Middle St. Croix Watershed Management Organization 2019 Water Monitoring Summary

Prepared For:

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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 2019 as well as previous years. In 2019 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 2019 (APPENDIX A). No samples exceeded the Minnesota Pollution Control Agency's (MPCA) standard for total phosphorus (TP), six samples exceeded the MPCA standard for chl-α corrected for pheophytin, four Secchi disk transparency readings exceeded the MPCA standard (APPENDIX A).

In 2019 McKusick Lake was classified as eutrophic and received a grade of B- (APPENDIX A). Three samples exceeded the MPCA shallow lake standard for TP. No samples exceeded the MPCA standard for chl-α corrected for pheophytin and no Secchi disk transparency measurements exceeded the MPCA shallow lake standard (APPENDIX A).

Stream and Stormwater Monitoring

In 2019 monitoring continued on the Greeley Street catchment of Lily Lake. The total discharge was the highest recorded at the site and was more than double the recorded discharge of 2018 (Figure 8 and Figure 9). The Greeley Street catchment base flow grab samples had

concentrations below standards of TP and total suspended solids (TSS), and were similar to results in past years (Table 5 and Table 6). As in previous years the storm event grab sample result was higher than base samples. 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 2019 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 higher than 2018, but base flow sample results were lower than storm samples, as expected (Table 7 and Table 8). *E. coli* results were high for all sites on Perro Creek during the storm event on 9/12/2019, with eight of the ten sites at or exceeding the standard testing limit of 2,420 most probable number of organisms (MPN) per 100/ml (Table 9). According to MPCA standards, Perro Creek is exceeding impairment standards at 6th Street in June and September (Table 10). Additional samples were collected at four of the ten locations to determine if human fecal DNA was present, with two samples resulting in positive detections at the 3rd Avenue site (Table 11).

The Brown's Creek Diversion Structure site, which exports to McKusick Lake, showed an increase in discharge in 2019, the highest ever recorded, to 112,468,888 cubic feet (cf) from 45,453,990 cf in 2018. The phosphorus load increased from 964 lbs. in 2018 to 3,598 lbs.in 2019. TSS export also increased from the Brown's Creek Diversion Structure to McKusick Lake, from 505,314 lbs. in 2018 to 2,707,186 lbs. in 2019 (Table 2 and Table 3). The TP and TSS loads were the highest ever recorded. A likely source of the high TP and TSS loads in the diversion drainage is the large number of head cuts on all three tributary branches of the drainage, upstream of the monitoring location. As with most past years, exceedances of metal

standards occurred frequently. Sources of metals for the Brown's Creek Diversion Structure site likely include improperly disposed waste, such as deep cycle batteries.

