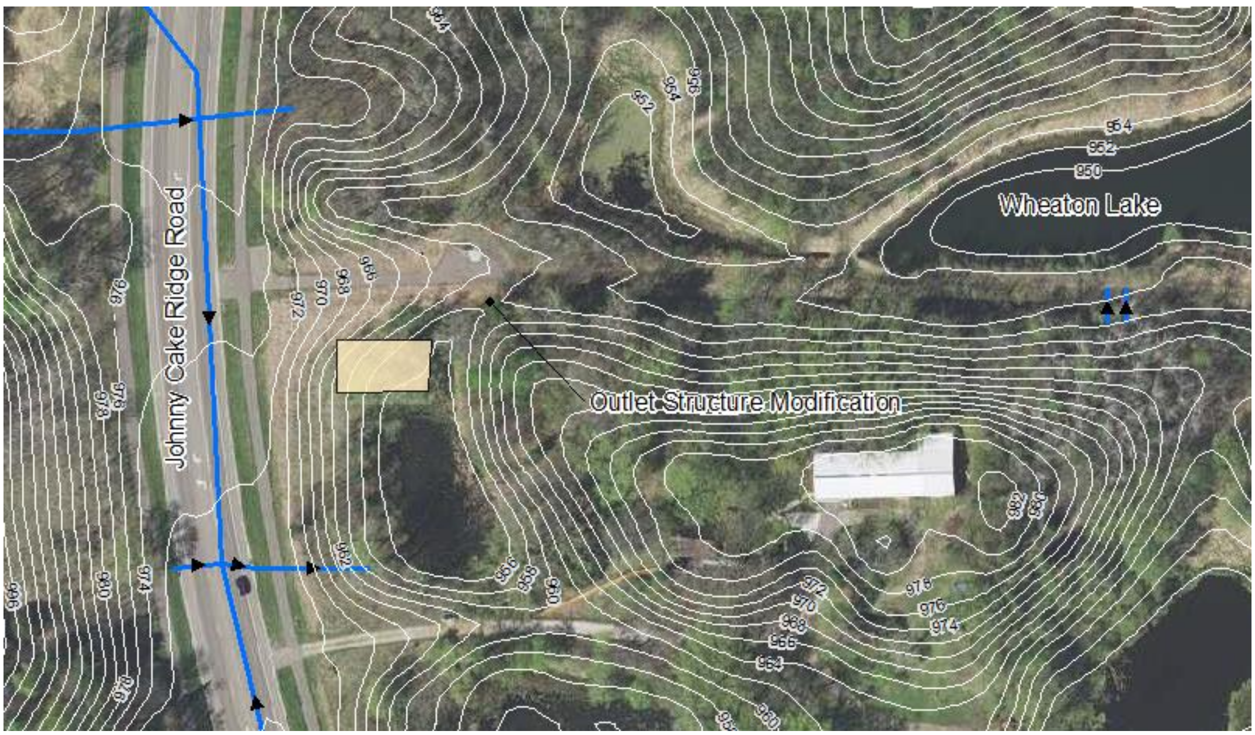
REG-6 (Jensen Lake)

The REG-6 BMP is a surface filtration bench retrofitted to an existing stormwater pond in the Jensen Lake subwatershed. Based on site constraints, the filtration area will likely need to be elevated above the pond and require a lift station to pump stormwater from the pond to the filtration area. The contributing watershed is approximately 134 acres with residential and highway land use. The P8 model estimated annual TP load is 10.1 lbs with a high dissolved phosphorus fraction. Due to the high dissolved phosphorus fraction, an IESF is proposed and sized to treat runoff from the 1.1-inch storm event. This project would reduce TP loads to Jensen Lake by approximately 5.8 lbs per year. The project includes earthwork, lift station, IESF basin (approximately 3,500 sf), berm, outlet structure modifications, and site restoration. The estimated construction cost is approximately $600,000. The 30-year life cycle cost estimate is approximately $1,035,000. The 30-year cost-benefit is $5,948/lb TP removed.

Concept overview of proposed filter bench location and approximate size.

REG-7 (Wheaton Lake)

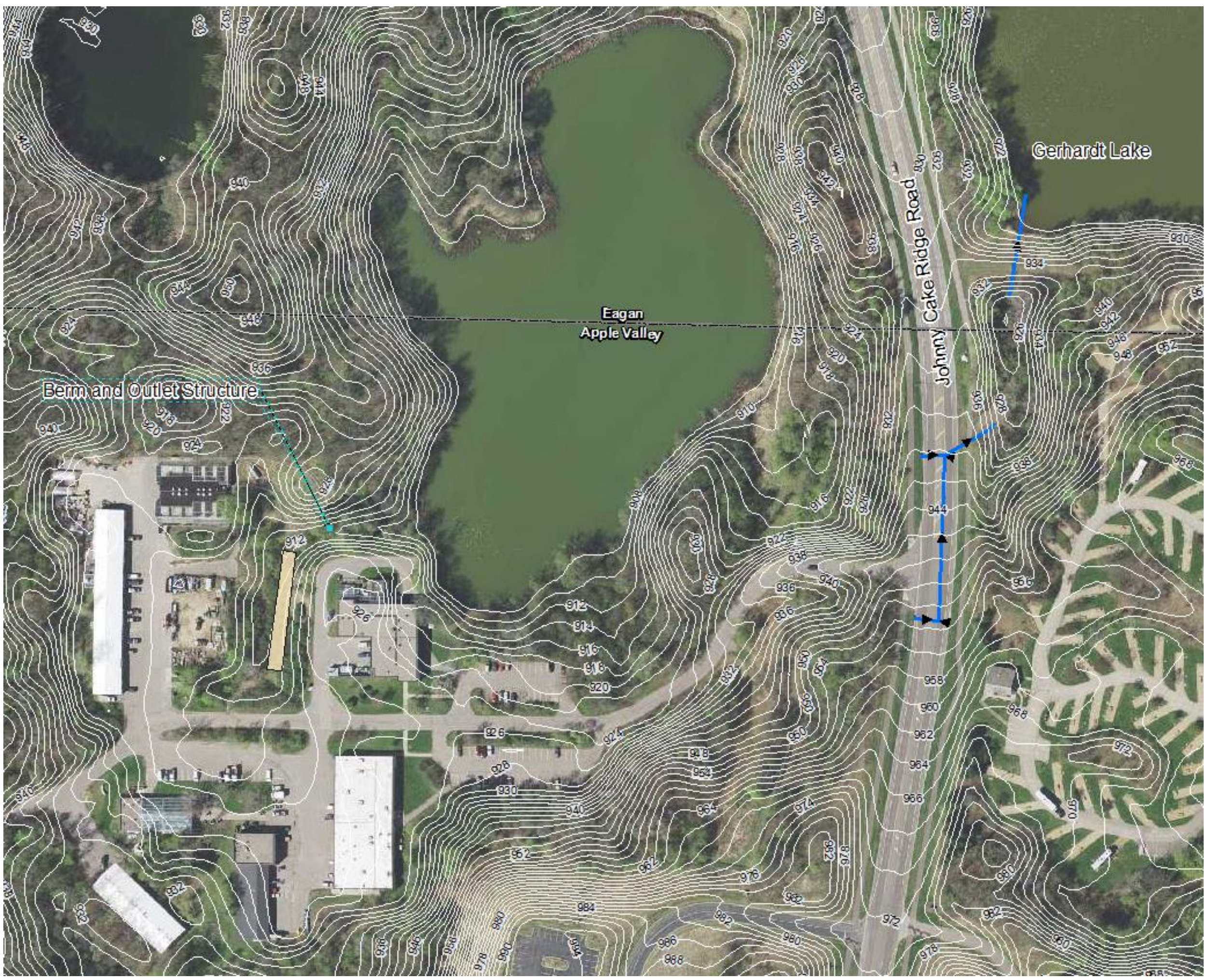
The REG-7 BMP is a filtration bench on a pond located just west Wheaton Lake. The contributing watershed is approximately 59 acres consisting of undeveloped areas and developed areas with large imperviousness that have some stromwater treatment. The P8 model estimated annual TP load out of this pond is 6.3 lbs with a high dissolved phosphorus fraction. Due to the high dissolved phosphorus fraction, an IESF is proposed and sized to treat runoff from the 1.1-inch storm event. This project is estimated to reduce watershed TP loads to Wheaton Lake by approximately 3.7 lbs per year. The project includes earthwork, IESF bench (approximately 2,300 sf), berm and outlet structure, and site restoration. The estimated construction cost is approximately $180,000. The 30-year life cycle cost estimate is approximately $485,000. The 30-year cost-benefit is $4,369/lb TP removed.



Concept overview of proposed filter bench location and approximate size.

REG-8 (Gerhardt Lake)

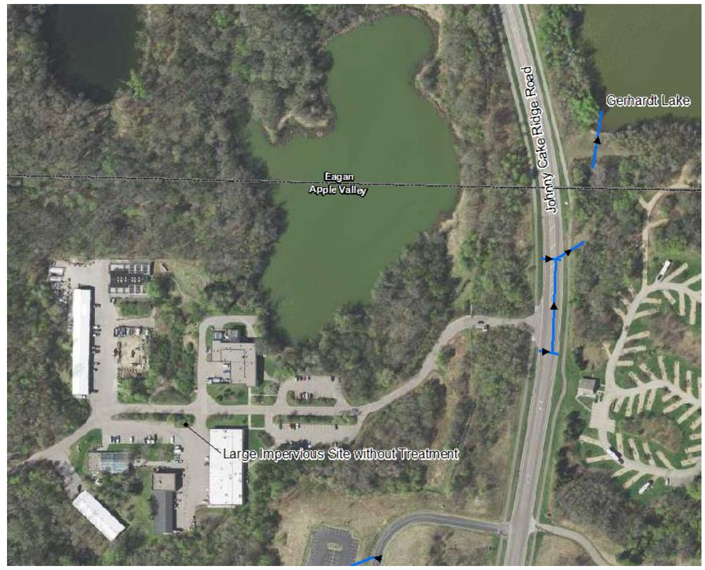
The REG-8 BMP is a small pond with a filtration bench located at an existing ravine that drains to pond BLP-1 upstream of Gerhardt Lake. The contributing watershed to this site is approximately 74 acres with large untreated impervious area. The P8 model estimated annual TP load is 10.7 lbs with a high dissolved phosphorus fraction. Due to the high dissolved phosphorus fraction, an IESF is proposed and sized to treat runoff from the 1.1-inch storm event. This project is estimated to reduce watershed TP loads to BLP-1 and Gerhardt Lake by 7.0 lbs per year. The project includes earthwork, IESF bench (approximately 2,500 sf), berm and outlet structure, and site restoration. The estimated construction cost is approximately $305,000. The 30-year life cycle cost estimate is approximately $770,000. The 30-year cost-benefit is $3,667/lb TP removed.



Concept overview of proposed filtration bench location and approximate size.

Impervious Areas with Minimal or No Treatment

In addition to the regional practices described above, four areas with relatively large impervious surfaces with minimal or no on-site rate control and/or water quality treatment were identified for potential practices. These areas are shown on Figure 5-1 and include: IMP-5, IMP-8, IMP-13, and IMP-16. It is recommended that the County investigate these sites closer to determine potential stormwater BMPs to slow flow and capture pollutants on-site prior to discharging to downstream waterbodies. Potential small-scale BMPs for these sites could include raingardens, stormwater ponds/retention basins, vegetated swales and pervious pavement.



Site IMP-16

Site IMP-13

Sites IMP-8 and IMP-5

5.3 EROSION BMPS

The assessment of potential erosion concerns within LHRP combined a desktop analysis with a field assessment, which included visits to over 30 sites within the park to document areas with active erosion or significant erosion potential. Based on a review of the conditions noted during the field assessment, many of the areas with erosion concerns within the park occur along trails. These areas can be addressed with natural surface trail maintenance and stabilization techniques. Additionally, two areas of potentially significant stream bank erosion concern were identified. These areas will require stream stabilization practices to properly address the erosion concerns including repairing the existing channel as well as preventing future erosion from occurring. The following sections provide a summary of the trail stabilization and maintenance recommendations along with specific recommendations for the two identified channel stabilization projects, including preliminary cost estimates. Appendix E provides general descriptions of common channel stabilization techniques that are used to improve failing channels.

5.3.1 Trail Stabilization and Maintenance Recommendations

Trail erosion in general should consider the following question: Where does flow come from and how is it traveling across and along the trail? If there is sheet flow on the trail that is concentrating and causing erosion, then the question needs to be: "Should the trail be modified or improved to prevent the runoff from concentrating?" If there is impervious surface runoff (i.e. parking lot) that is draining on to or along a gravel or woodchip trail, then the question should be: "What practices need to be installed to intercept and infiltrate the runoff before it impacts the trail?"

Based on review of the specific site visits during the field assessments, two improvement projects targeting trail erosion within the LHRP have been identified. For each project site, a description of the issue of concern, a preliminary design, and a cost estimate are provided below. The trail stabilization project locations are shown on Figure 5-1.

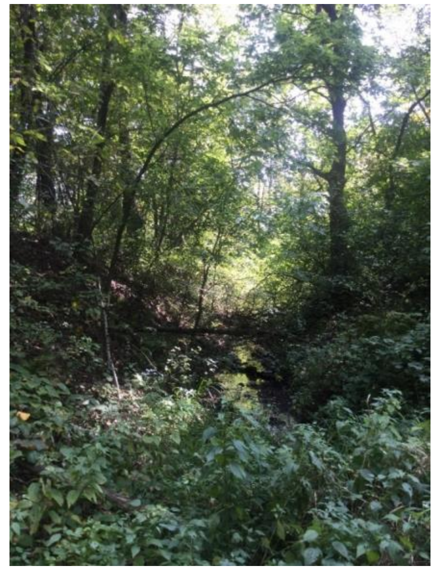
1M/4M (McDonough Lake)

Location 1M/4M is a trail crossing a channel connecting Wood Pond to McDonough Lake. The channel is wider closer to Wood Pond (4 feet wide, 3 feet tall), and becomes narrower as you approach McDonough Lake (2 feet wide, 1 foot tall). The channel is approximately 800 feet long from Wood Pond to the gravel trail culvert near McDonough (18" PVC corrugated) then approximately 180 feet from the culvert to McDonough Lake. Some erosion may be occurring at the trail crossing, where culverts may be undersized for creek flows. Otherwise, the channel is mostly stable with organic sand/silt in the stream bottom and woody debris scattered throughout providing habitat opportunities for aquatic and terrestrial organisms. Ongoing observation and maintenance of this channel should include clearing tree deadfalls that might obstruct flow in the channel or redirect flow into the bank and start an erosion scour. Trail maintenance should be done to correctly size and install an appropriate culvert. The estimated park maintenance cost is for this site is approximately $33,000 and includes tree thinning, culvert removal and replacement, and general trail maintenance/repairs. A detailed cost estimate table for this site is included in Appendix F.

Example of a tree that has fallen across the channel. When this tree decomposes and falls into the channel, it could redirect flow into the bank and create a scour.

3J (Jensen Lake)

Location 3J is a trail crossing a drainage swale receiving drainage from Valleywood Golf Course and an adjacent cul-de-sac that flows into a Reinforced Concrete Pipe (RCP) and is piped directly to Jensen Lake. There is some erosion evident as sediment is accumulating at the inlet of the RCP Culvert and the outlet of the pipe is slightly perched which should be stabilized with additional riprap to prevent undermining of the pipe structure (Figure 5-3). The erosion is most likely occurring from offsite drainage and therefore measures to intercept and infiltrate the stormwater should be taken. Steps should also be taken to stabilize the channel by thinning the tree canopy to open up for daylight to reach the ground and allow native grass vegetation to establish.



Existing drainage valley. To protect from increasing runoff, the canopy could be thinned to allow daylight to reach the ground and allow native grasses to establish.

The estimated park maintenance cost for this site is approximately $20,000 and includes cleanout of existing culverts, installing additional riprap to bolster existing culvert flared-end sections and clear tree deadfalls. A detailed cost estimate is provided in Appendix F. Tree clearing could be accomplished by hiring the Conservation Corps to clear trees and brush and hand broadcast seed along the channels to try and establish more native grass cover. Cost for the use of the Conservation Corps labor is $1,500 per 10-hour day for a crew of 5 people. Contracted costs by a general contractor are also included in the detailed cost estimate table in Appendix F.

Sediment accumulation on upstream end (left photo) of the culvert should be cleaned out to prevent remobilization. Outlet of existing culvert (right photo) should be cleaned out and additional riprap placed to prevent undercutting of the structure.

Other Trail Maintenance Sites

Some of the erosion that has been identified within the LHRP can be repaired with soft surface trail maintenance. This would include blading the trail with enough cross pitch to drain towards the desired pathway. Additionally, this could include reshaping the soft surface trail with a parallel drainage swale with rock check dams to the side of the trail, so the trail stays more dry and intact. Based on the field assessment this type of trail maintenance could be implemented at the following sites: 4S, 3S, 2S, 7J, 1J, and 2J. Appendix F includes specific project ideas and maintenance recommendations for each of these sites.

5.3.2 Channel Stabilization Practices

Based on review of the specific site visits during the field assessments, two stream channel improvement projects targeting erosion within the LHRP were identified. For each project site, a description of the issue of concern, a preliminary design, and a general cost estimate are provided below. The project locations are shown on Figure 5-1 which displays the identified BMP project sites. Each channel concept design recommends specific stabilization techniques for mitigating erosion and creating long-term solutions to the current issues. Appendix E contains brief descriptions of several different types of channel stabilization techniques, including: vegetated riprap, bank resloping, tree thinning/removal, and rootwads with toe logs. Each of the general descriptions in Appendix E are accompanied with project example photos and/or typical construction details.

Holland Lake Channel Project (5H-6H)

At erosion location 5H-6H, a wetland drains around a degraded Corrugate Metal Pipe (CMP) culvert that is no longer functioning properly. The CMP culvert is washed out overtop and runoff drains through an eroded gully/ditch approximately 75' in length, 5' wide, and 4' deep. The eroded ditch ends at another degraded CMP culvert underneath a walking trail. If the upstream culvert still has a function (trail crossing, controlled drainage, etc.) it should be replaced, otherwise this culvert can be removed. The downstream culvert has a rusted-out bottom and should be replaced before the trail is compromised. The replacement culvert should be either a high-density polyethylene (HDPE) plastic culvert or a reinforced concrete pipe (RCP) depending on the intended load crossing the culvert and the amount of cover that can be placed over the culvert. It is assumed in this report that an HDPE culvert will be sufficient.

The eroded channel has formed from an increase in runoff. It is likely that previously there was a natural channel with a slope that was tied into the downstream and upstream culverts. As runoff increased, a head cut formed at the downstream culvert. The head cut then migrated upstream until the point where it has now undermined and cut around the upstream culvert. Without stabilization, the head cut will continue to migrate upstream and export eroded soil to the downstream watershed. The existing conditions of the eroding ravine and the compromised culvert are shown in the photos to the right.

The proposed stabilization techniques include removing and replacing the downstream CMP culvert, stabilizing the toe of the channel with vegetated riprap, installing rock check dams in the channel to prevent future head cutting, removing the upstream CMP culvert, regrade the washed-out area of the channel, and placing a riprap spillway to prevent the head cut from reforming or migrating further upstream. Project construction would include grading work and selective tree removal upslope of the affected area to allow construction access and promote sunlight for the revegetated and reseeded areas. The priority for tree clearing will be in the order of:

1. Invasive species like buckthorn, exotic honeysuckles, etc.
2. Softwood pioneering or disease prone, problematic species like boxelder, ash and elm.
3. Trees leaning over the stream, large branches sweeping over the stream or other trees with exposed roots on the bank in danger of falling into the stream and causing a barrier to flow or uprooting the bank and causing a new erosion feature.
4. Other trees that are required for equipment access and safe operation by the construction crew or would otherwise benefit the outcome of the project.

The estimated construction cost for this project would be $35,160. Appendix F provides a detailed cost estimate for each of the recommended items discussed above. By stabilizing this site, it is estimated that TSS loads to Holland Lake would be reduced by approximately 4.5 tons per year and TP loads would be reduced by approximately 1 pound per year.

Schulze Lake Channel Project (1S)

Location 1S is a 18' wide channel, approximately 725' in length long that is mostly stable with organic sand/silt substrate as well and cobbles in the stream bottom. There is also woody debris scattered throughout the channel providing habitat opportunities for aquatic and terrestrial organisms. With increased runoff, the channel is migrating slightly and is creating undercutting along the banks of some outside channel bends. While channel migration is a natural process, it does export soil downstream and the increased runoff is accelerating this process beyond typical natural conditions. Protection of the banks will reduce the amount of soil being exported to downstream lakes, primarily Schulze Lake, within LHRP. Existing conditions of the channel in stable state compared to the eroding and undercut banks are shown in the graphics below.

Stabilization for this stream should be a more natural, bioengineered approach using native plantings and a combination of coir toe or cedar revetments, depending on streambank height and severity of erosion occuring, to rebuild the eroding outer bend sections that are eroding. Invasive species removal should be completed to remove the understory shading out existing grassy ground vegetation. Then the tree canopy can be assessed to see if selective removal of small pioneering, diseased or damaged, or low priority tree species will help to provide some additional sunlight and help revegetation efforts where bank restoration work is occurring. The coir log can be installed with shrub live stakes and/or bare-root plantings to build out and armor the toe of the bank. Cedar revetment would not be planted into, however the area above any cedar revetment or coir log toe work would be seeded with native, shade-tolerant grass and forb seed mix. No erosion control blanket would be needed since the seed would be broadcast and raked into the existing leaf litter. This project is estimated to reduce sediment loads to Schulze Lake by approximately 7 tons per year and phosphorus loads by approximately 1.5 pounds per year. The estimated construction cost for this project is $21,060. Appendix F contains a detailed cost estimate for this project.

Schulze Lake Channel - Existing Stable Channel

Schulze Lake Channel - Example of an Outer Bank Being Undercut

5.4 LAKE SEDIMENTS

As discussed in Section 3-2, TP release rates from the lake sediments were relatively low for the LHRP priority lakes compared to other lakes throughout Minnesota. Similarly, annual TP loading from the sediment was low and less than 10 pounds per year for O'Brien, McDonough, and Holland Lakes. For Jensen Lake, sediment TP loading was approximately 20 pounds per year and accounted for 28% of the lake's TP budget. Jensen Lake is currently meeting the 35 µg/L in-lake TP goal and only occasionally demonstrates elevated algae (chlorophyll-a) levels. Therefore, actions to reduce sediment TP loading are not recommended at this time. Schulze Lake, on the other hand, is not currently meeting the 35 µg/L TP goal and has elevated chlorophyll-a levels throughout the entire summer growing season. Schulze Lake TP loading from the sediment is 12 pounds per year and accounts for approximately 27% of the lakes' TP budget. Due to these factors, it is recommended that the County explore options to decrease sediment P-release in Schulze Lake. Based on our experience, the most common and cost-effective approach to address sediment P-release is aluminum sulfate (alum).

Alum is typically applied to lakes by injection of liquid alum just below the lake water surface. The alum quickly forms a floc and settles to the bottom of the lake, which converts highly mobile sediment phosphorus (redox-P) into an immobile phosphorus fraction (aluminum bound-P). This process reduces sediment phosphorus release rates, and ultimately reduces sediment phosphorus loading in lakes. The primary factors taken into consideration for developing alum cost estimates are the total area that requires treatment and the alum application rate. The prescribed treatment area is typically the area of the lake that experiences prolonged periods of anoxia near the sediment-water interface. Based on the 2017 temperature/dissolved oxygen monitoring data, it appears Schulze Lake does exhibit anoxia throughout much of the summer growing season, however it is inconclusive based on this data exactly what depth in the water column anoxia begins to occur. For the purposes of this study, it was assumed that the depth of anoxia is approximately 5 feet and therefore the 5-foot depth contour (~10 acres) was selected as the proposed alum treatment area. Based on the results of the sediment core analysis and our experience with similar lakes throughout the State of Minnesota, an alum application rate of 100 mg/m^2 for Schulze Lake should ensure that the available redox-P in the lake's sediment is permanently bound.

Based on the size of the proposed treatment area and the 100 mg/m^2 application rate, the total cost of an alum treatment for Schulze Lake would be approximately $60,000. This estimated cost includes bidding, permitting, specs, application observation, and follow-up monitoring. Our experience with internal load reduction using alum is that phosphorus release rates typically decrease by greater than 90%. In many cases, phosphorus release rates will decrease by 95-99%. Therefore, it can be assumed that an alum treatment for Schulze Lake would reduce the sediment release rate by 90% which would result in an annual TP load reduction of approximately 11 pounds per year. This reduction is approximately 79% of the annual reduction goal for Schulze Lake (Table 4-1).

Though it is not identified as a priority lake for this study, Gerhardt Lake is another lake in LHRP that should be considered for an alum treatment. The 2017 monitoring results for Gerhardt (Appendix A) indicate the lake is not meeting State standards for chlorophyll-a and Secchi depth. Gerhardt Lake did meet State standards for TP in 2017, however it did not meet the 35 µg/L shallow target established for this study. As discussed in Section 3.3, Gerhardt Lake exhibited the second highest sediment TP release rate (1.6 mg/m^2/day) of the six lakes sampled in LHRP. It is estimated that the cost of an alum treatment for Gerhardt Lake would be $45,000 and the treatment would result in an annual TP reduction of approximately 8.8 pounds. This cost estimate assumes that 75% of the lake's surface area (~11 acres) would be treated with alum and dosing rates were developed using the sediment core lab results. Detailed alum treatment cost estimates for both Schulze and Gerhardt Lakes are provided in Appendix F.

5.5 FISH MANAGEMENT

The fish community is an important component of the overall aquatic ecology of a lake and the composition of the fish community can have impacts on water quality. Shallow lakes can be susceptible to shifts in a fish community where the introduction of a few undesirable or invasive species can negatively impact lake water quality. For example, an overabundance of black bullheads and/or fathead minnows can have a significant impact on water quality and the lake's vegetation, aquatic invertebrate, and zooplankton communities. Currently there is limited available information regarding the fish communities of the lakes throughout LHRP. Most of the fish surveys and management efforts to date have focused on Holland Lake, which is the only deep lake among the priority lakes. Holland Lake has excellent water quality and water clarity and the information from previous DNR fish community surveys indicate there is an abundant and healthy fish population comprised of bluegills, sunfish, and northern pike. No further information is needed regarding the Holland Lake fish community. However, it would be prudent to continue to coordinate with the DNR on their planned survey timing and management efforts to ensure County and Park staff are knowledgeable on the status of the Holland Lake fishery and this community can continue to be a beneficial resource for park users.

There is limited fish community data available for the other four priority lakes (Jensen, McDonough, O'Brien, and Schulze) which are shallow lakes. Based on the water quality data it is highly recommended that fish community surveys be performed on all four of the priority shallow lakes as well as Gerhardt Lake. Surveys for these shallow lakes should use appropriate techniques (i.e. mini fyke nets) that sample and evaluate shallow lake fish communities. The baseline datasets will be used to ensure protection of water quality and vegetation communities and to development management goals and priorities for each lake.

5.6 SHORELINE VEGETATION

Eroding lake shorelines can result in additional sediment and nutrient loads being delivered to lakes. The priority lakes throughout LHRP have experienced varying amounts of water level fluctuations over the last decade which has impacted the shoreline vegetation community. Some tree species are not able to tolerate increased or fluctuating water levels that lead to periods of inundation. The increased or fluctuating water levels can ultimately lead to these trees dying. As the trees along a lake shore die this can create a shift in the vegetation community away from the large trees providing stabilization along the shoreline to more emergent marsh type vegetation that provides a lesser degree of stability. Existing trees along the shoreline that are currently dying back and falling into the lakes include green ash and American elm.

Management and revegetation of shorelines for impacted lakes within the LHRP is a management strategy that should be considered. Shoreline replanting efforts should focus on native species that are tolerant of fluctuating water levels while also providing the desired aesthetic experience along the lake shore. Now that the shoreline canopy is more open due to the loss of trees, replanting efforts would focus on a mix of native shrubs, grasses, and forbs. Species to be considered would include the following:

- Shrubs: willows (especially pussy willow, slender willow, and Bebb's willow; sandbar willow should be excluded), red-osier dogwood, speckled alder, and bog birch.
- Grasses: bluejoint, prairie cordgrass, and wild-rye.
- Sedges: wiregrass sedge, lake-bank sedge, tussock sedge, and prairie sedge.
- Others: northern marsh fern, tussock bulrush, and jewel-weed.

The species mix for specific shoreline revegetation efforts would be tailored to the site conditions as well as the specific desires from County staff. In instances where shoreline erosion is severe, coir logs can be installed at the shoreline toe to provide immediate stabilization allowing time for plantings to become established. Typical shoreline revegetation projects can be expected to range from $4,000 to $10,000 per 100 feet of shoreline including bank work, coir log or other stabilization materials, plant costs, and installation. Projects can be adjusted as needed to meet available budgets and the desires of LHRP staff.

Table 5-1. Summary of proposed BMP pollutant load reductions and cost analysis. BMPs are organized by lake subwatershed and life cycle cost per pound of TP removed.

