Middle St. Croix Watershed Management Organization 2018 Water Monitoring Summary

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WASHINGTON CONSERVATION DISTRICT

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Multiple agencies and individuals were directly involved in many aspects of this project, such as data collection and data analysis, as well as technical and administrative assistance.

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

Anoxic	Lacking oxygen
BCWD	Brown's Creek Watershed District
Benthic	The area nearest lake bed
Biweekly	Every two weeks
BMP	Best Management Practice
cf	cubic feet
cfs	cubic feet per second
Chl-α	Chlorophyll-α
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
IESF	Iron Enhanced Sand Filter
Littoral zone	The area of a body of water where sunlight penetrates all the way to the sediment and allows aquatic plants (macrophytes) to grow
MCES	Metropolitan Council Environmental Services
mg/L	milligram per liter
ml	milliliter
MN DNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MPN	Most probable number
MSCWMO	Middle St. Croix Watershed Management Organization
NCHFE	North Central Hardwood Forest Ecoregion
OHW	Ordinary High Water level
SOP	Standard Operating Procedure
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSI	Trophic State Index
TSMP	Trout Stream Mitigation Project
TSS	Total Suspended Solids
µg/L	micrograms per liter
µmhos/cm	micromhos per centimeter
WCD	Washington Conservation District

EXECUTIVE SUMMARY

This report focuses on the summary and comparison of lake and stream water quality data collected by the Washington Conservation District (WCD) in 2018 as well as previous years. In 2018 the Middle St. Croix Watershed Management Organization (MSCWMO) monitored both water quality and water surface elevation on McKusick Lake and Lily Lake, flow and water quality at the Greeley Street Inlet to Lily Lake and Perro Creek at the Diversion Structure, water quality at Perro Creek at the Perro Pond Outlet, Perro Creek at 5th Avenue, Perro Creek at 9th Street, Perro Creek at 8th Street, Perro Creek at 6th Street, Perro Creek at 4th Street, Perro Creek at St. Croix Trail Downstream, Perro Creek at Central Avenue, and Perro Creek at 3rd Avenue. The purpose of this monitoring is to assess and document current water quality conditions of the lakes and streams, as well as continuing a long-term monitoring program that will enable the MSCWMO to identify trends associated with best management practice (BMP) implementation and land use changes in the watershed.

Lake Monitoring

Lily Lake was classified as eutrophic and received a B- grade in 2018 (APPENDIX A). One sample exceeded the Minnesota Pollution Control Agency's (MPCA) standard for total phosphorus (TP), four samples exceeded the MPCA standard for chl-α corrected for pheophytin, four Secchi disk transparency readings exceeded the MPCA standard (APPENDIX A).

In 2018 McKusick Lake was classified as eutrophic and received a grade of C+ (APPENDIX A). No samples exceeded the MPCA shallow lake standard for TP, and one sample exceeded the MPCA standard for chl-α corrected for pheophytin. No Secchi disk transparency measurements exceeded the MPCA shallow lake standard (APPENDIX A).

Stream and Storm Monitoring

In 2018 monitoring continued on the Greeley Street catchment of Lily Lake. Results in 2018 were lower than results in prior years (Figure 8 and Figure 9). The Greeley Street catchment base flow grab samples had concentrations below standards of TP and Total suspended solids

TSS (Table 5 and Table 6). As in previous years the storm event grab sample result was higher than base samples. These sample results confirm previous results that the majority of loading to Lily Lake occurs during storm events.

The MSCWMO continued monitoring Perro Creek to identify where the greatest contribution of pollutants to the Saint Croix River was occurring. In 2018 Perro Creek at the Diversion Structure was the only site on Perro Creek monitored for TSS, total Kjeldahl nitrogen (TKN), TP, and *E. coli*. *E. coli* was also collected at several other locations along Perro Creek at the Perro Pond Outlet, Perro Creek at 5th Avenue, Perro Creek at 9th Street, Perro Creek at 8th Street, Perro Creek at 6th Street, Perro Creek at 4th Street, Perro Creek at St. Croix Trail Downstream, Perro Creek at Central Avenue, and Perro Creek at 3rd Avenue.

Perro Creek at the Diversion Structure sample results were on average lower than 2017, with base samples results lower than storm samples as expected (Table 7 and Table 8). The *E. coli* results for Perro Creek at the Diversion Structure, Perro Creek at the Perro Pond Outlet, and Perro Creek at 6th Street were higher in 2018 than 2017. All sites along Perro Creek had at least one *E. coli* sample that exceeded the MPCA impairment standard (Table 9). Perro Creek at 6th Street is exceeding MPCA impairment standards for geometric means of *E. coli* in June and September based on the last ten years of data (Table 10).

The Brown's Creek Diversion Structure site, which exports to McKusick Lake, showed an increase in discharge in 2018 to 45,453,990 cubic feet (cf) from 39,625,672 cf in 2017. The phosphorus load increased from 784 lbs. in 2017 to 964 lbs. in 2018. TSS had a decreased export from the Brown's Creek Diversion Structure to McKusick Lake, from 596,382 lbs. in 2017 to 505,314 lbs. in 2018 (Table 2 and Table 3). A source of the high TP and TSS loads in the diversion drainage was an eroding head cut north of Boutwell Road, upstream of the monitoring location. While this head cut was present during the 2018 monitoring season it was repaired in late November. As with most past years, exceedances of metal standards occurred frequently. Sources of metals for the Brown's Creek Diversion Structure site may include improperly disposed waste, such as deep cycle batteries.

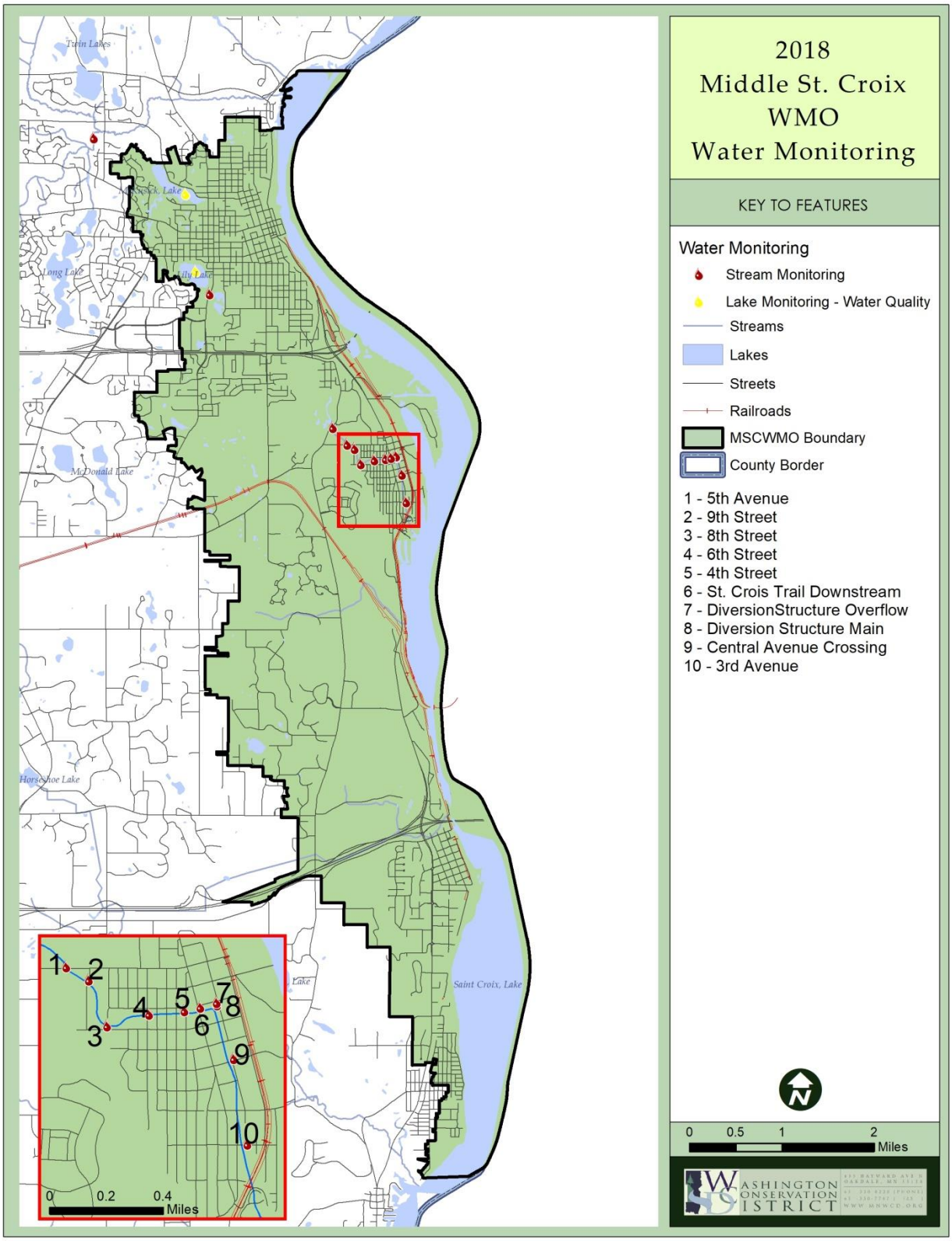

Figure 1. MSCWMO 2018 Water Monitoring Locations

LAKE MONITORING

A. METHODS, RESULTS AND DISCUSSION

In 2018 water quality data was collected biweekly on Lily Lake and McKusick Lake, over six consecutive months (May–October) by the Washington Conservation District. Measurements obtained during the summer sampling season (June–September) are averaged for a comparison of individual lake dynamics from year to year between lakes within the watershed and to the Minnesota Pollution Control Agency's (MPCA) impairment standards. Lake grades are based on the averages of samples collected May–September. Average values for all parameters are presented in APPENDIX A and Figure 4 through Figure 7, which show the current and historic summer averages for each parameter. Water quality samples were collected by the WCD with a two-meter (6.56 feet) integrated surface water column sampler. A full description of WCD Standard Operating Procedures is available on the Washington Conservation District website at http://www.mnwcd.org/water-quality-water-monitoring/. The Metropolitan Council Environmental Services (MCES) Laboratory analyzed the surface water samples for TP, chl-α, and TKN.

Total phosphorus is analyzed as it is a major nutrient involved in the eutrophication of lakes and is generally associated with the growth of aquatic plants and/or algal blooms. Common sources of phosphorus include runoff from agricultural fields, livestock areas, urban areas, lakeshore lawns, and improperly operating septic systems. With most lakes in this region, phosphorus is the least available nutrient; therefore, its abundance, or scarcity, controls the extent of algal growth. Excess algal growth, in turn, negatively affects the clarity, or transparency, and ability of light to penetrate the water. The MPCA sets lake eutrophication standards for aquatic life and recreation. The standard for TP is 0.040 mg/L for deep lakes and 0.060 mg/L for shallow lakes. In general, shallow lakes are defined as less than 15 feet deep, with greater than 80% littoral area, and less than 10 acres. The 2018 summer average of TP values of MSCWMO lakes can be found in Figure 4.

Chlorophyll-α is measured as it is the photosynthetic component found in algae and aquatic plants and is an indicator of algal productivity. The MPCA standard for pheophytin-corrected

chl-α is 14 µg/L for deep lakes and 20 µg/L for shallow lakes. The 2018 summer average chl-α concentrations of MSCWMO lakes can be found in Figure 5.

TKN, the sum of organic nitrogen and ammonia was analyzed in MSCWMO lakes. While no standard exists for TKN because TP is often limiting, TKN can contribute to eutrophication. The 2018 summer average TKN concentrations of MSCWMO lakes can be found in Figure 6.

Field measurements are recorded while collecting lake samples, including Secchi disk transparency. The measurement of light penetration using a Secchi disk gives a simple measure of water transparency, or clarity. A reduction in water transparency is typically the result of turbidity composed of suspended sediments, organic matter and/or phytoplankton (algae). The MPCA standard for Secchi disk transparency is 1.4 meters for deep lakes and 1.0 meter for shallow lakes.

User perception and physical/recreational suitability of lakes were recorded, along with temperature and dissolved oxygen (DO) profile measurements taken by the WCD during each sampling event. Profiles are recorded at one meter increments from the water surface to the lake bottom. The data show the extent of summer stratification and are useful in identifying the development of a thermocline (the layer of water in which the temperature rapidly declines). As a lake stratifies, the water column becomes more stable and mixing is less likely to occur. If mixing occurs during the growing season, nutrients from the lake bottom become available and can result in increased algal production. Lake DO profile data is useful in determining excessive production (algae/plants) in a lake. Increased production creates more DO, for a time, but as plants and algae die off and decay, the bacteria that decompose them consume DO. Low DO conditions may stress fish populations and under anoxic conditions nutrients may be released from the sediment. Data collected from the rankings and profiles are contained in a database at the WCD, and can be obtained by request, as well as on the MPCA website at http://cf.pca.state.mn.us/water/watershedweb/wdip/index.cfm.

A lake grading system is used in this summary, to allow for a better understanding of lake water quality data and to aid in the comparison of lakes. The lake water quality grading system was

developed following the 1989 sampling season by MCES. The concept of the lake grading system is a ranking of water quality characteristics by comparing measured values to those of other metro area lakes. The grading system represents percentile ranges for three water quality indicators: the May through September average values of TP, uncorrected trichromatic chl-α, and Secchi disk transparency. These percentiles use ranked data from 119 lakes sampled from 1980-1988 and are shown in Table 1. This method has since been replicated and the grading system has been verified with more recent data. The variables used in the grading system strongly correlate to open-water nuisance aspects of a lake (i.e. algal blooms), which can indicate accelerated aging (cultural eutrophication). There is a strong correlation when comparing trophic status to the lake grade. Summaries of all lake results are presented in APPENDIX A.