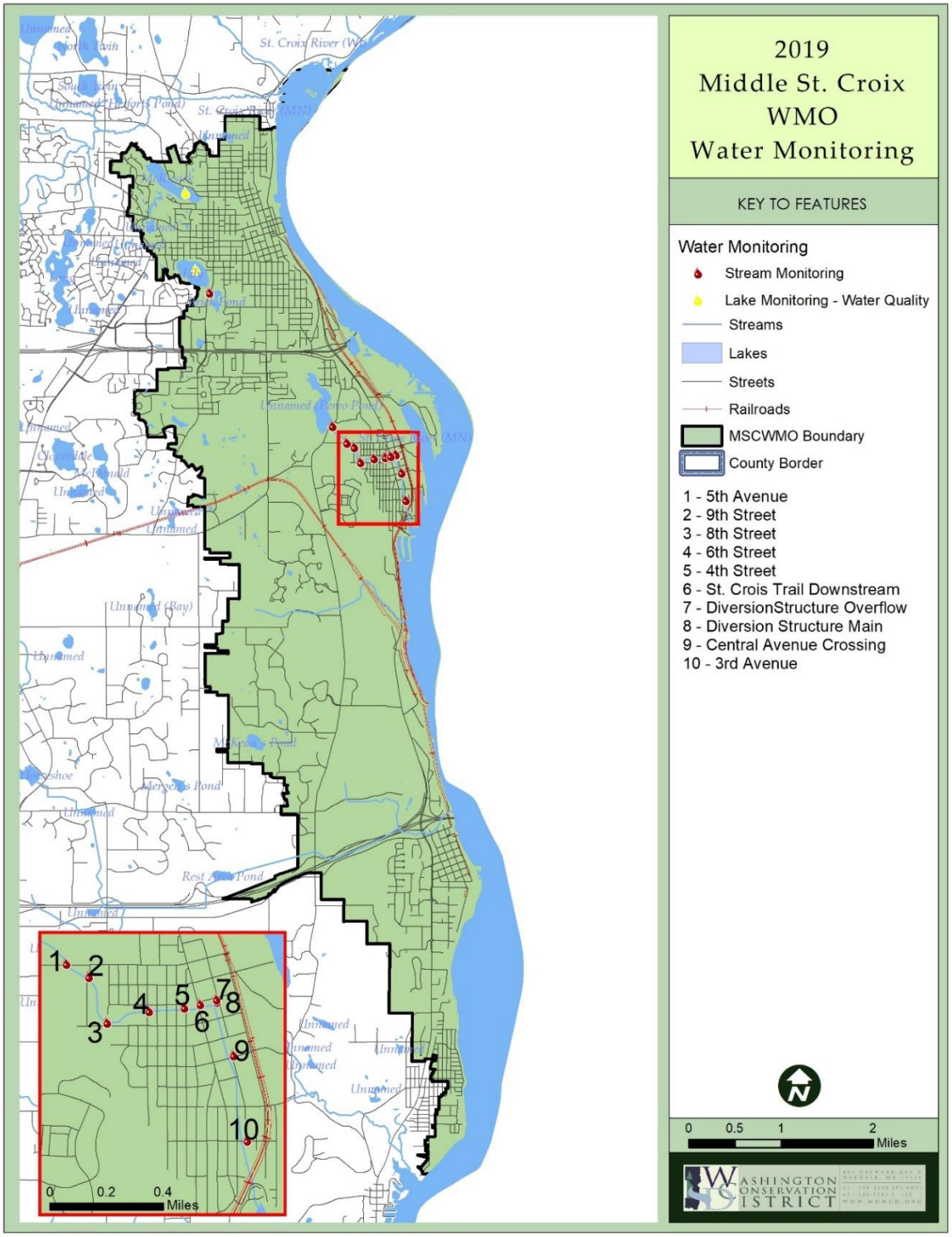

Figure 1. MSCWMO 2019 Water Monitoring Locations

LAKE MONITORING

A. METHODS, RESULTS AND DISCUSSION

In 2019 water quality data was collected biweekly on Lily Lake and McKusick Lake, over seven consecutive months (April–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 2019 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 2019 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 the limiting nutrient, TKN can contribute to eutrophication. The 2019 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 April to October 2019. 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 2019 for Lily Lake occurred on 8/19/2019 at 846.75 ft. and on 5/23/2019 at 855.01 ft. for McKusick Lake. Complete lake elevation data for 2019 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 2019 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 0.031 mg/L, which was lower than 2018 (Figure 4). None of the summertime results were greater than the MPCA lake nutrient impairment standard for TP. The 2019 average summertime concentration of chl-α was 21.5 μg/L, lower than the 22.6 μg/L measured in 2018 (Figure 5). Six 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 0.91 mg/L in 2019; lower than the 1.07 mg/L in 2018 (Figure 6). Secchi disk readings were measured in 2019 with a summertime average of 1.85 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 2019 which was the same as 2018. Temperature and DO profiles

[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.