BMP ID	Lake Subwatershed	BMP Type	Annual TP Load [lbs/yr]	TP Reduction [lbs/yr]	Construction Cost Estimate	Life Cycle Cost Estimate [30 yrs]	Construction Cost per pound of TP Removed	Life Cycle Cost per pound of TP Removed
REG-6	Jensen	Lift Station IESF Filtration Area	10.1	5.8	$600,000	$1,035,000	$3,448	$5,948
REG-5	Jensen	IESF Filtration Area	3.2	1.8	$165,000	$360,000	$3,056	$6,667
3J	Jensen	Trail Crossing Maintenance/Repairs	NA	NA	$20,400	$32,400*	NA	NA
REG-3	O'Brien	IESF Filtration Area	7.3	4.1	$190,000	$530,000	1,545	$4,309
REG-4	O'Brien	Sand Filtration Area	9.0	5.5	$415,000	$760,000	$2,515	$4,606
AL-1	Schulze	Alum Treatment	12.1	10.9	$60,000	$60,000	$183	$183
1S	Schulze	Channel Stabilization	1.5	1.5	$21,060	$33,060*	$468	$1,349
REG-1	Schulze (Portage)	IESF Filtration Area	28.9	16.1	$425,000	$1,245,000	$880	$2,578
REG-2	McDonough (Marsh)	IESF Filtration Benches	27.9	16.4	$645,000	$1,585,000	$1,311	$3,222
1M/4M	McDonough	Trail Crossing Maintenance/Repairs	NA	NA	$33,000	$45,000*	NA	NA
5H-6H	Holland	Channel Stabilization	1.0	1.0	$35,160	$47,160*	$1,172	$1,572
AL-2	Gerhardt	Alum Treatment	9.8	8.8	$45,000	$45,000	$170	$170
REG-8	Gerhardt	IESF Filtration Bench and Pond	10.7	7.0	$305,000	$770,000	$1,452	$3,667
REG-7	Wheaton	IESF Filtration Bench	6.3	3.7	$180,000	$485,000	$1,622	$4,369
As needed		Shoreline Vegetation	NA	NA	$4,000 - $10,000 per 100 feet of shoreline	NA	NA	NA

*The 30-year life cycle cost for these practices includes a $2,000 maintenance cost once every 5 years for tree thinning and/or vegetation planting/seedings as needed
NA = not applicable or was not enough information to estimate for this study

6.0 Summary and Recommendations

The primary objectives of this study were to identify and prioritize targeted watershed management strategies for LHRP that are aimed at protecting and improving the water quality and ecological communities throughout the park. These objectives were accomplished through review of existing/historic water quality data and biologic assessments, development of water quality models to predict flow and nutrient (mainly TP) loading to the priority lakes, establishment of TP reduction goals for each priority lake, and finally, identification of structural and in-lake BMPs to help meet the TP reduction goals and improve biotic communities. While the modeling and data collection for this study covered the entire LHRP system, the final analysis and reporting focused on five priority lakes in the park: Jensen, O'Brien, Schulze, McDonough, and Holland Lakes. Below is a summary of the final results and recommendations for each of the LHRP priority lakes, along with general recommendations for other resources throughout the park.

Jensen Lake

- Historic monitoring data for Jensen Lake indicates the lake is currently meeting State water quality standards and the 35 µg/L LHRP shallow lake TP target established for this study.
- Recent SAV surveys (2016) for Jensen Lake suggest the lake has a relatively abundant and diverse plant community and no observed AIS.
- Modeling results suggest TP loading to Jensen Lake is driven by watershed runoff (54%) followed by sediment (28%) and atmospheric (18%) inputs.
- This study set a TP load reduction goal of 10% (7 pounds per year) to ensure the lake continues to meet the LHRP shallow lake TP target
- Based on historic monitoring data and model results, protection efforts for Jensen Lake should focus on reducing watershed TP loads, protecting the current SAV communities, and AIS prevention.
- Three potential BMPs were sited in the Jensen watershed, including two regional stormwater treatment practices (REG-5 and REG-6) and one trail crossing maintenance/repair project (3J). If all three of these projects were implemented, TP loading to Jensen Lake would be reduced by approximately 8 pounds per year.

O'Brien Lake

- Historic monitoring data for O'Brien Lake indicates the lake has exceptional water quality and is currently meeting State water quality standards for TP, chlorophyll-a, and Secchi depth. With a historic average TP concentration of 22 µg/L, O'Brien Lake also currently meets the LHRP shallow lake TP target established for this study.
- Modeling results suggest TP loading to O'Brien Lake is driven by watershed runoff (49%) followed by inputs from upstream lakes and atmospheric deposition (both 21%) and the sediments (9%).
- This study set a TP load reduction goal of 5% (2 pounds per year) for O'Brien Lake. This goal is based on MPCA guidance for protecting lakes that currently meet State water quality standards.
- Based on historic monitoring data and model results, management efforts for O'Brien Lake should focus on reducing watershed TP loads and protecting/enhancing water quality in upstream lakes (primarily Jensen).

- Two potential regional stormwater BMPs were sited in the O'Brien Lake watershed (REG-3 and REG-4). Both of these BMPs are large sand filters that would have the potential to remove approximately 10 pounds of TP per year.

Schulze Lake

- The 2017 monitoring data for Schulze Lake indicates chlorophyll-a concentrations and Secchi depth are not currently meeting State water quality standards. The historic data for Schulze Lake suggests that Secchi depth has shown declining trends since the late 1990s. While average annual in-lake TP concentrations for Schulze Lake currently meet State standards, they do not meet the 35 µg/L LHRP shallow lake target established for this study.
- Modeling results suggest TP loading to Schulze Lake is split between P-release from the lake's sediment (27%), model residual load (25%), upstream lakes (23%), watershed (16%), and atmospheric deposition (9%). The model residual load for Schulze Lake represents the additional load needed to calibrate the lake response model to monitored in-lake TP concentrations. This load could include TP inputs from one or several unknown sources such as rough fish and/or an imbalanced fishery, CLP senescence, or inputs from the public swimming beach.
- Water quality in Portage Lake, which is the major upstream lake in the Schulze Lake watershed, is very good and currently meeting State water quality standards and the LHRP TP target.
- This study set a TP load reduction goal of 32% (14 pounds per year) in order for Schulze Lake to meet the 35 µg/L in-lake target concentration.
- Based on historic monitoring data and model results, management efforts for Schulze Lake should focus on reducing internal P-release from the lake's sediments, watershed improvements, and identifying and addressing the source of the model residual load.
- Three potential BMPs were sited in the Schulze watershed, including one regional stormwater treatment practice, one channel stabilization project, and an in-lake alum treatment.
    - The regional stormwater treatment practice (REG-1) is located upstream of Portage Lake and is therefore not located in the direct drainage area for Schulze Lake. However, this practice would potentially reduce TP loads to Portage Lake by approximately 16 pounds per year.
    - The channel stabilization project (1S) is a relatively cost-effective project and would potentially reduce TP loading in the Schulze Lake direct watershed by approximately 1.5 pounds per year.
    - The proposed Alum treatment for Schulze Lake (AL-1) would provide a significant load reduction (11 pounds per year) and is the most cost-effective practice sited in the Schulze Lake watershed. The alum treatment should help reduce algae levels, particularly nuisance algae blooms, that have become common in Schulze Lake during mid-late summer
- It is highly recommended that the County conduct a fish community assessment in Schulze Lake to determine the health of the fish community and its potential impact on water quality conditions within the lake.

McDonough Lake

- Historic monitoring data for McDonough Lake indicates all three water quality parameters are currently meeting State water quality standards, however in-lake TP concentrations do not currently meet the 35 µg/L LHRP shallow lake target established for this study.

- Modeling results suggest TP loading to Schulze Lake is driven primarily by inflow from upstream lakes (50%) followed by inputs from the direct watershed (23%), model residual load (16%), sediments (6%), and the atmosphere (5%). The model residual load for McDonough Lake could include TP inputs from one or several unknown sources such as rough fish and/or an imbalanced fishery, or CLP senescence.
- Three of the major lakes upstream of McDonough Lake, O'Brien and Marsh, currently exhibit very good water quality and therefore are not likely negatively impacting water quality in McDonough Lake. As discussed above, water quality in Schulze Lake is poor and, due to its proximity to McDonough Lake, is likely having a significant impact on McDonough Lake.
- This study set a TP load reduction goal of 25% (22 pounds per year) in order for McDonough Lake to meet the LHRP shallow lake target concentration.
- Based on historic monitoring data and model results, management efforts for McDonough Lake should focus on improving water quality in Schulze Lake, watershed improvements, and identifying and addressing the source of the model residual load.
- Two potential BMPs were sited in the McDonough watershed, including one regional stormwater treatment practices and one trail crossing maintenance/repair project (1M/4M). The regional stormwater practice, REG-2, is actually located in the Marsh Lake subwatershed and, if implemented, would potentially reduce TP loads to Marsh by approximately 16.4 pounds per year. This practice has the largest potential TP reduction of all the BMPs sited in the report and is relatively cost-effective. This project would help protect current water quality conditions in Marsh Lake while also benefitting McDonough Lake.
- It is also recommended that the County conduct a fish community assessment in McDonough Lake to determine the health of the fish community and its potential impact on water quality conditions within the lake.

Holland Lake

- Holland Lake is the only deep lake within LHRP, and, due to its depth and small watershed to lake area ratio, has an extremely long residence time (~16 years).
- Historic monitoring data for Holland Lake indicates the lake has exceptional water quality and is currently meeting State water quality standards for all three parameters. With a historic average TP concentration of 18 µg/L, Holland Lake also currently meets the 20 µg/L TP target for deep lakes in LHRP established for this study.
- Recent SAV surveys (2016) for Holland Lake suggest the lake currently has two AIS, CLP and EWM, at low to moderate densities throughout the lake.
- Modeling results suggest TP loading to Holland Lake is driven by watershed runoff (54%) followed by atmospheric deposition (27%) and P-release from the lake's sediments (19%).
- This study set a TP load reduction goal of 5% (2 pounds per year) for Holland Lake. This goal is based on MPCA guidance for protecting lakes that currently meet State water quality standards.
- Based on historic monitoring data and model results, management efforts for Holland Lake should focus on reducing watershed TP loads and managing AIS to promote native vegetation growth and a healthier SAV community.

- One channel stabilization project (1S) was sited within the Holland Lake direct watershed. This project is a relatively cost-effective project and would potentially reduce TP loading to the lake by approximately 1.5 pounds per year.

Other Lakes and Water Resources in LHRP

- This study focused on five priority lakes throughout LHRP. However, there are other lakes throughout the park that could be targeted for similar studies and improvement projects. Gerhardt Lake is one lake in particular that should be targeted for more water quality monitoring and assessments. Water quality sampling was conducted on Gerhardt Lake in 2017 and results indicate the lake is currently not meeting State standards for chlorophyll-a and Secchi depth. Gerhardt Lake did meet State standards for TP in 2017, however it did not meet the 35 µg/L shallow target established for this study. This study identified two potential BMPs (one regional BMP and an alum treatment) to reduce TP loads to Gerhardt Lake.
- The primary focus of this study was to assess and provide management recommendations for the priority lakes throughout LHRP. This study did not explicitly assess uplands (i.e. prairie and forest) and/or wetland features throughout the park system. Assessing, managing, protecting and restoring these features to ensure they are in a healthy state will have a positive effect on the lakes and other resources throughout the park. Dakota County Parks is currently working on several upland restoration and improvement projects throughout the park, and it is recommended that these types of projects continue to be a high priority in the future.

Future Monitoring Recommendations

- Currently, there is very limited water quality data for the lakes in LHRP. The 2017 monitoring data was extremely valuable for this study in developing the models and assessing the current state of the lakes in the park. It is highly recommended that the County continue to perform routine water quality sampling for the priority lakes within the park for at least 3-5 years. Collecting this data will provide a solid baseline dataset that can be used in the future to update models, determine long-term trends, evaluate potential BMPs, and track changes in water quality as BMPs are implemented.
- It is recommended that fish surveys be conducted on the five priority lakes in LHRP, as well as Gerhardt Lake. The fish surveys should be performed using equipment (i.e. mini fyke nets) intended to sample shallow lake fish communities.
- Schulze, McDonough and Holland Lakes currently have AIS that covers over 39% of the lakes' surface area. However, density of existing AIS in these lakes is relatively low suggesting chemical treatments may not be necessary at this time. That said, FQI scores for four of the five priority lakes do not currently meet state thresholds. It is recommended that the County continue to perform annual SAV surveys to track trends/changes in AIS and general SAV community health over time, and to re-assess the need for treatments in the future.
- This study identified and sited 8 regional stormwater BMPs that have relatively large potential TP load reductions. Load reduction estimates for these BMPs are based on modeled data, not monitored concentrations, and therefore it is highly recommended that the County collect at least one season's worth (minimum of 5 samples) of grab samples at each proposed BMP location prior to moving forward with any of the practices. The samples should be collected from the pond outlet (for filtration bench BMPs) or the channel itself (for filtration basin BMPs) during various flow conditions.

Samples should be analyzed for TSS, TP, and ortho-phosphorus. Flow rates (if possible), temperature and dissolved oxygen data should also be collected in conjunction with the water quality grab samples. Collecting this data will help verify modeling results and anticipated pollutant reduction loads which will further help BMP prioritization and feasibility of the proposed practices.

7.0 References

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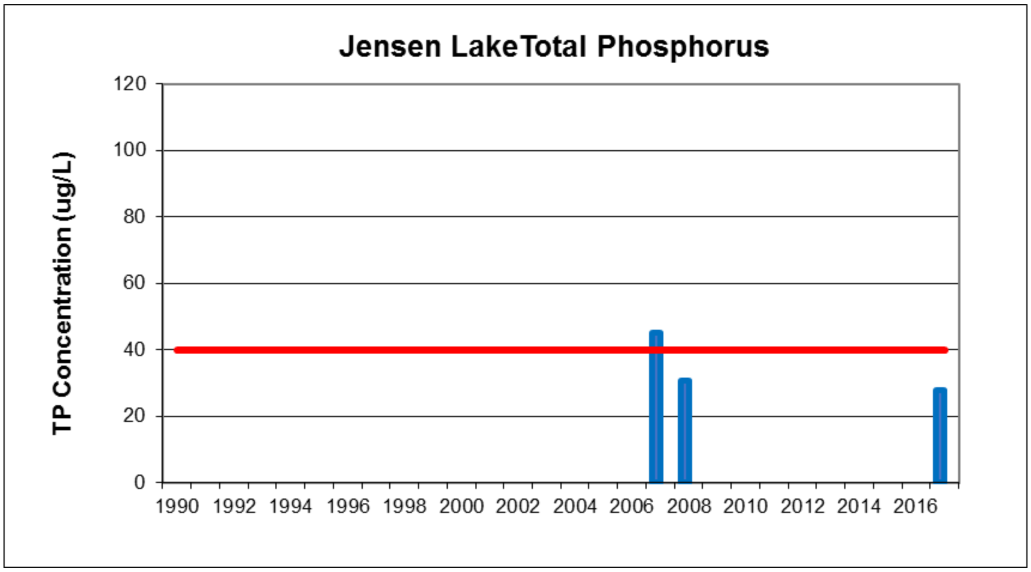
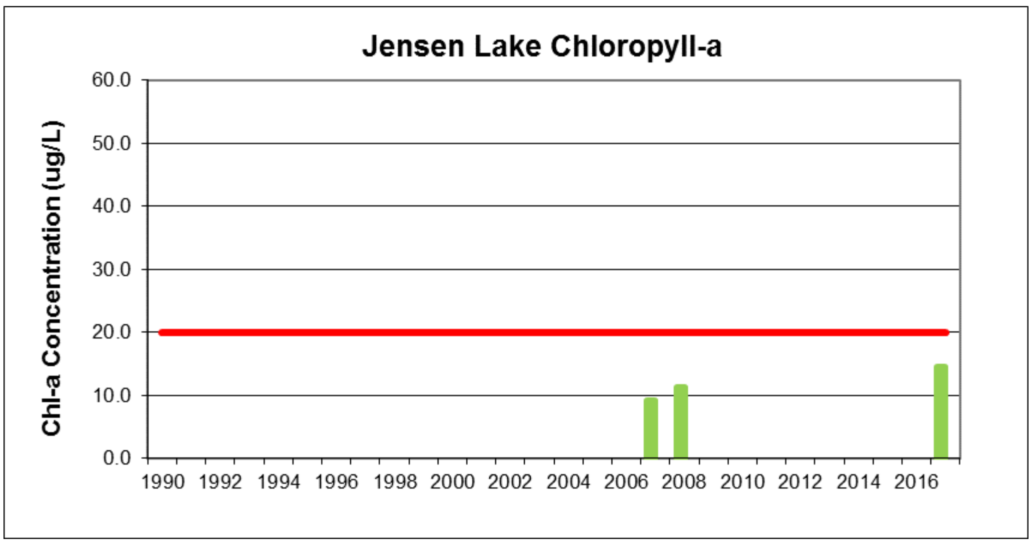
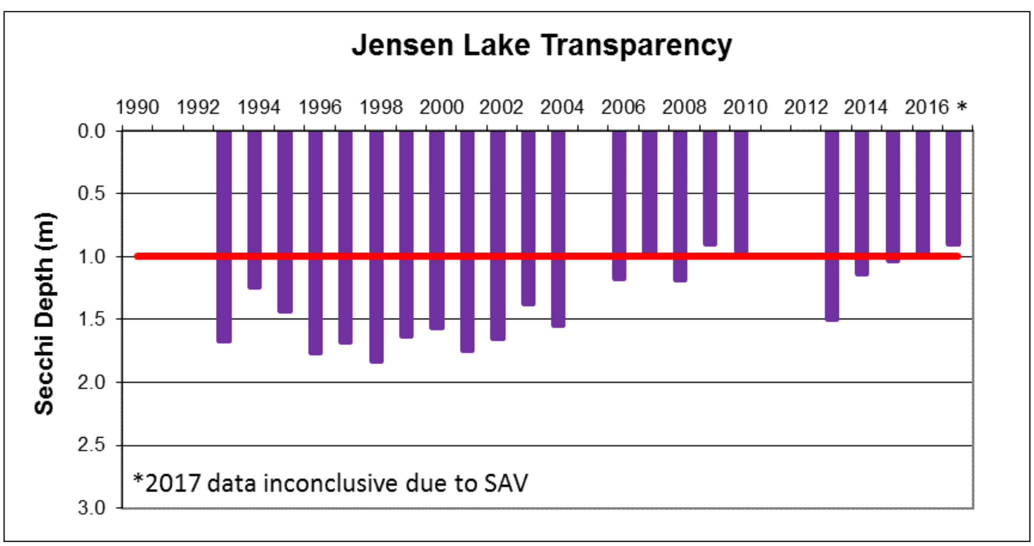
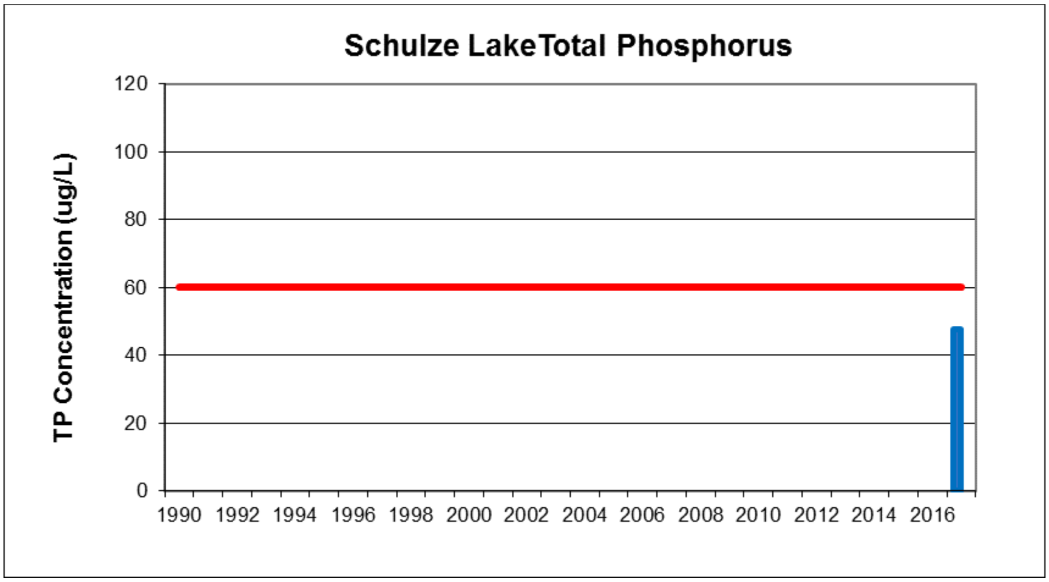
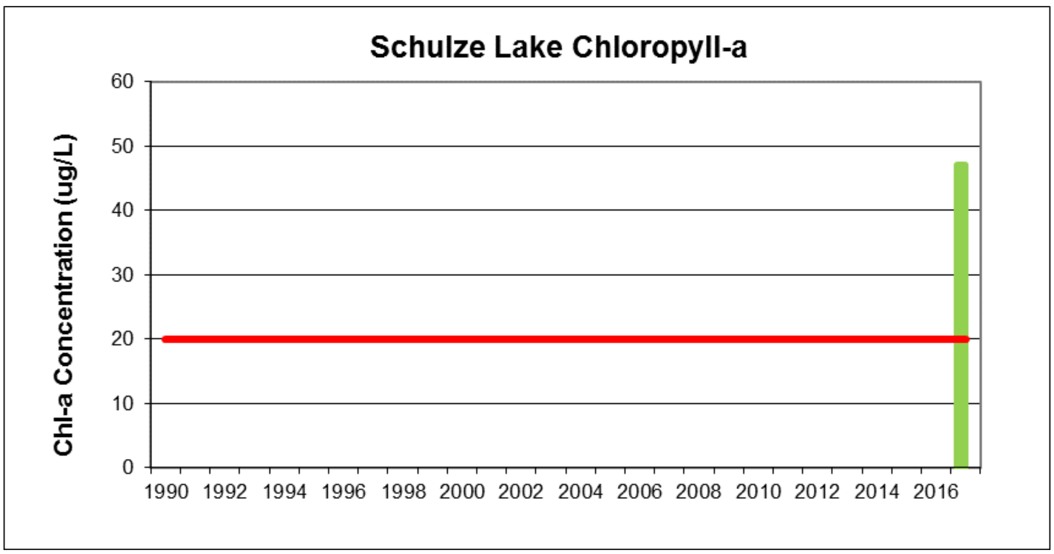
Appendix A: Lake Water Quality Data

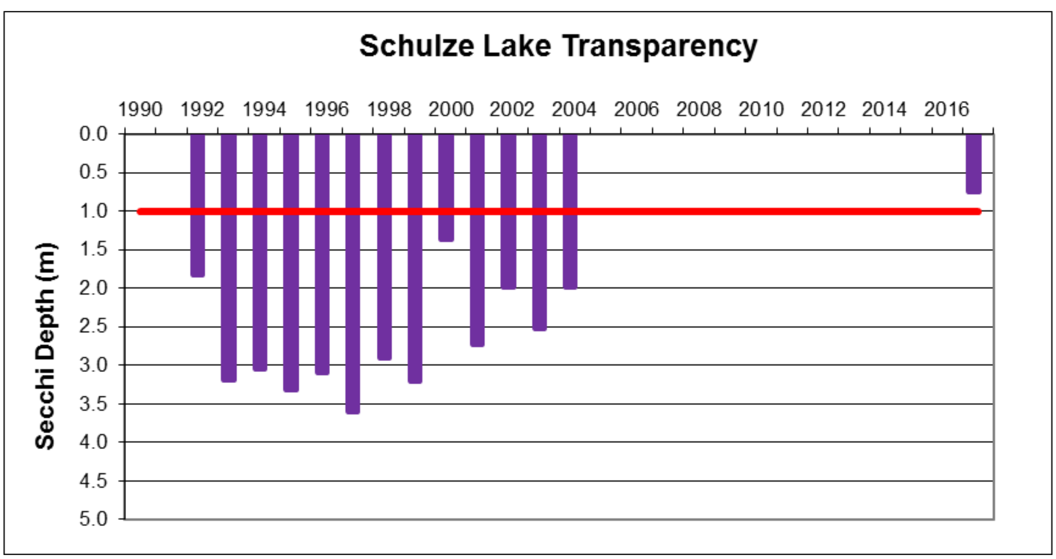

Jensen LakeTotal Phosphorus
TP Concentration (ug/L)
120
100
80
60
40
20
0
1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016

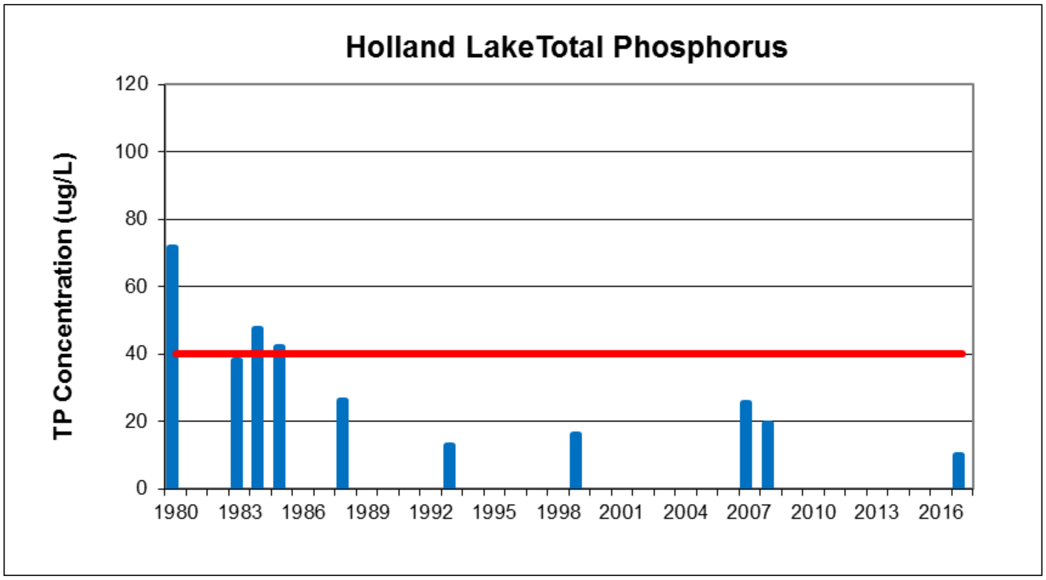

Jensen Lake Chloropyll-a
Chl-a Concentration (ug/L)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016

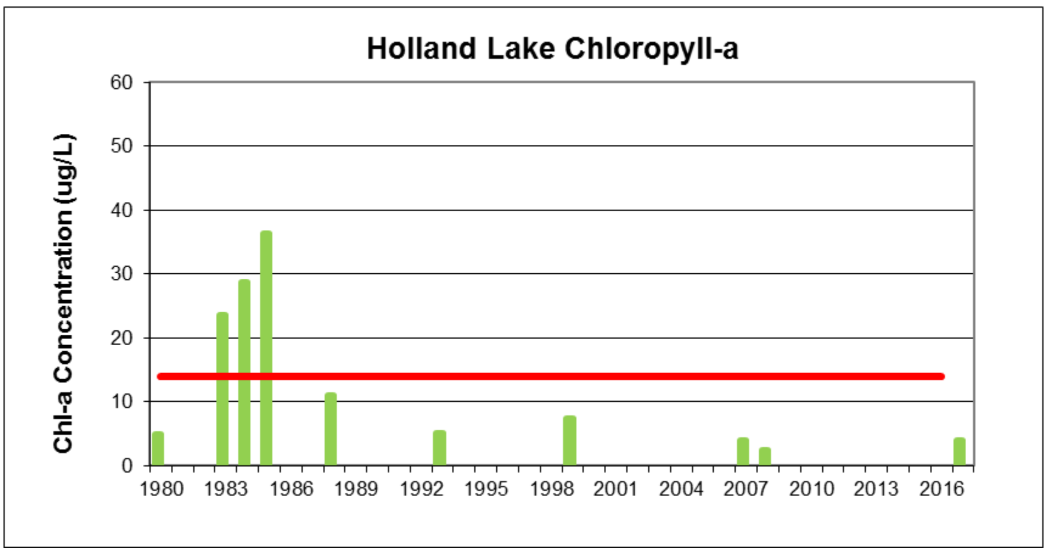

Jensen Lake Transparency
Secchi Depth (m)
1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 *
0.0
0.5
1.0
1.5
2.0
2.5
3.0
*2017 data inconclusive due to SAV

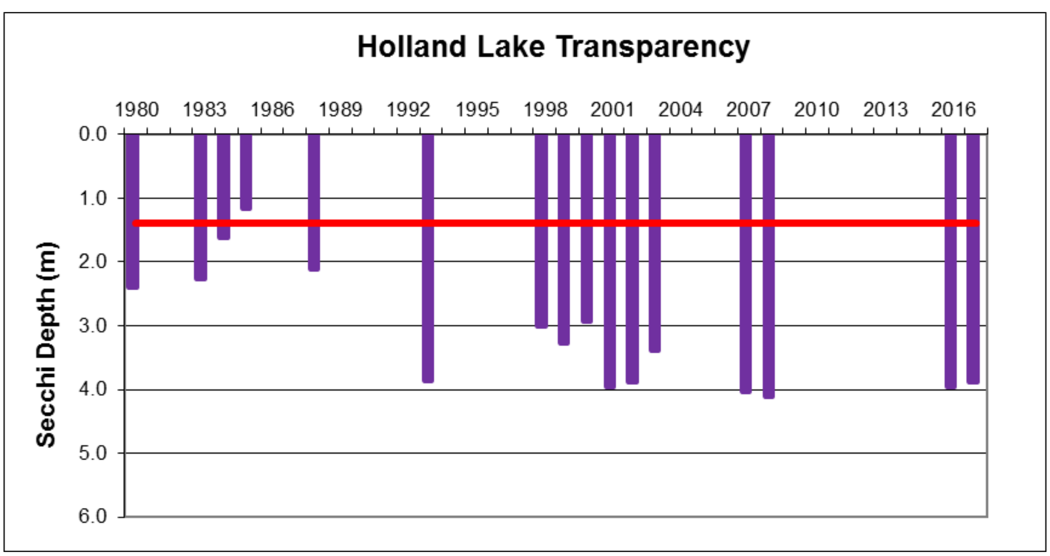

Schulze LakeTotal Phosphorus
TP Concentration (ug/L)
0
20
40
60
80
100
120
1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016