Table 1. Lake Grade Ranges

Grade	Percentile	TP (µg/L)	Chl-α (µg/L)	SD (m)
A	<10	<23	<10	>3.0
B	10-30	23-32	10-20	2.2-3.0
C	30-70	32-68	20-48	1.2-2.2
D	70-90	68-152	48-77	0.70-1.2
F	>90	>152	>77	<0.70

There are several metrics and systems that can also be used to assess lakes including the Carlson Trophic State Index (TSI) and ecoregion values. The Carlson Trophic State Index is used to quantify the relationship between water quality data and trophic status. Trophic states vary from oligotrophic (low biological activity and high clarity) to hypereutrophic (highly productive with very low clarity). The MSCWMO is located in the North Central Hardwood Forest Ecoregion where lakes are often mesotrophic. Ecoregion values are assigned for TP, TKN, chl- α, and Secchi disk transparency. This report will focus on the methods used by the MPCA and the Metropolitan Council, as previously discussed.

Water elevation monitoring was conducted on two lakes, McKusick and Lily, from May to October 2018. Lake elevation readings are compared to the lake's Ordinary High Water level

(OHW)[1]. The OHW for Lily and McKusick Lakes are 844.8 ft and 851.7 ft, respectively. Changes in lake water elevation are often attributed to the changes in precipitation. The highest recorded elevation in 2018 for Lily Lake occurred on 7/16/18 at 846.24 ft and on 10/11/18 at 854.99 ft for McKusick Lake. Complete lake elevation data for 2018 can be found in Figure 2 and Figure 3. For historical lake elevations, visit the MN DNR Lake Finder webpage at http://www.dnr.state.mn.us/lakefind/index.html.

1. LILY LAKE

In 2018 WCD staff conducted two-tailed Kendall's Tau statistical analysis based on data collected by professional agencies for both lakes monitored in MSCWMO to determine trends for TP, Secchi, and chl-α ($p<0.05$). Lily Lake had a statistically significant improving trend for TP, a statistically significantly declining trend for chl-α and no trend was found for average Secchi disk transparency. Lily Lake had an average summertime TP concentration of 0.032 mg/L, which was lower than 2017 (Figure 4). One of the nine summertime results were greater than the MPCA lake nutrient impairment standard for TP. The 2018 average summertime concentration of chl-α was 22.6 μg/L, which is greater than the 18.5 μg/L measured in 2017 (Figure 5). Four of the nine water quality results for chl-α impairment exceeded the MPCA lake standard (APPENDIX A). Lily Lake had an average summertime TKN concentration of 1.07 mg/L in 2017; higher than the 1.00 mg/L seen in 2017 (Figure 6). Secchi disk readings were measured in 2018 with a summertime average of 1.69 meters (Figure 7), with four of the nine water quality readings exceeding the MPCA lake standard for Secchi disk transparency (APPENDIX A). Lily Lake received a grade of B- in 2018; an improvement from the 2017 grade of a C+. Temperature and DO profiles indicate that Lily Lake exhibited thermal

[1] Minnesota State Statutes defines the ordinary high water level (OHW) as follows: Minnesota Statutes 103G.005 Subd. 14. Ordinary High Water Level. "Ordinary high water level" means the boundary of water basins, watercourses, public waters and public waters wetlands, and: The ordinary high water level is an elevation delineating the highest water level that has been maintained for a sufficient period of time to leave evidence upon the landscape, commonly the point where the natural vegetation changes from predominantly aquatic to predominantly terrestrial;

1) For watercourses, the ordinary high water level is the elevation of the top of the bank of the channel; and
2) For reservoirs and flowages, the ordinary high water level is the operating elevation of the normal summer pool.
3) For reservoirs and flowages, the ordinary high water level is the operating elevation of the normal summer pool.

stratification during the summer months with the thermocline around 4 meters; therefore the lake was less likely to completely mix throughout the summer. Lily Lake was below the OHW for two elevation readings, falling to its lowest recorded level on 5/21/18 with an elevation of 845.44 ft. The elevation was above the OHW for most of the monitoring season, reaching its highest recorded level on 7/16/18 with a level of 846.24 ft. (Figure 2). A summary of all lake results is presented in APPENDIX A.

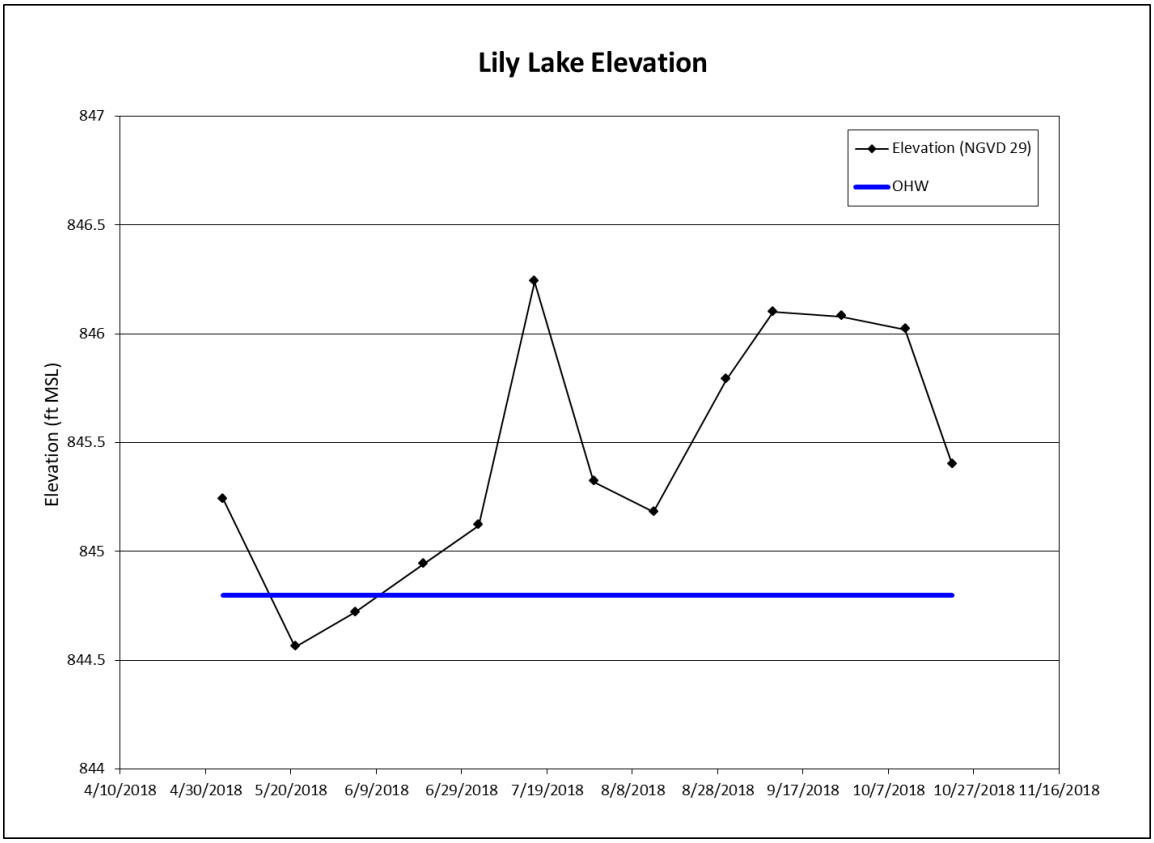

Figure 2. Lily Lake 2018 Elevations

2. MCKUSICK LAKE

A two-tailed Kendall's Tau analysis based on data collected by professional agencies showed that McKusick Lake has statistically significant ($p<0.05$) improving trends for TP and Secchi transparency, and no trend is present for chl-α. The McKusick Lake summertime average TP concentration in 2018 was 0.045 mg/L; lower than the 0.056 mg/L observed in 2017 (Figure 4), with no water quality samples exceeding the MPCA TP impairment standard for shallow lakes (APPENDIX A). McKusick Lake had a summertime average chl-α concentration of 9.8 µg/L; lower than the chl-α average of 10.8 µg/L from 2017 (Figure 5). Of the nine summertime

samples collected in 2018, one exceeded the MPCA shallow lake standard for chl-α. The average summertime TKN concentration for 2018 was 0.78 mg/L; lower than the 0.89 mg/L measured in 2017 (Figure 6). The 2018 summertime average water transparency measured by Secchi disk was 1.90 meters (Figure 7). All of the summertime Secchi disk readings in 2018 were better than the MPCA shallow lake impairment standard. The overall water quality of McKusick Lake is comparable to the previous year, receiving a grade of C+ for 2018. No change in grade was seen from 2017. Temperature and DO profiles indicate that McKusick Lake exhibited thermal stratification during the summer months in the deepest portion of the lake with the thermocline around 3 meters. A majority of McKusick Lake is very shallow and does not stratify, and therefore is likely to have mixed throughout the summer. The elevation of McKusick Lake remained above the OHW for the entire monitoring season, reaching its highest recorded level on 10/11/18 with a level of 854.99 ft. and the lowest recorded level occurred on 8/13/18 with an elevation of 854.19 ft. (Figure 3). A summary of all lake results is presented in APPENDIX A.