indicate that Lily Lake exhibited thermal stratification during the summer months with the thermocline between 4 and 5 meters; therefore the lake was less likely to completely mix throughout the summer. Lily Lake was below the OHW for one elevation reading, falling to its lowest recorded level of the monitoring season on 10/7/2019 with an elevation of 845.68 ft. The elevation was above the OHW for most of the monitoring season, reaching its highest recorded level on 8/19/2019 with a level of 846.75 ft. (Figure 2). A summary of all lake results is presented in APPENDIX A.

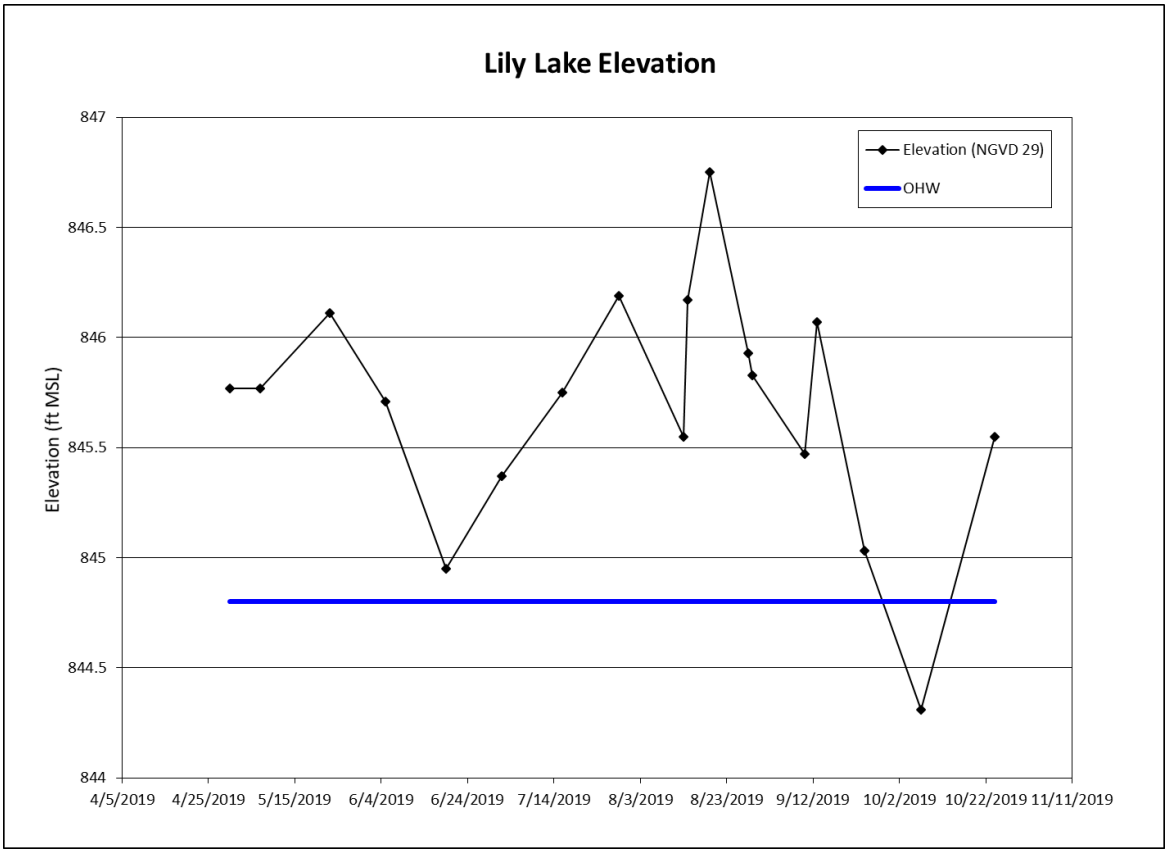

Figure 2. Lily Lake 2019 Elevations

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 2019 was 0.057 mg/L; higher than the 0.045 mg/L observed in 2018 (Figure 4), with three of the nine summertime water quality samples exceeding the MPCA TP impairment standard for shallow lakes (APPENDIX A). McKusick Lake had a summertime average chl-α

concentration of 9.1 µg/L; lower than the chl-α average of 9.8 µg/L from 2018 (Figure 5). None of the nine summertime samples collected in 2019 exceeded the MPCA shallow lake standard for chl-α. The average summertime TKN concentration for 2019 was 0.71 mg/L; lower than the 0.78 mg/L measured in 2018 (Figure 6). The 2019 summertime average water transparency measured by Secchi disk was 1.69 meters (Figure 7). Five of the nine summertime Secchi disk readings in 2019 were worse than the MPCA shallow lake impairment standard. McKusick Lake received a grade of a B- in 2019, an improvement from the C+ it received from 2016 to 2018. 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 of the season on 5/23/2019 with a level of 855.01 ft. and the lowest recorded level of the season occurred on 6/19/2019 with an elevation of 854.69 ft. (Figure 3). A summary of all lake results is presented in APPENDIX A.