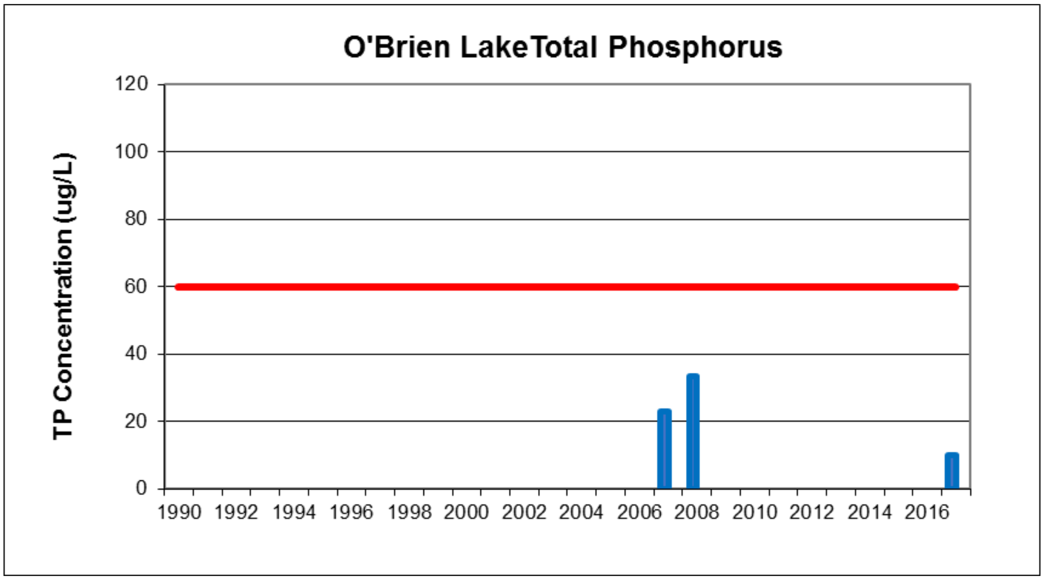

Schulze Lake Chloropyll-a
Chl-a Concentration (ug/L)
0
10
20
30
40
50
60
1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016


Schulze Lake Transparency
Secchi Depth (m)
1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0

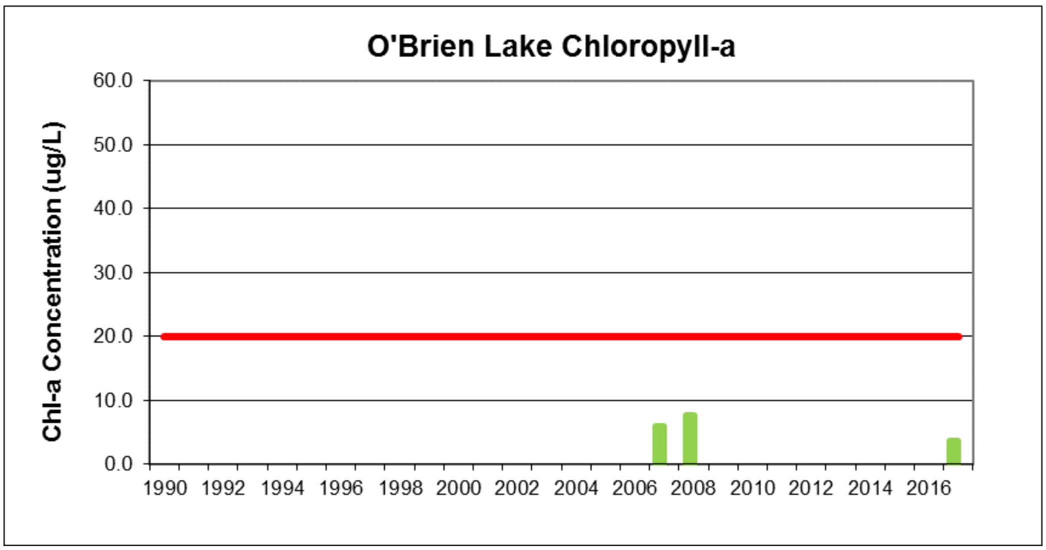

Holland LakeTotal Phosphorus
TP Concentration (ug/L)
120
100
80
60
40
20
0
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
2016


Holland Lake Chloropyll-a
Chl-a Concentration (ug/L)
60
50
40
30
20
10
0
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
2016

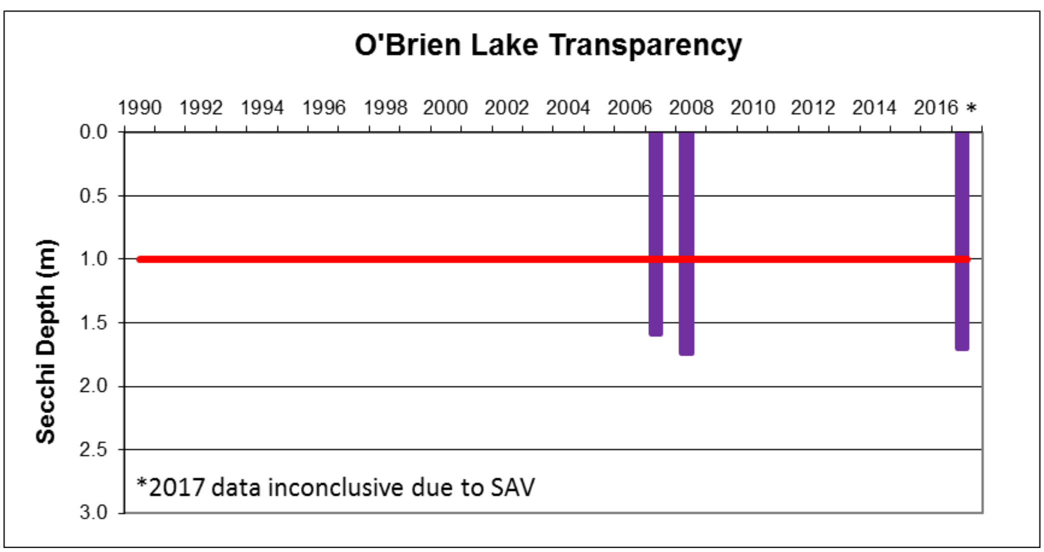

Holland Lake Transparency
Secchi Depth (m)
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
2016
0.0
1.0
2.0
3.0
4.0
5.0
6.0



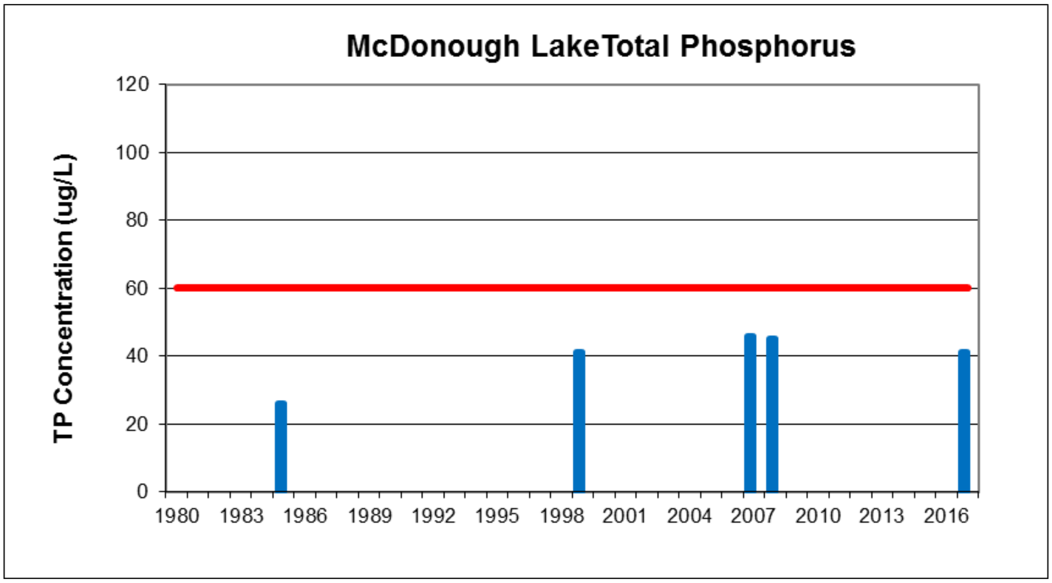
O'Brien LakeTotal Phosphorus
TP Concentration (ug/L)
120
100
80
60
40
20
0
1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016

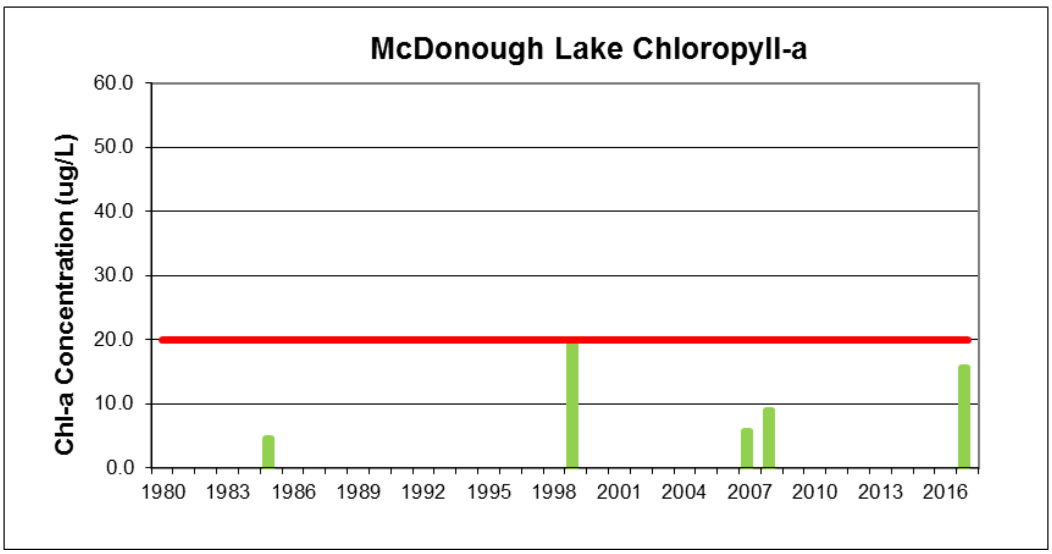


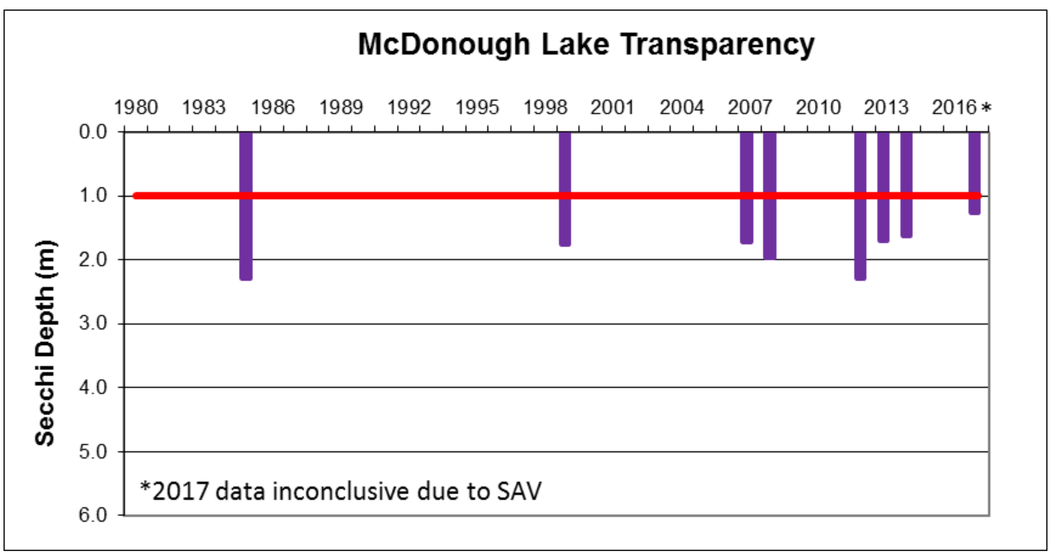
O'Brien Lake Chloropyll-a
Chl-a Concentration (ug/L)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016

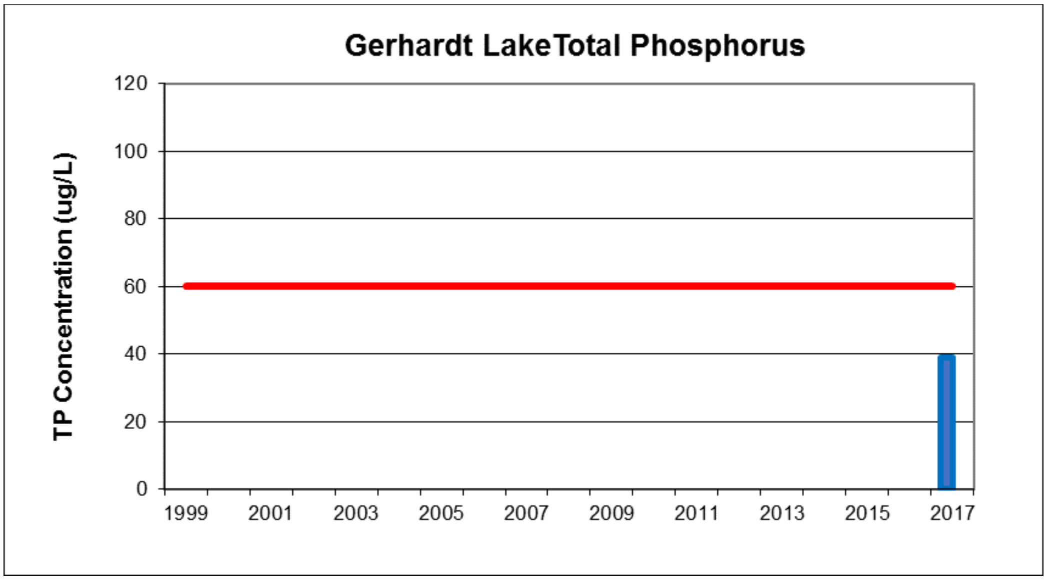


O'Brien Lake Transparency
1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 *
Secchi Depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
*2017 data inconclusive due to SAV

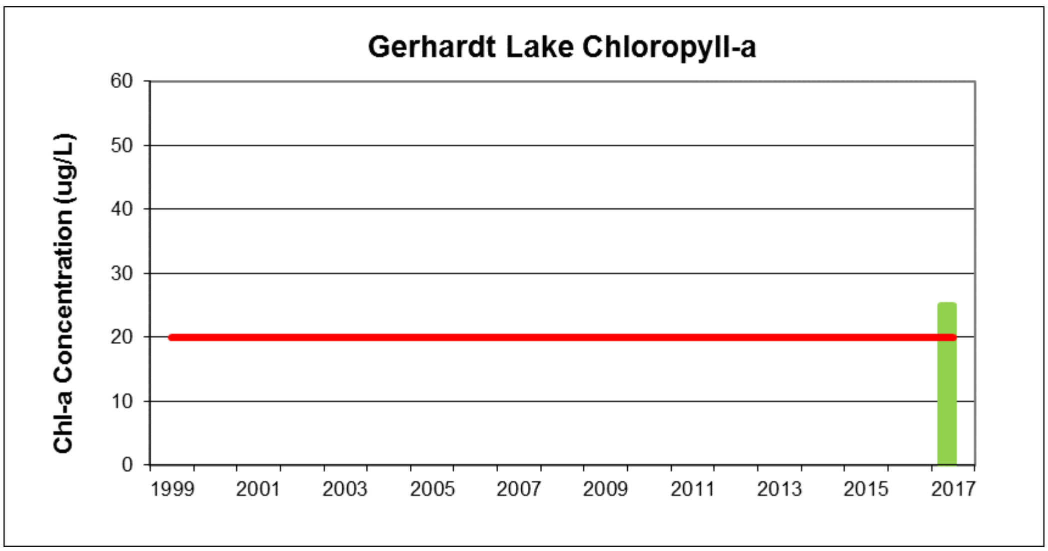

McDonough LakeTotal Phosphorus
TP Concentration (ug/L)
120
100
80
60
40
20
0
1980 1983 1986 1989 1992 1995 1998 2001 2004 2007 2010 2013 2016


McDonough Lake Chloropyll-a
Chl-a Concentration (ug/L)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1980 1983 1986 1989 1992 1995 1998 2001 2004 2007 2010 2013 2016

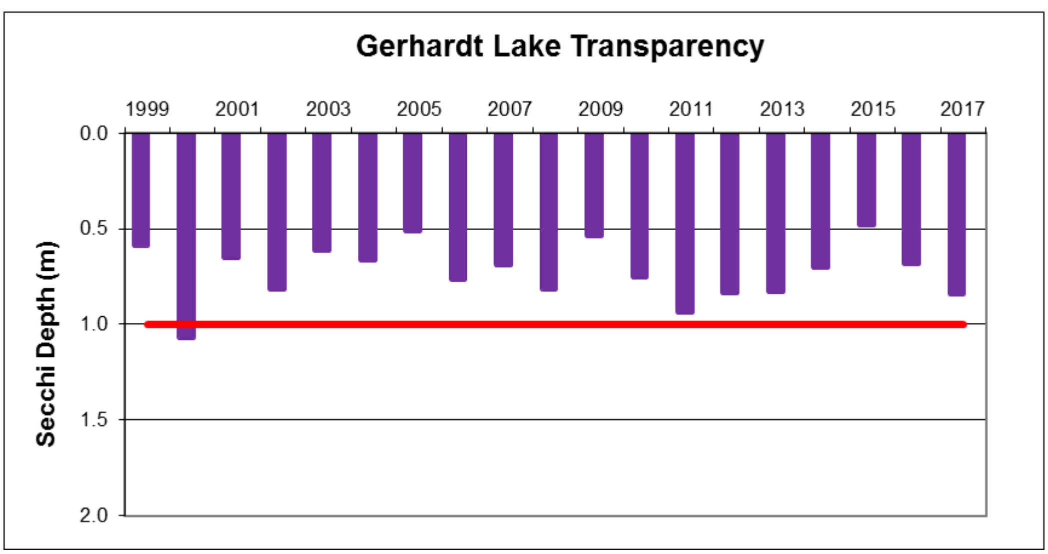

McDonough Lake Transparency
1980 1983 1986 1989 1992 1995 1998 2001 2004 2007 2010 2013 2016 *
Secchi Depth (m)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
*2017 data inconclusive due to SAV



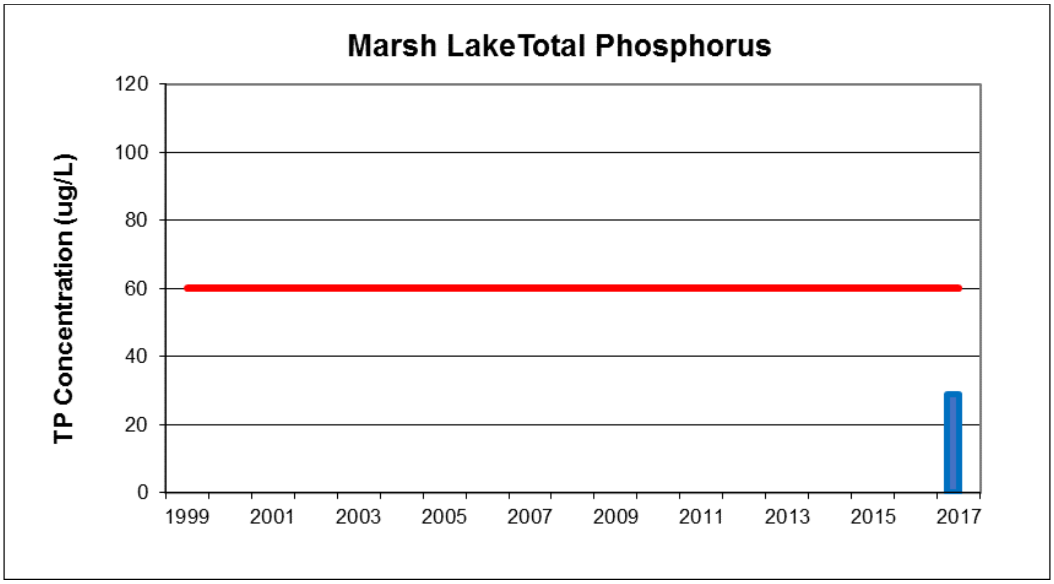
Gerhardt LakeTotal Phosphorus
TP Concentration (ug/L)
120
100
80
60
40
20
0
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017

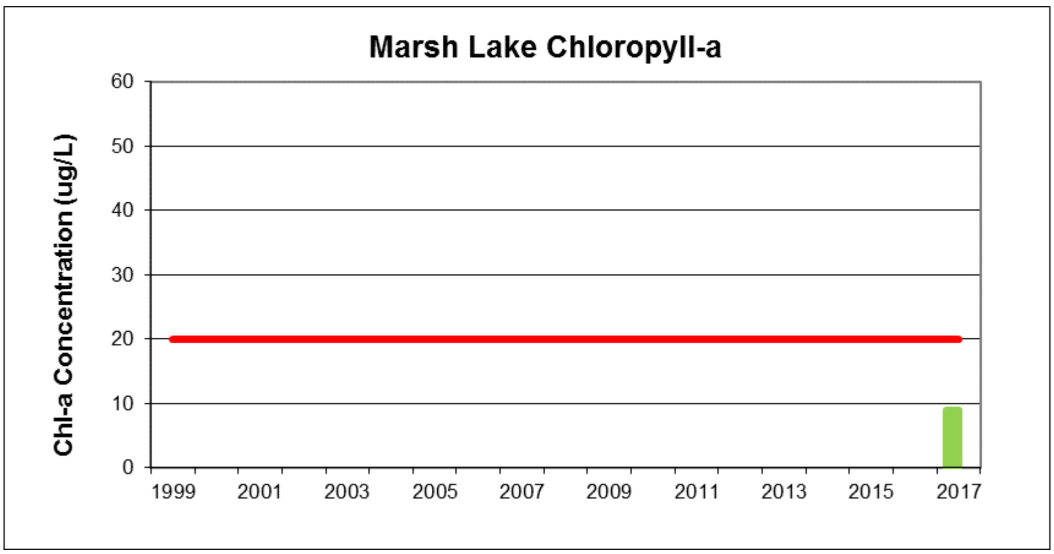


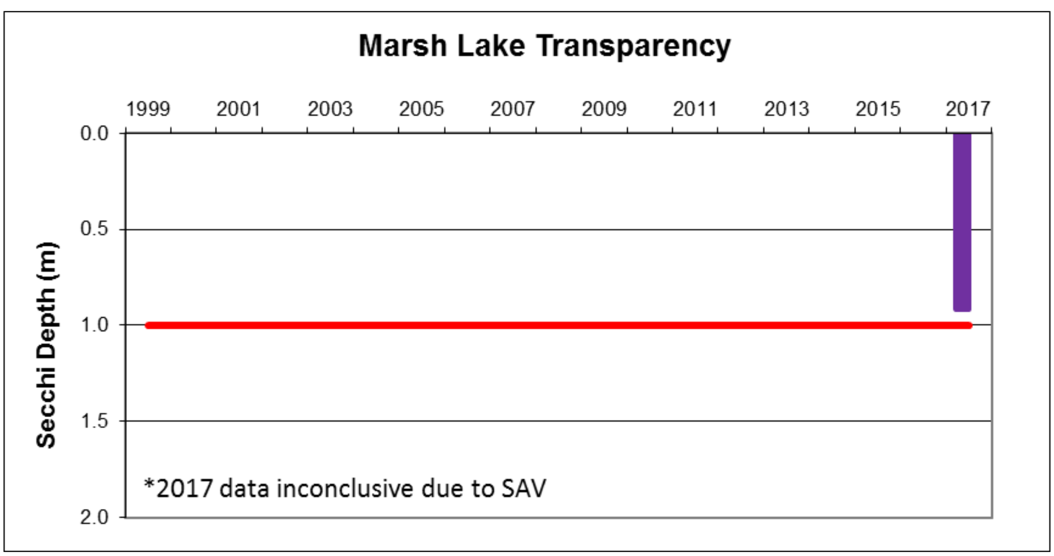
Gerhardt Lake Chloropyll-a
Chl-a Concentration (ug/L)
60
50
40
30
20
10
0
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017

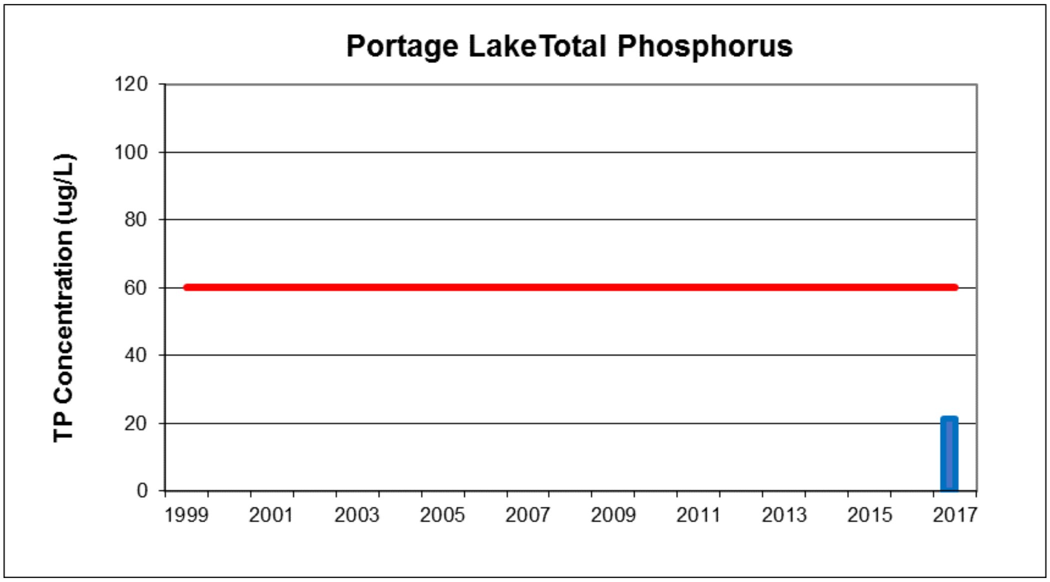


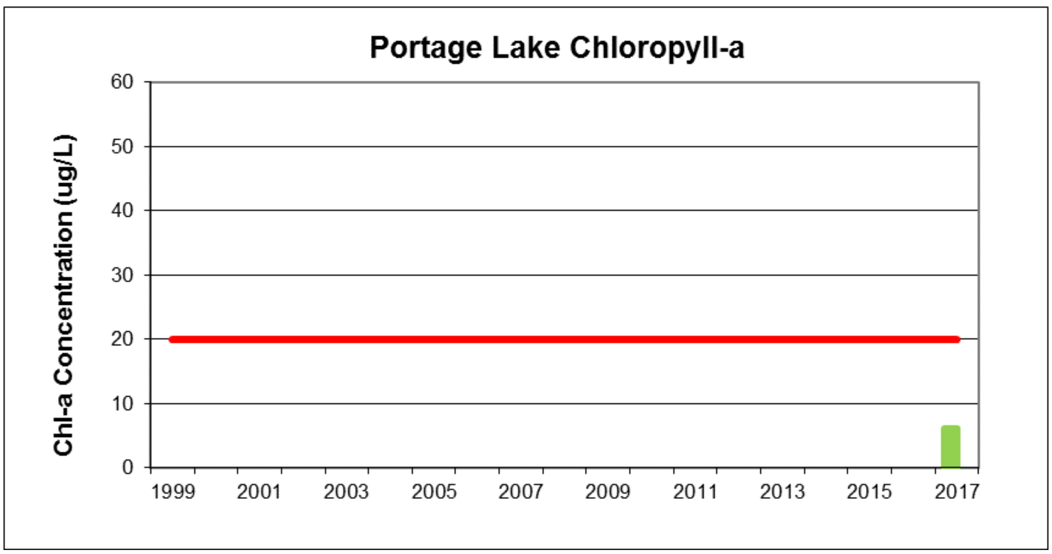
Gerhardt Lake Transparency
Secchi Depth (m)
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
0.0
0.5
1.0
1.5
2.0

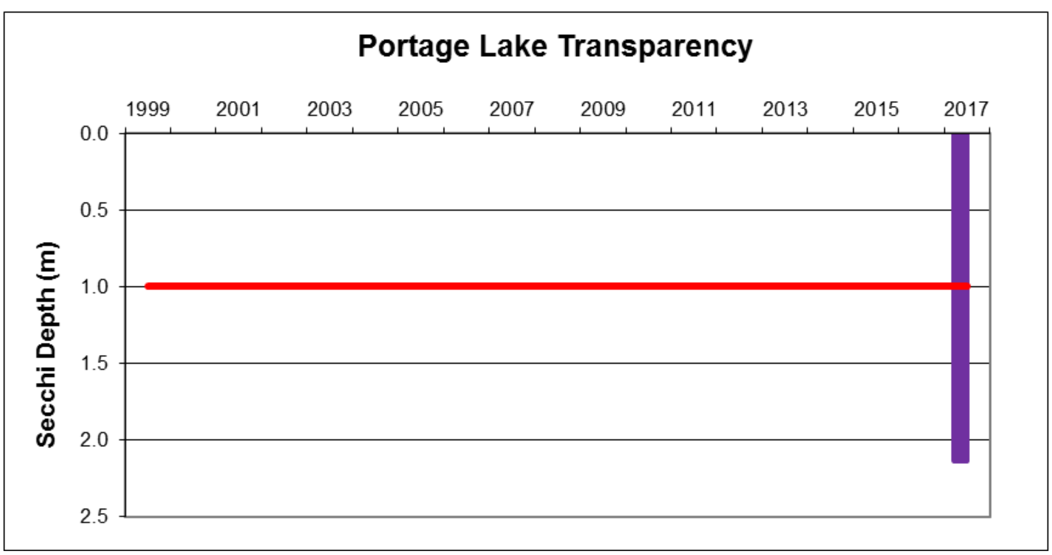

Marsh LakeTotal Phosphorus
TP Concentration (ug/L)
120
100
80
60
40
20
0
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017