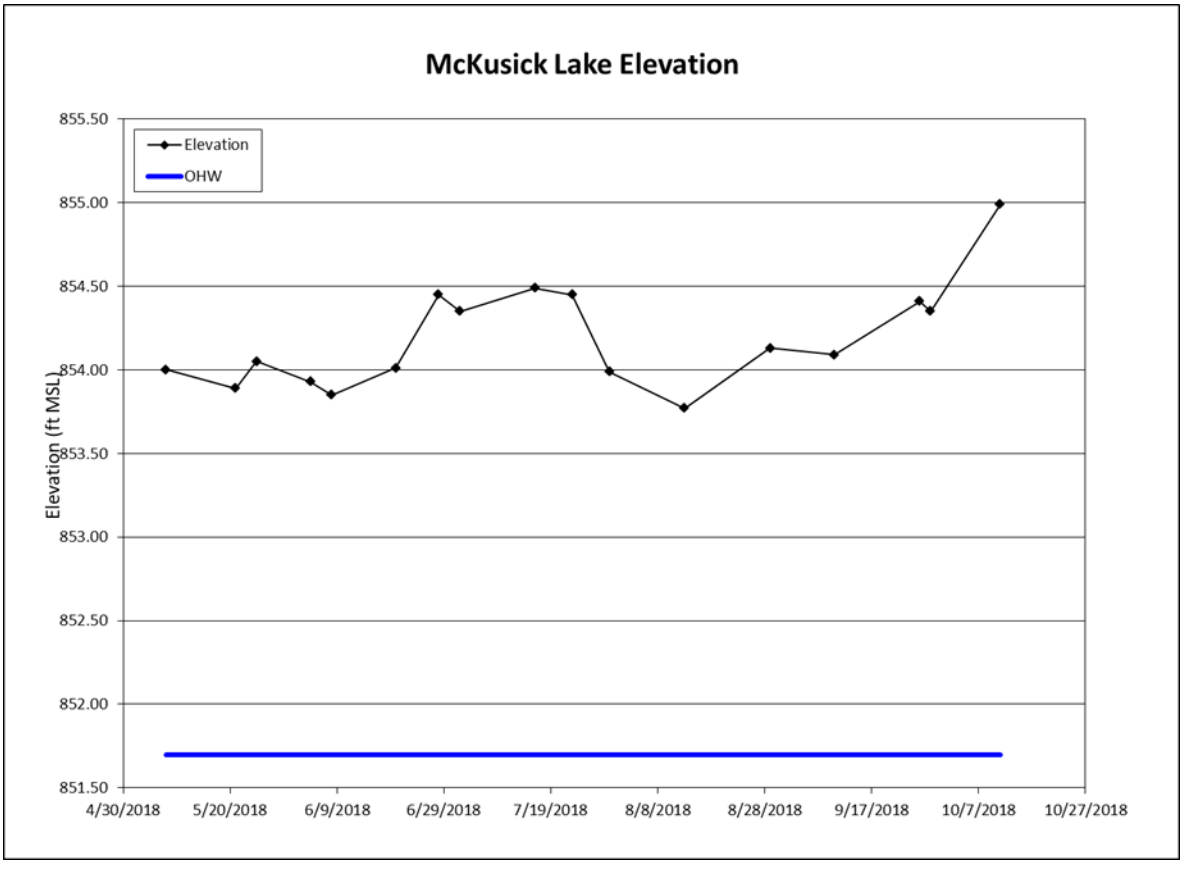

Figure 3. McKusick Lake 2018 Elevations

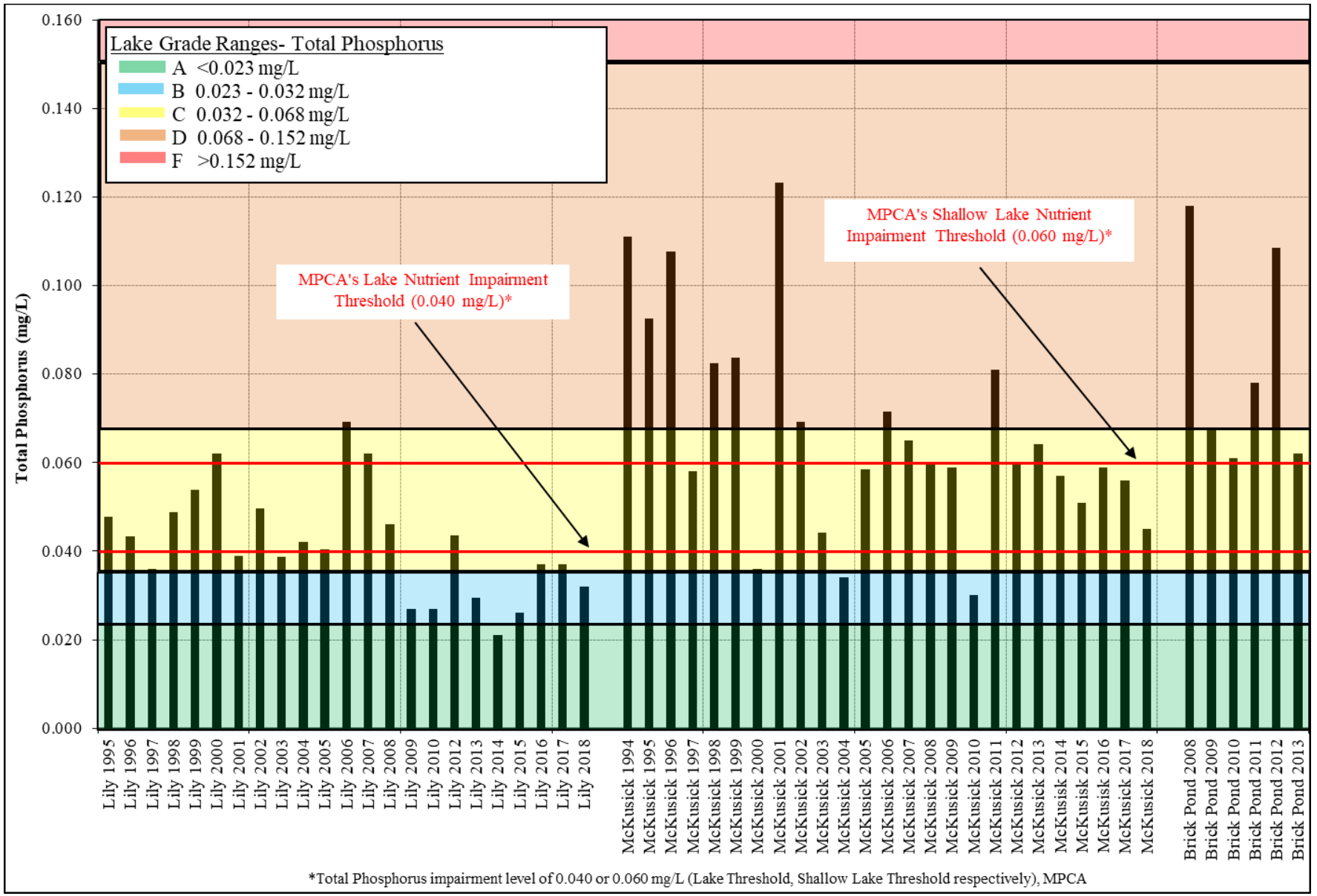

Figure 4. MSCWMO Historic Summer Average Total Phosphorus

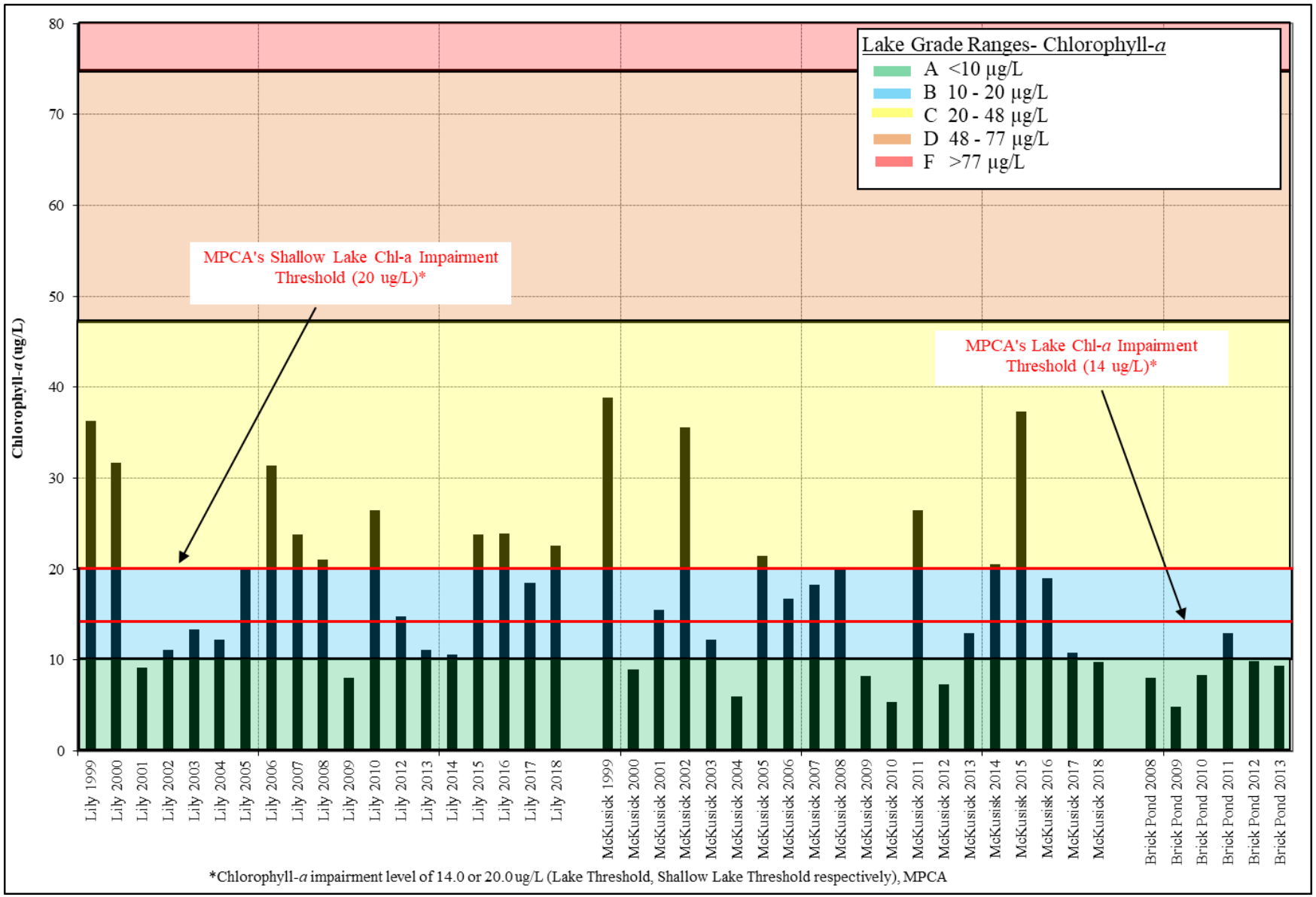

Figure 5. MSCWMO Historic Summer Average Chlorophyll-α

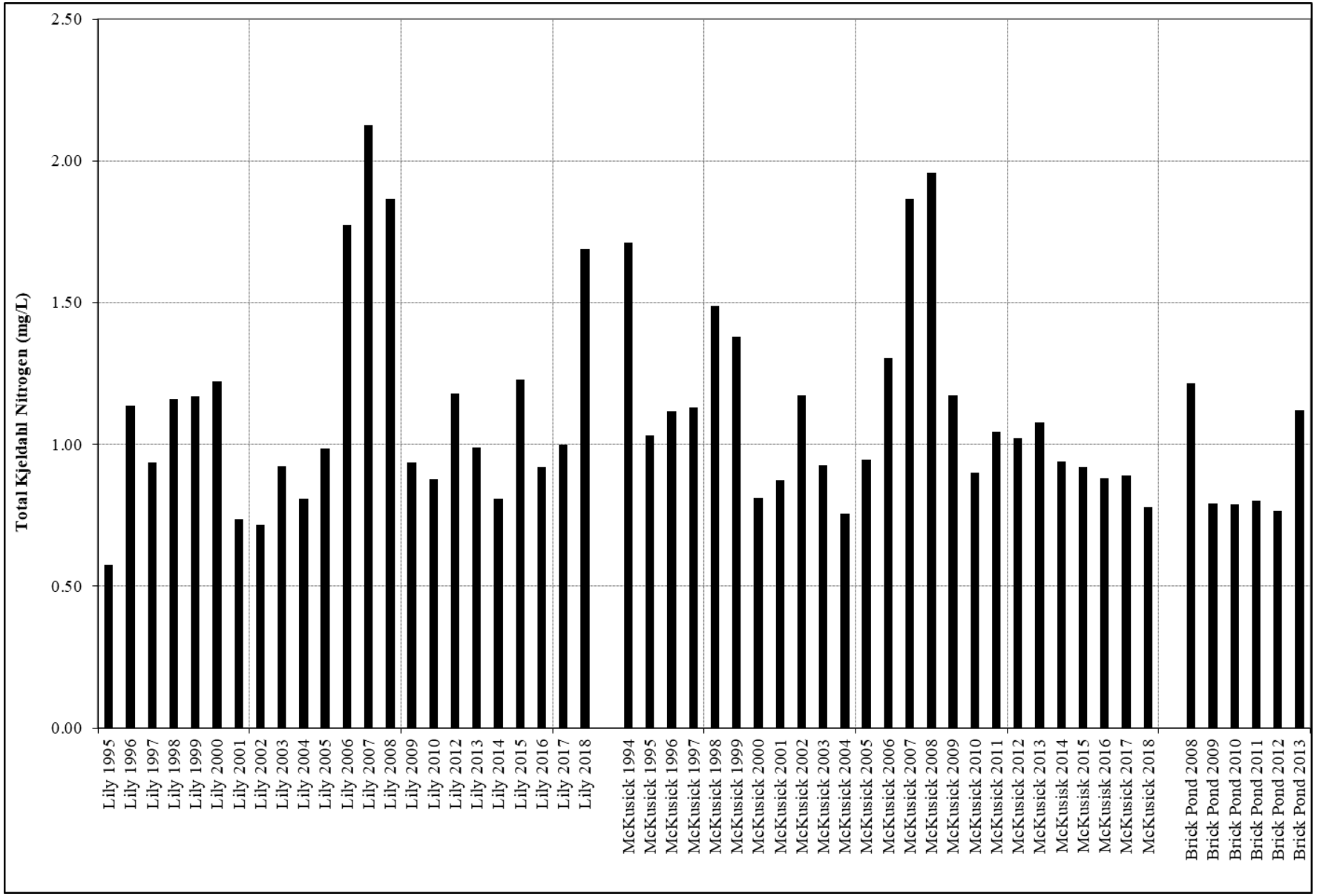

Figure 6. MSCWMO Historic Summer Average Total Kjeldahl Nitrogen

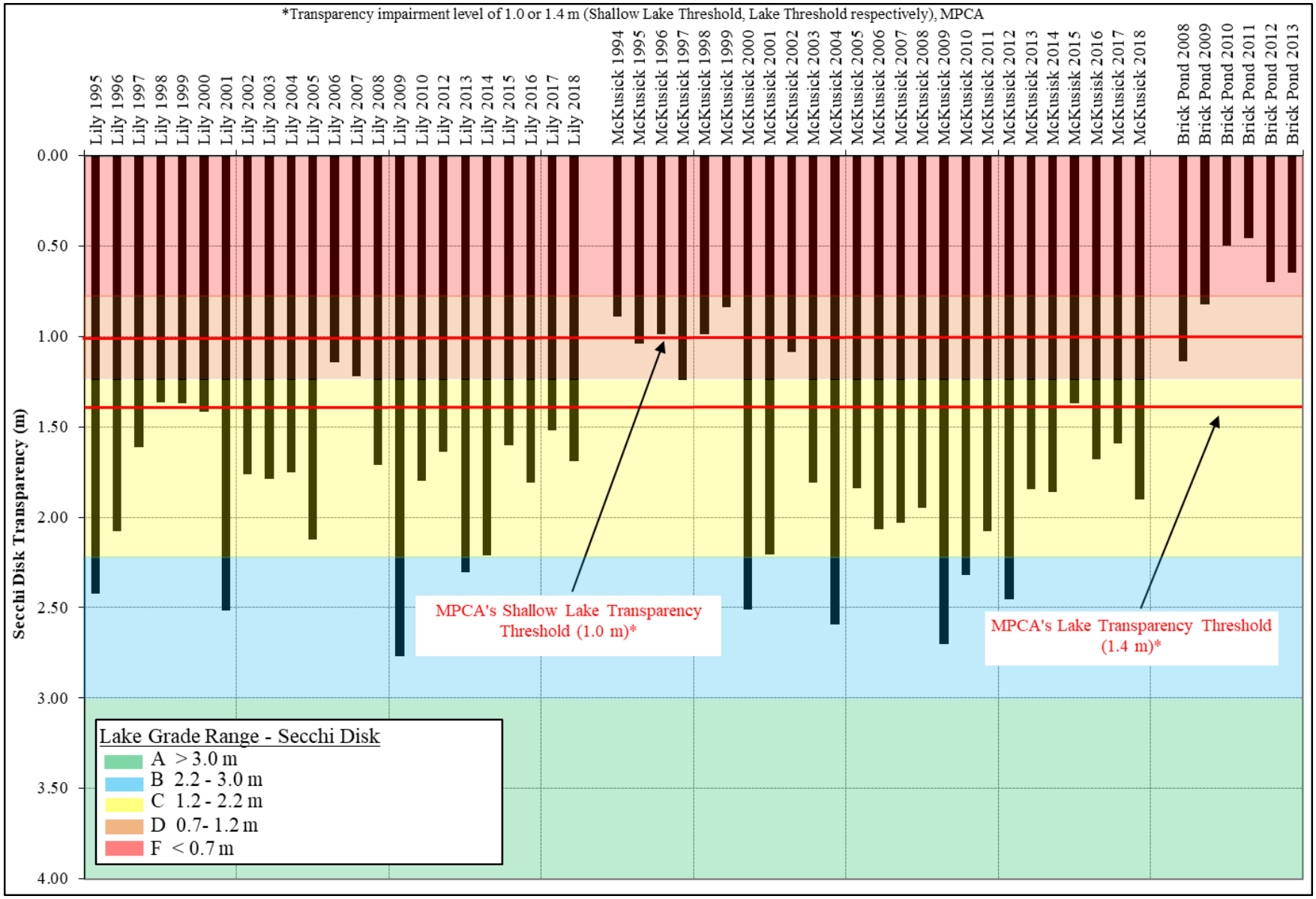

Figure 7. MSCWMO Historic Summer Average Secchi Disk Transparency

3. BROWN'S CREEK DIVERSION STRUCTURE

As part of Brown's Creek Watershed District's long term monitoring, the WCD collected grab samples and automated flow-weighted samples during both base flow and storm event conditions at the Brown's Creek Diversion Structure for BCWD in 2018, and that data is provided to the MSCWMO. The City of Stillwater constructed the diversion structure in June of 2003, as part of the completion of the Trout Stream Mitigation Project (TSMP). It has been functioning to divert water from the 1,800-acre annexation area away from Brown's Creek through McKusick Lake, and ultimately to the St. Croix River. While this diversion structure keeps the warmer urban stormwater runoff from the southern tributary out of the temperature and nutrient sensitive Brown's Creek Ravine, it means that this water will be discharged to McKusick Lake, and could affect the lake water quality. Data collected at this site by the WCD includes continuous stage and total discharge, and water quality samples analyzed for nutrients, sediment, and metals. No bacteria samples were collected at the site in 2018. Discharge increased from 2017 to 2018, with a volume of 45,453,990 cubic feet exported to McKusick Lake (Table 2 and Table 3). All stream flow and chemistry data from 2018 can be found in Table 2 through Table 4.