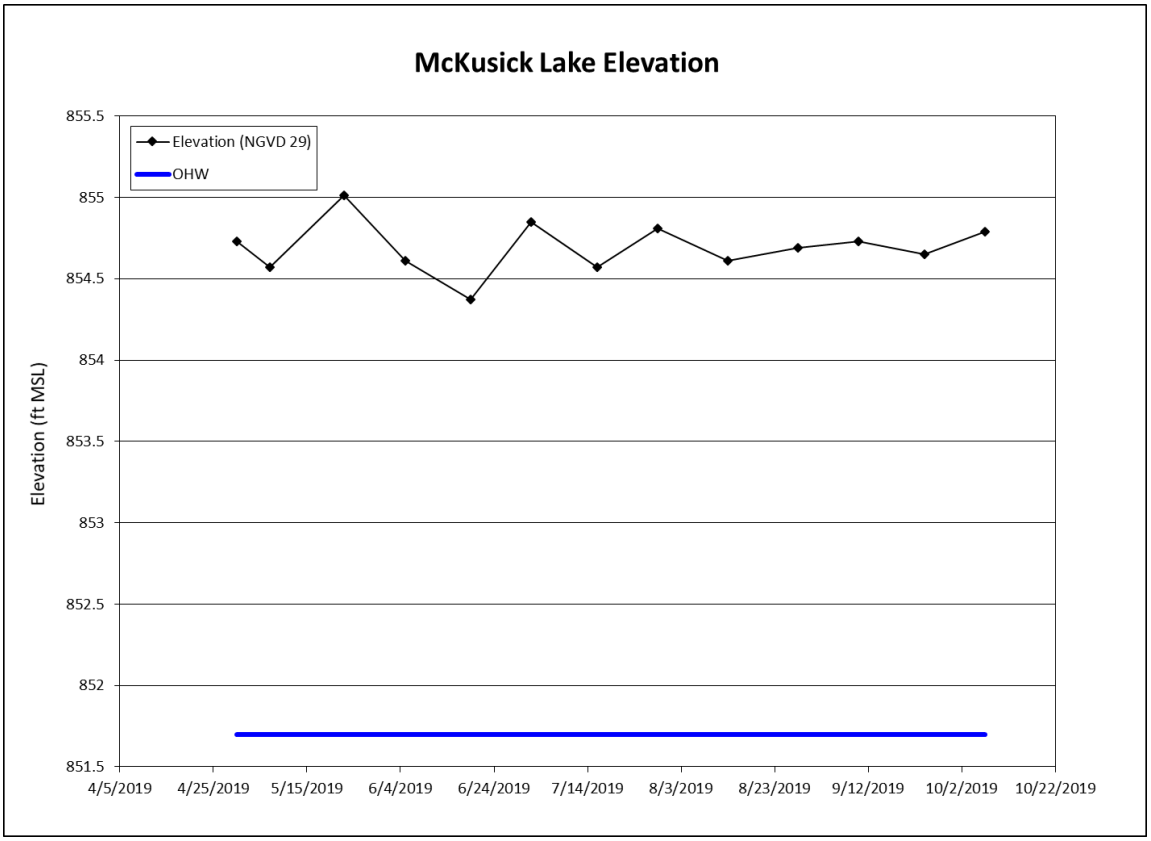

Figure 3. McKusick Lake 2019 Elevations

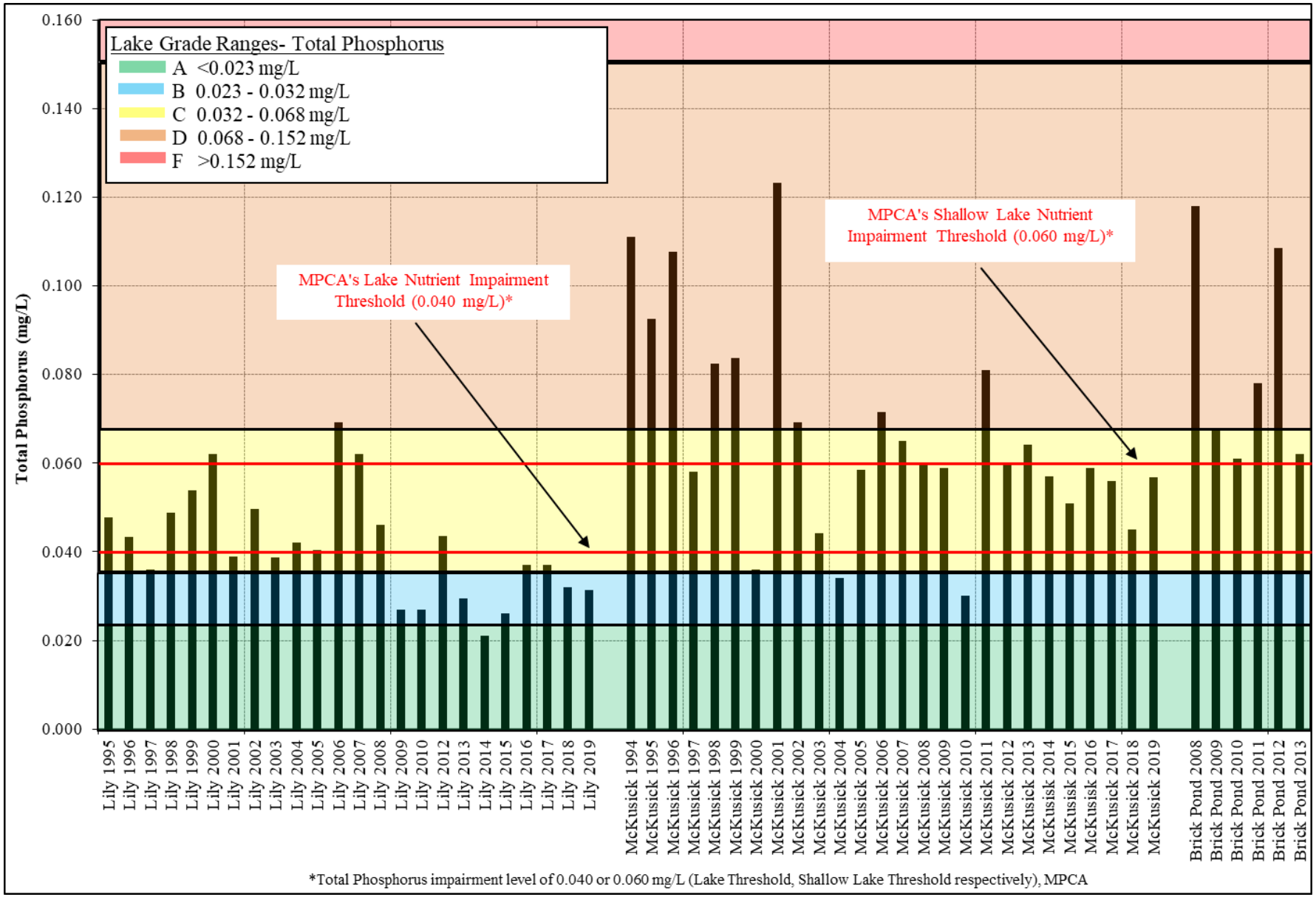

Figure 4. MSCWMO Historic Summer Average Total Phosphorus

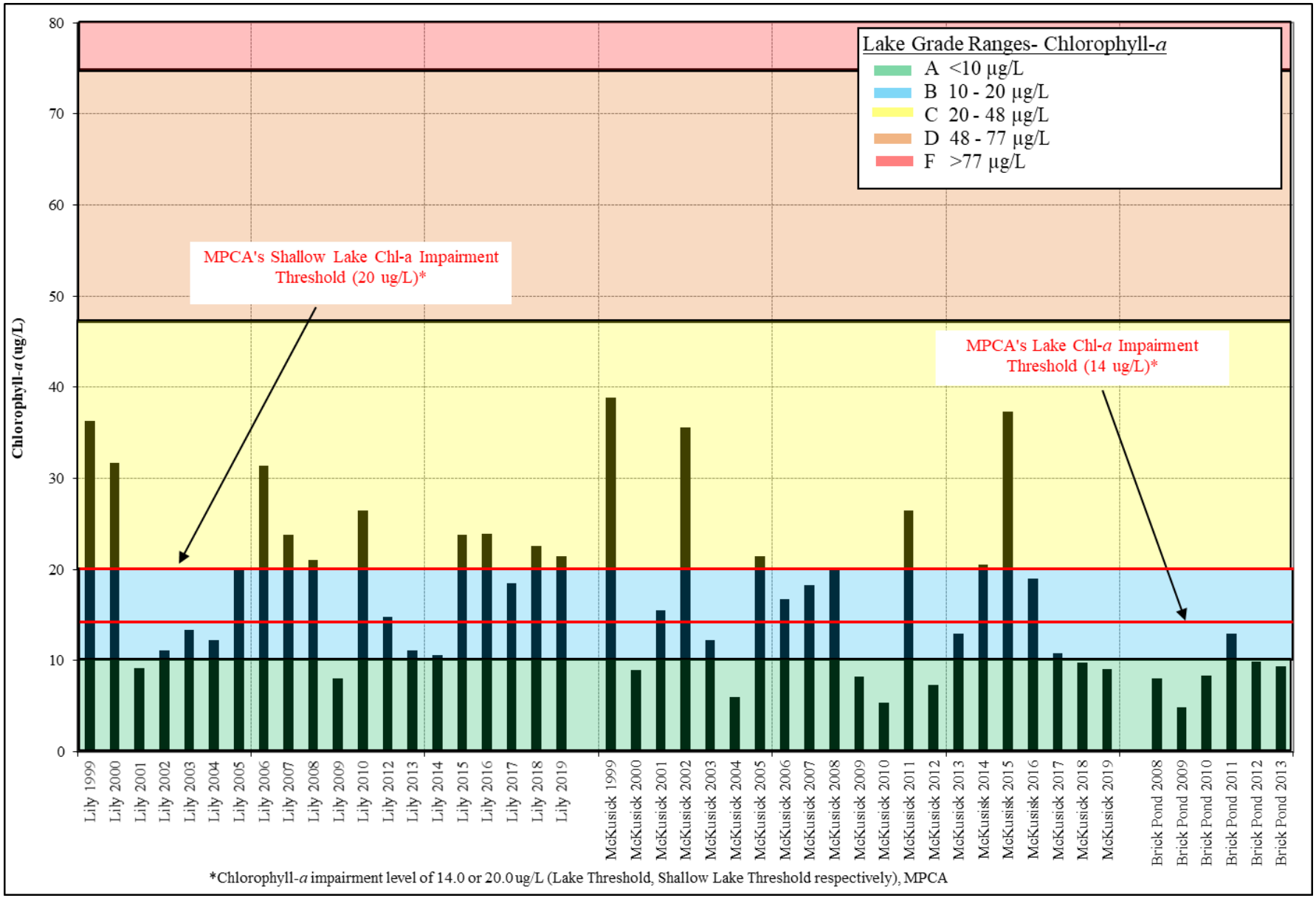

Figure 5. MSCWMO Historic Summer Average Chlorophyll-*α*

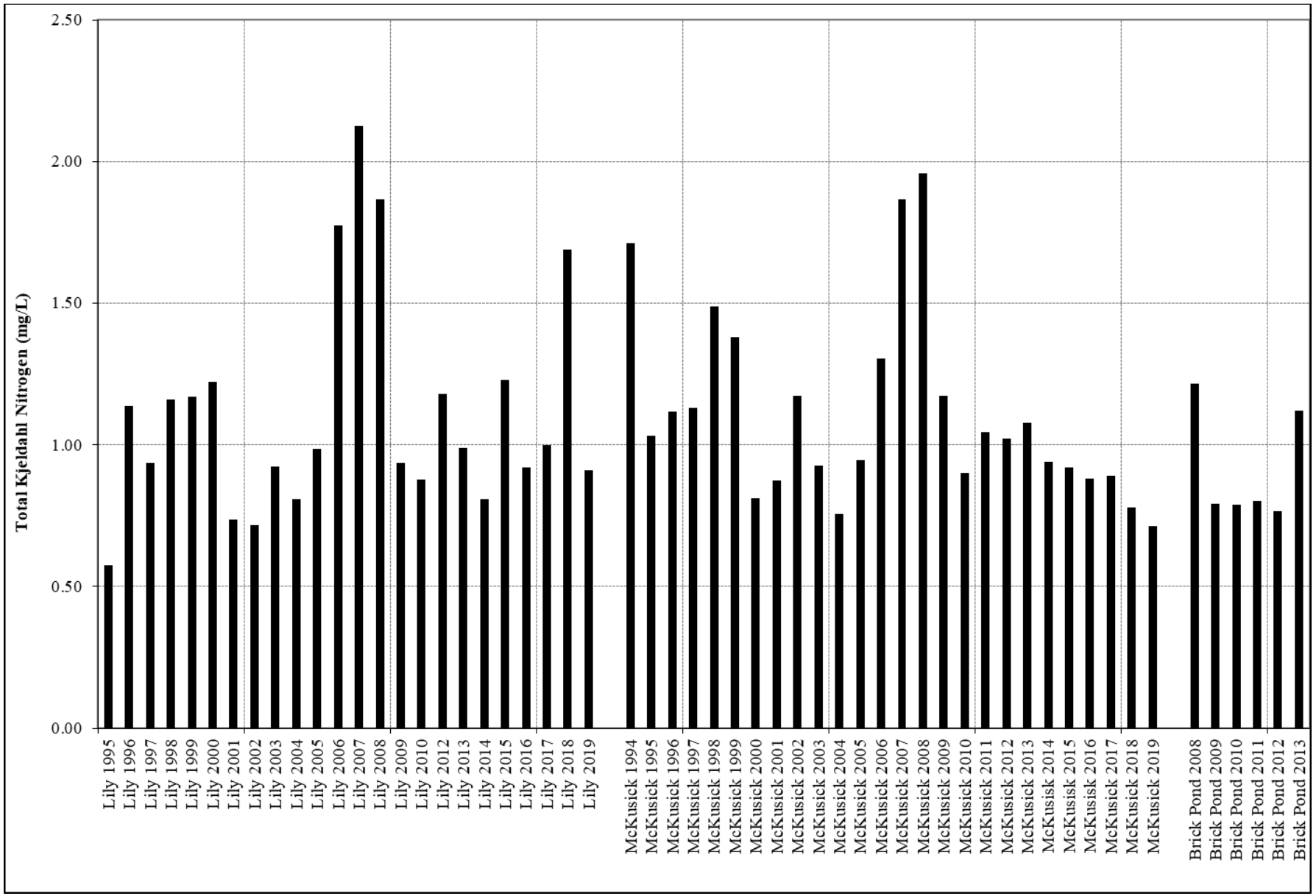

Figure 6. MSCWMO Historic Summer Average Total Kjeldahl Nitrogen

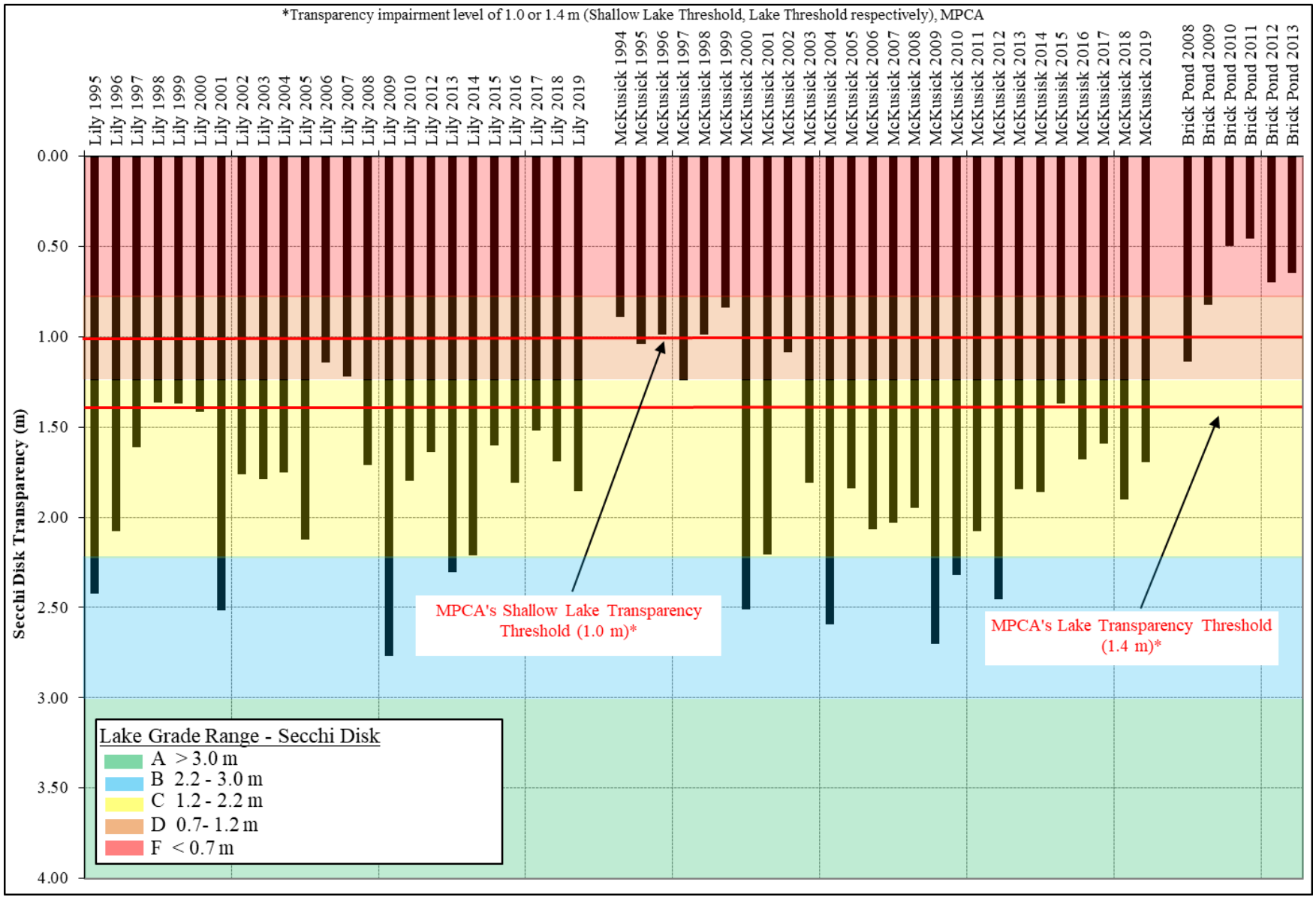

Figure 7. MSCWMO Historic Summer Average Secchi Disk Transparency

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 2019, 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 is 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 2019. Discharge increased from 2018 to 2019, and was the highest ever recorded, with a volume of 112,468,888 cubic feet exported to McKusick Lake (Table 2 and Table 3). All stream flow and chemistry data from 2019 can be found in Table 2 through Table 4.