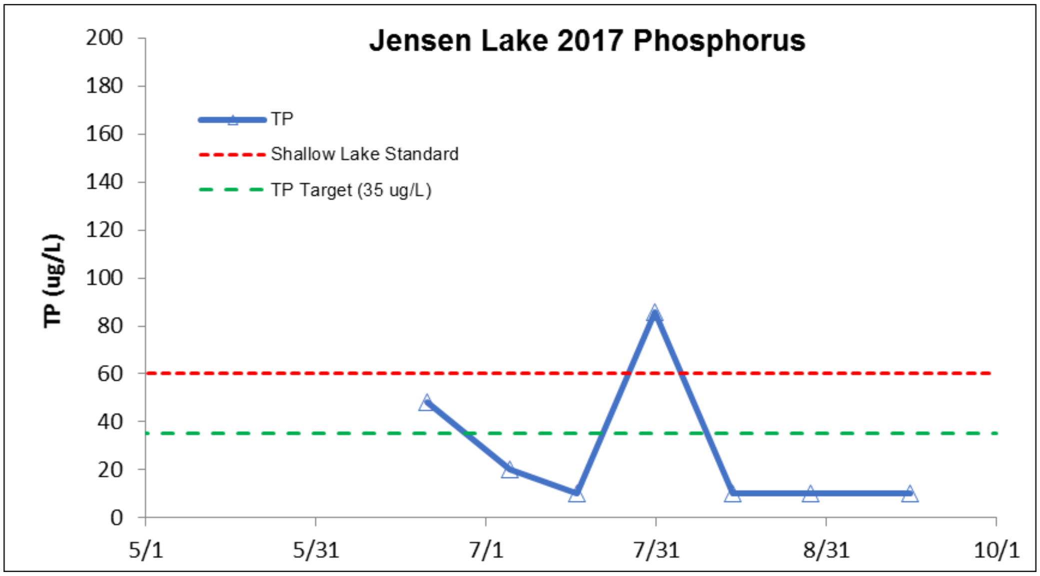

Marsh Lake Chloropyll-a
Chl-a Concentration (ug/L)
60
50
40
30
20
10
0
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017


Marsh Lake Transparency
Secchi Depth (m)
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
0.0
0.5
1.0
1.5
2.0
*2017 data inconclusive due to SAV

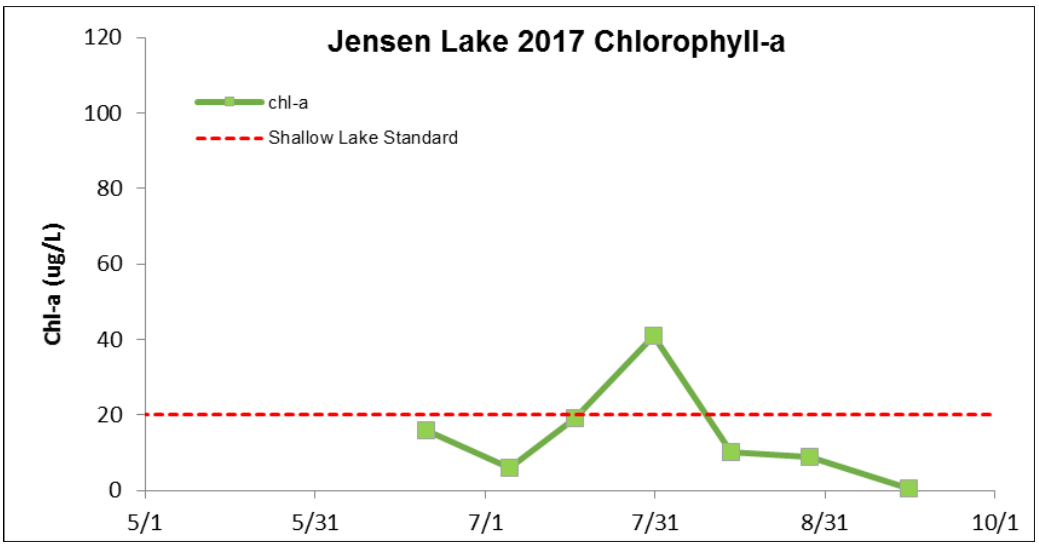

Portage LakeTotal Phosphorus
TP Concentration (ug/L)
120
100
80
60
40
20
0
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017


Portage Lake Chloropyll-a
Chl-a Concentration (ug/L)
60
50
40
30
20
10
0
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017

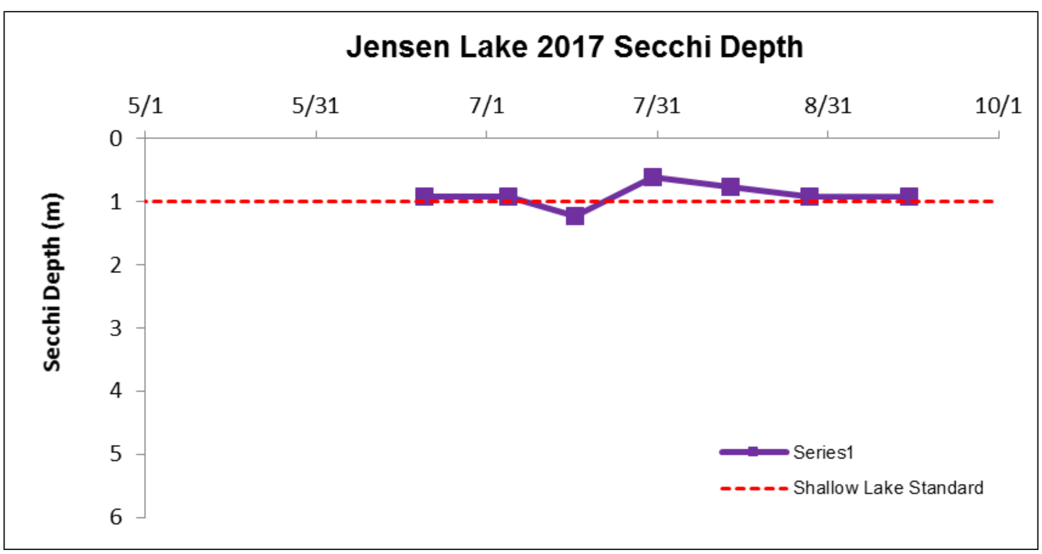

Portage Lake Transparency
Secchi Depth (m)
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
0.0
0.5
1.0
1.5
2.0
2.5



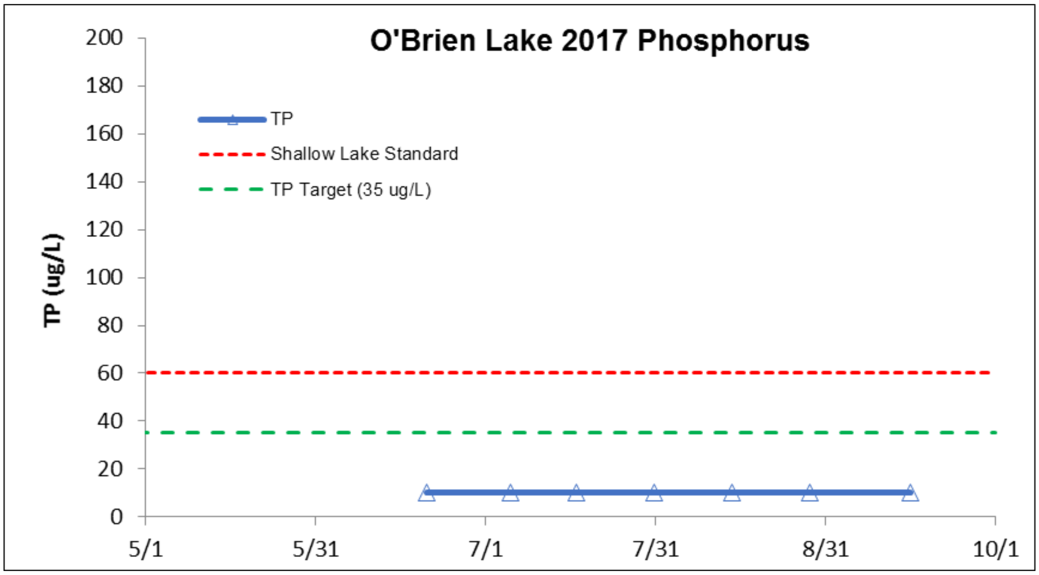
Jensen Lake 2017 Phosphorus
TP (ug/L)
TP
Shallow Lake Standard
TP Target (35 ug/L)
0
20
40
60
80
100
120
140
160
180
200
5/1
5/31
7/1
7/31
8/31
10/1

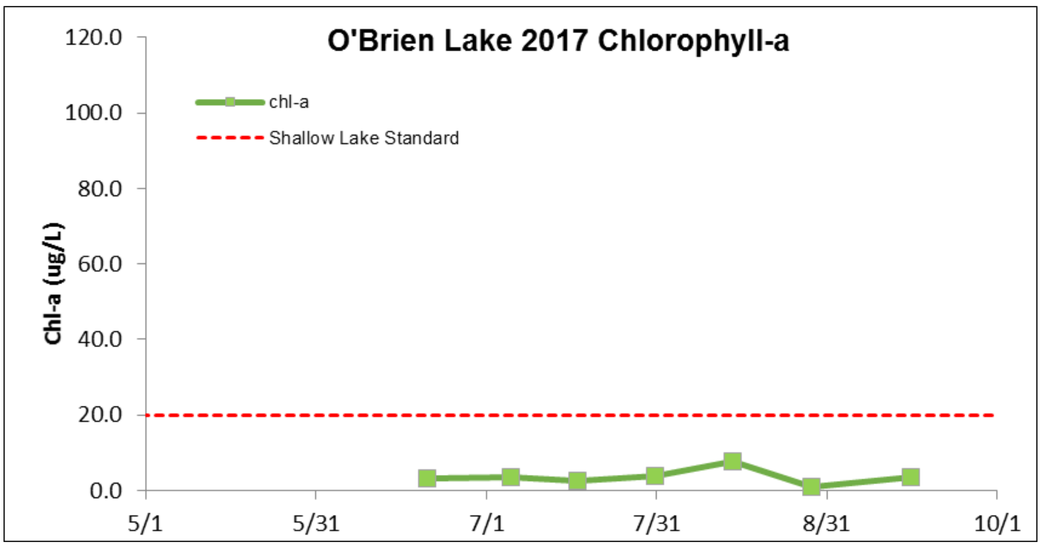


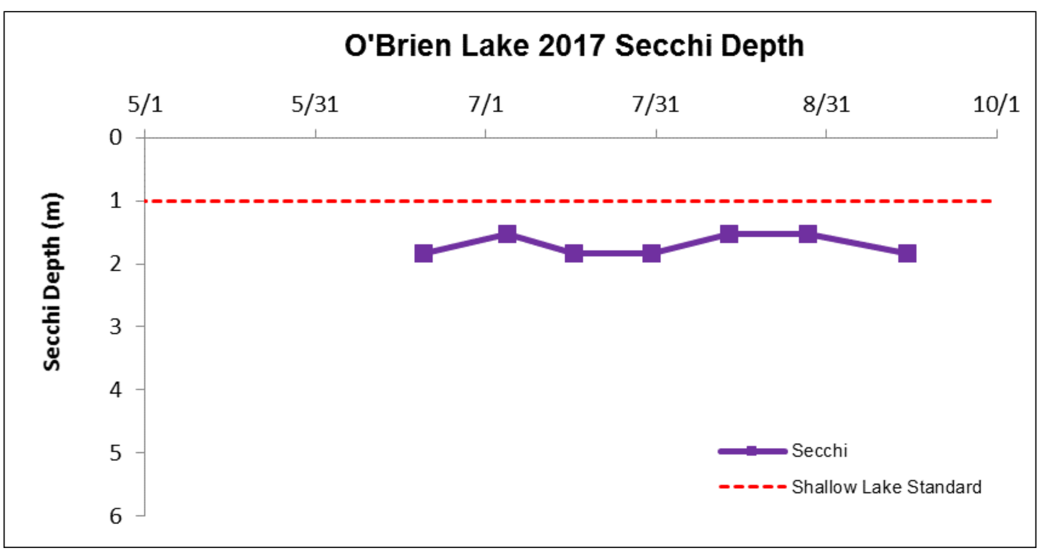
Jensen Lake 2017 Chlorophyll-a
Chl-a (ug/L)
chl-a
Shallow Lake Standard
0
20
40
60
80
100
120
5/1
5/31
7/1
7/31
8/31
10/1

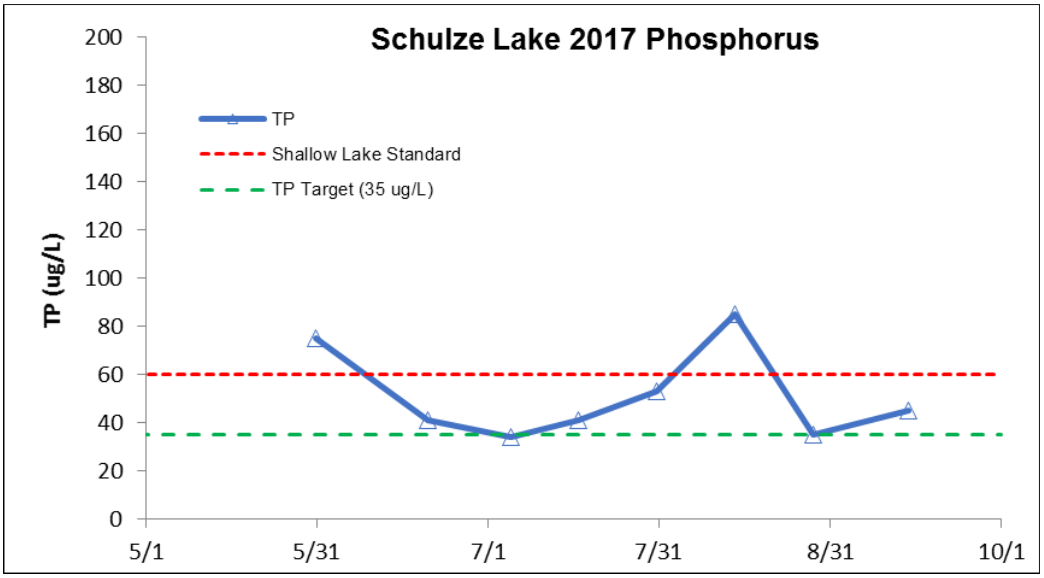


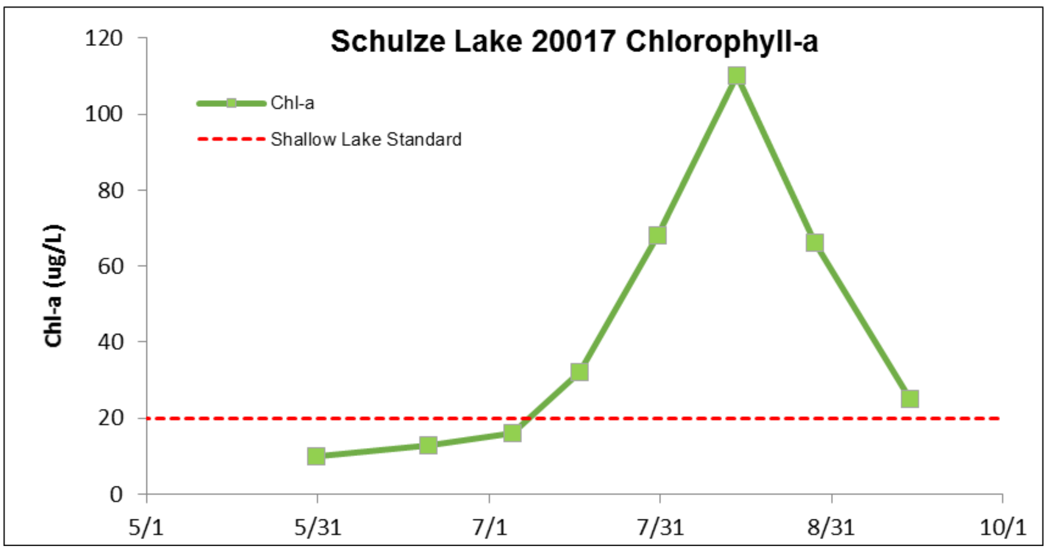
Jensen Lake 2017 Secchi Depth
Secchi Depth (m)
5/1
5/31
7/1
7/31
8/31
10/1
0
1
2
3
4
5
6
Series1
Shallow Lake Standard


O'Brien Lake 2017 Phosphorus
TP
Shallow Lake Standard
TP Target (35 ug/L)
TP (ug/L)
200
180
160
140
120
100
80
60
40
20
0
5/1
5/31
7/1
7/31
8/31
10/1


O'Brien Lake 2017 Chlorophyll-a
chl-a
Shallow Lake Standard
Chl-a (ug/L)
120.0
100.0
80.0
60.0
40.0
20.0
0.0
5/1
5/31
7/1
7/31
8/31
10/1


O'Brien Lake 2017 Secchi Depth
5/1
5/31
7/1
7/31
8/31
10/1
Secchi Depth (m)
0
1
2
3
4
5
6
Secchi
Shallow Lake Standard


Schulze Lake 2017 Phosphorus
TP (ug/L)
TP
Shallow Lake Standard
TP Target (35 ug/L)
0
20
40
60
80
100
120
140
160
180
200
5/1
5/31
7/1
7/31
8/31
10/1


Schulze Lake 20017 Chlorophyll-a
Chl-a (ug/L)
Chl-a
Shallow Lake Standard
0
20
40
60
80
100
120
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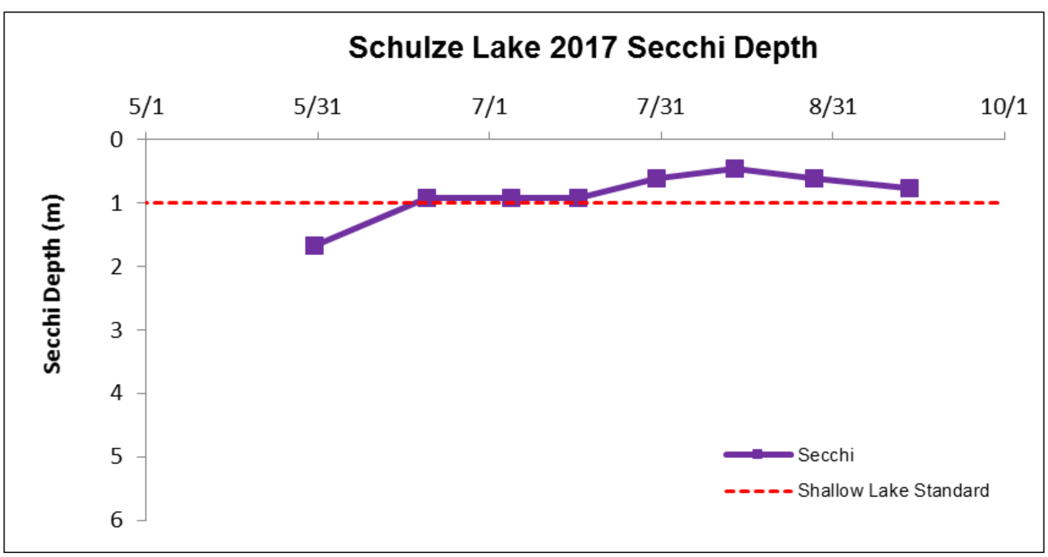
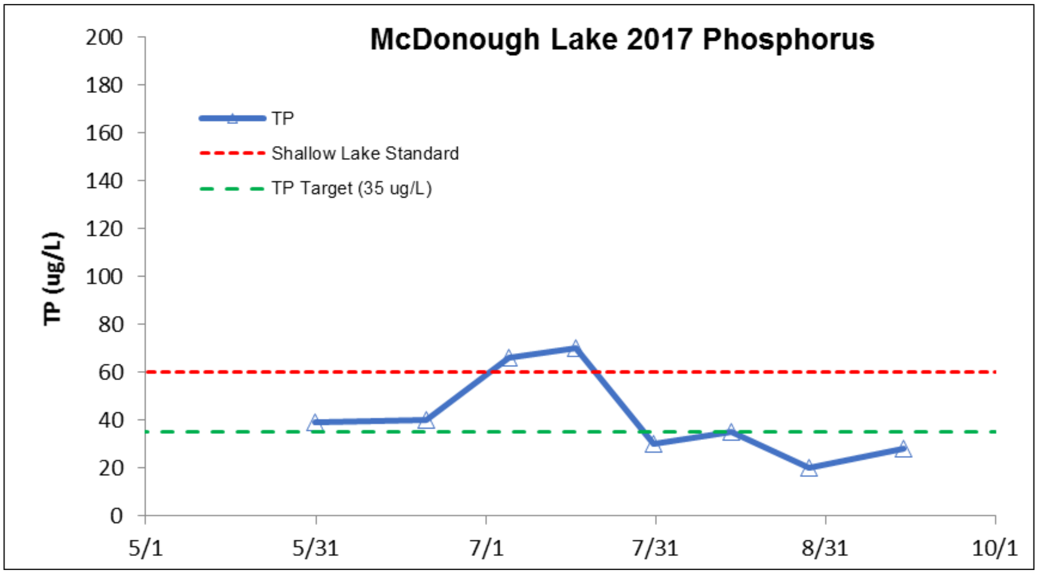
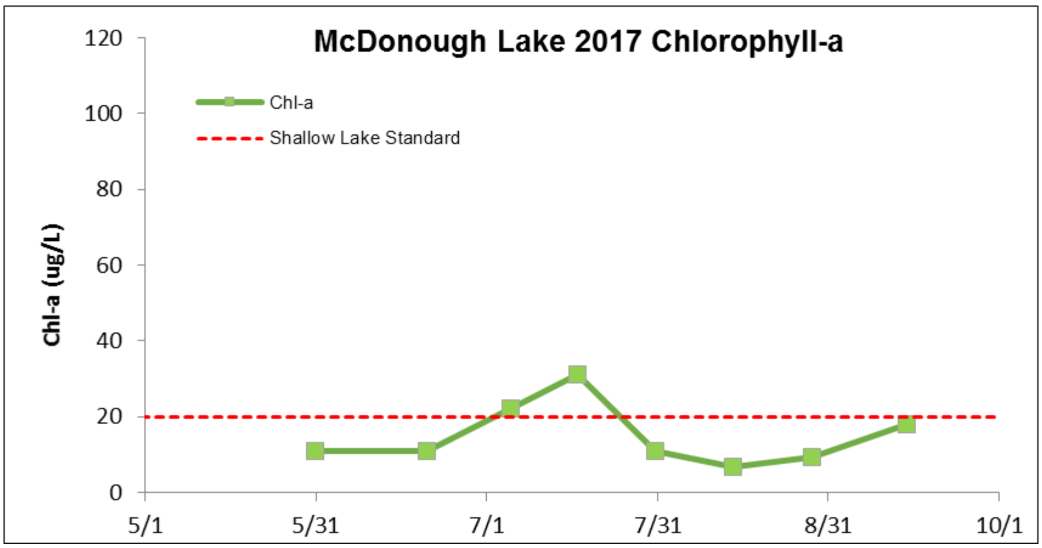
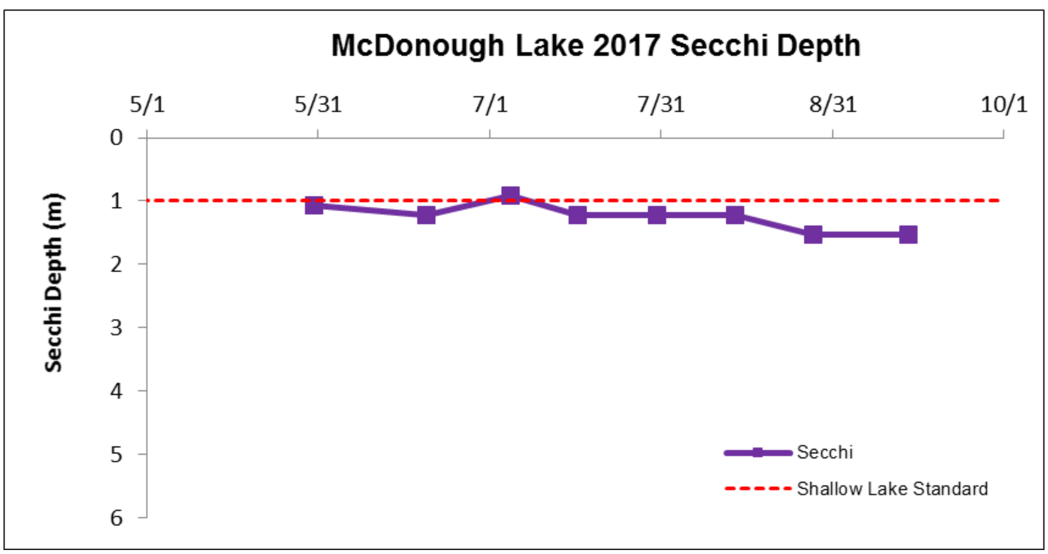
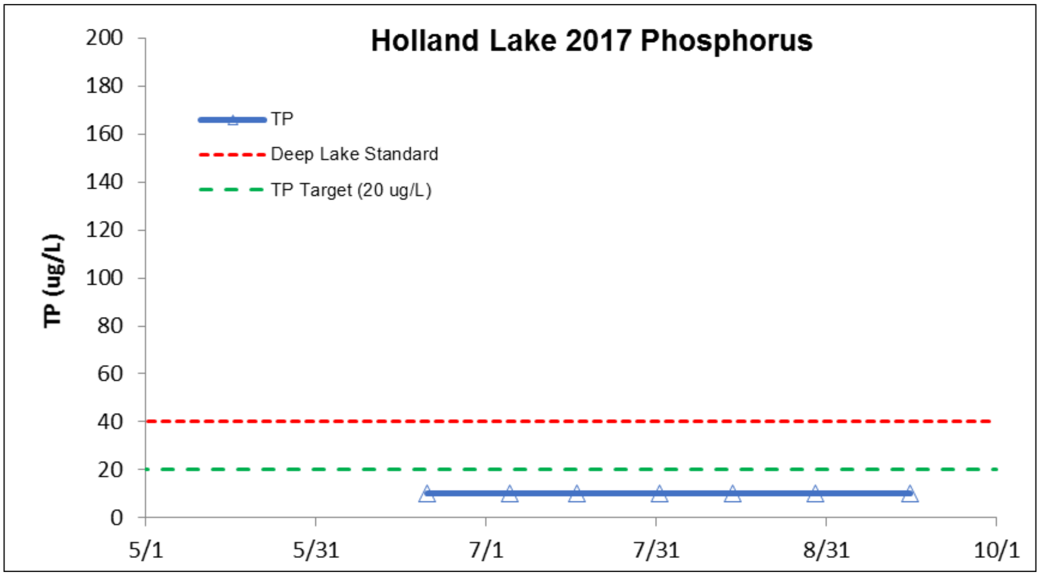
7/1
7/31
8/31
10/1

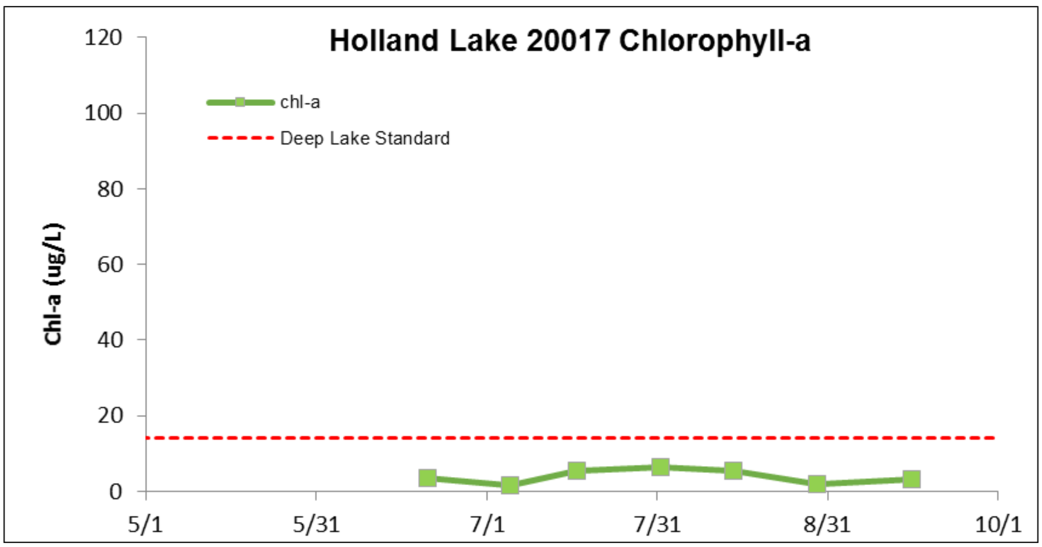

Schulze Lake 2017 Secchi Depth
Secchi Depth (m)
5/1
5/31
7/1
7/31
8/31
10/1
0
1
2
3
4
5
6
Secchi
Shallow Lake Standard

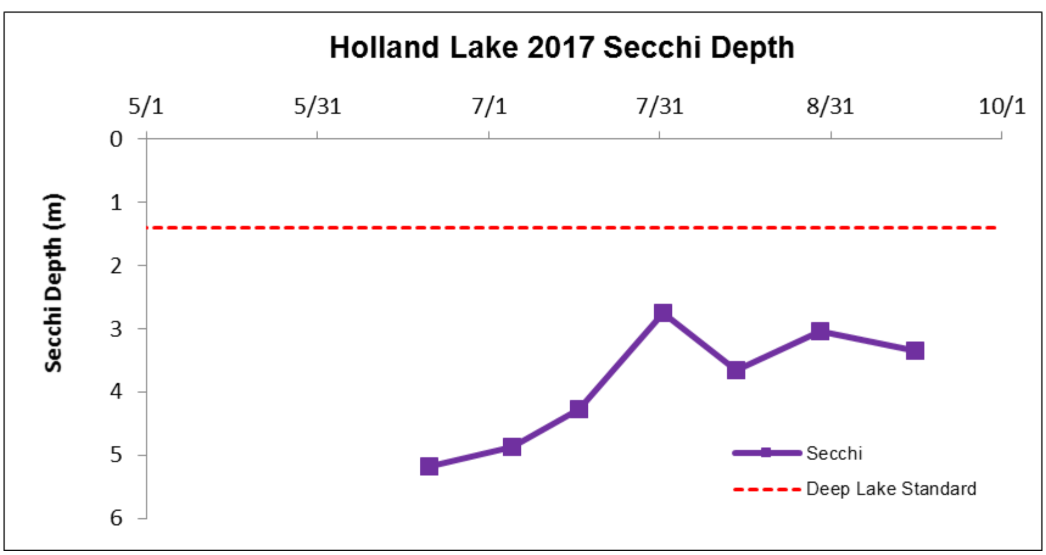

McDonough Lake 2017 Phosphorus
TP (ug/L)
TP
Shallow Lake Standard
TP Target (35 ug/L)
200
180
160
140
120
100
80
60
40
20
0
5/1
5/31
7/1
7/31
8/31
10/1