The TP load to McKusick Lake increased in 2018 from the year prior to 964 pounds of phosphorus (0.250 pounds per acre) (Table 2 and Table 3). The TSS load decreased from the year prior to 505,314 pounds of sediment, equating to 131.08 pounds per acre of watershed land (Table 2 and Table 3). One source of the high TP and TSS loads in the diversion drainage in 2018 and previous years was an erosional head cut north of Boutwell Road, upstream of the monitoring location. This head cut was repaired in late November, and is expected to reduce nutrient loads in the drainage. Additionally, the Iron Enhanced Sand Filter (IESF) upstream of the monitoring site continues to operate to reduce TP loads in this subwatershed.

In 2018 there were a number of metal standard exceedances. Exceedances are based on the MPCA metal standards. The calculation of metal standards are described in the Minnesota Administrative Rules Part 7050.0222 and are divided into three categories of toxicity; chronic, maximum, and final acute value (FAV). The chronic standard protects organisms from long term exposure to a pollutant with minimal effects, the maximum standard from short term

exposure with no or little mortality, and the FAV is the concentration at which mortality can be expected. As with past years copper continues to be an issue, with the final acute value exceeded by one sample and the maximum standard exceeded by one sample. The maximum standard for zinc was exceeded by one sample, and several chronic standard exceedances of copper, lead, and zinc were recorded. A summary of metals results can be seen in (Table 4). The occurrence of heavy metal exceedances exported to McKusick Lake and its wetland complex are particularly concerning due to the potential to kill aquatic life at high concentrations, as opposed to nutrient or sediment loading which typically degrades habitat and populations of aquatic life over time. One possible source of these elevated metals is the erosion that was occurring upstream of the site. Additional sources may be from unseen deposits of improperly disposed waste, such as batteries.

Table 2. Brown's Creek Diversion Structure Drainage Historical Annual Discharge and Loading Amounts

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Brown's Creek Diversion Structure										
Discharge (cf)	31,166,264	38,197,468	52,981,553	21,810,789	46,435,271	53,519,017	46,276,327	70,780,581	39,625,672	45,453,990
Total pounds of Phosphorus exported	544	608	2,099	251	527	392	1,837	1,574	784	964
TP (lbs/ac/yr)	0.141	0.158	0.544	0.065	0.137	0.102	0.447	0.408	0.203	0.250
Total pounds of TSS exported	227,372	353,007	1,387,050	127,435	211,977	99,532	1,008,346	1,533,496	596,382	505,314
TSS (lbs/ac/yr)	58.98	91.57	359.81	33.06	54.99	25.82	261.57	397.79	154.70	131.08

Table 3. Brown's Creek Diversion Structure Drainage 2018 Total Suspended Solids (TSS) and Total Phosphorus (TP) Loading

	Sample Collection Time				Loading Interval					
Sample Type	Start	End	TSS (mg/L)	TP (mg/L)	Start	End	Interval Volume (cf)	Interval Volume (ac-ft)	Interval TSS (lb)	Interval TP (lb)
*Base**			*7*	*0.073*	*1/1/2018 0:00*	*3/26/2018 14:45*	*2,558,745*	*58.77*	*1,118*	*11.69*
*Snowmelt**			*22*	*0.160*	*3/26/2018 14:45*	*3/28/2018 17:45*	*165,240*	*3.80*	*227*	*1.65*
*Base**			*7*	*0.073*	*3/28/2018 17:45*	*4/11/2018 11:45*	*594,000*	*13.64*	*260*	*2.71*
*Snowmelt**			*22*	*0.160*	*4/11/2018 11:45*	*4/12/2018 18:00*	*108,900*	*2.50*	*150*	*1.09*
*Base**			*7*	*0.073*	*4/12/2018 18:00*	*4/19/2018 11:15*	*435,375*	*10.00*	*190*	*1.99*
Snowmelt Grab*	4/23/2018 8:33	4/23/2018 8:33	22	0.160	4/19/2018 11:15	4/23/2018 19:30	1,013,310	23.27	1,392	10.12
*Base**			*7*	*0.073*	*4/23/2018 19:30*	*4/26/2018 10:15*	*338,850*	*7.78*	*148*	*1.55*
Base			*7*	*0.073*	*4/26/2018 10:15*	*5/6/2018 18:15*	*1,442,760*	*33.14*	*630*	*6.59*
*Base**			*7*	*0.073*	*5/6/2018 18:15*	*5/8/2018 9:30*	*187,223*	*4.30*	*82*	*0.86*
Base			*7*	*0.073*	*5/8/2018 9:30*	*5/8/2018 10:30*	*3,757*	*0.09*	*2*	*0.02*
Storm			*810*	*1.474*	*5/8/2018 10:30*	*5/9/2018 8:30*	*299,857*	*6.89*	*15,162*	*27.59*
Base			*7*	*0.073*	*5/9/2018 8:30*	*5/23/2018 14:30*	*1,101,250*	*25.29*	*481*	*5.03*
Unexplained Event			*510*	*0.954*	*5/23/2018 14:30*	*5/23/2018 22:30*	*49,232*	*1.13*	*1,567*	*2.93*
Base			*7*	*0.073*	*5/23/2018 22:30*	*5/25/2018 1:30*	*60,538*	*1.39*	*26*	*0.28*
Storm			*810*	*1.474*	*5/25/2018 1:30*	*5/25/2018 12:30*	*61,687*	*1.42*	*3,119*	*5.68*
Base			*7*	*0.073*	*5/25/2018 12:30*	*5/29/2018 9:30*	*231,403*	*5.32*	*101*	*1.06*
Base Grab	5/30/2018 9:45	5/30/2018 9:45	16	0.130	5/29/2018 9:30	5/31/2018 9:30	149,244	3.43	149	1.21
Base			*7*	*0.073*	*5/31/2018 9:30*	*6/16/2018 6:30*	*825,978*	*18.97*	*361*	*3.77*
Storm			*810*	*1.474*	*6/16/2018 6:30*	*6/16/2018 15:30*	*42,226*	*0.97*	*2,135*	*3.89*
Base			*7*	*0.073*	*6/16/2018 15:30*	*6/17/2018 22:30*	*86,282*	*1.98*	*38*	*0.39*
Storm Composite	6/18/2018 1:12	6/18/2018 14:01	1,790	2.430	6/17/2018 22:30	6/18/2018 14:30	139,350	3.20	15,571	21.14
Base			*7*	*0.073*	*6/18/2018 14:30*	*6/24/2018 12:30*	*405,998*	*9.33*	*177*	*1.86*
Storm Composite	6/24/2018 13:48	6/25/2018 1:21	810	1.790	6/24/2018 12:30	6/25/2018 2:30	172,068	3.95	8,701	19.23
Storm Grab	6/25/2018 10:13	6/25/2018 10:13	52	0.219	6/25/2018 2:30	6/26/2018 2:30	118,086	2.71	383	1.61
Storm Composite	6/26/2018 6:35	6/26/2018 13:59	1,690	3.900	6/26/2018 2:30	6/26/2018 14:30	152,856	3.51	16,126	37.21
Base			*7*	*0.073*	*6/26/2018 14:30*	*6/29/2018 8:30*	*379,351*	*8.71*	*166*	*1.73*
Storm Composite**	6/29/2018 9:43	6/29/2018 17:35	6,200	4.360	6/29/2018 8:30	6/29/2018 18:30	301,605	6.93	116,734	82.09
Base			*7*	*0.073*	*6/29/2018 18:30*	*7/1/2018 10:30*	*626,981*	*14.40*	*274*	*2.87*
Storm Composite	7/1/2018 10:28	7/1/2018 15:20	1,200	1.300	7/1/2018 10:30	7/1/2018 16:30	91,070	2.09	6,822	7.39
Base			*7*	*0.073*	*7/1/2018 16:30*	*7/4/2018 10:30*	*334,596*	*7.69*	*146*	*1.53*
Storm			*810*	*1.474*	*7/4/2018 10:30*	*7/4/2018 17:30*	*62,544*	*1.44*	*3,163*	*5.75*
Base			*7*	*0.073*	*7/4/2018 17:30*	*7/12/2018 17:30*	*533,768*	*12.26*	*233*	*2.44*
Storm Composite	7/12/2018 18:18	7/13/2018 3:08	170	0.558	7/12/2018 17:30	7/13/2018 10:30	1,802,810	41.41	19,132	62.80
Base			*7*	*0.073*	*7/13/2018 10:30*	*7/16/2018 8:30*	*963,627*	*22.13*	*421*	*4.40*
Storm			*810*	*1.474*	*7/16/2018 8:30*	*7/16/2018 18:30*	*544,243*	*12.50*	*27,520*	*50.08*
Base			*7*	*0.073*	*7/16/2018 18:30*	*7/18/2018 13:30*	*2,050,730*	*47.10*	*896*	*9.37*
Unexplained Event			*510*	*0.954*	*7/18/2018 13:30*	*7/19/2018 1:30*	*500,565*	*11.50*	*15,931*	*29.81*
Base			*7*	*0.073*	*7/19/2018 1:30*	*7/19/2018 12:30*	*282,214*	*6.48*	*123*	*1.29*
Unexplained Event			*510*	*0.954*	*7/19/2018 12:30*	*7/20/2018 2:30*	*489,105*	*11.23*	*15,566*	*29.13*
Base			*7*	*0.073*	*7/20/2018 2:30*	*7/20/2018 8:30*	*100,864*	*2.32*	*44*	*0.46*
Unexplained Event			*510*	*0.954*	*7/20/2018 8:30*	*7/21/2018 4:30*	*527,536*	*12.12*	*16,789*	*31.42*
Base			*7*	*0.073*	*7/21/2018 4:30*	*7/23/2018 10:30*	*307,211*	*7.06*	*134*	*1.40*
Unexplained Event			*510*	*0.954*	*7/23/2018 10:30*	*7/25/2018 4:30*	*447,487*	*10.28*	*14,242*	*26.65*
Base Grab	7/25/2018 9:18	7/25/2018 9:18	6	0.068	7/25/2018 4:30	7/26/2018 9:30	137,209	3.15	51	0.58
Base			*7*	*0.073*	*7/26/2018 9:30*	*8/21/2018 8:30*	*1,647,030*	*37.83*	*720*	*7.53*
Base Grab	8/22/2018 8:40	8/22/2018 8:40	3	0.092	8/21/2018 8:30	8/24/2018 10:30	98,009	2.25	18	0.56
Storm Composite	8/24/2018 12:51	8/24/2018 22:54	1,350	2.640	8/24/2018 10:30	8/24/2018 22:30	208,133	4.78	17,540	34.30
Base			*7*	*0.073*	*8/24/2018 22:30*	*8/27/2018 17:30*	*432,645*	*9.94*	*189*	*1.98*
Storm			*810*	*1.474*	*8/27/2018 17:30*	*8/27/2018 22:30*	*41,744*	*0.96*	*2,111*	*3.84*
Base			*7*	*0.073*	*8/27/2018 22:30*	*9/2/2018 8:30*	*970,455*	*22.29*	*424*	*4.43*
Storm			*810*	*1.474*	*9/2/2018 8:30*	*9/2/2018 17:30*	*166,536*	*3.83*	*8,421*	*15.32*
Base			*7*	*0.073*	*9/2/2018 17:30*	*9/4/2018 14:30*	*572,550*	*13.15*	*250*	*2.62*
Storm Composite	9/4/2018 17:44	9/5/2018 9:52	716	1.080	9/4/2018 14:30	9/5/2018 10:30	658,590	15.13	29,437	44.40
Base			*7*	*0.073*	*9/5/2018 10:30*	*9/20/2018 13:30*	*3,021,160*	*69.39*	*1,320*	*13.81*
Storm Composite	9/20/2018 14:42	9/21/2018 0:40	292	0.701	9/20/2018 13:30	9/21/2018 14:30	1,332,800	30.61	24,295	58.32
Base			*7*	*0.073*	*9/21/2018 14:30*	*9/26/2018 8:30*	*2,477,180*	*56.90*	*1,082*	*11.32*
Base Grab	9/27/2018 8:25	9/27/2018 8:25	6	0.046	9/26/2018 8:30	9/28/2018 8:30	512,394	11.77	192	1.47
Base			*7*	*0.073*	*9/28/2018 8:30*	*10/3/2018 17:30*	*415,210*	*9.54*	*181*	*1.90*
Storm			*810*	*1.474*	*10/3/2018 17:30*	*10/4/2018 1:30*	*46,971*	*1.08*	*2,375*	*4.32*
Base			*7*	*0.073*	*10/4/2018 1:30*	*10/8/2018 8:30*	*641,745*	*14.74*	*280*	*2.93*
Storm Composite	10/8/2018 9:06	10/9/2018 17:22	30	0.121	10/8/2018 8:30	10/9/2018 17:30	384,941	8.84	721	2.91
Storm			*810*	*1.474*	*10/9/2018 17:30*	*10/11/2018 14:30*	*1,845,730*	*42.39*	*93,330*	*169.83*
Base			*7*	*0.073*	*10/11/2018 14:30*	*10/17/2018 14:30*	*3,375,600*	*77.53*	*1,475*	*15.43*
Base Grab	10/18/2018 14:07	10/18/2018 14:07	4	0.030	10/17/2018 14:30	10/19/2018 14:30	447,716	10.28	112	0.84
Base			*7*	*0.073*	*10/19/2018 14:30*	*10/29/2018 11:30*	*1,199,070*	*27.54*	*524*	*5.48*
*Base**			*7*	*0.073*	*10/29/2018 11:30*	*12/1/2018 0:00*	*2,107,350*	*48.40*	*921*	*9.63*
*Base**			*7*	*0.073*	*12/1/2018 0:00*	*12/27/2018 14:00*	*1,148,400*	*26.38*	*502*	*5.25*
*Storm**			*810*	*1.474*	*12/27/2018 14:00*	*12/28/2018 9:00*	*239,400*	*5.50*	*12,105*	*22.03*
*Base**			*7*	*0.073*	*12/28/2018 9:00*	*1/1/2019 0:00*	*234,900*	*5.40*	*103*	*1.07*
StormAverage			810	1.474						
Base Average			7	0.073						
All Average			510	0.954						
Total							**45,453,990**	**1,044**	**505,314**	**964**
Brown's Creek Major Subwatershed Total Acres							3,855			
Total TSS/TP(lb/ac/yr)									131.08	0.250
Total TSS/TP (kg/ha/yr)									146.92	0.280