The TP and TSS load to McKusick Lake was the highest ever recorded at 3,598 pounds of phosphorus and 2,707,186 pounds of sediment, equating to 0.933 and 702.25 pounds per acre of watershed land, respectively (Table 2 and Table 3). The head cut near Boutwell Avenue identified as a major source of high TP and TSS loads in prior monitoring summaries was repaired in November 2018, and was expected to significantly reduce nutrient loads in the drainage. However, a spring drone flight and field investigations by the BCWD's engineer found a large number of additional head cuts on all three tributary branches of the drainage that were likely produced or aggravated by excess runoff. To help lower phosphorus loading in the subwatershed there is an Iron Enhanced Sand Filter (IESF) upstream of the monitoring site.

In 2019 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 in past years copper continues to be an issue; one sample exceeded the final acute value, four samples exceeded the maximum standard, and one exceeded the chronic standard. The maximum standard for zinc was exceeded by two samples, and eight chronic standard exceedances of lead 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 is 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

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Brown's Creek Diversion Structure										
Discharge (cf)	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	112,468,888
Total pounds of Phosphorus exported	608	2,099	251	527	392	1,837	1,574	784	964	3,598
TP (lbs/ac/yr)	0.158	0.544	0.065	0.137	0.102	0.447	0.408	0.203	0.250	0.933
Total pounds of TSS exported	353,007	1,387,050	127,435	211,977	99,532	1,008,346	1,533,496	596,382	505,314	2,707,186
TSS (lbs/ac/yr)	91.57	359.81	33.06	54.99	25.82	261.57	397.79	154.70	131.08	702.25