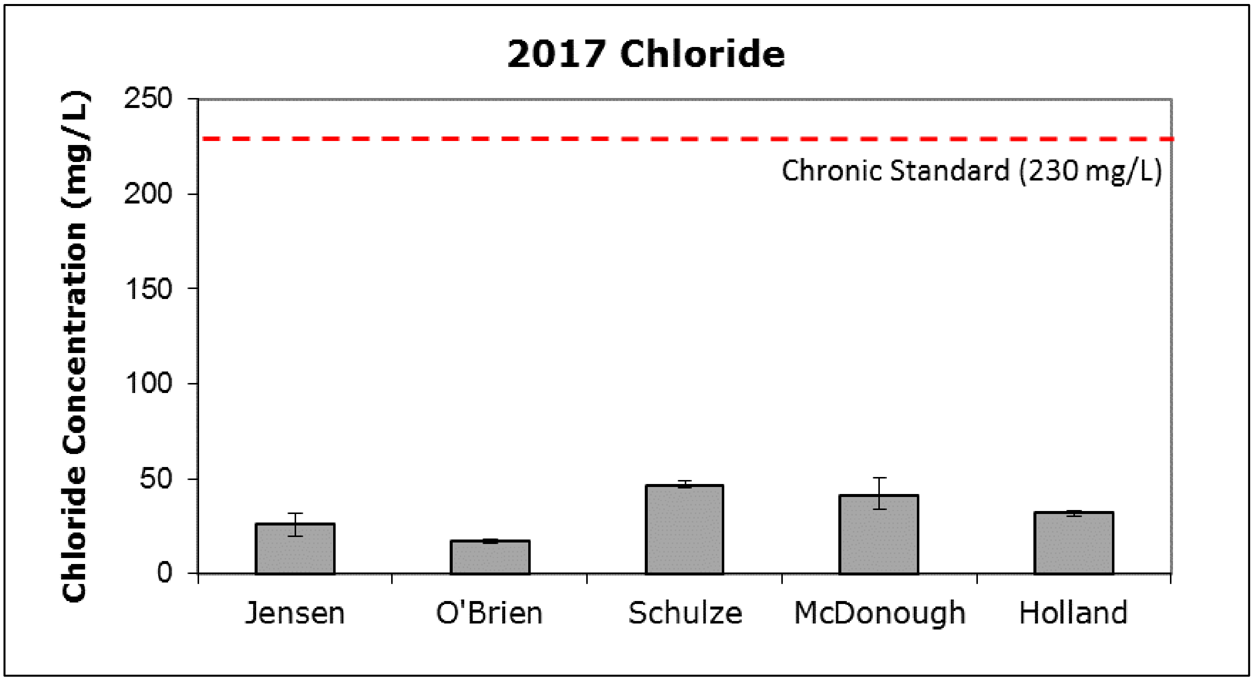

McDonough Lake 2017 Chlorophyll-a
Chl-a (ug/L)
Chl-a
Shallow Lake Standard
120
100
80
60
40
20
0
5/1
5/31
7/1
7/31
8/31
10/1


McDonough Lake 2017 Secchi Depth
Secchi Depth (m)
5/1
5/31
7/1
7/31
8/31
10/1
0
1
2
3
4
5
6
Secchi
Shallow Lake Standard


Holland Lake 2017 Phosphorus
TP (ug/L)
200
180
160
140
120
100
80
60
40
20
0
TP
Deep Lake Standard
TP Target (20 ug/L)
5/1
5/31
7/1
7/31
8/31
10/1


Holland Lake 20017 Chlorophyll-a
Chl-a (ug/L)
120
100
80
60
40
20
0
chl-a
Deep Lake Standard
5/1
5/31
7/1
7/31
8/31
10/1


Holland Lake 2017 Secchi Depth
Secchi Depth (m)
5/1
5/31
7/1
7/31
8/31
10/1
0
1
2
3
4
5
6
Secchi
Deep Lake Standard


2017 Chloride
Chloride Concentration (mg/L)
250
200
150
100
50
0
Chronic Standard (230 mg/L)
Jensen
O'Brien
Schulze
McDonough
Holland

Appendix B: Sediment Analysis Report

Evaluation of Internal Phosphorus Loading and Sediment Characteristics in Lebanon Hills Lakes, Minnesota

2 November, 2017

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OBJECTIVES

Phosphorus (P) is a key nutrient that usually limits primary production in freshwater systems. Increased or excess P loading can lead to cultural eutrophication, degradation of water quality, and development of toxic cyanobacterial blooms (Boström et al. 1982, Carpenter et al. 1998, Smith et al. 1998, Cooke et al. 2005, Elser et al. 2007, Havens 2008). Excessive anthropogenic P loading also leads to various problems, such as loss of oxygen, fish kills, and a loss of biodiversity within the lake (Smith and Schindler 2009). Phosphorus sources can originate from the watershed (i.e. external loading) or from P stored as sediment that is later released and recycled into the water column for uptake by algae (i.e. internal loading; Boström 1984, Jeppesen et al. 2005, Mortimer 1941,1942, Nürnberg et al. 1986; Sondergaard et al. 2001). It is important to quantify external and internal P loading in order to identify important P sources for targeted management strategies.

The objectives of this research were to evaluate the potential for internal P loading from sediments in lakes located in Lebanon Hills Regional Park, Dakota County, Minnesota. Specifically,

1. quantify rates of P release from intact sediment cores under anaerobic conditions and
2. examine sediment physical-textural characteristics biologically-labile (i.e., subject to recycling via Eh, pH, and bacterially-mediated reactions in the sediment; loosely-bound, iron-bound, and labile organic P) P fractions.

APPROACH

Sediment coring stations and gravity coring methodology

Sediment coring stations and numbers of cores collected for analytical purposes are identified in Table 1. Three intact sediment cores were collected from all lakes for determination of rates of P release under anaerobic conditions. Additional sediment cores collected from Gerhardt and Jensen Lakes were sectioned vertically at 2-cm intervals over the upper 6-cm layer to evaluate variations in sediment physical-textural and chemical characteristics. A gravity sediment coring device (Aquatic Research Instruments, Hope ID) equipped with an acrylic core liner (6.5-cm ID and 50-cm length) was used to collect sediment in July, 2017, by Wenck Associates, Inc. The core liners, containing both sediment and overlying water, were immediately sealed using rubber stoppers and stored in a covered container in a cool location until analysis. Additional lake water was collected for incubation with the sediment. Sediment cores were sectioned within 24 hours of collection. Fresh sediment sections were stored in glass jars and refrigerated until analysis.

Rates of phosphorus release from sediment under anaerobic conditions

In the laboratory, sediment cores were carefully drained of overlying water and the upper 10 cm of sediment transferred intact to a smaller acrylic core liner (6.5-cm dia and 20-cm ht) using a core remover tool. Surface water collected from the lake was filtered through a glass fiber filter (Gelman A-E), with 300 mL then siphoned onto the sediment contained in the small acrylic core liner without causing sediment resuspension. Sediment incubation systems consisted of the upper 10-cm of sediment and filtered overlying water contained in acrylic core liners that were sealed with rubber stoppers. They were placed in a darkened environmental chamber and incubated at a constant temperature (20 ^{o}C). The oxidation-reduction environment in the overlying water was controlled by gently bubbling nitrogen (anaerobic) through an air stone placed just above the sediment surface in each system. Bubbling action insured complete mixing of the water column but did not disrupt the sediment. Triplicate sediment incubation systems were prepared for rate determination.

Water samples for soluble reactive P (SRP) were collected from the center of each system using an acid-washed syringe and filtered through a 0.45 µm membrane syringe filter (Nalge). The water volume removed from each system during sampling was replaced by addition of filtered lake water preadjusted to the proper oxidation-reduction condition. These volumes were accurately measured for determination of dilution effects. Soluble reactive P was measured colorimetrically using the ascorbic acid method (APHA 2005). Rates of P release from the sediment (mg/m^2 d) were calculated as the linear change in mass in the overlying water divided by time (days) and the area (m^2) of the incubation core liner. Regression analysis was used to estimate rates over the linear portion of the data.

Sediment chemistry

A known volume of sediment was dried at 105 ^oC for determination of moisture content, wet and dry bulk density, and burned at 550 ^oC for determination of loss-on-ignition organic matter content (Avnimelech et al. 2001, Håkanson and Jansson 2002; Table 2). Phosphorus fractionation was conducted according to Hieltjes and Lijklema (1980), Psenner and Puckso (1988), and Nürnberg (1988) for the determination of ammonium-chloride-extractable P (loosely-bound P), bicarbonate-dithionite-extractable P (i.e., iron-bound P), and sodium hydroxide-extractable P (i.e., aluminum-bound P). A subsample of the sodium hydroxide extract was digested with potassium persulfate to determine nonreactive sodium hydroxide-extractable P (Psenner and Puckso 1988). Labile organic P was calculated as the difference between reactive and nonreactive sodium hydroxide-extractable P.

The loosely-bound and iron-bound P fractions are readily mobilized at the sediment-water interface as a result of anaerobic conditions that lead to desorption of P from sediment and diffusion into the overlying water column (Mortimer 1971, Boström et al. 1982, Boström 1984, Nürnberg 1988; Table 3). The sum of the loosely-bound and iron-bound P fraction represents redox-sensitive P (i.e., the P fraction that is active in P release under anaerobic and reducing conditions; redox-P).

In addition, labile organic P can be converted to soluble P via bacterial mineralization (Jensen and Andersen 1992) or hydrolysis of bacterial polyphosphates to soluble phosphate under anaerobic conditions (Gächter et al. 1988, Gächter and Meyer 1993, Hupfer et al. 1995). The sum of redox-P and labile organic P collectively represent biologically-labile P. This fraction is active in recycling pathways that result in exchanges of phosphate from the sediment to the overlying water column and potential assimilation by algae.

RESULTS AND INTERPRETATION

Sediment phosphorus release rates

Under anaerobic conditions, P mass and concentration increased moderately in the overlying water column over the incubation period (Figure 1 and 2). Overall, anaerobic P release rates were moderate to low, ranging between 0.44 mg/m^2 d (±0.14 standard error, SE) for O'Brian to 1.87 mg/m^2 d (±0.37 SE) for Schultz (Table 4 and Figure 3). Anaerobic diffusive P flux for McDonough and O'Brian sediment was less than 1.0 mg/m^2 d while fluxes were between 1 and 2 mg/m^2 d for the other lakes.

Sediment characteristics in Gerhardt and Jensen Lakes

Both Gerhardt and Jensen Lakes exhibited moderately high moisture content, low wet and dry bulk density, and moderately high organic matter content in the upper 6-cm of sediment (Figure 4). Both lake sediments exhibited a surface maximum in biologically-labile P concentration (Figure 5). Concentrations of biologically-labile P were also relatively high and dominated by labile organic P (Figure 5). Iron-bound P concentrations were lower at 0.265 and 0.134 mg/g in Gerhardt and Jensen Lake sediment, respectively, and represented ~ 17-28% of the biologically-labile P.

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Table 1. Lake sediment sampling stations and numbers of sediment cores collected for determination of rates of phosphorus (P) flux under anaerobic conditions and biologically-labile P fractions (see Table 2).

Lake	Station location	Anaerobic P flux	Sediment characteristics
Gerhardt	central basin	3	1
Holland	central basin	3	
Jensen	central basin	3	1
McDonough	central basin	3	
O'Brian	central basin	3	
Schultz	central basin	3	

Table 2. Sediment physical-textural characteristics, phosphorus species, and metals variable list.

Category	Variable
Physical-textural	Moisture content
	Wet and dry sediment bulk density
	organic matter content
Phosphorus species	Loosely-bound P
	Iron-bound P
	Labile organic P

Table 3. Sediment sequential phosphorus (P) fractionation scheme, extractants used, and definitions of recycling potential.

Variable	Extractant	Recycling Potential
Loosely-bound P	1 M Ammonium Chloride	Biologically labile; Soluble P in interstitial water and adsorbed to $CaCO_3$; Recycled via direct diffusion, eH and pH reactions, and equilibrium processes
Iron-bound P	0.11 M Sodium Bicarbonate-dithionate	Biologically labile; P adsorbed to iron oxyhydroxides (Fe(OOH); Recycled via eH and pH reactions and equilibrium processes
Labile organic P	Persulfate digestion of the NaOH extraction	Biologically labile; Recycled via bacterial mineralization of organic P and mobilization of polyphosphates stored in cells

Table 4. Mean rates of phosphorus (P) release under anaerobic conditions (n = 3) for intact sediment cores collected in various lakes in the Lebanon Hills Regional Park.

Lake	Anaerobic diffusive P flux	
	(mg/m^2 d)	(SE)
Gerhardt	1.64	0.17
Holland	1.50	0.36
Jensen	1.13	0.43
McDonough	0.63	0.26
O'Brian	0.44	0.14
Schultz	1.87	0.37

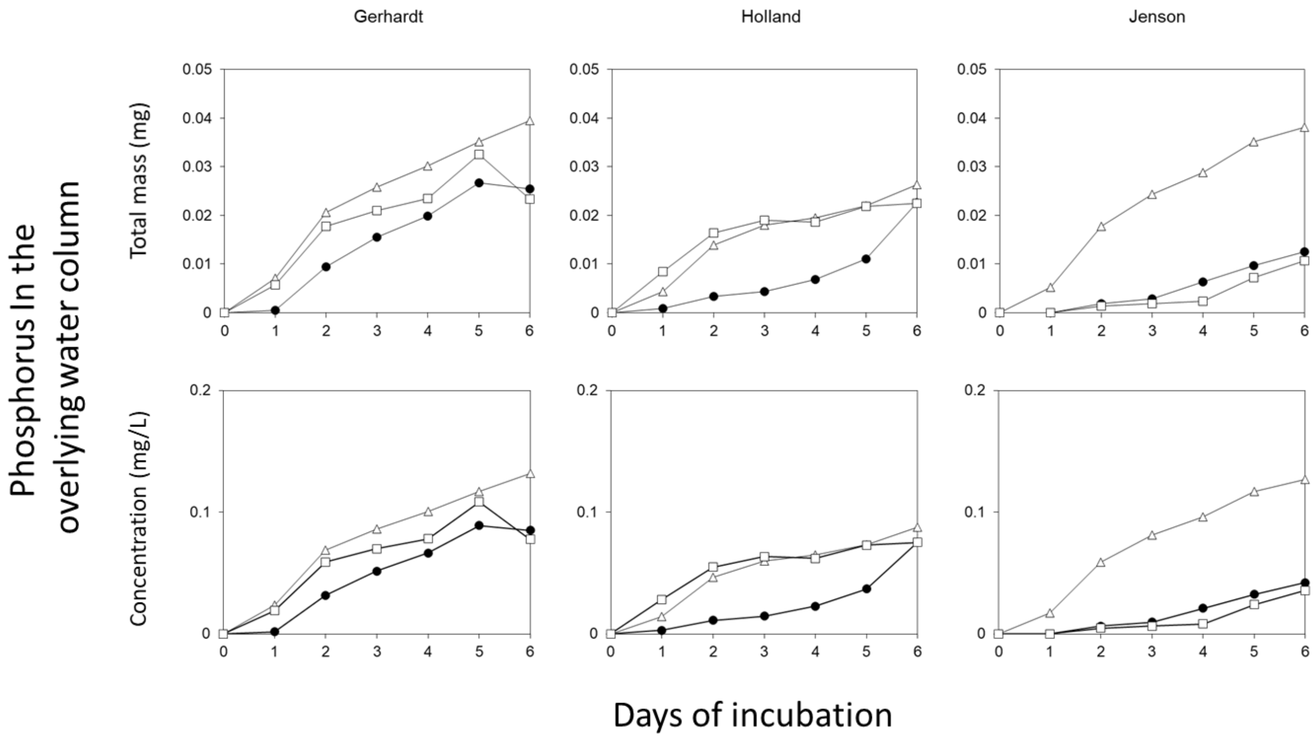


Figure 1. Changes in soluble reactive phosphorus mass and concentration in the overlying water column under anaerobic conditions versus time for sediment cores collected Gerhardt, Holland, and Jensen Lakes.

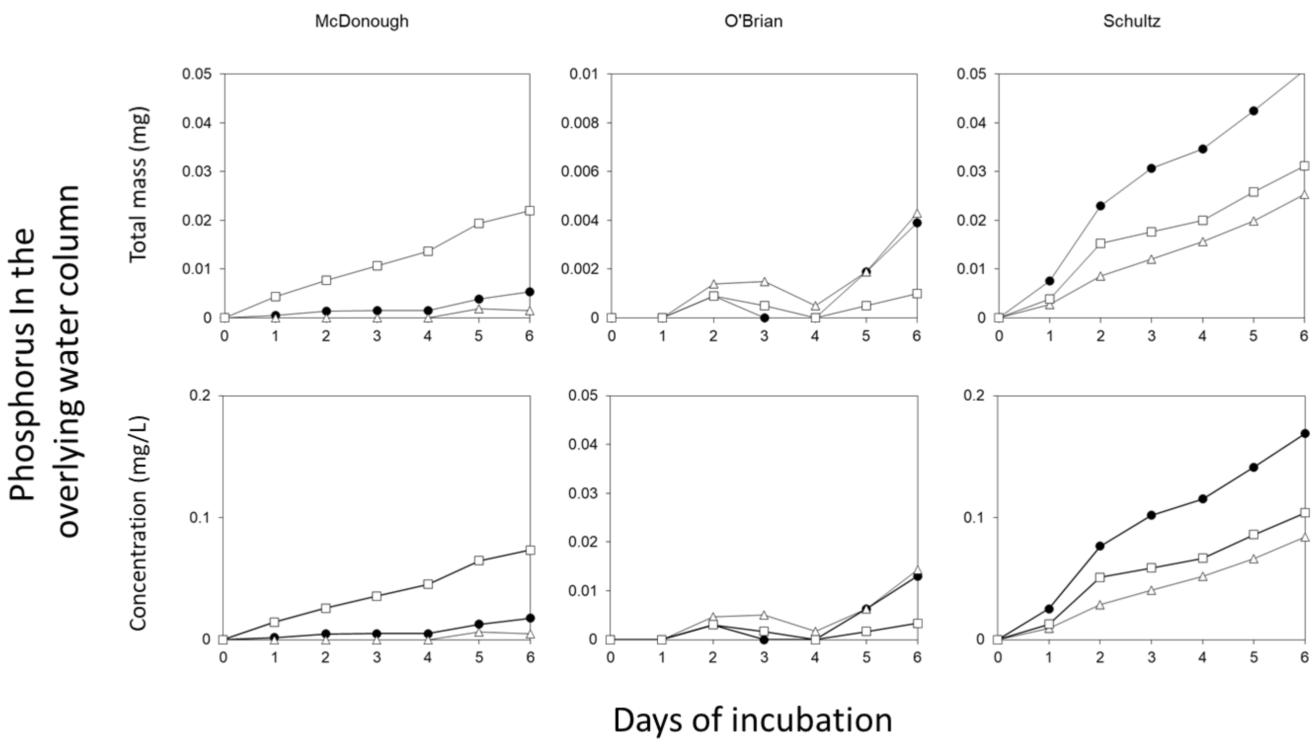


Figure 2. Changes in soluble reactive phosphorus mass and concentration in the overlying water column under anaerobic conditions versus time for sediment cores collected McDonough, O'Brian, and Shultz Lakes.

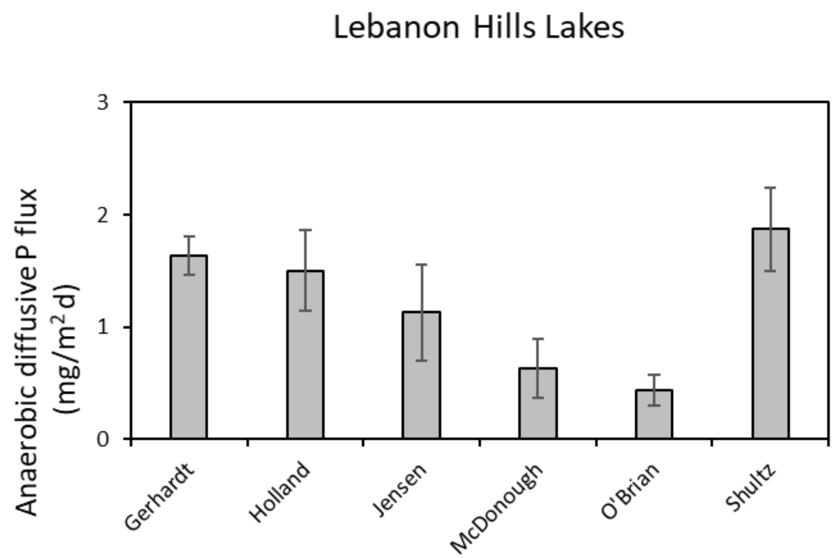


Figure 3. A comparison of mean rates of diffusive P flux from sediment under anaerobic conditions. Vertical lines represent ± 1 standard error.

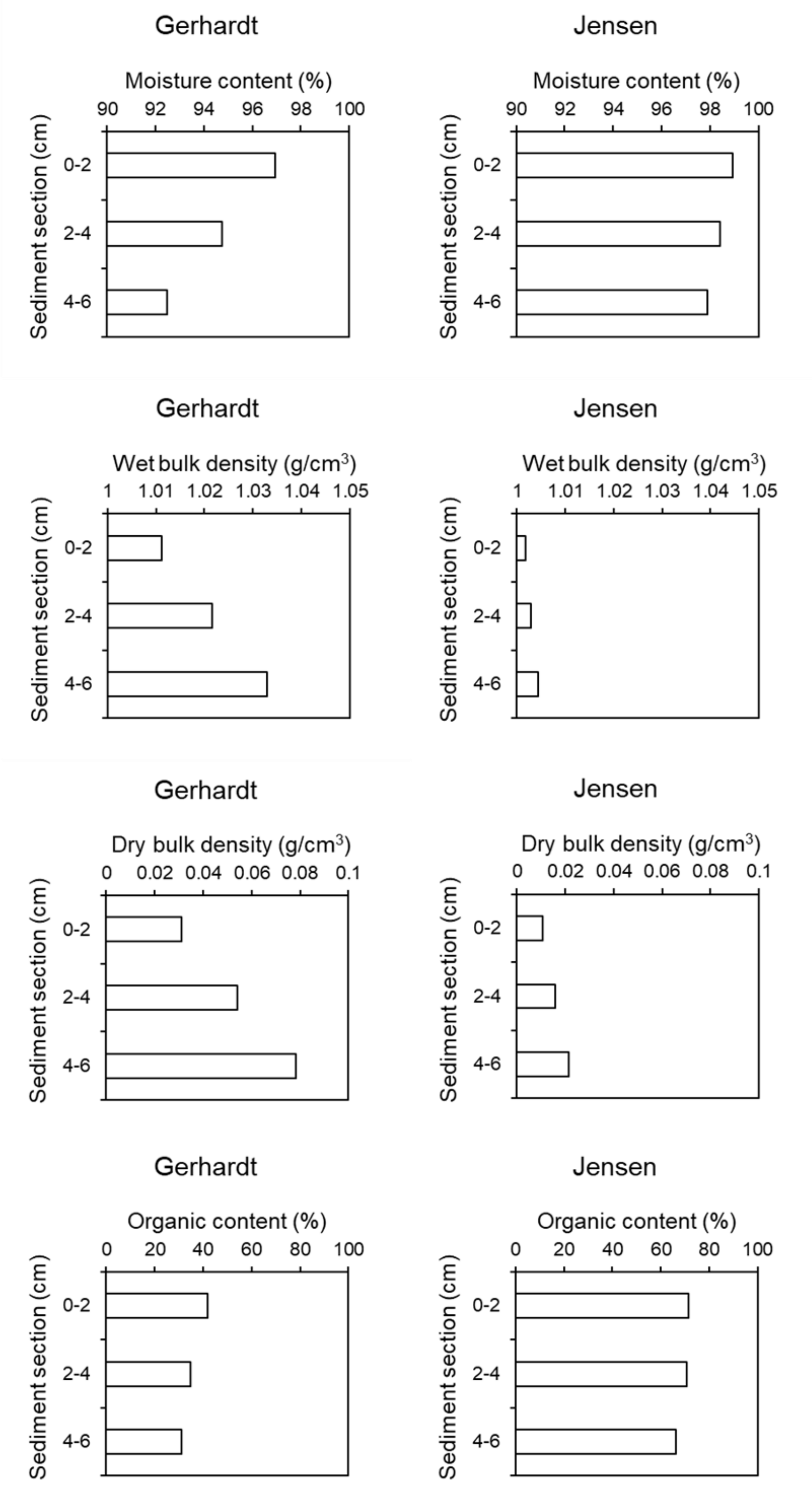


Figure 4. Vertical variations in moisture content, organic matter content, and wet and dry bulk density for sediment cores collected from Gerhardt and Jensen Lakes in Lebanon Hills Regional Park.

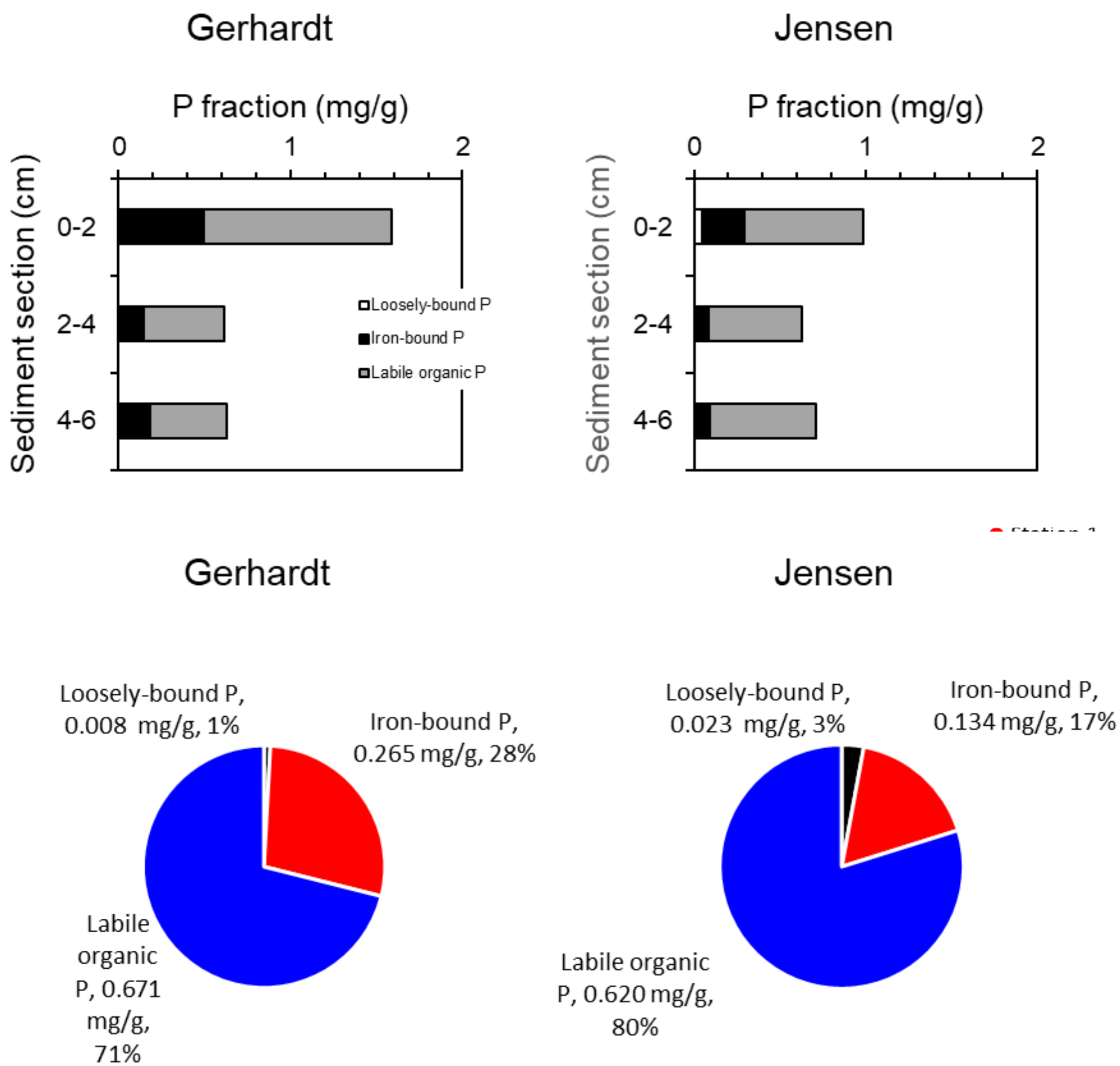


Figure 5. Vertical variations (upper panels) and pie charts (lower panels) showing the composition of biologically-labile phosphorus for sediment cores collected from Gerhardt and Jensen Lakes in Lebanon Hills Regional Park.

Appendix C: Sample Plan

Technical Memo

WENCK ASSOCIATES

Responsive partner.
Exceptional outcomes.