Italics indicate estimated concentrations based on average base and storm flow concentrations.

*Interval volumes were estimated using similar flow conditions.

**Sample results excluded from averages

Table 4. Brown's Creek Diversion Structure Drainage 2018 Chemistry Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved P (mg/L)	Copper (mg/L)	Nickel (mg/L)	Lead (mg/L)	Zinc (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Chloride (mg/L)	Nitrite N (mg/L)	Nitrate N (mg/L)	Ammonia Nitrogen (mg/L)	Hardness (mg/L _CaCO3)
Snowmelt Grab	4/23/2018 8:33	4/23/2018 8:33	22	7	0.61	0.160	~0.046	0.00080	0.00100	~0.00046	<0.00500	<0.00020	0.00066	49.8	<0.03	0.27	0.12	101
Storm Composite	6/18/2018 1:12	6/18/2018 14:01	1,790	569	11.00	2.430	~0.049	0.01740	0.01970	0.01090	0.06290	0.00080	0.01590	46.4	<0.03	0.28	~0.03	134
Storm Composite	6/24/2018 13:48	6/25/2018 1:21	810	252	8.00	1.790	0.088	0.01160	0.01230	0.00810	0.04070	0.00062	0.01050	41.1	<0.03	0.31	<0.02	111
Storm Grab	6/25/2018 10:13	6/25/2018 10:13	52	16	1.10	0.219	0.074	0.00190	0.00200	0.00100	<0.00500	<0.00020	0.00150	49.8	<0.03	0.22	~0.04	154
Storm Composite	6/26/2018 6:35	6/26/2018 13:59	1,690	520	14.00	3.900	0.184	0.02500	0.02780	0.03800	0.09390	0.00096	0.02140	41.1	<0.03	0.18	<0.02	118
Storm Composite	6/29/2018 9:43	6/29/2018 17:35	6,200	1,500	20.00	4.360	0.082	0.02880	0.03170	0.02620	0.11200	0.00110	0.03010	97.2	0.05	0.12	0.08	52
Storm Composite	7/1/2018 10:28	7/1/2018 15:20	1,200	264	4.00	1.300	0.081	0.01120	0.01210	0.01000	0.04270	~0.00033	0.01290	73.2	0.06	0.74	~0.02	114
Storm Composite	7/12/2018 18:18	7/13/2018 3:08	170	47	2.50	0.558	0.134	0.00490	0.00440	0.00320	0.01640	<0.00020	0.00480	18.6	0.03	0.48	0.32	37
Storm Composite	8/24/2018 12:51	8/24/2018 22:54	1,350	447	10.00	2.640	0.090	0.01430	0.02420	0.01150	0.05630	~0.00044	0.01960	53.0	0.03	0.41	~0.04	99
Storm Composite	9/4/2018 17:44	9/5/2018 9:52	716	151	4.60	1.080	0.094	0.00780	0.00720	0.00600	0.02620	~0.00029	0.00770	64.6	<0.03	0.27	~0.05	92
Storm Composite	9/20/2018 14:42	9/21/2018 0:40	292	72	2.90	0.701	0.099	0.00520	0.00620	0.00410	0.01680	<0.00020	0.00800	29.2	<0.03	0.59	~0.04	71
Storm Composite	10/8/2018 9:06	10/9/2018 17:22	30	11	1.00	0.121	~0.045							17.7	<0.03	0.14	~0.03	
Base Grab	5/30/2018 9:45	5/30/2018 9:45	16	5	0.75	0.130	~0.035	0.00063	0.00110	~0.00028	0.00210	<0.00020	0.00062	49.8	<0.03	0.46	0.08	226
Base Grab	7/25/2018 9:18	7/25/2018 9:18	6	~2	0.56	0.068	0.054	~0.00058	~0.00054	~0.00014	<0.00500	<0.00020	0.00038	96.7	<0.03	0.33	<0.02	83
Base Grab	8/22/2018 8:40	8/22/2018 8:40	3	~2	0.33	0.092	~0.037	<0.00030	~0.00039	~0.00026	<0.00080	<0.00020	0.00029	23.8	<0.03	0.49	~0.04	199
Base Grab	9/27/2018 8:25	9/27/2018 8:25	6	~2	0.54	~0.046	~0.037	<0.00030	~0.00044	~0.00033	<0.00500	<0.00020	0.00033	128.1	<0.03	0.13	~0.02	70
Base Grab	10/18/2018 14:07	10/18/2018 14:07	4	~2	0.51	~0.030	~0.023	~0.00034	~0.00040	~0.00010	<0.00080	<0.00020	<0.00050	98.2	<0.03	0.19	<0.02	89

Exceeds Water Quality Standard
No Exceedance Determinable
Exceeds Chronic Standard
Exceeds Max Standard
Exceeds Final Acute Standard

STREAM AND STORMWATER MONITORING

A. LILY LAKE INLET MONITORING

In 2015 the MSCWMO received grant funding to conduct targeted water quality monitoring on Lily Lake with the goal of identifying priority areas for nutrient load reduction to the lake. The MSCWMO worked closely with the WCD to develop and implement a monitoring plan to achieve this goal.

In 2018, as in 2017, monitoring focused on the Greeley Street catchment recording; stage, velocity, and total discharge. Discharge was calculated using an area/velocity relationship from a sensor located at the inlet of the Greeley Street catchment. Total reported discharge was calculated using both logged data and estimations, which were made during periods when logged data was unavailable.

The discharge to Lily Lake decreased by a little more than a quarter from the prior year to a total volume of 3,497,626 cubic feet. All discharge data from 2018 can be found in Table 5. Additionally, grab samples were collected and analyzed for the following water quality parameters: Total Phosphorus (TP), Total Kjeldhal Nitrogen (TKN), and Total Suspended Solids (TSS). Grab samples were divided into base and storm conditions based on logged stage and discharge data. Water quality results can be found in Table 6.

Sample results in 2018 were similar to results in prior years. The Greeley Street catchment base flow grab samples had low levels of TP and TSS. The 2018 average TP was 0.066 mg/L; similar to the 0.060 mg/L seen in 2017. The 2018 average TSS concentration was 4 mg/L; similar to the 3 mg/L seen in 2016 (Table 5, Table 6, Figure 8, and Figure 9). One storm event sample was collected in 2018, which followed previous years' observations with concentrations much higher than base samples. The TP concentration for the storm sample was 0.316 mg/L. This concentration was higher than the 2017 average storm concentration of 0.104 mg/L. The TSS storm concentration in 2018 was 518 mg/L; lower than the average storm concentration of 35 mg/L in 2017 (Table 5, Table 6, Figure 8, and Figure 9). Storm sample comparisons from 2018 to 2017 are restricted because of the small sample size. The TP load to Lily Lake from Greeley

Street was 14.411 lbs., lower than the load of 21.652 lbs. in 2017. The TSS load was 846.08 lbs., lower than the 3,386.62 lbs. in 2017. The lower concentrations of TP and TSS for storm samples may be due to confined ability to collect storm samples in 2018. Limited sampling is based on the nature of the site as storms events at the Greeley Street Inlet are flashy. Storm events occur quickly as urban runoff is transported swiftly. This makes capturing a storm event more difficult with constrained staff availability during these periods. Results should be considered with caution. 2018 results support previous years' results that the majority of loading to Lily Lake occurs during storm events (Table 5).

Table 5. Greeley Street 2018 Total Suspended Solids (TSS) and Total Phosphorus (TP) Loading

Site	Date range	Total Estimated Flow (CF)	Total Estimated Flow (ac-ft)	Average Phosphorus Concentration (mg/L)	Phophorus Range (mg/L)	Average TSS Concentration (mg/L)	TSS Range (mg/L)	TP Load (lbs.)	TSS Load (lbs.)
Greeley Street Base	4/25 - 10/31*^	3,497,626	80.34	0.066	0.040-0.126	4	1-8	14.41	846.08

*Indicates that estimations of flow occur during period using similar logged flow conditions

^9/20 results excluded from averages and ranges

Table 6. Greeley Street 2018 Water Quality Results

Date	Greeley Street			
	Sample Type	TP (mg/L)	TSS (mg/L)	TKN (mg/L)
6/6/2018	Base	0.096	4	1.2
6/18/2018	Base	~0.045	6	0.84
6/25/2018	Base	~0.040	~2	0.72
7/13/2018	Base	0.081	6	1
7/23/2018	Base	0.061	~2	0.81
8/24/2018	Base	0.126	8	1.2
9/5/2018	Base	~0.045	~2	0.67
9/20/2018*	Storm	0.316	518	1.5
10/23/2018	Base	~0.034	~1	0.47