Table 3. Brown's Creek Diversion Structure Drainage 2019 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**			*10*	*0.073*	*1/1/2019 0:00*	*3/13/2019 15:00*	*3,094,200*	*71.07*	*1,932*	*14.10*
Snowmelt Grab*	3/14/2019 11:20	3/14/2019 11:20	135	0.585	3/13/2019 15:00	3/16/2019 5:00	2,455,200	56.39	20,691	89.66
*Base**			*10*	*0.073*	*3/16/2019 5:00*	*3/20/2019 15:00*	*2,480,400*	*56.97*	*1,548*	*11.30*
*Snowmelt**			*104*	*0.404*	*3/20/2019 15:00*	*3/28/2019 0:00*	*8,156,160*	*187.34*	*52,952*	*205.70*
Snowmelt Grab*	3/28/2019 9:05	3/28/2019 9:05	73	0.222	3/28/2019 0:00	3/28/2019 16:00	316,800	7.28	1,444	4.39
*Base**			*10*	*0.073*	*3/28/2019 16:00*	*4/6/2019 5:00*	*2,214,000*	*50.85*	*1,382*	*10.09*
*Storm**			*2,140*	*2.613*	*4/6/2019 5:00*	*4/7/2019 4:00*	*703,800*	*16.17*	*94,022*	*114.80*
*Base**			*10*	*0.073*	*4/7/2019 4:00*	*4/14/2019 11:00*	*1,890,000*	*43.41*	*1,180*	*8.61*
*Snowmelt**			*104*	*0.404*	*4/14/2019 11:00*	*4/17/2019 12:00*	*1,314,000*	*30.18*	*8,531*	*33.14*
*Storm**			*2,140*	*2.613*	*4/17/2019 12:00*	*4/18/2019 7:00*	*560,880*	*12.88*	*74,929*	*91.49*
*Base**			*10*	*0.073*	*4/18/2019 7:00*	*4/22/2019 6:00*	*1,710,000*	*39.28*	*1,067*	*7.79*
*Storm**			*2,140*	*2.613*	*4/22/2019 6:00*	*4/23/2019 1:00*	*581,400*	*13.35*	*77,670*	*94.84*
*Base**			*10*	*0.073*	*4/23/2019 1:00*	*5/1/2019 15:15*	*2,227,500*	*51.16*	*1,391*	*10.15*
Base			*10*	*0.073*	*5/1/2019 15:15*	*5/8/2019 10:15*	*1,268,180*	*29.13*	*792*	*5.78*
Storm Composite	5/8/2019 15:52	5/9/2019 8:32	2,900	3.280	5/8/2019 10:15	5/9/2019 9:15	701,522	16.11	127,001	143.64
Base			*10*	*0.073*	*5/9/2019 9:15*	*5/18/2019 4:15*	*3,552,830*	*81.60*	*2,218*	*16.19*
Storm			*2,140*	*2.613*	*5/18/2019 4:15*	*5/18/2019 11:15*	*84,850*	*1.95*	*11,335*	*13.84*
Base			*10*	*0.073*	*5/18/2019 11:15*	*5/19/2019 1:15*	*158,400*	*3.64*	*99*	*0.72*
Storm Composite[Y]	5/19/2019 6:03	5/19/2019 23:39	7,960	3.850	5/19/2019 1:15	5/20/2019 0:15	512,955	11.78	254,894	123.28
Base			*10*	*0.073*	*5/20/2019 0:15*	*5/21/2019 18:15*	*918,738*	*21.10*	*574*	*4.19*
Storm Composite	5/21/2019 22:47	5/22/2019 8:24	2,600	3.020	5/21/2019 18:15	5/22/2019 13:15	561,047	12.89	91,062	105.77
Base			*10*	*0.073*	*5/22/2019 13:15*	*5/27/2019 7:15*	*2,227,570*	*51.16*	*1,391*	*10.15*
Storm Composite	5/27/2019 14:36	5/28/2019 4:19	1,380	2.370	5/27/2019 7:15	5/28/2019 6:15	1,176,670	27.03	101,368	174.09
Base Grab	5/30/2019 14:02	5/30/2019 14:02	15	0.090	5/28/2019 6:15	5/31/2019 14:15	3,315,590	76.16	3,105	18.63
Base			*10*	*0.073*	*5/31/2019 14:15*	*6/24/2019 0:15*	*3,559,190*	*81.75*	*2,222*	*16.22*
Storm			*2,140*	*2.613*	*6/24/2019 0:15*	*6/24/2019 18:15*	*132,052*	*3.03*	*17,641*	*21.54*
Base Grab	6/25/2019 9:35	6/25/2019 9:35	16	0.130	6/24/2019 18:15	6/27/2019 10:15	267,863	6.15	268	2.17
Storm			*2,140*	*2.613*	*6/27/2019 10:15*	*6/27/2019 16:15*	*33,229*	*0.76*	*4,439*	*5.42*
Base			*10*	*0.073*	*6/27/2019 16:15*	*6/30/2019 7:15*	*244,644*	*5.62*	*153*	*1.11*
Storm			*2,140*	*2.613*	*6/30/2019 7:15*	*6/30/2019 19:15*	*76,374*	*1.75*	*10,203*	*12.46*
Base			*10*	*0.073*	*6/30/2019 19:15*	*7/1/2019 19:15*	*161,028*	*3.70*	*101*	*0.73*
Storm Composite	7/1/2019 20:45	7/2/2019 7:58	1,510	2.890	7/1/2019 19:15	7/2/2019 8:15	438,282	10.07	41,314	79.07
Base			*10*	*0.073*	*7/2/2019 8:15*	*7/9/2019 15:15*	*1,794,140*	*41.21*	*1,120*	*8.18*
Storm			*2,140*	*2.613*	*7/9/2019 15:15*	*7/9/2019 21:15*	*69,938*	*1.61*	*9,343*	*11.41*
Base			*10*	*0.073*	*7/9/2019 21:15*	*7/14/2019 21:15*	*822,127*	*18.88*	*513*	*3.75*
Storm			*2,140*	*2.613*	*7/14/2019 21:15*	*7/15/2019 3:15*	*24,540*	*0.56*	*3,278*	*4.00*
Base			*10*	*0.073*	*7/15/2019 3:15*	*7/15/2019 18:15*	*53,280*	*1.22*	*33*	*0.24*
Storm			*2,140*	*2.613*	*7/15/2019 18:15*	*7/16/2019 1:15*	*122,005*	*2.80*	*16,299*	*19.90*
Base			*10*	*0.073*	*7/16/2019 1:15*	*7/20/2019 8:15*	*1,101,730*	*25.31*	*688*	*5.02*
Storm Composite	7/20/2019 9:49	7/20/2019 19:09	977	1.220	7/20/2019 8:15	7/20/2019 19:15	233,832	5.37	14,261	17.81