To: Mike Behan, Dakota County Environmental Services

From: Jeff Strom and Jeff Madejczyk, Wenck Associates

Date: July 12, 2017

Subject: Lebanon Hills Region Park Water Resource Sample Plan

1. Background

Wenck Associates, Inc. (Wenck) is currently working with Dakota County (County) to perform a subwatershed assessment for the Lebanon Hills Regional Park (LHRP). As part of this project, the County has requested a review of existing water resources data and information throughout the LHRP system to identify potential data gaps and develop a work plan to address these data gaps. To date, Wenck has reviewed the following data and information pertaining to water resources within LHRP and the surrounding cities draining to the park:

- 2006 Lebanon Hills Stormwater Management Plan
- 2016 Aquatic Plant Point-Intercept Surveys for Selected Dakota County Parks Lakes
- 2016 Potential for P-Release, Curlyleaf Pondweed, and Eurasian Watermilfoil Growth in Dakota County Parks Lakes Based on Lake Sedimentation Characteristics
- Water quality data available in MPCA's EQuIS database for all lakes in LHRP
- Fisheries data for all lakes in LHRP available on DNR Lakfinder website
- Lake level data for all lakes in LHRP available on DNR Lakefinder website
- Wetland Health Evaluation Program (WHEP) monitoring results for wetland sites within LHRP and surrounding cities draining to LHRP

Based on our review of the above documents and studies we have concluded that the existing baseline data set is very limited in terms of its scope and description of the water resources within LHRP and contributing watershed. We recommend that the County begin collecting, or work toward collecting the following baseline data/information to further assess resources within LHRP:

- Water quality and lake level
- Fisheries assessments/surveys
- Wetland assessments/surveys
- Identify stream and gully erosion

We believe collecting these data and information will help the County move toward a more holistic approach in assessing, evaluating, tracking, and managing water resources throughout the LHRP. The following sections of this memo outline methodologies and an initial plan & strategy to collect the data and information outlined above.

2. Lake Water Quality and Lake Level

Based on our initial data review, only six lakes (Jensen, Schulze, O'Brien, McDonough, Gerhardt, and Holland) within LHRP have been monitored for water quality in the most recent 10 years. Of these lakes, only four lakes (Jensen, O'Brien, McDonough, and Holland) have been monitored for total phosphorus (TP) and chlorophyll-a (Chl-a) and these parameters have not been collected since 2008. The County identified five priority lakes within the scope of work for the subwatershed assessment, including McDonough, Schultz, O'Brien, Jensen, and Holland. Lake water quality protection is a key component of the subwatershed assessment including development of management goals. Therefore we recommend that the County perform intensive lake water quality monitoring in 2017 on the priority lakes to be included in the LHRP subwatershed assessment (Figure 1). Table 1 summarizes the recommended water quality monitoring parameters, depth, and frequency for the LHRP priority lakes.

Table 1: Proposed 2017 intensive water quality monitoring for LHRP priority lakes.

<table>
<tr><th>Lake Name</th><th>Lake Type</th><th>Field Parameters</th><th>Lab Parameters</th><th>Sample Frequency</th></tr>
<tr><td>McDonough</td><td rowspan="4">Shallow</td><td rowspan="4">Surface and one meter depth profile: Secchi (surface), Temperature, Dissolved Oxygen</td><td rowspan="4">Surface samples: TP, ortho-P, Chl-a, TSS, Chloride, TKN, nitrate+nitrite</td><td rowspan="6">Approximately 2X per month or once every two weeks from June through September</td></tr>
<tr><td>Schultz</td></tr>
<tr><td>O'Brien</td></tr>
<tr><td>Jensen</td></tr>
<tr><td rowspan="2">Holland</td><td rowspan="2">Deep</td><td rowspan="2">Surface and one meter depth profile: Secchi (surface), Temperature, Dissolved Oxygen</td><td>Surface samples: TP, ortho-P, Chl-a, TSS, Chloride, TKN, nitrate+nitrite</td></tr>
<tr><td>Deep samples (approximately one meter from bottom): TP, ortho-P, Chloride</td></tr>
</table>

In addition to the priority lakes, we have identified five additional lakes and ponds for less intensive water quality monitoring in 2017 (Figure 1 and Table 2). These basins are all located upstream of the LHRP priority lakes and were selected based on results of historic monitoring and surveys and their potential influence on downstream lakes in LHRP. Table 2 summarizes the recommended water quality monitoring parameters, depth and frequency for the non-priority lakes, ponds, and wetlands.

Table 2: Additional lake/pond water quality monitoring for 2017.

<table>
<tr><th>Lake/Pond Name</th><th>Lake/Pond Type</th><th>Field Parameters</th><th>Lab Parameters</th><th>Sample Frequency</th></tr>
<tr><td>Marsh Lake</td><td rowspan="5">Shallow</td><td rowspan="5">Surface and bottom measurement: Secchi (surface), Temperature, Dissolved Oxygen</td><td rowspan="5">Surface samples: TP, ortho-P, Chl-a, TSS, TKN</td><td rowspan="5">Approximately 1X per month from June through September</td></tr>
<tr><td>Portage Lake</td></tr>
<tr><td>Gerhardt Lake</td></tr>
<tr><td>L26-3-4.4 (pond)</td></tr>
<tr><td>Valleywood Golf Course pond</td></tr>
</table>

One of the major issues/concerns highlighted in the LHRP Master Plan is the impact stormwater runoff has on lake level fluctuation and bounce throughout the park. Large lake level fluctuations can have significant impacts on lake hydrology, internal loading, shoreline vegetation and erosion, and the lake's fish and plant communities. Based on our review of the data there is no recent lake level information for the lakes within the LHRP. We recommend that lake level staff gauges be installed in 2017, with lake water levels recorded at least once every two weeks. Staff gages and lake water elevations should be surveyed at the time of installation and removal of the staff gages each season.

3. Fisheries Assessments/Surveys

The aquatic biotic community of a lake can a specific and often significant influence on the water quality within a lake. Top down control by biotic communities (i.e. fish and invertebrates) is extremely important in maintaining the health and ecosystem services of both deep and shallow lakes. Trophic cascades occur when predators suppress the abundance or alter the behavior of their prey, thereby releasing the next lower trophic level (their prey's prey) from predation, resulting in altering abundances and biomass across trophic levels. This cascading effect is often more prominent in shallow lake systems and can have profound influences on the health of the ecosystem. For example, overabundance of certain fish species such as common carp, bullheads, and fathead minnows can have a significant impact on water quality and the lake's vegetation, aquatic invertebrate, and zooplankton communities. Thus, sampling and assessing the fish communities of the lakes throughout LHRP will be a key piece to understand potential influencing factors on lake water quality, as well as developing protection and management goals and priorities for each lake.

Though similar fish species often exist within shallow and deep lakes, how these communities are sampled has varied among resource management groups (i.e. Minnesota DNR (MnDNR), university researchers, etc.). Historically MnDNR has surveyed game fish populations in deep lakes using standardized trap and gill net survey methods (Schlagenhaft 1993). Recently, the MnDNR has begun implementing methods to capture, identify, and evaluate more non-game type species (i.e. darter species, shiner species) in deep lakes through nearshore backpack electrofishing and beach seining efforts (here after: nearshore surveys). Historically, the MnDNR has done very little to assess and manage fish communities in shallow lakes throughout the state due to the boom/bust nature of their fishery. Although historical fish community surveys of shallow lakes has been limited, recent efforts by the MnDNR and local St. Thomas University (among others) have identified the importance of fisheries in shallow lake management. Thus, these groups have begun assessing, developing, and implementing shallow lake-specific techniques that use slightly different sampling gear and protocols for fish community surveys compared to deep lakes.

Based on our review of DNR Lakefinder, Holland (2013) and McDonough (2015) are the only lakes within LHRP with recent DNR fisheries assessments. We strongly recommend that Dakota County begin sampling and assessing the fish communities of selected lakes throughout LHRP to provide baseline data of the fish community. The baseline datasets will be used to ensure protection of water quality and vegetation communities and to development management goals and priorities for each lake. Fish surveys for shallow lakes should follow the methods that are currently being developed by the MnDNR and St. Thomas University, while fish surveys on deep lakes would utilize a combination of standardized and near shore sample methods utilized by the MnDNR. Wenck will provide the County a list of priority lakes for fish surveys and other fish sampling recommendations once the water quality data collection and watershed models have been completed and reviewed.

4. Wetland Assessments/Surveys

Various tools and indices exist to assess wetlands. The Minnesota Pollution Control Agency (MPCA) developed the Rapid Floristic Quality Assessment (RFQA) as a tool to measure and quantify the health of a wetland (MPCA 2014). The RFQA metrics were modeled to demonstrate a biological response to anthropogenic impacts along the Biological Condition Gradient. Conditions are scored for each community type, then each community type within a wetland site is area weighted to determine overall assessment area (AA) score for that wetland. RFQA scores range from 1 (best condition) to 4 (worst condition). The RFQA assigns a score to a wetland based on plant species richness (number of species), abundance (percent cover), and a species score of Conservatism (C-score). In weighting species this way, the RFQA can distinguish between wetlands that have a diversity of native vs. non-native species and between wetlands that have a diversity of rare wetland species vs. common wetland species.

Another wetland assessment tool developed by the MPCA is the Wetland Health Evaluation Program (WHEP). The WHEP is a citizen based monitoring program that allows a rudimentary assessment and quantification of a wetland's vegetation and macroinvertebrate community. WHEP utilizes a similar sampling and scoring framework as the RFQA, however the vegetation scoring tool is less detailed and quantitative in overall assessment. WHEP does score the macroinvertebrate community within the wetland which is a parameter the RFQA does not evaluate.

Dakota County began sponsoring the WHEP in 1997. Since then, approximately 181 wetlands have been monitored throughout the County, seven of which are located within LHRP and its watershed (Figure 1). Table 3 provides a summary of WEHP results for five wetlands located in LHRP and two wetlands located outside the park but within the park's watershed. In general, wetlands within the park have shown a wide range of scores and none of the sites have sufficient data to evaluate long-term trends.

We feel the WHEP provides a useful tool to assess and track wetlands in LHRP and recommend the County expand the program to include more wetland sites throughout the park and continue monitoring the existing sites within to evaluate long-term trends. The County should also consider assessing certain wetlands within LHRP using the RFQA tool described above. The RFQA provides more quantitative scoring of the wetland's vegetation community and therefore could be used to assess high priority wetlands in the park. The RFQA could also provide a useful tool for evaluating effectiveness of wetland restoration projects as they are completed throughout the park. Wenck will provide the County a potential list of wetlands that should be considered for the WHEP and/or RFQA once the water quality data collection and watershed models have been completed and reviewed.

Table 3: Summary of WHEP results for wetlands in LHRP and its watershed.

Site ID and Description	Year(s) monitored	Average Invertebrate Score	Average Invertebrate Score Description	Average Vegetation Score	Average Vegetation Score Description
E27 (Thomas Woods Site)	2009	18	Moderate	21	Moderate

LH1 (Lilypad Pond)	2000, 2002	27	Excellent	31	Excellent
E29 (Lily Pond)	2010	12	Poor	27	Excellent
DC2 (Buck Pond)	2015	10	Poor	13	Poor
E38 (Gerhardt Lake)	2014	24	Excellent	19	Moderate
R5 (Wilde Lake)	2001, 2002	22	Moderate	17	Moderate
AV20 (Valleywood Golf Course)	2013-2015	20	Moderate	14	Poor

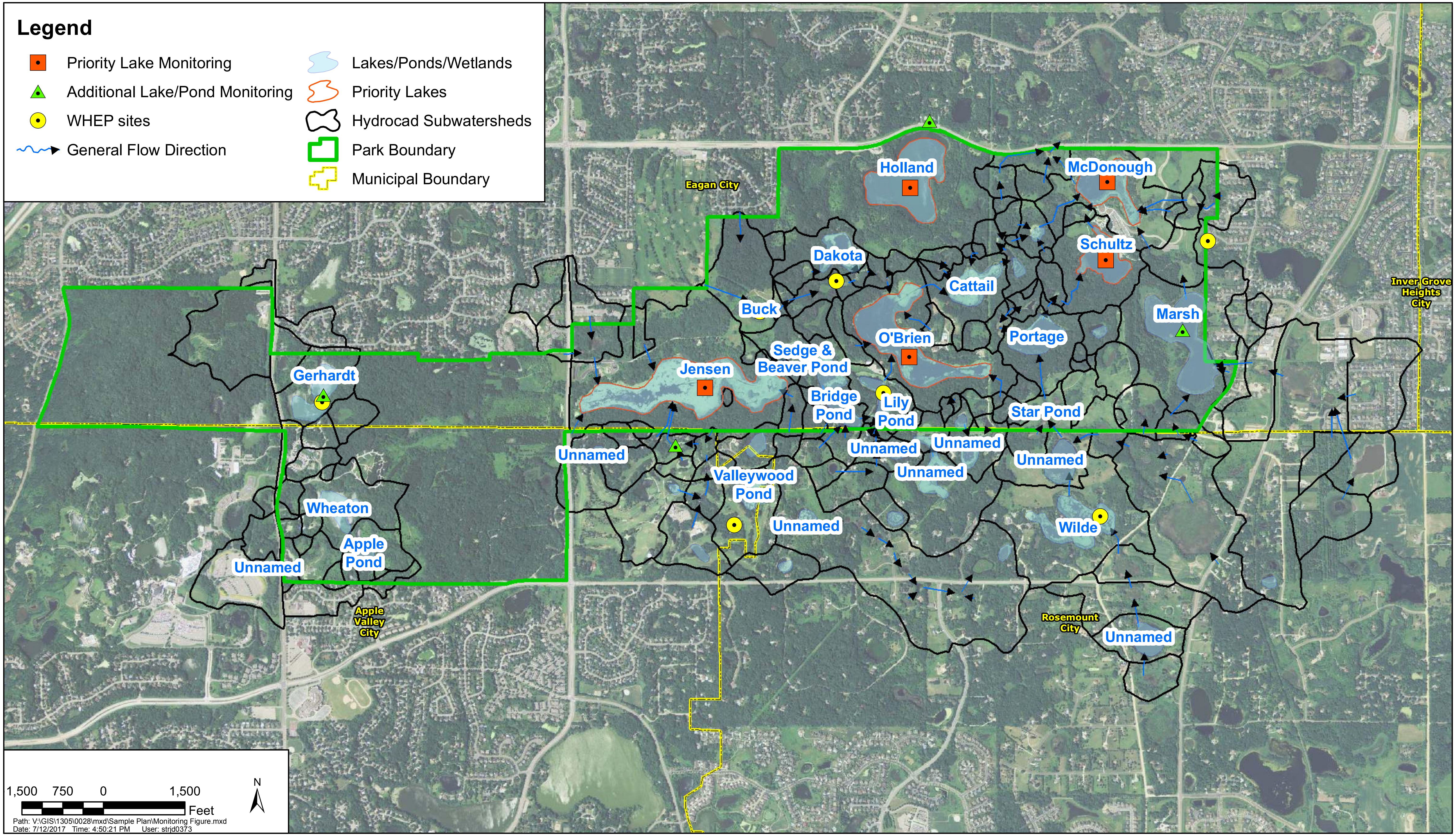
5. Identify Stream and Gully Erosion

Based on discussion with County staff, stream and gully erosion is a major concern in LHRP. To date, there have been no surveys or data collected to assess the amount of streambank and gully erosion within LHRP. The water quality models currently being developed for the LHRP subwatershed assessment are focused primarily on TSS and TP loading from urban sources and therefore may not accurately account for loading from stream and gully erosion within the park itself. Stream Power Index (SPI) is a GIS exercise that calculates the erosive power of overland flow which can be used to help identify potential gully flow erosion "hot spots". SPI takes into account both local slope geometry and site location in the landscape and is calculated in GIS according to the following equation:

$$SPI = \ln (A * Slope)$$

Where A is catchment area (flow accumulation). As catchment area and slope gradient increase, flow velocities and the amount of water contributed by upslope areas also increase leading to higher erosion potential and SPI values.

Wenck used available lidar data to calculate SPI throughout the entire LHRP system, however SPI analysis for this memo focused on areas near the five priority lakes since erosion from these areas are more likely to effectively deliver sediment to the lakes. Figure 2 shows lidar contours throughout LHRP while Figure 3 shows several potential priority gully erosion hot spots near the priority lakes. These priority areas were determined based on overlaying the SPI layer and lidar contours to identify gully features with high SPI values. We recommend the County perform site visits to verify if the priority areas are experiencing erosion and should be targeted for slope stabilization and/or other BMPs. Wenck will also coordinate with the County to supply the GIS files displayed in Figures 2 and 3 and help develop appropriate protocol to assess and quantify erosion at these sites or other sites throughout the park.



DAKOTA COUNTY ENVIRONMENTAL SERVICES

Lebanon Hills Regional Park Sampling Plan

WENCK ASSOCIATES

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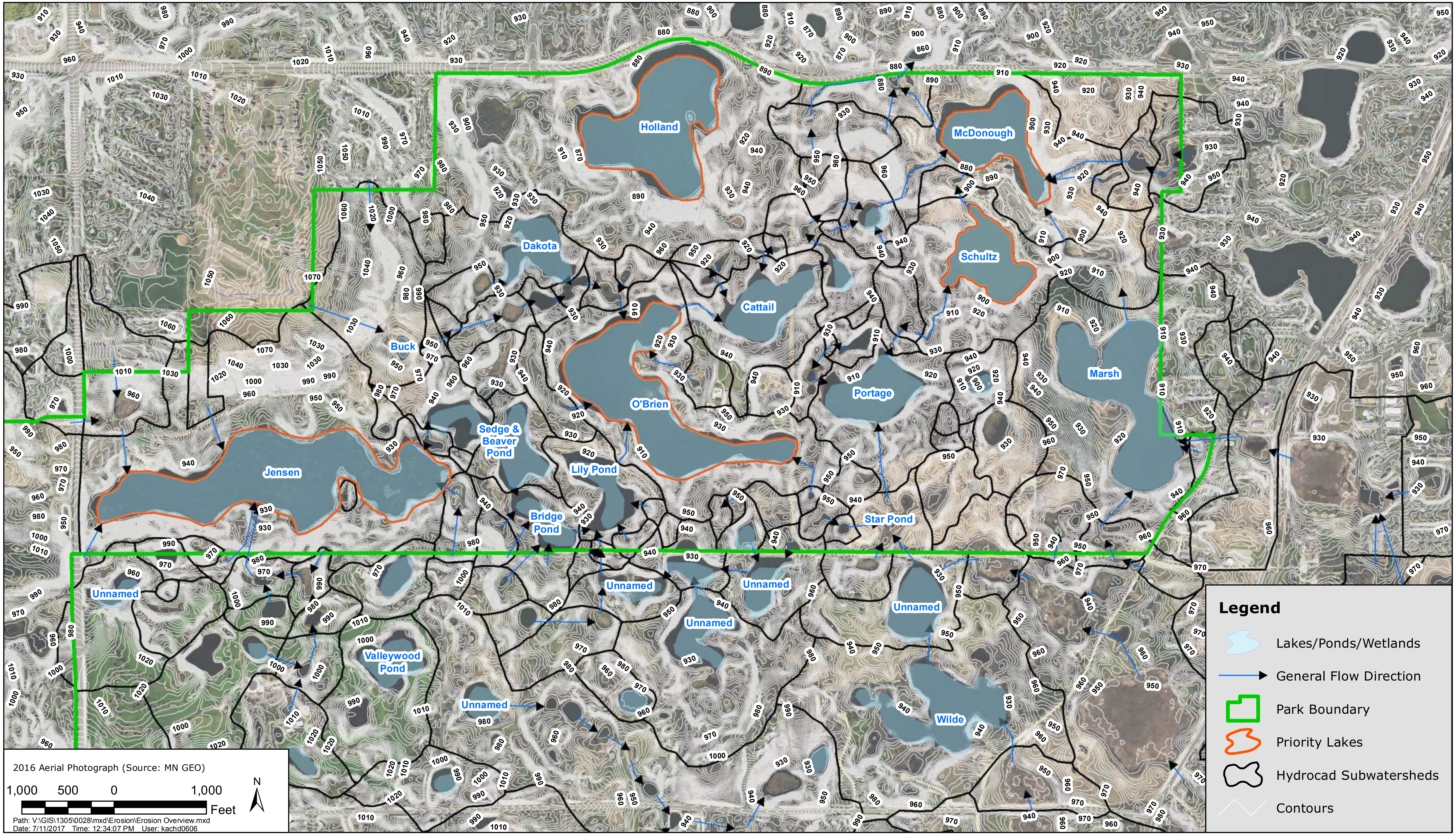
Figure 1



DAKOTA COUNTY ENVIRONMENTAL SERVICES

Lebanon Hills Regional Park - Topography

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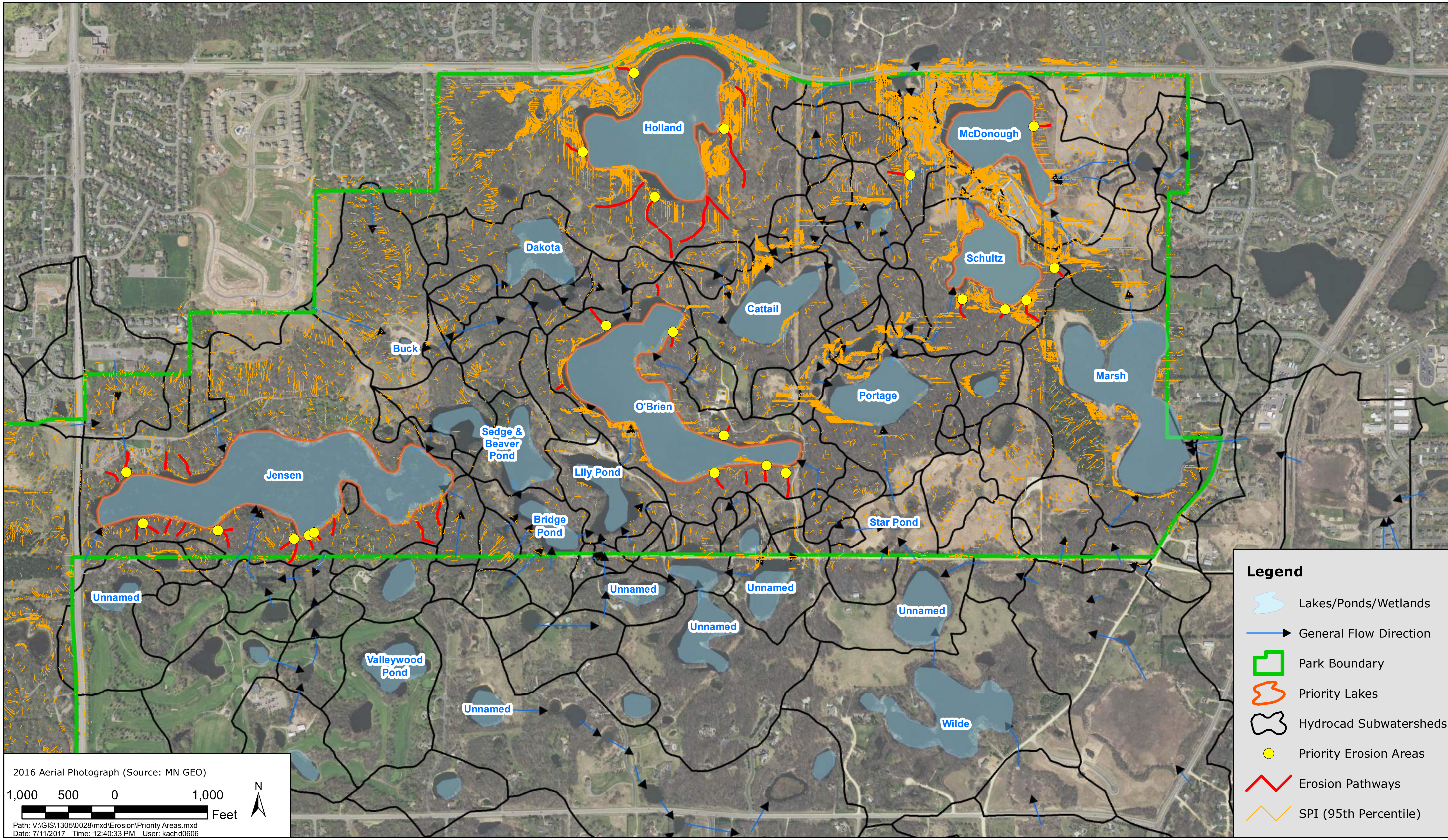
Figure 2



DAKOTA COUNTY ENVIRONMENTAL SERVICES

Lebanon Hills Regional Park - Priority Areas

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Figure 3

Appendix D: Modeling Methods and Output

Table D-1: Estimated impervious percent and pervious curve numbers for each land use type used in the LHRP P8 model.

Land Use	Impervious Fraction (%)	Pervious Curve Number						
		A	A/D	B	B/D	C	C/D	D
Agricultural	0.05	49	66.5	69	76.5	79	81.5	84
Airport	0.30	68	78.5	79	84.0	86	87.5	89
Farmstead	0.10	49	66.5	69	76.5	79	81.5	84
Golf Course	0.10	39	59.5	61	70.5	74	77.0	80
Industrial and Utility	0.50	68	78.5	79	84.0	86	87.5	89
Institutitional	0.32	39	59.5	61	70.5	74	77.0	80
Major Highway	0.50	49	66.5	69	76.5	79	81.5	84
Mixed Use Commercial	0.67	49	66.5	69	76.5	79	81.5	84
Mixed Use Industrial	0.50	68	78.5	79	84.0	86	87.5	89
Mixed Use Residential	0.60	39	59.5	61	70.5	74	77.0	80
Multifamily	0.60	39	59.5	61	70.5	74	77.0	80
Open Water	0.00	85	85.0	85	85.0	85	85.0	85
Office	0.32	39	59.5	61	70.5	74	77	80
Park, Recreational, or Preserve	0.10	39	59.5	61	70.5	74	77	80
Railway	0.20	68	78.5	79	84	86	87.5	89
Retail and Other Commercial	0.67	49	66.5	69	76.5	79	81.5	84
Single Family Attached	0.30	39	59.5	61	70.5	74	77	80
Single Family Detached	0.20	39	59.5	61	70.5	74	77	80
Undeveloped	0.05	39	59.5	61	70.5	74	77	80