*Result excluded from averages

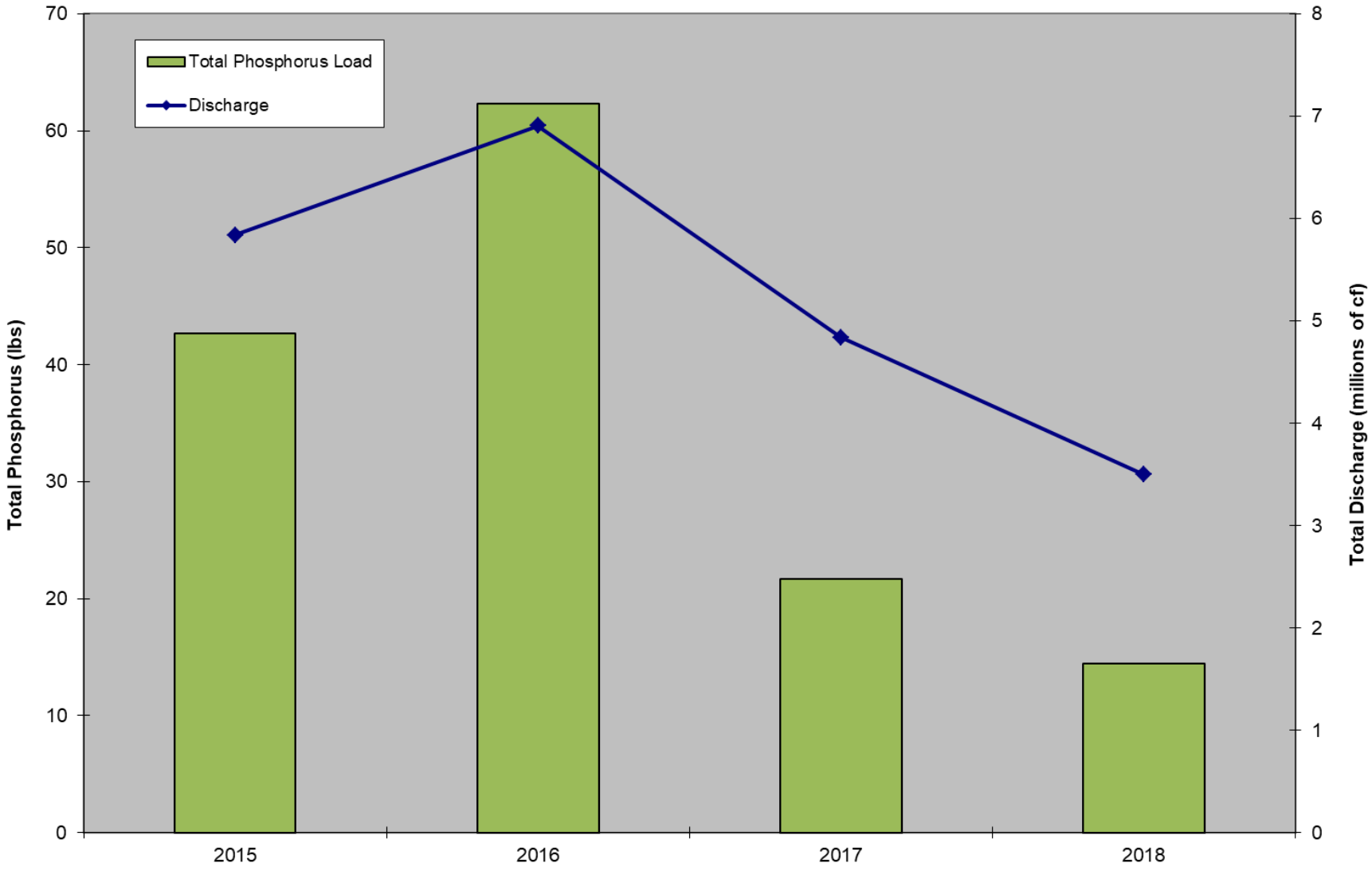

Figure 8. Greeley Street Annual Discharge and Total Phosphorus Load

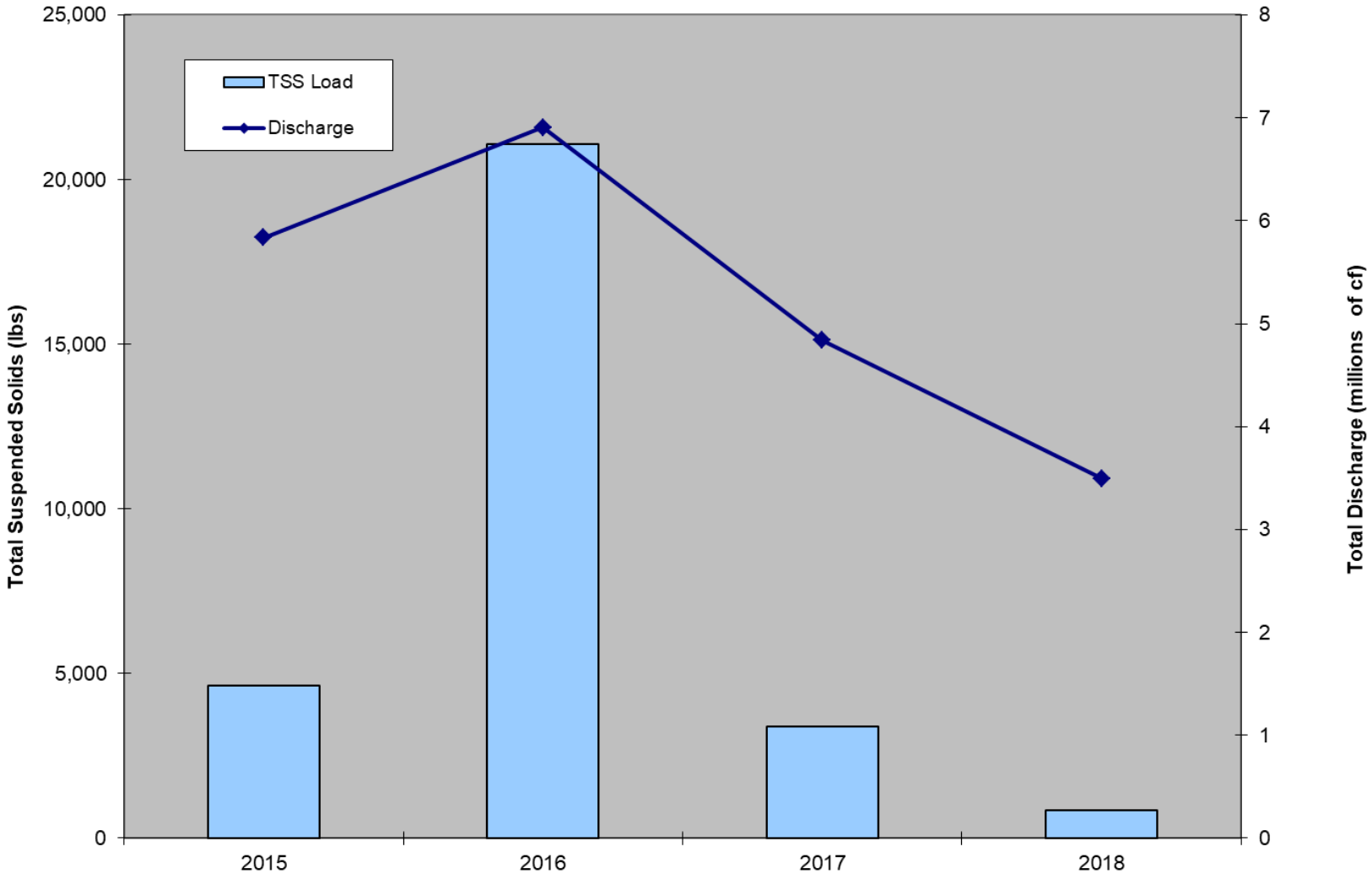

Figure 9. Greeley Street Annual Discharge and Total Suspended Solids Load

B. PERRO CREEK MONITORING

The goal of monitoring Perro Creek in 2016-2017 was to identify where the greatest contribution of nutrients and sediment to the Saint Croix River was occurring. Monitoring continued in 2018 to further refine previous observations. In 2018 base and storm grab samples were collected at the Perro Creek at the Diversion Structure site, and analyzed for Total Phosphorus (TP), Total Kjeldhal Nitrogen (TKN), Total Suspended Solids (TSS) and *E. coli*. Samples were collected and analyzed for *E. coli* at Perro Creek at the Perro Pond Outlet, Perro Creek at 5th Avenue, Perro Creek at 9th Street, Perro Creek at 8th Street, Perro Creek at 6th Street, Perro Creek at 4th Street, Perro Creek at St. Croix Trail Downstream, Perro Creek at Central Avenue, and Perro Creek at 3rd Avenue. Monitoring will continue at these sites in 2019.

In 2018 Perro Creek at the Diversion Structure had lower average results than 2017. The average phosphorus concentration was 0.065 mg/L with a range of 0.020-0.252 mg/L, lower than the average phosphorus concentration in 2017 of 0.069 mg/L. The average TSS concentration was 9.4 mg/L; lower than 20 mg/L in 2017. Perro Creek at the Diversion Structure TSS results had a range of 1-31 mg/L, which was a lower range than 1-76 mg/L in 2017 (Table 7 and Table 8).

The equipment at Perro Creek at the Diversion Structure was installed further downstream in 2018 to a more stable site. The area velocity sensor was moved from its location in 2017 due to challenges that prevented accurate estimation of discharge, including channel obstructions such as debris. The frequency of manipulations of the creek also caused issues with collecting accurate data, as they caused sediment deposition, which constantly changed the shape and depth of the channel. The frequent occurrence of obstructions from various sources impacted the consistency and quality of logged data. The 2018 location remedied these issues by moving the probe into the 3.5 ft culvert downstream from the v-notch weir at the diversion structure. The new location was less impacted by debris and succeeded in collecting more consistent data. Additional monitoring is planned for 2019 to further refine these observations

There were notable differences in *E. coli* results between sites along Perro Creek in 2018. Sample results seem to indicate that there is an increased prevalence of *E. coli* downstream of the 8th street monitoring location. It should be noted that between the Perro at 8th Street site and the next site, Perro at 6th Street, there is a known decommissioned cesspool. This cesspool was filled in during the summer of 2018 and may be a contributing source of *E. coli* to Perro Creek. After 6th Street *E. coli* results generally increase moving downstream, with a few exceptions. Half of the sampling events indicate a drop in *E. coli* occurs at two sites, Perro Creek at the Diversion Structure and Perro Creek at Central Ave. The drop in *E. coli* results at these two sites may suggest that there is an additional source of water diluting the *E. coli* along this portion of Perro Creek.

E. coli results are calculated by estimating the most probable number of *E. coli* organisms in a stream. The primary source of *E. coli* is human and animal waste. *E.coli* can cause diarrhea and abdominal cramps and is considered life-threatening for vulnerable populations such as children, and the elderly, making high *E. coli* presence a concern for human health. *E. coli* results were high for all sites during the storm event on 9/20/2018, with eight of the ten sites exceeding the standard testing limit of 2,420 most probable number of organisms (MPN) per 100/ml. These samples were further tested in the lab as a diluted sample with results varying from 17,500-54,600 MPN per 100/ml. The highest individual *E. coli* result occurred at the Perro Creek at the St. Croix Trail Downstream site on 9/20/2018 (Table 9). According to the MPCA standards, Perro Creek is exceeding impairment standards at 6th Street in June and September (Table 10). Impairment standards are based on MPCA protocol which includes the last ten years of data and requires at least 5 samples in a calendar month to calculate the geometric mean (average).

Table 7. Perro Creek 2018 Total Suspended Solids (TSS) and Total Phosphorus (TP)

Site	Estimated Discharge (CFS)	Total Estimated Flow (ac-ft)	Proportion of Total Flow	Average Phosphorus Concentration (mg/L)	Phosphorus Range (mg/L)	Average TSS Concentration (mg/L)	TSS Range (mg/L)	TP Load (lbs.)	TSS Load (lbs.)
Perro at Diversion Structure Overflow 5/17-10/29	2,365,007	54.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Perro at Diversion Structure Base 5/17-10/29*	6,905,082	158.60	0.9408	0.036	0.020-0.058	4	1-16	15.518	1724.23
Perro at Diversion Structure Storm 5/17-10/29*	434,571	9.98	0.0592	0.124	0.047-0.252	20	8-31	3.364	549.35

*Nonlogged period of 6/29-8/9 excluded

Table 8. Perro Creek 2018 Water Quality Results

Date	Perro Creek at the Diversion Structure			
	Sample Type	TP (mg/L)	TSS (mg/L)	TKN (mg/L)
5/22/2018	Base	~0.038	3	0.39
6/6/2018	Storm	0.252	21	2.00
6/18/2018	Base	~0.026	3	0.45
6/25/2018	Base	0.058	16	0.58
7/13/2018	Storm	~0.047	8	0.72
7/23/2018	Base	~0.043	~1	0.30
8/1/2018	Base	~0.045	~1	0.34
8/24/2018	Storm	0.105	31	0.62
9/5/2018	Base	~0.039	4	0.43
9/20/2018	Storm	0.090	21	0.80
9/27/2018	Base	~0.022	3	0.29
10/16/2018	Base	<0.020	<1	0.16

Table 9. Perro Creek 2018 *E. coli* Results

Site	*E. coli* Results					
	5/22/2018	6/19/2018	7/19/2018	8/29/2018	9/20/2018	10/16/2018
Perro at Perro Pond Outlet	15	42	17	9	>2420	7
Perro at 5th Ave	45	56	80	21	1733	18
Perro at 9th Street	48	65	28	16	1733	8
Perro at 8th Street	49	127	133	37	>2420	27
Perro at 6th Street	58	488	153	59	>2420	125
Perro at 4th Street	50	548	261	73	>2420	186
Perro at St. Croix Trail Downstream	64	579	579	66	>2420	299
Perro at Diversion Structure	50	>2420	517	88	>2420	205
Perro at Central Ave	55	1986	276	66	>2420	249
Perro at 3rd Ave	228	>2420	548	79	>2420	101

Table 10. Monthly Geometric Means of *E. Coli* Latest Ten Years

Monthly Geometric Means for *E. coli* (#/100 mL)

Site	April	May	June	July	August	September	October
Perro at Perro Pond Outlet	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
Perro at 5th Ave	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
Perro at 9th Street	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
Perro at 8th Street	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
Perro at 6th Street	Insufficient Data	68	181	120	102	333	Insufficient Data
Perro at 4th Street	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
Perro at St. Croix Trail Downstream	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
Perro at Diversion Structure	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
Perro at Central Ave	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
Perro at 3rd Ave	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data

Exceeds geometric mean of 126 #/100mL from not less than 5 samples in a calendar month

10% of samples taken in the last 10 years exceed 1,260 #/100mL (Doesn't necessarily exceed geometric mean standard)

*Based on MPCA protocol: "*Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31.*"

MSCWMO: CONCLUSIONS AND RECOMMENDATIONS

A. LAKES

Lake monitoring in MSCWMO continues to provide valuable baseline water quality information. To determine the health of the lakes in MSCWMO, physical and chemical parameters are compared on a year-to-year basis and to other lakes in the region. Water quality in a lake depends on a number of different variables such as: size of the contributing watershed, external nutrient sources, depth of the lake, and the current amount of nutrients available to be periodically released from the lake bottom. Low water quality ratings of MSCWMO lakes are most likely due to long-term contribution of urban runoff (Lily Lake) or due to the sensitivity of shallow lakes being prone to summertime mixing (McKusick Lake). Shallow lakes typically exist in a low algal production, clear-water state with abundant aquatic macrophytes or in a high-algal production, turbid water state. Shallow lakes may not completely stratify in the summer, and therefore have the capability to continually mix throughout the summer. That mixing causes phosphorus to be distributed throughout the water column, causing more frequent and heavy algal blooms. This is unlike deeper, stratified lakes where phosphorus below the thermocline is not available for primary production.

The MPCA listed both Lily and McKusick Lake on the 303(d) Impaired Waters list for nutrient/eutrophication impairment; however McKusick Lake was delisted in 2012. If a water body is listed, it indicates that it does not currently meet water quality criteria. In order to meet those criteria, a total maximum daily load (TMDL) must be implemented. A TMDL outlines what pollutants are degrading the water quality and what will need to be done in order to meet current water quality standards. The MPCA had tentatively scheduled a three lake TMDL for Long Lake (Brown's Creek Watershed District), Lily Lake, and McKusick Lake in 2010, but because of improving water quality trends in those lakes over recent years the TMDL has been postponed. The MSCWMO, BCWD, and the City of Stillwater will utilize the City of Stillwater's existing Lake Management Plan, the completed Lily and McKusick Lake subwatershed assessments, and Lily Lake inlet monitoring data to further guide project implementation in an effort to continue to improve the water quality of the lakes. The MPCA will consider the need for a TMDL again in the future.