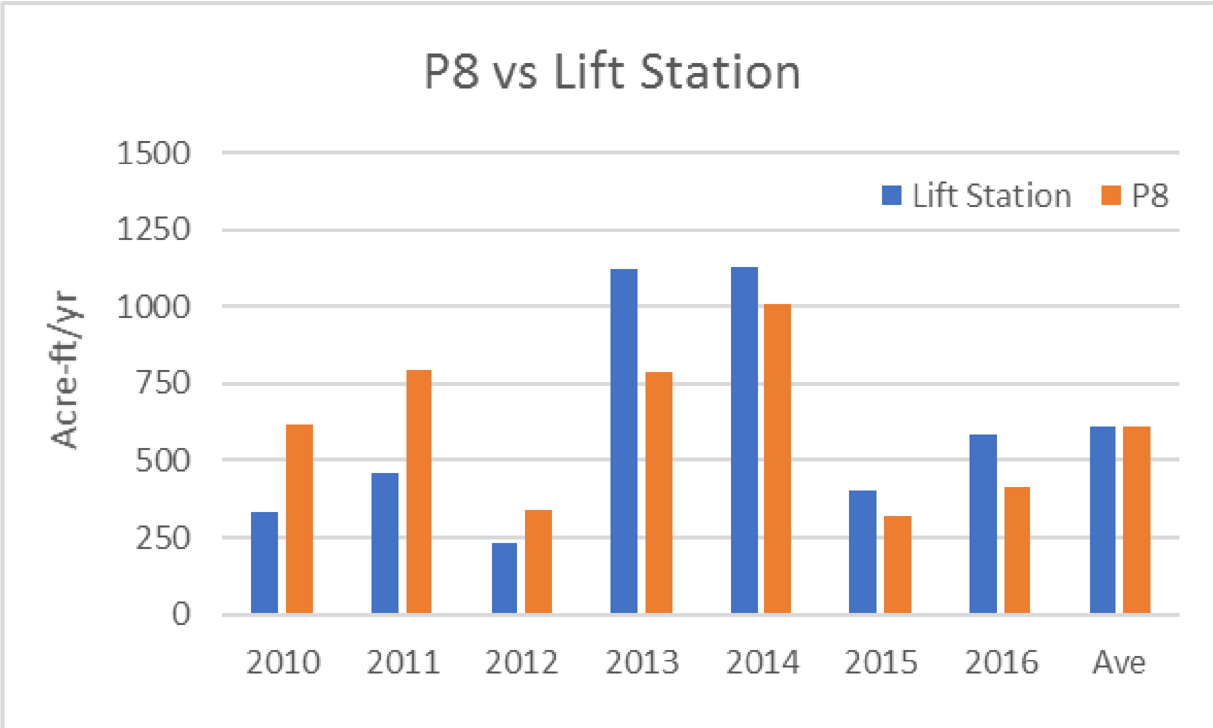
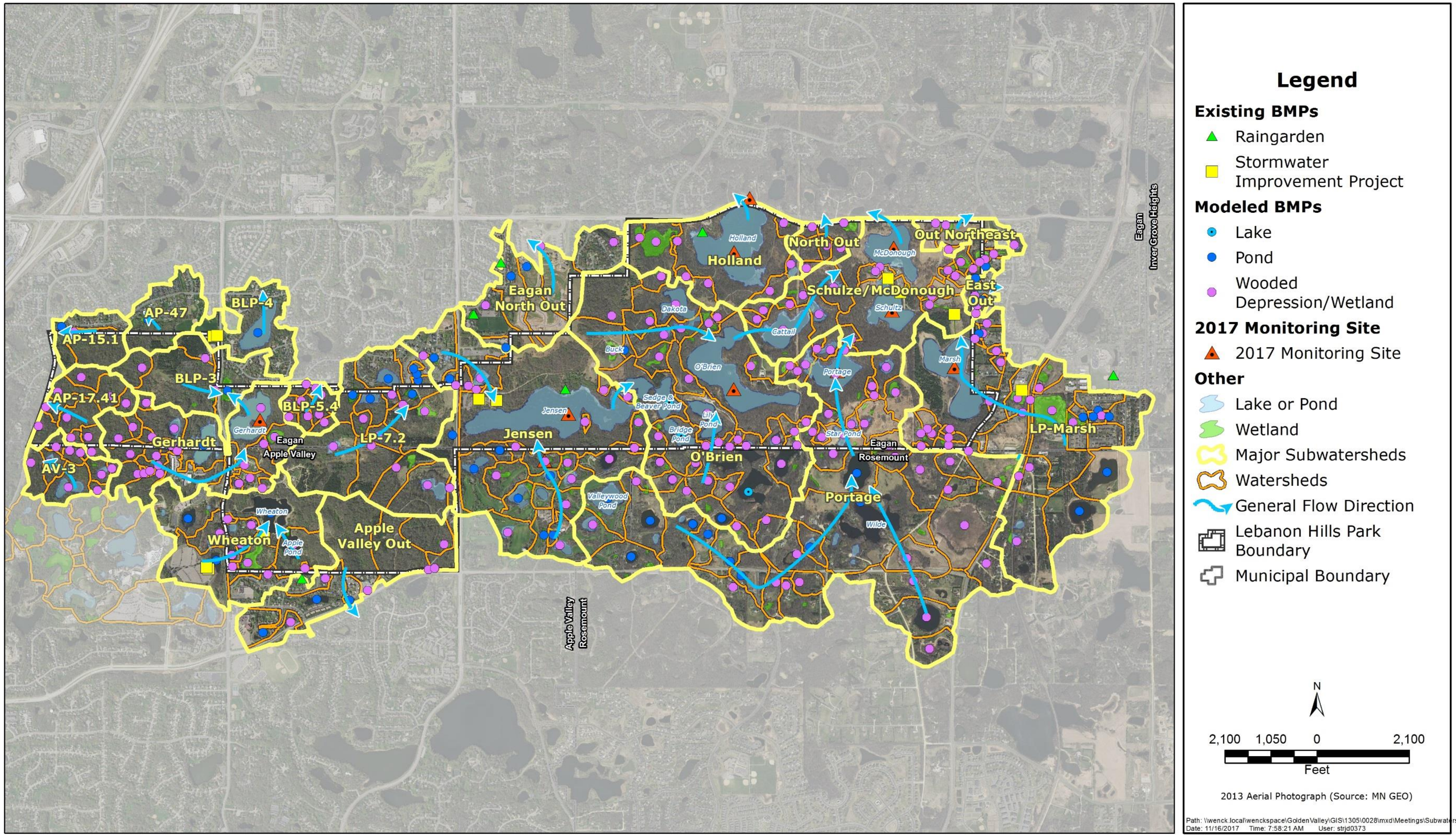
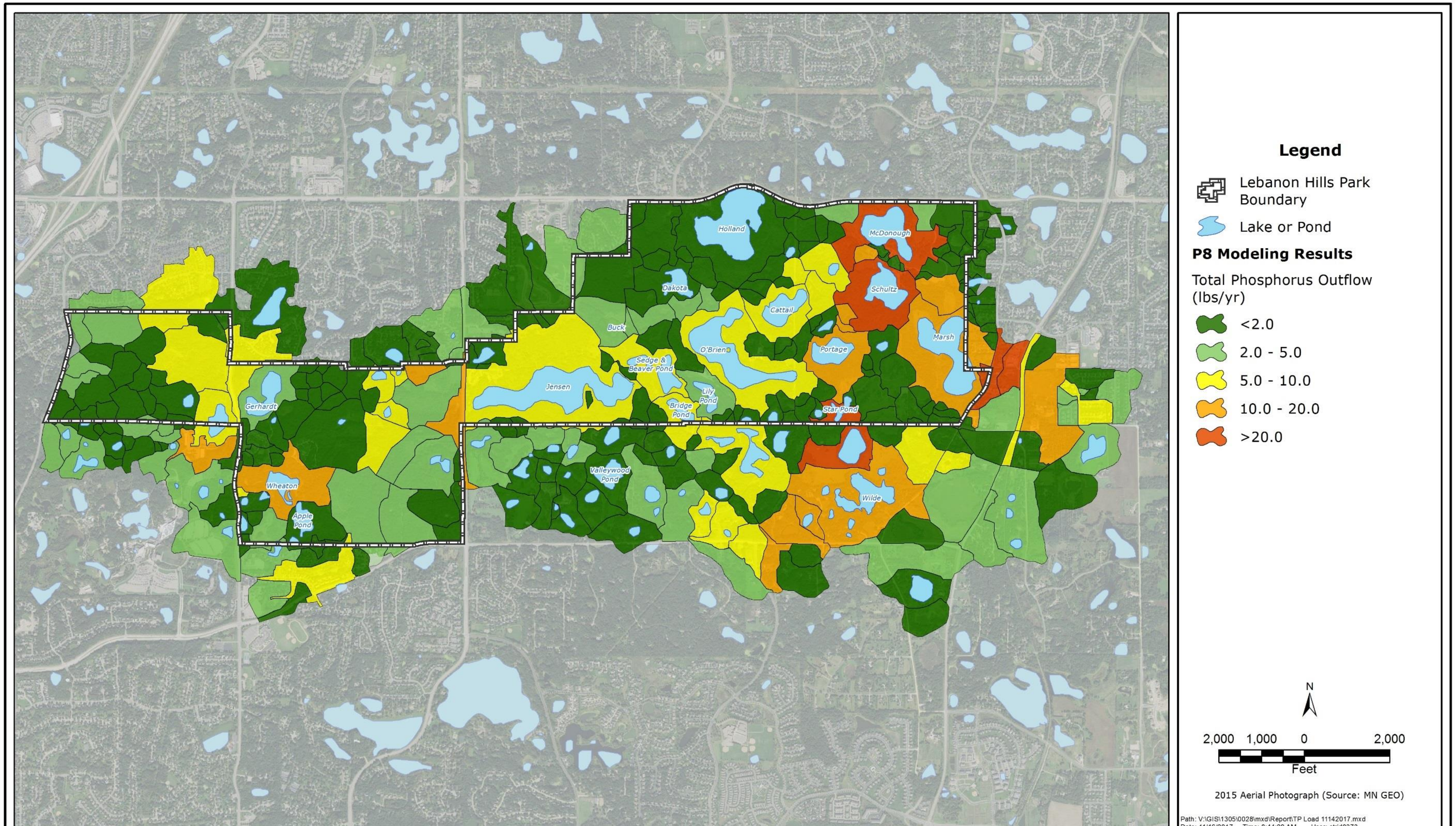


Figure D-1: Flow Calibration for the LHRP P8 Model.



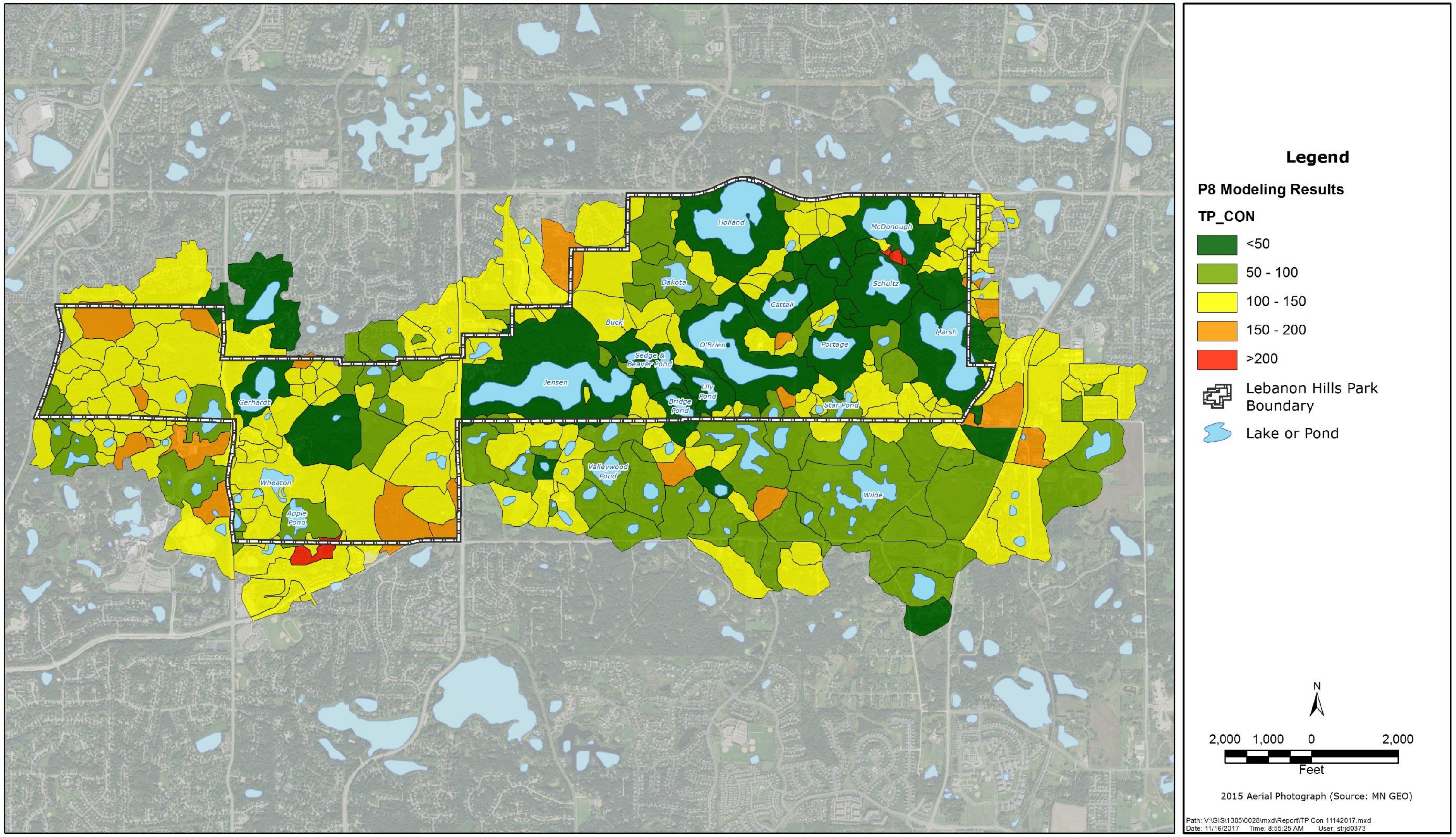
DAKOTA COUNTY ENVIRONMENTAL SERVICES	WENCK Responsive partner. Exceptional outcomes.	NOV 2017
Lebonon Hills Drainage Area		Figure D-2

Figure D-2: Subwatersheds, Flow Directions and Existing BMPs



DAKOTA COUNTY ENVIRONMENTAL SERVICES	WENCK	NOV 2017
Phosphorus Outflow from Subwatershed (lbs/yr)	Responsive partner. Exceptional outcomes.	Figure D-3

Figure D-3: P8 Predicted TP Outflow Loads by Subwatershed



DAKOTA COUNTY ENVIRONMENTAL SERVICES	WENCK Responsive partner. Exceptional outcomes.	NOV 2017
Phosphorus Outflow from Subwatershed (ug/L)		Figure D-4

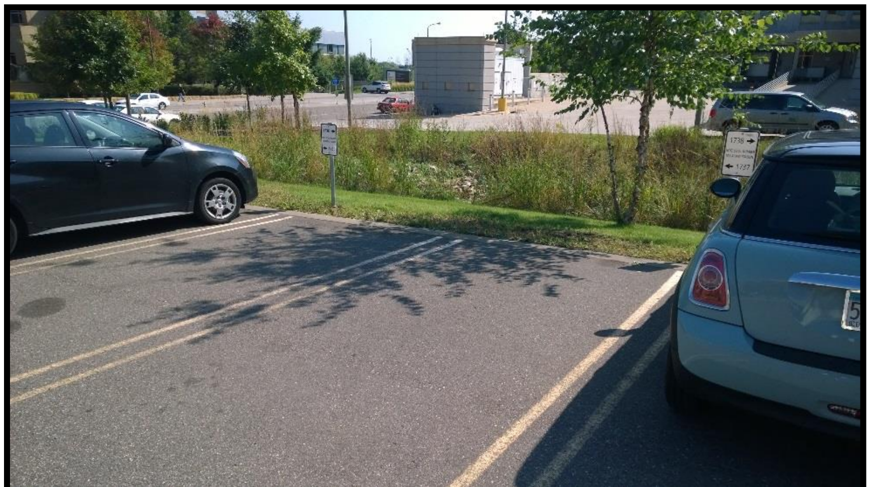
Figure D-4: P8 Predicted TP Outflow Concentration by Subwatershed

Appendix E: BMP Descriptions and Examples

This appendix provides general descriptions of several types of BMPs that could be implemented within the study area to reduce runoff volume, peak discharge, phosphorus and sediment loads.

INFILTRATION BASIN

Infiltration basins combine surface storage, infiltration, biological treatment, plant uptake, and evapotranspiration into a single BMP. Stormwater is collected into the treatment area which consists of a grass buffer strip, sand bed, ponding area, organic or mulch layer, planting soil, and plants. The infiltration system incorporates the more natural means of managing stormwater than any other treatment type.



Infiltration basin along a parking lot in St. Paul, MN.

The adjacent pictures show an infiltration basin along the perimeter of a parking lot in downtown St. Paul. Note the ribbon curb that defines the edge of the pavement but also allows runoff to flow over the curb, through the vegetated buffer and into the bioretention basin.

“Stepped” infiltration basin in Oakdale, MN.

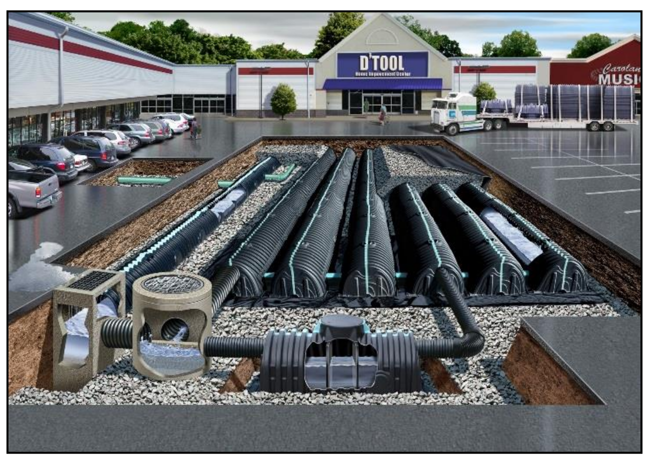
Opportunities to include infiltration systems in the landscape include landscaping islands, cul-de-sacs, parking lot margins, commercial setbacks, open space, rooftop drainage and streetscapes (i.e., between the curb and sidewalk). Infiltration basins are extremely versatile because of their ability to be incorporated into landscaped areas. Maintenance activities typically include sediment removal and maintenance of the vegetation. Invasive species need to be managed, dead vegetation must be removed, and dead plants must be replaced.

INFILTRATION TRENCH/DITCH


Photo credit: StormTech website

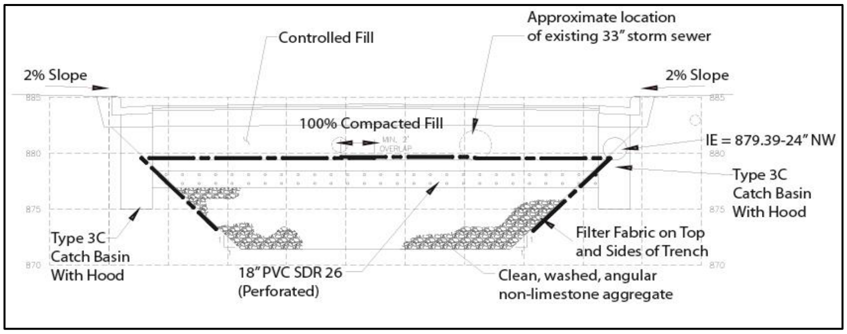
Infiltration trenches/ditches are stormwater practices that can be implemented within exiting roadside ditch systems that are currently collecting and conveying stormwater runoff. Infiltration trench design includes an engineered soil at the ditch bottom to infiltrate surface water from low flow events. To maximize treatment storage volume, the design also includes underground storage which is typically a combination of chambers and/or aggregate void space. High flows bypass the infiltration trench by either flow continuing through the ditch past the infiltration areas, or bypassing through a flow splitter structure to a receiving water body. This type of infiltration trench/ditch design was recently incorporated within a county road ditch system in Dakota County that drains a highly impervious industrial park. These systems have performed very well in infiltrating a significant portion of the stormwater runoff and removing TSS and TP.

UNDERGROUND INFILTRATION SYSTEMS



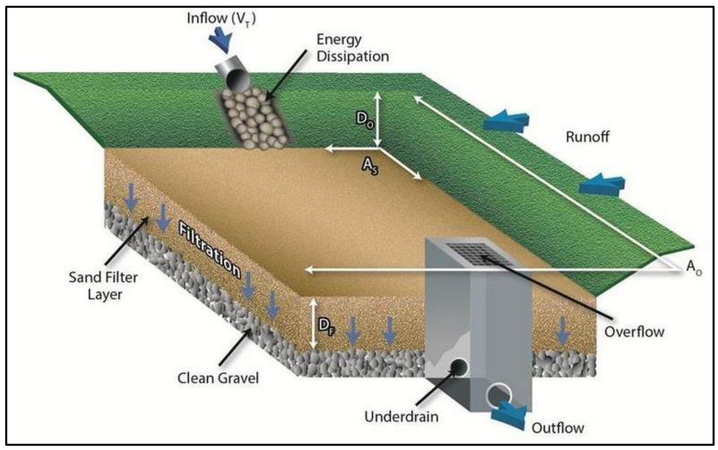
Underground infiltration systems are an adaptable stormwater BMP technique where space is limited, and is most suitable for highly urban areas where space is limited. Underground infiltration consists of perforated pipes, vaults, modular structures, or cisterns placed beneath a developed or open area. An example is shown to the right. Stormwater runoff is directed to this area via storm sewer for storage and infiltration. A manhole, filter, or hydrodynamic device provides pretreatment for runoff entering the storage area. In large storm events, the storage volume above the outlet reduces flow rates and discharge is directed into the storm sewer. Large angular rock (1-3 inches) surrounds the perforated pipes and provides additional storage capacity and structural stability for soils above. The design can be modified to include a filtration layer when infiltration is not practical.

Street replacement also provides an opportunity for this type of BMP. Underground infiltration systems can be placed beneath roads where no utilities are present. During road reconstruction the system can be added to the project to reduce downstream pollutant loads. Maintenance includes periodic removal of sediment accumulated in the pretreatment devices. To maintain system functionality, sediment deposition should not exceed 1 foot in depth.



SAND FILTERS

Filtration BMPs use a porous media, typically sand, to remove pollutants from stormwater before entering the downstream waterbody or BMP. Sand filters can be used in areas where infiltration is not feasible due to high water tables, limited infiltration capacity of the soil, or contaminated soil conditions. Both the surface basins and underground systems described previously can be designed as filtration BMPs rather than infiltration systems. Because filtration BMPs are not designed to infiltrate or store stormwater, these systems require use of an underdrain to convey treated stormwater out of the system. Surface filtration basins that incorporate vegetation into the practice will provide biological removal of nutrients via uptake by the vegetation. However, since filtration BMPs are not designed to infiltrate they do not provide stormwater volume reduction benefits and typically have lower pollutant removal capabilities compared to infiltration BMPs. Moreover, the underdrains and pipe work associated with filtration practices can make them more expensive than infiltration BMPs.



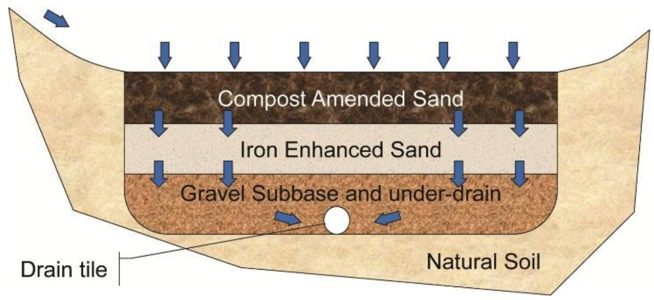
IRON-ENHANCED SAND FILTERS

Iron-enhanced sand filters are filtration BMPs that incorporate filtration media mixed with iron. The iron removes several dissolved constituents, including phosphate, from stormwater. Iron-enhanced sand filters could potentially include a wide range of filtration BMPs with the addition of iron; however, iron is not appropriate for all filtration practices due to the potential for iron loss or plugging in low oxygen or persistently inundated filtration practices.

Iron-enhanced sand filters may be applied in the same manner as other filtration practices and are more suited to urban land use with high imperviousness and moderate solids loads.

Because the primary treatment mechanisms are filtration and chemical binding and not volume reduction, vegetating the filter is not needed and may impair the filter function.

Iron-enhanced sand filters require underdrains that serve to convey filtered and treated stormwater and to aerate the filter bed between storms. The exit drain from the iron-enhanced sand filter should be exposed to the atmosphere and above downstream high water levels in order to keep the filter bed aerated. Iron-enhanced sand filters may be used in a treatment sequence, as a stand-alone BMP, or as a retrofit. If an iron-enhanced sand filter basin is used as a stand-alone BMP, an overflow diversion is recommended to control the volume of water, or more specifically, the inundation period in the BMP. As with all filters, it is important to have inflow be relatively free of solids or to have a pre-treatment practice in sequence.



Maintenance of the iron-enhanced sand filters consists of removing accumulated sediment and debris, pulling out all vegetation throughout the growing season, and tilling the soil to prevent clumping and preferential flow paths.

STORMWATER REUSE

Stormwater reuse is the practice of collecting runoff from impermeable surfaces and storing it for future use. There are a number of systems used for the collection, storage and distribution of rain water including rain barrels, cisterns, evaporative control systems, and irrigation. Most commonly, these systems capture “free water” from a storage point and irrigate (after filtering) green space. For this study, the proposed stormwater reuse would use runoff collected in an underground chamber near a large green space area. Stormwater reuse systems typically includes an intake, pump/controls building, and irrigation network. One limitation of stormwater reuse is that it is not very effective during wet periods when much of the nutrient transport takes place.

STORMWATER PONDS

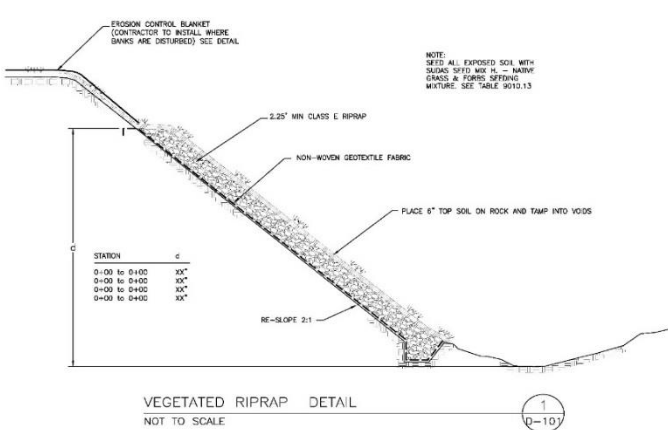
Stormwater ponds are the most commonly used practice for treating and reducing stormwater pollutant loads. Stormwater ponds rely on physical, biological, and chemical processes to remove pollutants from incoming stormwater runoff. The primary treatment mechanism is gravitational settling of particulates and their associated pollutants as stormwater runoff resides in the pond. In general, the longer the runoff remains in the pond, the more settling (and associated pollutant removal) and other treatment can occur, and after the particulates reach the bottom of the pond, the permanent pool protects them from resuspension when additional runoff enters the basin. Another mechanism for the removal of pollutants (particularly nutrients) is uptake by algae and aquatic vegetation.

Stormwater ponds are also one of the best and most cost-effective stormwater treatment practices for providing runoff detention storage for channel protection and overbank flood control. These goals are achieved with the use of extended detention storage, where runoff is stored above the permanent pool and released at a specified rate through a control structure.

CHANNEL STABILIZATION BMPS

Vegetated Riprap

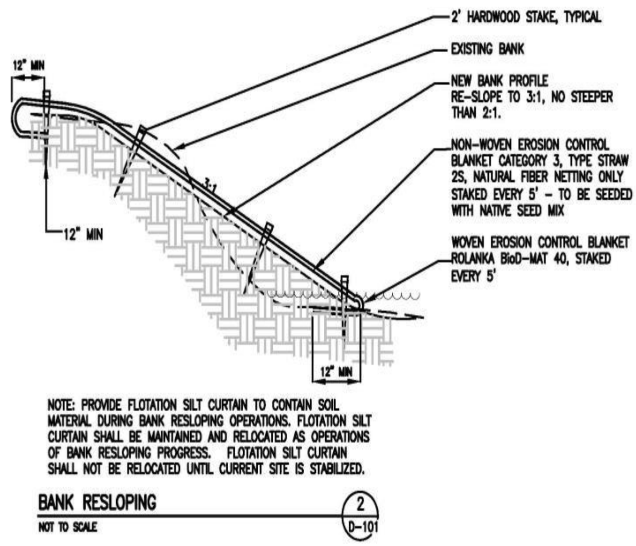
Vegetated riprap is a slope stabilization technique to be used in instances where flow velocity (5 – 20 FPS) requires hard armoring (rock) instead of bioengineered techniques. For this technique, the vegetation included in the design adds a more natural aesthetic by camouflaging the rock. Vegetated riprap is intended to provide toe protection on taller (> 4'), vertical, eroding stream banks. Riprap would be installed at the existing toe line of the side slopes and be keyed in slightly below the stream bed. Some bank disturbance would be required to make the vertical bank less steep (ideally, 2:1 H:V or less) by grading from the top of the bank to the new riprap toe. Final stabilization of the riprap toe areas would include revegetation with native seed and either erosion control blanket along the channel where high flows are expected and straw mulch or hydro-mulch in the upland areas. Installation of the riprap toe would follow the existing bank, would balance cut and fill on site and would not alter the channel cross section.



Detail of Vegetated Riprap and photo of installed practice on channel project one year after construction.

Bank Resloping with seed & erosion control blanket

Bank resloping is a bioengineering stabilization technique to be used in instances where flow conditions allow (i.e. when channel velocities are less than 6 FPS) and/or for the portions of the bank above the normal high water level of a channel. Bank resloping is intended to establish native vegetation and provide toe protection on shorter (<3'), steep stream banks. Resloping the bank ranges from 3:1(H:V) or less (preferred), to no steeper than 2:1.



Black sloping detail and photo of resloped banks constructed during winter on Elm Creek.

It is intended to provide a stable slope for new vegetation to establish. The roots of the vegetation hold the slope during periods of inundation and reduce soil migration.

Tree Thinning/Tree Removal

Thinning existing trees to presettlement vegetation densities of 5 – 10 trees per acre, allows for more sunlight to reach the soil. Increased sunlight encourages the amount and vigor of ground plane grasses and forbs within the understory. This practice helps to stabilize floodplains adjacent to stream channel, thus mitigating soil movement into the adjacent and downstream waterbodies.

One year after clearing trees, the existing seed bank grew into a healthy grass buffer on Coon Creek.

Rootwads with Log Toe

Rootwads with log toe is a bioengineered slope stabilization technique to be used in instances where flow velocity (5 – 20 FPS) would require hard armoring (rock), but wood is available from onsite tree thinning and a more natural aesthetic is required. Another benefit of rootwads and log toe is providing in-stream woody habitat for terrestrial and aquatic organisms.

Rootwads with log toe is intended to provide toe protection on taller (> 4'), vertical, eroding stream banks and would be installed at the existing toe line of the side slopes and be keyed in slightly below the stream bed. Some bank disturbance would be required to install the rootwads and log toe, with the top of bank restored to be less steep (ideally, 2:1 H:V or less) by grading from the top of the bank to the new rootwads with log toe. Final stabilization of the rootwad and log toe areas would include revegetation with native seed and erosion control blanket along the channel where high flows are expected or straw mulch or hydro-mulch for stabilization in the upland areas. The rootwads and log toe would follow the existing bank, would balance cut and fill on site and would not alter the channel cross section.

Installed rootwads two years after vegetation establishment and maintenance. The rootwads have grown into the stream bank. Log toe was installed, but is not visible (submerged under the water line) in this photo.

Appendix F: Detailed BMP Cost Estimates

Table F-1. REG-1 Detailed Construction, Maintenance, and 30-year Life Cycle Cost Estimate

			Engineer's Estimate	
Item	**Units**	**Qty**	**Unit Price**	**Total Price**
MOBILIZATION/DEMOBILIZATION (5%)	LS	1	$12,646.25	$12,646.25
CLEARING AND GRUBBING	LS	1	$2,500.00	$2,500.00
TEMPORARY DEWATERING	LS	1	$5,000.00	$5,000.00
TEMPORARY CONSTRUCTION ENTRANCE	EA	1	$2,500.00	$2,500.00
SILT FENCE, TYPE MACHINE SLICED - MAINTAINED	LF	200	$5.00	$1,000.00
8" BIOLOG - MAINTAINED	LF	400	$8.00	$3,200.00
FLOTATION SILT CURTAIN - MAINTAINED	LF	40	$20.00	$800.00
SALVAGE EXISTING TOPSOIL - STRIPPING, STOCKPILE, AND RESPREADING	CY	1500	$6.00	$9,000.00
SEED MIXTURE	SY	2700	$2.00	$5,400.00
EROSION CONTROL BLANKET	SY	2700	$3.00	$8,100.00
PLANTINGS (TREES AND SHRUBS)	EA	5	$350.00	$1,750.00
COMMON EXCAVATION - ONSITE (EV)	CY	3700	$10.00	$37,000.00
MUCK EXCAVATION - OFFSITE (EV)	CY	0	$30.00	$0.00
SUITABLE BORROW MATERIAL (LV)	CY	0	$25.00	$0.00
REMOVALS	LF	0	$30.00	$0.00
8" SLOTTED PVC DRAINTILE	LF	450	$30.00	$13,500.00
SOLID PVC SCH 40	LF	110	$25.00	$2,750.00
CLEANOUT WITH VENT SCREEN	EA	12	$775.00	$9,300.00
48" CONCRETE MANHOLE	EA	1	$3,500.00	$3,500.00
15" RCP CLASS V	LF	80	$60.00	$4,800.00
15" RCP FLARED-END SECTION W/TRASH GUARD	EA	3	$2,500.00	$7,500.00
SELECT GRANULAR BORROW IRON ENHANCED (MNDOT 3149.2B)	CY	345	$175.00	$60,375.00
COARSE FILTER AGGREGATE	CY	345	$80.00	$27,600.00
45 MIL SMOOTH EPDM LINER	SF	10500	$3.00	$31,500.00
OUTLET CONTROL STRUCTURE	EA	1	$10,000.00	$10,000.00
RIPRAP CLASS III	TN	45	$130.00	$5,850.00
		TOTAL		**$265,571.25**
ENGINEERING (20%)				$53,114
CONSTRUCTION ADMINISTRATION (10%)				$26,557
CONTINGENCY (30%)				$79,671.38
		Total Construction Cost		**$424,914.00**
		Annual Maintenance Cost		**$1,500.00**
		10-year Maintenance Cost		**$134,299.20**
		Total 30-year Life Cycle Cost		**$ 1,245,000.00**

Table F-2. REG-2 Detailed Construction, Maintenance, and 30-year Life Cycle Cost Estimate

			Engineer's Estimate	
Item	**Units**	**Qty**	**Unit Price**	**Total Price**
MOBILIZATION/DEMOBILIZATION (5%)	LS	1	$19,152.50	$19,152.50
CLEARING AND GRUBBING	LS	1	$7,500.00	$7,500.00
TEMPORARY DEWATERING	LS	1	$5,000.00	$5,000.00
TEMPORARY CONSTRUCTION ENTRANCE	EA	1	$2,500.00	$2,500.00
SILT FENCE, TYPE MACHINE SLICED - MAINTAINED	LF	300	$5.00	$1,500.00
8" BIOLOG - MAINTAINED	LF	725	$8.00	$5,800.00
FLOTATION SILT CURTAIN - MAINTAINED	LF	200	$20.00	$4,000.00
SALVAGE EXISTING TOPSOIL - STRIPPING, STOCKPILE, AND RESPREADING	CY	1500	$6.00	$9,000.00
SEED MIXTURE	SY	6050	$2.00	$12,100.00
EROSION CONTROL BLANKET	SY	6050	$3.00	$18,150.00
PLANTINGS (TREES AND SHRUBS)	EA	5	$350.00	$1,750.00
COMMON EXCAVATION - ONSITE (EV)	CY	4500	$10.00	$45,000.00
MUCK EXCAVATION - OFFSITE (EV)	CY	1500	$30.00	$45,000.00
SUITABLE BORROW MATERIAL (LV)	CY	480	$25.00	$12,000.00
REMOVALS - 15" RCP PIPE	LF	300	$30.00	$9,000.00
8" SLOTTED PVC DRAINTILE	LF	580	$30.00	$17,400.00
SOLID PVC SCH 40	LF	60	$25.00	$1,500.00
CLEANOUT WITH VENT SCREEN	EA	10	$775.00	$7,750.00
48" CONCRETE MANHOLE	EA	4	$3,500.00	$14,000.00
15" RCP CLASS V	LF	400	$60.00	$24,000.00
15" RCP FLARED-END SECTION W/TRASH GUARD	EA	2	$2,500.00	$5,000.00
SELECT GRANULAR BORROW IRON ENHANCED (MNDOT 3149.2B)	CY	335	$175.00	$58,625.00
COARSE FILTER AGGREGATE	CY	335	$80.00	$26,800.00
45 MIL SMOOTH EPDM LINER	SF	11275	$3.00	$33,825.00
OUTLET CONTROL STRUCTURE	EA	1	$10,000.00	$10,000.00
RIPRAP CLASS III	TN	45	$130.00	$5,850.00
		TOTAL		**$402,202.50**
ENGINEERING (20%)				$80,441
CONSTRUCTION ADMINISTRATION (10%)				$40,220
CONTINGENCY (30%)				$120,660.75
Construction Cost Total				**$643,524.00**
Annual Maintenance Cost				**$1,500.00**
10-year Maintenance Cost				**$156,063.60**
Total 30-year Life Cycle Cost				**$1,585,000.00**

Table F-3. REG-3 Detailed Construction, Maintenance, and 30-year Life Cycle Cost Estimate

			Engineer's Estimate	
Item	**Units**	**Qty**	**Unit Price**	**Total Price**
MOBILIZATION/DEMOBILIZATION (5%)	LS	1	$5,606.00	$5,606.00
CLEARING AND GRUBBING	LS	1	$2,500.00	$2,500.00
TEMPORARY DEWATERING	LS	1	$2,500.00	$2,500.00
TEMPORARY CONSTRUCTION ENTRANCE	EA	1	$2,500.00	$2,500.00
SILT FENCE, TYPE MACHINE SLICED - MAINTAINED	LF	150	$5.00	$750.00
8" BIOLOG - MAINTAINED	LF	310	$8.00	$2,480.00
FLOTATION SILT CURTAIN - MAINTAINED	LF	40	$20.00	$800.00
SALVAGE EXISTING TOPSOIL - STRIPPING, STOCKPILE, AND RESPREADING	CY	500	$6.00	$3,000.00
SEED MIXTURE	SY	900	$2.00	$1,800.00
EROSION CONTROL BLANKET	SY	900	$3.00	$2,700.00
PLANTINGS (TREES AND SHRUBS)	EA	5	$350.00	$1,750.00
COMMON EXCAVATION - ONSITE (EV)	CY	500	$10.00	$5,000.00
MUCK EXCAVATION - OFFSITE (EV)	CY	0	$30.00	$0.00
SUITABLE BORROW MATERIAL (LV)	CY	250	$25.00	$6,250.00
REMOVALS - CULVERT	LF	20	$30.00	$600.00
8" SLOTTED PVC DRAINTILE	LF	200	$30.00	$6,000.00
SOLID PVC SCH 40	LF	50	$25.00	$1,250.00
CLEANOUT WITH VENT SCREEN	EA	8	$775.00	$6,200.00
48" CONCRETE MANHOLE	EA	2	$3,500.00	$7,000.00
15" RCP CLASS V	LF	30	$60.00	$1,800.00
15" RCP FLARED-END SECTION W/TRASH GUARD	EA	2	$2,500.00	$5,000.00
SELECT GRANULAR BORROW IRON ENHANCED (MNDOT 3149.2B)	CY	100	$175.00	$17,500.00
COARSE FILTER AGGREGATE	CY	100	$80.00	$8,000.00
45 MIL SMOOTH EPDM LINER	SF	3630	$3.00	$10,890.00
OUTLET CONTROL STRUCTURE	EA	1	$10,000.00	$10,000.00
RIPRAP CLASS III	TN	45	$130.00	$5,850.00
		TOTAL		**$117,726.00**
ENGINEERING (20%)				$23,545
CONSTRUCTION ADMINISTRATION (10%)				$11,773
CONTINGENCY (30%)				$35,317.80
	Construction Cost Total			**$188,361.60**
	Annual Maintenance Cost			**$1,500.00**
	10-year Maintenance Cost			**$47,754.00**
	Total 30-year Life Cycle Cost			**$ 530,000.0**

Table F-4. REG-4 Detailed Construction, Maintenance, and 30-year Life Cycle Cost Estimate

			Engineer's Estimate	
Item	**Units**	**Qty**	**Unit Price**	**Total Price**
MOBILIZATION/DEMOBILIZATION (5%)	LS	1	$12,675.00	$12,675.00
CLEARING AND GRUBBING	LS	1	$7,500.00	$7,500.00
TEMPORARY DEWATERING	LS	1	$2,500.00	$2,500.00
TEMPORARY CONSTRUCTION ENTRANCE	EA	1	$2,500.00	$2,500.00
SILT FENCE, TYPE MACHINE SLICED - MAINTAINED	LF	500	$5.00	$2,500.00
8" BIOLOG - MAINTAINED	LF	500	$8.00	$4,000.00
FLOTATION SILT CURTAIN - MAINTAINED	LF	40	$20.00	$800.00
SALVAGE EXISTING TOPSOIL - STRIPPING, STOCKPILE, AND RESPREADING	CY	1500	$6.00	$9,000.00
SEED MIXTURE	SY	1650	$2.00	$3,300.00
EROSION CONTROL BLANKET	SY	2650	$3.00	$7,950.00
PLANTINGS (TREES AND SHRUBS)	EA	5	$350.00	$1,750.00
COMMON EXCAVATION - ONSITE (EV)	CY	3000	$10.00	$30,000.00
MUCK EXCAVATION - OFFSITE (EV)	CY	0	$30.00	$0.00
SUITABLE BORROW MATERIAL (LV)	CY	600	$25.00	$15,000.00
REMOVALS - MISC	LS	1	$10,000.00	$10,000.00
8" SLOTTED PVC DRAINTILE	LF	700	$30.00	$21,000.00
SOLID PVC SCH 40	LF	80	$25.00	$2,000.00
CLEANOUT WITH VENT SCREEN	EA	8	$775.00	$6,200.00
48" CONCRETE MANHOLE	EA	1	$3,500.00	$3,500.00
15" RCP CLASS V	LF	75	$60.00	$4,500.00
15" RCP FLARED-END SECTION W/TRASH GUARD	EA	1	$2,500.00	$2,500.00
SELECT GRANULAR BORROW (MNDOT 3149.2B)	CY	505	$30.00	$15,150.00
COARSE FILTER AGGREGATE	CY	505	$80.00	$40,400.00
45 MIL SMOOTH EPDM LINER	SF	15200	$3.00	$45,600.00
OUTLET CONTROL STRUCTURE	EA	1	$10,000.00	$10,000.00
RIPRAP CLASS III	TN	45	$130.00	$5,850.00
		TOTAL		**$266,175.00**
ENGINEERING (20%)				$39,926
CONSTRUCTION ADMINISTRATION (10%)				$26,618
CONTINGENCY (30%)				$79,852.50
	Total Construction Cost			**$412,571.25**
	Annual Maintenance Cost			**$1,500.00**
	10-year Maintenance Cost			**$49,249.20**
	Total 30-year Life Cycle Cost			**$760,000.0**

Table F-5. REG-5 Detailed Construction, Maintenance, and 30-year Life Cycle Cost Estimate

			Engineer's Estimate	
Item	**Units**	**Qty**	**Unit Price**	**Total Price**
MOBILIZATION/DEMOBILIZATION (5%)	LS	1	$4,881.50	$4,881.50
CLEARING AND GRUBBING	LS	1	$5,000.00	$5,000.00
TEMPORARY DEWATERING	LS	1	$10,000.00	$10,000.00
TEMPORARY CONSTRUCTION ENTRANCE	EA	1	$2,500.00	$2,500.00
SILT FENCE, TYPE MACHINE SLICED - MAINTAINED	LF	125	$5.00	$625.00
8" BIOLOG - MAINTAINED	LF	125	$8.00	$1,000.00
FLOTATION SILT CURTAIN - MAINTAINED	LF	0	$20.00	$0.00
SALVAGE EXISTING TOPSOIL - STRIPPING, STOCKPILE, AND RESPREADING	CY	900	$5.00	$4,500.00
SEED MIXTURE	SY	900	$2.00	$1,800.00
EROSION CONTROL BLANKET	SY	900	$3.00	$2,700.00
PLANTINGS (TREES AND SHRUBS)	EA	5	$350.00	$1,750.00
COMMON EXCAVATION - ONSITE (EV)	CY	900	$10.00	$9,000.00
MUCK EXCAVATION - OFFSITE (EV)	CY	0	$30.00	$0.00
SUITABLE BORROW MATERIAL (LV)	CY	250	$25.00	$6,250.00
REMOVALS	LF	0	$30.00	$0.00
8" SLOTTED PVC DRAINTILE	LF	50	$30.00	$1,500.00
SOLID PVC SCH 40	LF	25	$25.00	$625.00
CLEANOUT WITH VENT SCREEN	EA	4	$775.00	$3,100.00
48" CONCRETE MANHOLE	EA	3	$3,500.00	$10,500.00
15" RCP CLASS V	LF	50	$60.00	$3,000.00
15" RCP FLARED-END SECTION W/TRASH GUARD	EA	2	$2,500.00	$5,000.00
SELECT GRANULAR BORROW IRON ENHANCED (MNDOT 3149.2B)	CY	35	$175.00	$6,125.00
COARSE FILTER AGGREGATE	CY	35	$80.00	$2,800.00
45 MIL SMOOTH EPDM LINER	SF	1335	$3.00	$4,005.00
OUTLET CONTROL STRUCTURE	EA	1	$10,000.00	$10,000.00
RIPRAP CLASS III	TN	45	$130.00	$5,850.00
		TOTAL		**$102,511.50**
ENGINEERING (20%)				$20,502
CONSTRUCTION ADMINISTRATION (10%)				$10,251
CONTINGENCY (30%)				$30,753.45
Total Construction Cost				**$164,018.40**
Annual Maintenance Cost				**$1,500.00**
10-year Maintenance Cost				**$22,348.20**
Total 30-year Life Cycle Cost				**$360,000.0**

Table F-6. REG-6 Detailed Construction, Maintenance, and 30-year Life Cycle Cost Estimate

			Engineer's Estimate	
Item	**Units**	**Qty**	**Unit Price**	**Total Price**
MOBILIZATION/DEMOBILIZATION (5%)	LS	1	$5,364.75	$5,364.75
CLEARING AND GRUBBING	LS	1	$5,000.00	$5,000.00
TEMPORARY DEWATERING	LS	1	$2,500.00	$2,500.00
TEMPORARY CONSTRUCTION ENTRANCE	EA	1	$2,500.00	$2,500.00
SILT FENCE, TYPE MACHINE SLICED - MAINTAINED	LF	200	$5.00	$1,000.00
8" BIOLOG - MAINTAINED	LF	200	$8.00	$1,600.00
FLOTATION SILT CURTAIN - MAINTAINED	LF	40	$20.00	$800.00
SALVAGE EXISTING TOPSOIL - STRIPPING, STOCKPILE, AND RESPREADING	CY	370	$6.00	$2,220.00
SEED MIXTURE	SY	1000	$2.00	$2,000.00
EROSION CONTROL BLANKET	SY	1000	$3.00	$3,000.00
PLANTINGS (TREES AND SHRUBS)	EA	5	$350.00	$1,750.00
COMMON EXCAVATION - ONSITE (EV)	CY	550	$10.00	$5,500.00
MUCK EXCAVATION - OFFSITE (EV)	CY	500	$30.00	$15,000.00
SUITABLE BORROW MATERIAL (LV)	CY	0	$25.00	$0.00
REMOVALS	LF	0	$30.00	$0.00
8" SLOTTED PVC DRAINTILE	LF	120	$30.00	$3,600.00
SOLID PVC SCH 40	LF	40	$25.00	$1,000.00
CLEANOUT WITH VENT SCREEN	EA	4	$775.00	$3,100.00
48" CONCRETE MANHOLE	EA	1	$3,500.00	$3,500.00
15" RCP CLASS V	LF	75	$60.00	$4,500.00
15" RCP FLARED-END SECTION W/TRASH GUARD	EA	1	$2,500.00	$2,500.00
SELECT GRANULAR BORROW IRON ENHANCED (MNDOT 3149.2B)	CY	85	$175.00	$14,875.00
COARSE FILTER AGGREGATE	CY	85	$80.00	$6,800.00
45 MIL SMOOTH EPDM LINER	SF	2900	$3.00	$8,700.00
OUTLET CONTROL STRUCTURE	EA	1	$10,000.00	$10,000.00
RIPRAP CLASS III	TN	45	$130.00	$5,850.00
		TOTAL		**$112,659.75**
ENGINEERING (20%)				$22,532
CONSTRUCTION ADMINISTRATION (10%)				$11,266
CONTINGENCY (30%)				$33,797.93
		Total Construction Cost		**$180,255.60**
		Annual Maintenance Cost		**$1,500.00**
		10-year Maintenance Cost		**$41,538.00**
		Total 30-year Life Cycle Cost		**$ 1,035,000.0**

Table F-7. REG-7 Detailed Construction, Maintenance, and 30-year Life Cycle Cost Estimate

			Engineer's Estimate	
Item	**Units**	**Qty**	**Unit Price**	**Total Price**
MOBILIZATION/DEMOBILIZATION (5%)	LS	1	$9,086.25	$9,086.25
CLEARING AND GRUBBING	LS	1	$10,000.00	$10,000.00
TEMPORARY DEWATERING	LS	1	$2,500.00	$2,500.00
TEMPORARY CONSTRUCTION ENTRANCE	EA	2	$2,500.00	$5,000.00
SILT FENCE, TYPE MACHINE SLICED - MAINTAINED	LF	200	$5.00	$1,000.00
8" BIOLOG - MAINTAINED	LF	400	$8.00	$3,200.00
FLOTATION SILT CURTAIN - MAINTAINED	LF	50	$20.00	$1,000.00
SALVAGE EXISTING TOPSOIL - STRIPPING, STOCKPILE, AND RESPREADING	CY	2500	$6.00	$15,000.00
SEED MIXTURE	SY	5000	$2.00	$10,000.00
EROSION CONTROL BLANKET	SY	5000	$3.00	$15,000.00
PLANTINGS (TREES AND SHRUBS)	EA	5	$350.00	$1,750.00
COMMON EXCAVATION - ONSITE (EV)	CY	1850	$10.00	$18,500.00
MUCK EXCAVATION - OFFSITE (EV)	CY	0	$30.00	$0.00
SUITABLE BORROW MATERIAL (LV)	CY	350	$25.00	$8,750.00
REMOVALS	LS	1	$1,000.00	$1,000.00
8" SLOTTED PVC DRAINTILE	LF	350	$30.00	$10,500.00
SOLID PVC SCH 40	LF	30	$25.00	$750.00
CLEANOUT WITH VENT SCREEN	EA	4	$775.00	$3,100.00
48" CONCRETE MANHOLE	EA	1	$3,500.00	$3,500.00
15" RCP CLASS V	LF	250	$60.00	$15,000.00
15" RCP FLARED-END SECTION W/TRASH GUARD	EA	2	$2,500.00	$5,000.00
SELECT GRANULAR BORROW IRON ENHANCED (MNDOT 3149.2B)	CY	95	$175.00	$16,625.00
COARSE FILTER AGGREGATE	CY	95	$80.00	$7,600.00
45 MIL SMOOTH EPDM LINER	SF	3700	$3.00	$11,100.00
OUTLET CONTROL STRUCTURE	EA	1	$10,000.00	$10,000.00
RIPRAP CLASS III	TN	45	$130.00	$5,850.00
		TOTAL		**$190,811.25**
ENGINEERING (20%)				$38,162
CONSTRUCTION ADMINISTRATION (10%)				$19,081
CONTINGENCY (30%)				$57,243.38
		Total Construction Cost		**$305,298.00**
		Annual Maintenance Cost		**$1,500.00**
		10-year Maintenance Cost		**$69,753.60**
		Total 30-year Life Cycle Cost		**$ 485,000.0**

Table F-8. REG-8 Detailed Construction, Maintenance, and 30-year Life Cycle Cost Estimate

			Engineer's Estimate	
Item	**Units**	**Qty**	**Unit Price**	**Total Price**
MOBILIZATION/DEMOBILIZATION (5%)	LS	1	$17,807.50	$17,807.50
CLEARING AND GRUBBING	LS	1	$2,500.00	$2,500.00
TEMPORARY DEWATERING	LS	1	$2,500.00	$2,500.00
TEMPORARY CONSTRUCTION ENTRANCE	EA	1	$2,500.00	$2,500.00
SILT FENCE, TYPE MACHINE SLICED - MAINTAINED	LF	550	$5.00	$2,750.00
8" BIOLOG - MAINTAINED	LF	250	$8.00	$2,000.00
FLOTATION SILT CURTAIN - MAINTAINED	LF	50	$20.00	$1,000.00
SALVAGE EXISTING TOPSOIL - STRIPPING, STOCKPILE, AND RESPREADING	CY	500	$6.00	$3,000.00
SEED MIXTURE	SY	2250	$2.00	$4,500.00
EROSION CONTROL BLANKET	SY	2250	$3.00	$6,750.00
PLANTINGS (TREES AND SHRUBS)	EA	5	$350.00	$1,750.00
COMMON EXCAVATION - ONSITE (EV)	CY	500	$10.00	$5,000.00
MUCK EXCAVATION - OFFSITE (EV)	CY	1150	$30.00	$34,500.00
LIFT STATION	LS	1	$200,000.00	$200,000.00
REMOVALS - OUTLET STRUCTURE	EA	1	$2,500.00	$2,500.00
8" SLOTTED PVC DRAINTILE	LF	150	$30.00	$4,500.00
SOLID PVC SCH 40	LF	40	$25.00	$1,000.00
CLEANOUT WITH VENT SCREEN	EA	6	$775.00	$4,650.00
48" CONCRETE MANHOLE	EA	1	$3,500.00	$3,500.00
15" RCP CLASS V	LF	75	$60.00	$4,500.00
15" RCP FLARED-END SECTION W/TRASH GUARD	EA	2	$2,500.00	$5,000.00
SELECT GRANULAR BORROW IRON ENHANCED (MNDOT 3149.2B)	CY	130	$175.00	$22,750.00
COARSE FILTER AGGREGATE	CY	130	$80.00	$10,400.00
45 MIL SMOOTH EPDM LINER	SF	4250	$3.00	$12,750.00
OUTLET CONTROL STRUCTURE	EA	1	$10,000.00	$10,000.00
RIPRAP CLASS III	TN	45	$130.00	$5,850.00
		TOTAL		**$373,957.50**
ENGINEERING (20%)				$74,792
CONSTRUCTION ADMINISTRATION (10%)				$37,396
CONTINGENCY (30%)				$112,187.25
Total Construction Cost				**$598,332.00**
Annual Maintenance Cost				**$1,500.00**
10-year Maintenance Cost				**$64,982.40**
Total 30-year Life Cycle Cost				**$ 770,000.0**

Table F-9. 1M/4M Trail Stabilization Construction Cost Estimate

Opinion of Probable Cost

No.	Item	Units	Qty	Unit Price		Total	
1	Mobilization/Demobilization	LS	1	$	2,000.00	$	2,000.00
2	Site Access & Restoration	LS	1	$	7,500.00	$	7,500.00
3	Remove Existing CMP and Replace	LS	1	$	7,500.00	$	7,500.00
6	Class III Rip Rap (Veg. Riprap)	TON	10	$	130.00	$	1,300.00
7	Geotextile (mnDOT typ. 5)	SY	40	$	5.00	$	200.00
5	Tree Thinning	LS	1	$	5,000.00	$	5,000.00
9	Erosion Control Blanket	SY	40	$	3.00	$	120.00
10	Seeding (MN state mix 34-261)	SY	2000	$	2.00	$	4,000.00
					SUBTOTAL	$	27,620.00
					20% CONTINGENCY	$	5,524.00
					TOTAL	$	33,144.00

Table F-10. Site 3J Construction Cost Estimate

Opinion of Probable Cost

No.	Item	Units	Qty	Unit Price		Total	
1	Mobilization/Demobilization	LS	1	$	1,000.00	$	1,000.00
2	Site Access & Restoration	LS	1	$	7,500.00	$	7,500.00
3	Cleanout of Existing Culvert	EA	2	$	500.00	$	1,000.00
4	Class III Rip Rap (Veg. Riprap)	TON	5	$	200.00	$	1,000.00
5	Tree Thinning	LS	1	$	5,000.00	$	5,000.00
6	Seeding (MN state mix 34-261)	SY	750	$	2.00	$	1,500.00
					SUBTOTAL	$	17,000.00
					20% CONTINGENCY	$	3,400.00
					TOTAL	$	20,400.00

Table F-11. General Trail Repair Summary

Site	Problem Description	Photo Img #s	Project Ideas	Project Priority (1 = high, 3 = low)
4S	Erosion off trail - 48' length, 3' wide, 0-0.5' height. Sheet erosion. Actively eroding, shallow concentrated flow, moderate slope, brown silty sand, buckthorn, sparse vegetation, slight to moderate lateral recession rate. Could use erosion control mat and reseeding likely.	0524-0527	Control runoff; soil looks sandy, intercept flow into an infiltration basin (raingarden).	3
3S	59' long, 3' wide, 0-0.5' height. Sheet erosion. Silty clay soils. Erosion/drainage from trail - shallow concentrated flow. Slight to moderate lateral recession rate. Could use erosion control mat and reseeding likely.	0528-0531	Intercept surface runoff and infiltrate or control it's flow with a drainage swale with rock check dams to the side of the trail so the trail stays more dry and intact.	3
2S	51' long, 3' wide, 0-0.5' height. Clayey silt. Shallow concentrated flow. Sheet erosion. Slight to moderate lateral recession rate. Could use erosion control mat and reseeding likely.	0533-0543	Intercept surface runoff and infiltrate or control it's flow with a drainage swale with rock check dams to the side of the trail so the trail stays more dry and intact.	3
7J	Moderate erosion of gravel/equestrian trail at two locations onto Carriage Hill Dr. Rill erosion.	0565-0567	Split rail fence to prevent cow pathing and then revegetate.	3
1J	Significant gravel trail gully erosion downcutting from off parking lot canoe access/launch trail.	0571-0572	Intercept surface runoff and infiltrate or control it's flow with a drainage swale with rock check dams to the side of the trail so the trail stays more dry and intact.	2
2J	3-4' wide, sheet erosion, 0-.5' deep, approx. 100' in length (sheet flow to shallow concentrated within 30 feet of trail crossing) Organic sands. Slight to moderate lat. Recession rate.		Build up the trail? Boardwalk?	3

Table F-12. Holland Lake Channel Project Construction Cost Estimate

Holland Lake Channel Estimate of Probable Cost					
No.	**Item**	**Units**	**Qty**	**Unit Price**	**Total**
1	Mobilization/Demobilization	LS	1	$ 2,500.00	$ 2,500.00
2	Site Access & Restoration	LS	1	$ 7,500.00	$ 7,500.00
3	Remove CMP Culvert	EA	2	$ 1,500.00	$ 3,000.00
4	HDPE Pipe w/Flared End Section	EA	2	$ 2,000.00	$ 4,000.00
5	Bank Resloping	LF	200	$ 10.00	$ 2,000.00
6	Class III Rip Rap (Veg. Riprap)	TON	60	$ 130.00	$ 7,800.00
7	Geotextile (mnDOT typ. 5)	SY	140	$ 5.00	$ 700.00
8	Floating silt curtin	LF	50	$ 20.00	$ 1,000.00
9	Erosion Control Blanket	SY	160	$ 3.00	$ 480.00
10	Seeding (MN state mix 34-261)	SY	160	$ 2.00	$ 320.00
				SUBTOTAL	$ 29,300.00
				20% CONTINGENCY	$ 5,860.00
				TOTAL	$ 35,160.00

Table F-13. Schulze Lake Channel Project Construction Cost Estimate

Schulze Lake Channel Estimate of Probable Cost					
No.	**Item**	**Units**	**Qty**	**Unit Price**	**Total**
1	Mobilization/Demobilization	LS	1	$ 2,500.00	$ 2,500.00
2	Invasive Species Removal & Selective Tree Felling	LS	1	$ 5,000.00	$ 5,000.00
3	Coir Log Toe	LF	150	$ 40.00	$ 6,000.00
4	Cedar Revetment (Cedar trees provided by owner)	LF	150	$ 15.00	$ 2,250.00
5	Live Stakes	EA	50	$ 15.00	$ 750.00
6	Bare Root Plants	EA	250	$ 5.00	$ 1,250.00
7	Seeding (MN state mix 33-262)	SY	400	$ 2.00	$ 800.00
				SUBTOTAL	$ 17,550.00
				20% CONTINGENCY	$ 3,510.00
				TOTAL	$ 21,060.00

Table F-14. Schulze Lake Alum Application Cost Estimate

Schulze Lake Application Cost Estimate				
Item	**Unit**	**Quantity**	**Unit Cost**	**Total Cost**
1st Sodium Aluminate Application	Gal NaAlO2	1,985	$5.00	$10,000
1st Alum Application	Gal $AlSO_4$	3,970	$1.80	$7,000
2nd Sodium Aluminate Application	Gal NaAlO2	1,985	$5.00	$10,000
2nd Alum Application	Gal $AlSO_4$	3,970	$1.80	$7,000
MOBILIZATION	LUMP SUM	1	$10,000.00	$10,000
Application Cost Estimate				$44,000
Application Management Services				$1,000
Bidding, Permitting, and Specification Development				$5,000
Coring for Design and Follow up Monitoring				$10,000
Total Cost Estimate				**$60,000**

Table F-15. Gerhardt Lake Alum Application Cost Estimate

Gerhardt Lake Alum Application Cost Estimate				
Item	**Unit**	**Quantity**	**Unit Cost**	**Total Cost**
Initial Aluminum Sulfate Application	Gal $AlSO_4$	2,620	$ 1.80	$5,000
Initial Sodium Aluminate Application	Gal $NaAlO_2$	1,310	$ 5.00	$7,000
Initial Aluminum Sulfate Application	Gal $AlSO_4$	2,620	$ 1.80	$5,000
Initial Sodium Aluminate Application	Gal $NaAlO_2$	1,310	$ 5.00	$7,000
MOBILIZATION	LUMP SUM	1	$10,000.00	$10,000
Application Cost Estimate				$34,000
Application observation and monitoring				$1,000
Bidding, Permitting, and Specification Development				$5,000
Follow Up Monitoring				$5,000
Total Cost Estimate				**$45,000**