Summertime (June-September) TP, chlorophyll-α, and Secchi disk transparency averages have remained relatively consistent over the last twenty years in Lily Lake with the exceptions of 1995, 2001, 2009, 2013, and 2014 where overall water quality dramatically improved (Figure 4, Figure 5, and Figure 7). In 2001 phosphorus and chl-α levels dropped and the lake grade improved significantly. In 2006-2008, summer average TP, chl-α, and Secchi disk transparency deteriorated when compared to the averages seen from 2001 to 2005. In 2018 Lily Lake received a grade of a B-, close to the long-term average lake grade of a C+.

The cause of these one-year increases (1995, 2001, 2009, 2013, and 2014) in water quality is presently unknown, and there may be several possible explanations which could be investigated further in the future. Lily Lake has received herbicide and algaecide treatments from 1995-2011 and 2016-2018. In 2018 the City of Stillwater and the Lily Lake Association did not request any large scale herbicide and algaecide treatments, departing from past years, under the directive of the MSCWMO Board. Individual landowner treatment did still occur in 2018. Native buffer planting at the public access was installed in 2010. The Lily Lake watershed underwent a subwatershed assessment in 2010. As a result, fifteen raingardens were constructed in the Lily Lake watershed from 2011-2012, six large raingardens were installed in 2014, a gully stabilization project was installed at Lakeview Hospital discharging to Brick Pond in 2017, and a large gully stabilization and stormwater treatment system discharging to Brick Pond was constructed in 2018. The effects of these BMPs may have been seen from 2012 to 2018 monitoring seasons with the 2016-2018 seasons having a statistically significant ($p<0.05$) improving trend for total phosphorus. Continued monitoring is needed to show changes to long term trends due to the implementation of these BMPs. In 2018, the Lily Lake Impaired Waters Delisting Road Map was complete. This study identifies the final locations for BMPs to address the highest remaining loads in the Lily Lake Watershed. The report includes an Internal Load Study conducted by Wenck Engineering that identifies an estimated internal phosphorus load reduction of up to 120 pounds per year with an aluminum sulfate (alum) treatment. More information about the Lily Lake Impaired Waters Delisting Road Map can be found at http://www.mscwmo.org/subwatershed-assessments.

A subwatershed assessment was conducted on the McKusick Lake watershed in 2010. In 2011 six raingardens were constructed as a result of the subwatershed assessment. With renewed funding, seven additional raingardens were to be installed in the McKusick Lake watershed in 2013 but because of issues with utilities, six larger raingardens were installed in 2014. The impacts of previously installed raingardens may have been seen in 2017-2018 with statistically significant ($p<0.05$) improving trends for average TP and average Secchi disk transparency. For more information on the McKusick Lake subwatershed assessment refer to the McKusick Lake Stormwater Retrofit Assessment found at http://www.mscwmo.org/subwatershed-assessments.

B. TARGETED MONITORING

The targeted monitoring of Lily Lake had the goal of more accurately identifying the major sources of nutrients to the lake and to help steer targeting and design of stormwater management practices. Based on 2016 results, 78% of phosphorus loading to Lily Lake occurs during storm events. The highest contributing catchments during these events are Greeley Street and Lake Street, which combined account for 55% of the load. The remaining 22% of the phosphorus load was from base flow periods, with very low phosphorus concentration, from Brick Pond to Lily Lake, as indicated by the monitoring station at Greeley Street. However, base flow from Brick Pond accounted for 65% of the total discharge to the lake. While further reducing the phosphorus concentration discharging from Brick Pond is possible, it is not recommended due to the comparatively small reduction in phosphorus load to Lily Lake.

The phosphorus load from the Greeley Street catchment appears to be discharge driven, with a majority of flow coming from direct street runoff and not through Brick Pond. This was again observed in 2018 at the Greeley Street catchment with a storm event phosphorus result of 0.316 mg/L. Base flow from Brick Pond had low TSS results with the highest result being 8 mg/L. The storm result for TSS was 518 mg/L. These results confirmed the previous investigation in regards to the Greeley Street catchment having low sample results for TP and TSS during base flow and higher results during storm events.

Therefore, it is recommended that steps be taken to implement best management practices in the areas of the Greeley Street catchment that are directly discharging to Lily Lake, with less of an

emphasis being placed on water entering Brick Pond. Continued monitoring at the Greeley Street catchment will help monitor the impact of BMPs installed in the Greeley Street catchment.

Loading estimates indicate the next priority would be the Lake Street catchment, which showed the highest average and discrete phosphorus concentrations. However, reducing the discharge and/or the phosphorus concentration at any of the four catchments identified as high contributors should have a significant impact on improving the water quality in Lily Lake. Therefore, it is recommended that these results be used in conjunction with implementation factors of stormwater management practices for targeting improvements to the catchments.

C. STREAMS

Monitoring of Perro Creek started in 2016 to determine where the greatest contribution of nutrients and sediment to the St. Croix River was occurring. This investigation continued in 2018. Based on past consistently low TP and TSS results monitoring at the Perro Pond Outlet was discontinued in 2018. Under current conditions it can be assumed that Perro Pond would not be a significant source of nutrient loading to the St. Croix River, and therefore not benefit significantly from retrofits. Monitoring at Perro Creek at the Diversion Structure continued in 2018. The average total phosphorus result was 0.065 mg/L, lower than 0.069 mg/L in 2017.

Perro Creek *E. coli* results are low at both sites prior to the creek entering the City of Bayport. Results increase substantially from the Perro Creek at 5th Ave site to the Perro Creek at 3rd Ave site, indicating that there may be sources contributing *E. coli* to the creek somewhere in the City of Bayport. *E. coli* results do not increase at all sites moving downstream as expected. The *E. coli* results increase significantly after the Perro Creek at 8th Street Site. This site is located upstream from a decommissioned cesspool, which may be a source of *E. coli*. Additionally there is a drop in *E. coli* results around the Perro Creek at the Diversion Structure and Perro Creek at Central Ave sites. This indicates that a source of groundwater, or piped drinking water, may be contributing to Perro Creek upstream of these sites and diluting *E. coli*. Perro Creek crosses under Andersen Elementary School upstream of these sites. Any potential groundwater or piped drinking water contributions from this stretch are unknown to the WCD. Monitoring will continue in 2019 to further investigate the source of *E. coli* entering Perro Creek.

APPENDIX A
WATER QUALITY DATA – LILY LAKE AND MCKUSICK LAKE

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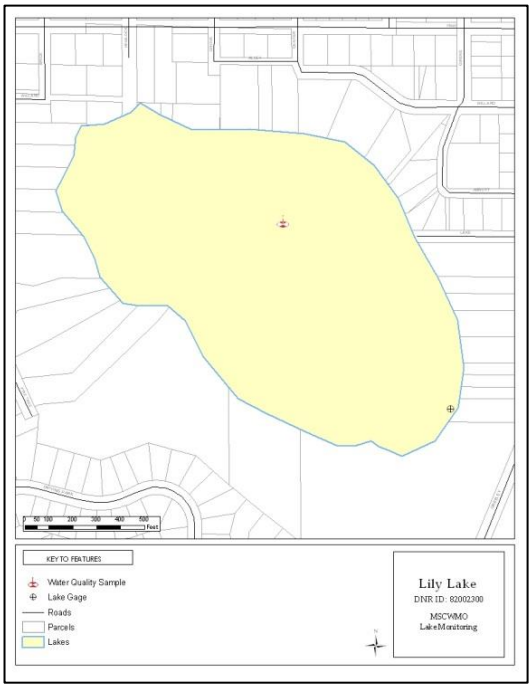
LILY LAKE

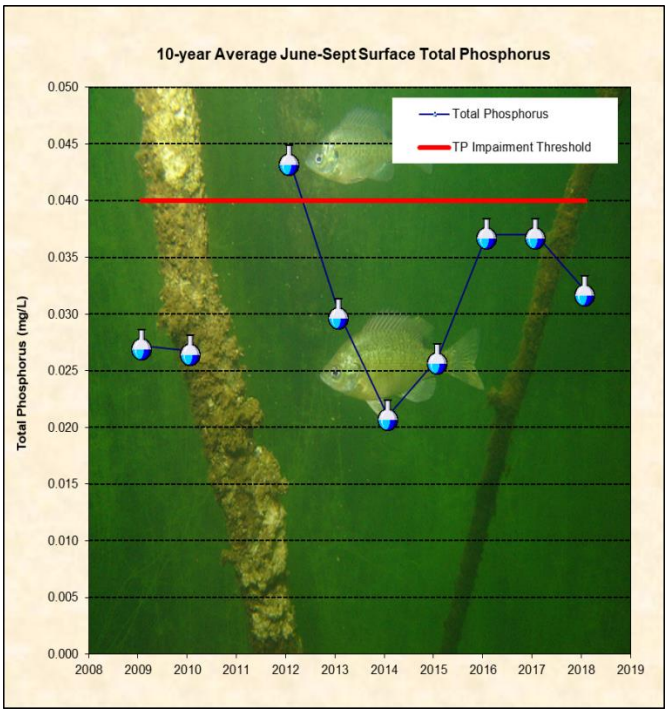
2018 Lake Grade: B-

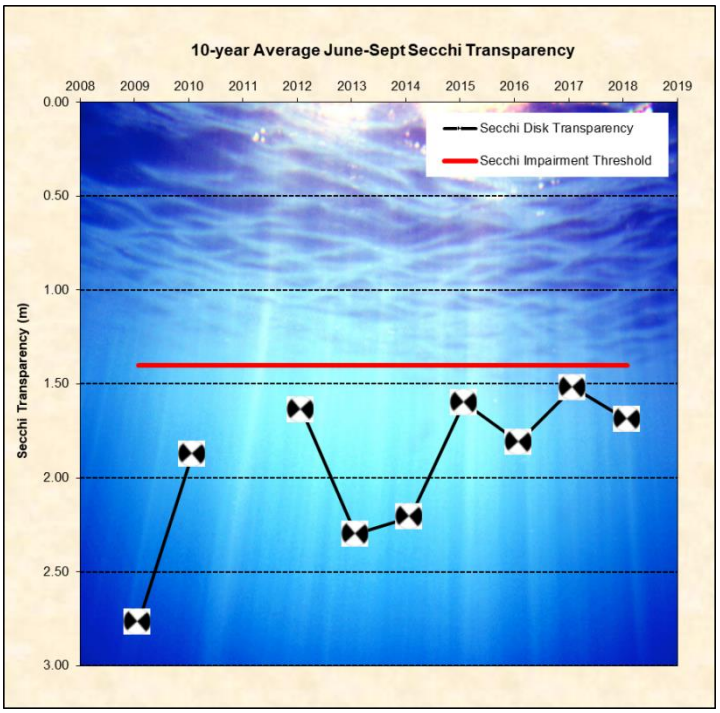
- DNR ID #: 820023
- Municipality: City of Stillwater
- Location: NE ¼ Section 32, T30N-R20W
- Lake Size: 35.90 Acres
- Maximum Depth (2018): 46.0 ft
- Ordinary High Water Mark: 844.8 ft
- 55%Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.
- Publically accessible



Summary Points

- Based on the chlorophyll-α results Lily Lake was considered eutrophic in 2018, according to the Carlson Trophic State Index.
- Using a Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for average total phosphorus, a statistically significant **declining** trend for average chlorophyll-α, and no trend is present for average Secchi transparency.
- The major land use is urban/residential.
- The lake stratified in 2018 with the thermocline around 4 meters deep.
- Lily Lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List.





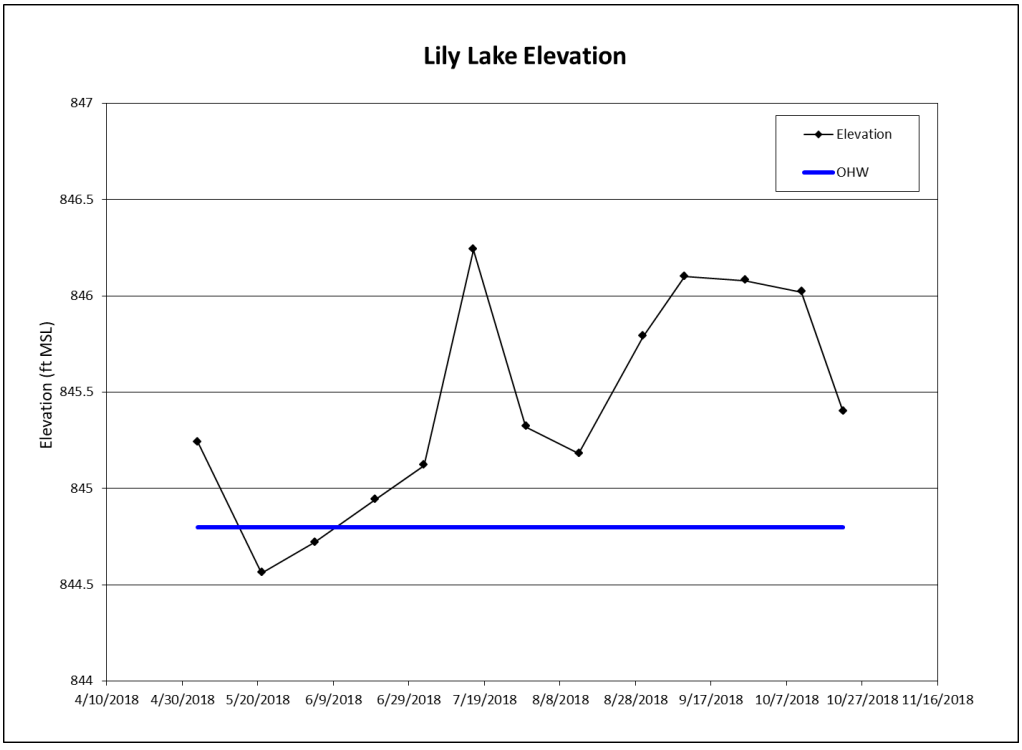
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/7/2018 13:45	0.025	9.7	8.5	0.83	1.52	19.1	11.69
5/21/2018 8:13	0.027	2.1	1.3	0.65	3.51	18.9	8.79
6/4/2018 10:39	0.036	8.1	7.5	0.85	2.44	21.4	7.51
6/20/2018 11:46	0.033	14.0	13.0	0.80	2.13	24.4	7.45
7/3/2018 9:00	0.027	15.0	14.0	0.78	2.13	25.8	8.20
7/16/2018 13:07	0.022	8.6	8.1	0.89	2.29	28.0	7.75
7/30/2018 8:24	0.025	32.0	34.0	1.30	0.91	24.7	10.26
8/13/2018 13:04	0.028	41.0	42.0	1.40	0.46	28.1	10.30
8/30/2018 10:42	0.033	47.0	45.0	1.20	0.91	21.8	6.71
9/10/2018 12:00	0.048	30.0	29.0	1.30	0.91	21.5	7.10
9/26/2018 13:22	0.034	12.0	11.0	1.10	3.05	17.8	5.90
10/11/2018 14:56	0.021	16.0	15.0	0.72	2.74	11.1	7.97
2018 Average	0.030	19.6	19.0	0.99	1.92	21.9	8.30
2018 Summer Average	0.032	23.1	22.6	1.07	1.69	23.7	7.91

Water quality thresholds are 0.04 mg/L TP, 14 µg/L CL-a, 1.4 m Secchi depth*

Shallow lake water quality thresholds are 0.06 mg/L TP, 20 µg/L CL-a, 1.0 m Secchi depth*

	High	High Date	Low	Low Date	Average
2018 Elevation (ft)	846.24	7/16/2018	844.56	5/21/2018	845.44

*Data requirements and determinations of use assessment according to the MPCA's Guidance Manual for Assessing the Quality of Minnesota Surface Waters: "Samples must be collected over a minimum of 2 years and data used for assessments must be collected from June to September. Typically, a minimum of 8 individual data points for TP, corrected chlorophyll-a (chl-a corrected for pheophytin), and Secchi are required. Data used for phosphorus and chlorophyll-a calculations are limited to those collected from the upper most 3 meters of the water column (surface). If more than one sample is collected in a lake per day, these values are averaged to yield a daily average value. Following this step, all June to September data for the 10-year assessment window are averaged to determine summer-mean values for TP, corrected chl-a, and Secchi depth. These values are then compared to the standards and the assessment is made."



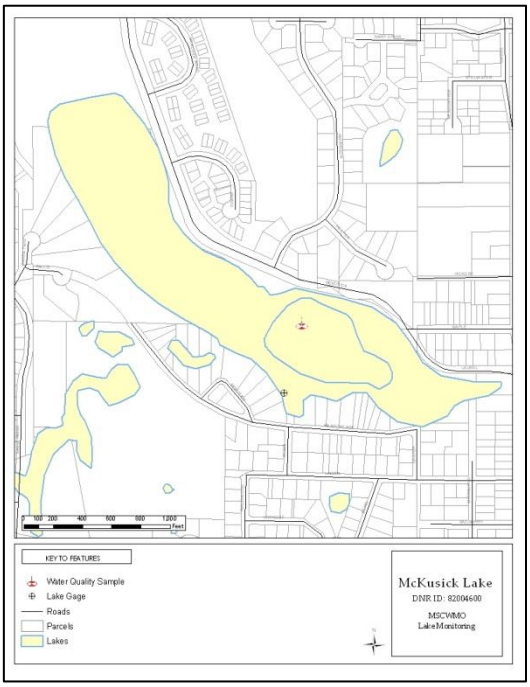
Lake Water Quality Summary										
	Summertime Lake Grades (May-Sept)									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/L)	B	C	C	B	A	B	C	NA	B	B
Chlorophyll-*a* (ug/L)	B	B	C	C	B	B	B	NA	C	A
Secchi depth (ft)	C	C	B	C	B	B	C	NA	C	B
Overall	**B-**	**C+**	**C+**	**C+**	**B+**	**B**	**C+**	**NA**	**C+**	**B+**

MCKUSICK LAKE

2018 Lake Grade: C+

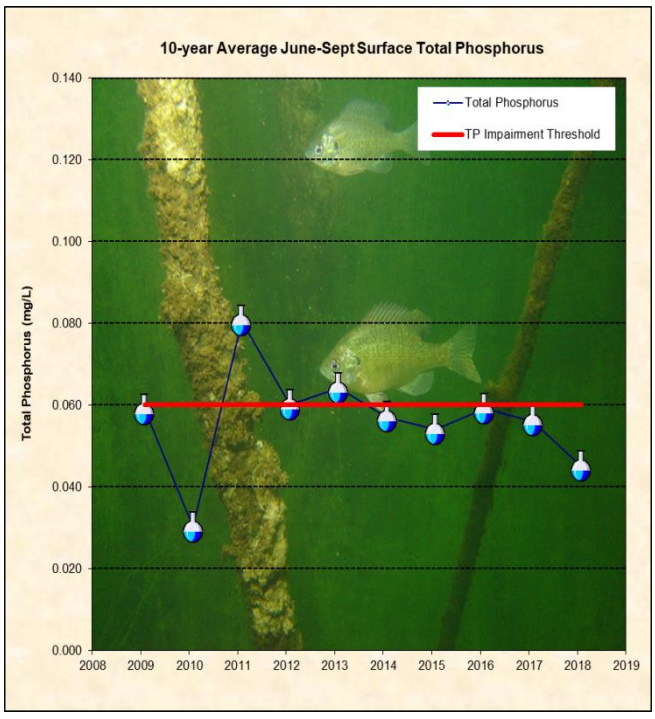
DNR ID #: 820020

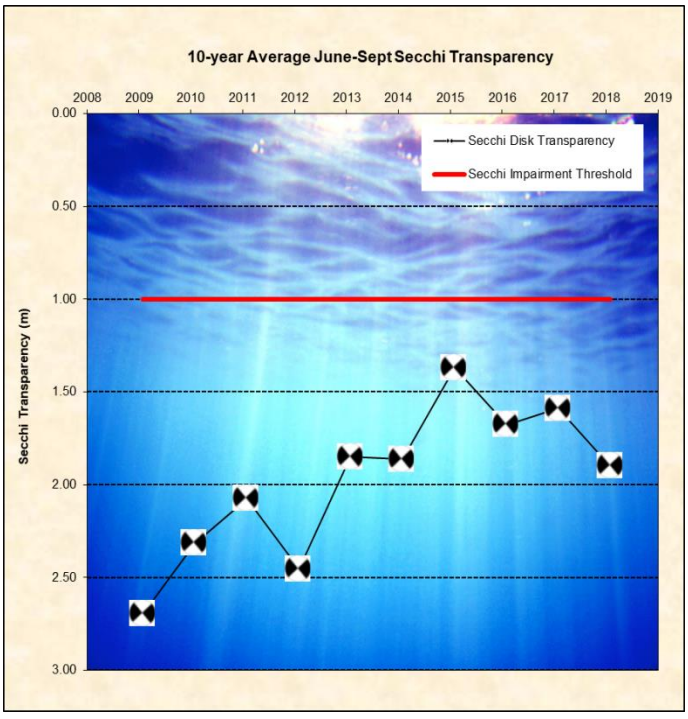
- Municipality: City of Stillwater
- Location: NE ¼ Section 29, T30N-R20W
- Lake Size: 46 Acres
- Maximum Depth (2018): 15 ft
- Ordinary High Water Mark: 851.7 ft
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on the chlorophyll-α results McKusick Lake was considered eutrophic in 2018, according to the Carlson Trophic State Index.
- Using a Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for average Secchi transparency and average total phosphorus, and no trend for average chlorophyll-α.
- The major land use is urban/residential.
- The deepest portion of the lake stratified in 2018 with the thermocline around 3 meters deep.
- McKusick Lake was delisted in 2012 for its impairment for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List.





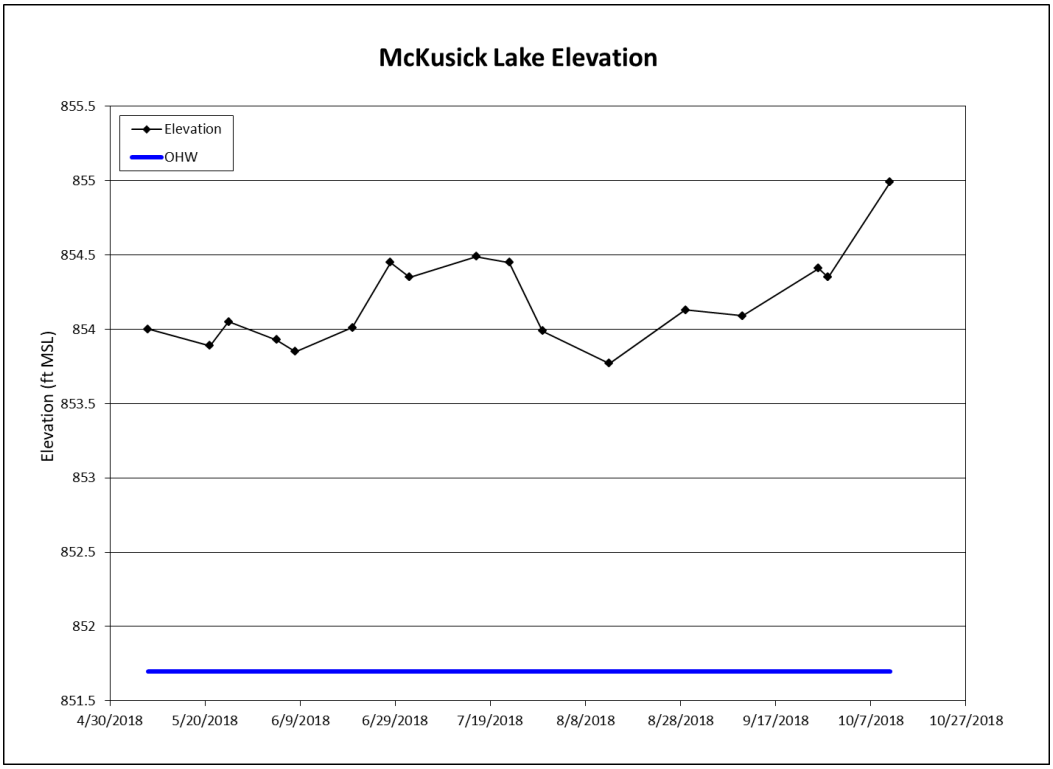
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/9/2018 13:48	0.045	18.0	15.0	0.80	0.91	18.3	7.73
5/21/2018 8:53	0.023	3.1	1.0	0.62	2.53	19.5	7.14
6/4/2018 11:23	0.036	4.4	3.5	0.80	2.44	21.3	6.16
6/20/2018 13:04	0.053	5.7	4.6	0.72	1.98	25.0	5.26
7/2/2018 13:00	0.050	7.5	6.5	0.64	1.98	25.4	4.43
7/16/2018 13:43	0.046	6.2	5.4	0.78	1.52	26.8	3.30
7/30/2018 8:52	0.044	6.0	5.8	0.93	1.68	23.3	3.47
8/13/2018 13:37	0.054	15.0	13.0	0.94	1.22	26.0	7.89
8/29/2018 13:10	0.043	33.0	30.0	0.76	1.68	21.4	2.36
9/10/2018 13:20	0.036	8.0	7.1	0.72	2.90	21.4	3.83
9/26/2018 12:51	0.045	13.0	12.0	0.76	1.68	16.1	5.14
10/11/2018 14:26	0.039	17.0	16.0	0.78	1.83	9.5	8.60
2018 Average	0.043	11.4	10.0	0.77	1.86	21.2	5.44
2018 Summer Average	0.045	11.0	9.8	0.78	1.90	23.0	4.65

Water quality thresholds are 0.04 mg/L TP, 14 µg/L CL-a, 1.4 m Secchi depth*

Shallow lake water quality thresholds are 0.06 mg/L TP, 20 µg/L CL-a, 1.0 m Secchi depth*

	High	High Date	Low	Low Date	Average
2018 Elevation (ft)	854.99	10/11/2018	853.77	8/13/2018	854.19

*Data requirements and determinations of use assessment according to the MPCA's Guidance Manual for Assessing the Quality of Minnesota Surface Waters: "Samples must be collected over a minimum of 2 years and data used for assessments must be collected from June to September. Typically, a minimum of 8 individual data points for TP, corrected chlorophyll-a (chl-a corrected for pheophytin), and Secchi are required. Data used for phosphorus and chlorophyll-a calculations are limited to those collected from the upper most 3 meters of the water column (surface). If more than one sample is collected in a lake per day, these values are averaged to yield a daily average value. Following this step, all June to September data for the 10-year assessment window are averaged to determine summer-mean values for TP, corrected chl-a, and Secchi depth. These values are then compared to the standards and the assessment is made."



Lake Water Quality Summary										
	Summertime Lake Grades (May-Sept)									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/L)	C	C	C	C	C	C	C	D	B	C
Chlorophyll-*a* (ug/L)	B	B	B	C	C	B	A	C	A	A
Secchi depth (ft)	C	C	C	C	C	C	B	C	B	B
Overall	**C+**	**C+**	**C+**	**C**	**C**	**C+**	**B**	**C-**	**B+**	**B**