Base Grab	7/23/2019 14:53	7/23/2019 14:53	16	0.088	7/20/2019 19:15	7/26/2019 20:15	1,635,570	37.57	1,634	8.99
Storm			*2,140*	*2.613*	*7/26/2019 20:15*	*7/27/2019 5:15*	*122,616*	*2.82*	*16,381*	*20.00*
Base			*10*	*0.073*	*7/27/2019 5:15*	*8/13/2019 17:15*	*2,720,430*	*62.49*	*1,698*	*12.40*
Storm Composite	8/13/2019 18:13	8/13/2019 22:37	2,750	2.900	8/13/2019 17:15	8/14/2019 3:15	313,193	7.19	53,766	56.70
Base			*10*	*0.073*	*8/14/2019 3:15*	*8/16/2019 3:15*	*1,258,680*	*28.91*	*786*	*5.74*
Storm			*2,140*	*2.613*	*8/16/2019 3:15*	*8/16/2019 9:15*	*301,081*	*6.92*	*40,222*	*49.11*
Base			*10*	*0.073*	*8/16/2019 9:15*	*8/16/2019 14:15*	*256,125*	*5.88*	*160*	*1.17*
Storm			*2,140*	*2.613*	*8/16/2019 14:15*	*8/16/2019 22:15*	*477,398*	*10.97*	*63,777*	*77.87*
Base			*10*	*0.073*	*8/16/2019 22:15*	*8/18/2019 2:15*	*1,440,180*	*33.08*	*899*	*6.56*
Storm			*2,140*	*2.613*	*8/18/2019 2:15*	*8/19/2019 4:15*	*3,459,330*	*79.46*	*462,139*	*564.28*
Base			*10*	*0.073*	*8/19/2019 4:15*	*8/25/2019 13:15*	*5,984,960*	*137.47*	*3,736*	*27.27*
Base Grab	8/26/2019 13:31	8/26/2019 13:31	6	0.063	8/25/2019 13:15	8/26/2019 14:15	277,879	6.38	104	1.09
Storm			*2,140*	*2.613*	*8/26/2019 14:15*	*8/26/2019 19:15*	*108,016*	*2.48*	*14,430*	*17.62*
Base			*10*	*0.073*	*8/26/2019 19:15*	*9/2/2019 22:15*	*1,903,130*	*43.71*	*1,188*	*8.67*
Storm			*2,140*	*2.613*	*9/2/2019 22:15*	*9/3/2019 13:15*	*894,062*	*20.54*	*119,439*	*145.84*
Base			*10*	*0.073*	*9/3/2019 13:15*	*9/11/2019 4:15*	*3,654,320*	*83.94*	*2,281*	*16.65*
Storm			*2,140*	*2.613*	*9/11/2019 4:15*	*9/11/2019 11:15*	*133,499*	*3.07*	*17,834*	*21.78*
Base			*10*	*0.073*	*9/11/2019 11:15*	*9/12/2019 4:15*	*331,885*	*7.62*	*207*	*1.51*
Storm Composite	9/12/2019 8:00	9/12/2019 12:49	2,860	1.370	9/12/2019 4:15	9/12/2019 22:15	875,022	20.10	156,225	74.84
Base			*10*	*0.073*	*9/12/2019 22:15*	*9/22/2019 13:15*	*5,427,060*	*124.65*	*3,388*	*24.73*
Base Grab	9/23/2019 13:47	9/23/2019 13:47	4	0.046	9/22/2019 13:15	9/24/2019 13:15	397,122	9.12	99	1.14
Base			*10*	*0.073*	*9/24/2019 13:15*	*9/29/2019 5:15*	*760,198*	*17.46*	*475*	*3.46*
Storm			*2,140*	*2.613*	*9/29/2019 5:15*	*9/29/2019 12:15*	*41,381*	*0.95*	*5,528*	*6.75*
Base			*10*	*0.073*	*9/29/2019 12:15*	*10/1/2019 14:15*	*307,972*	*7.07*	*192*	*1.40*
Storm			*2,140*	*2.613*	*10/1/2019 14:15*	*10/1/2019 23:15*	*164,945*	*3.79*	*22,035*	*26.91*
Base			*10*	*0.073*	*10/1/2019 23:15*	*10/2/2019 14:15*	*281,060*	*6.46*	*175*	*1.28*
Storm			*2,140*	*2.613*	*10/2/2019 14:15*	*10/2/2019 22:15*	*156,408*	*3.59*	*20,895*	*25.51*
Base			*10*	*0.073*	*10/2/2019 22:15*	*10/4/2019 15:15*	*823,432*	*18.91*	*514*	*3.75*
Storm			*2,140*	*2.613*	*10/4/2019 15:15*	*10/4/2019 22:15*	*170,282*	*3.91*	*22,748*	*27.78*
Base			*10*	*0.073*	*10/4/2019 22:15*	*10/5/2019 5:15*	*170,106*	*3.91*	*106*	*0.78*
Storm			*2,140*	*2.613*	*10/5/2019 5:15*	*10/5/2019 20:15*	*676,710*	*15.54*	*90,403*	*110.38*
Base			*10*	*0.073*	*10/5/2019 20:15*	*10/15/2019 3:15*	*4,352,870*	*99.98*	*2,717*	*19.84*
Storm			*2,140*	*2.613*	*10/15/2019 3:15*	*10/15/2019 8:15*	*72,564*	*1.67*	*9,694*	*11.84*
Base			*10*	*0.073*	*10/15/2019 8:15*	*10/21/2019 7:15*	*1,498,810*	*34.43*	*936*	*6.83*
Storm			*2,140*	*2.613*	*10/21/2019 7:15*	*10/22/2019 1:15*	*1,794,660*	*41.22*	*239,752*	*292.74*
Base			*10*	*0.073*	*10/22/2019 1:15*	*10/22/2019 7:15*	*282,889*	*6.50*	*177*	*1.29*
Storm			*2,140*	*2.613*	*10/22/2019 7:15*	*10/22/2019 21:15*	*963,082*	*22.12*	*128,660*	*157.10*
Base Grab	10/24/2019 8:50	10/24/2019 8:50	8	0.051	10/22/2019 21:15	10/25/2019 9:15	3,621,650	83.19	1,809	11.53
Base			*10*	*0.073*	*10/25/2019 9:15*	*10/29/2019 10:15*	*2,612,840*	*60.01*	*1,631*	*11.91*
*Base**			*10*	*0.073*	*10/29/2019 10:15*	*11/21/2019 3:00*	*3,431,925*	*78.83*	*2,142*	*15.64*
*Storm**			*2,140*	*2.613*	*11/21/2019 3:00*	*11/21/2019 11:00*	*158,400*	*3.64*	*21,161*	*25.84*
*Base**			*10*	*0.073*	*11/21/2019 11:00*	*12/28/2019 14:00*	*4,811,400*	*110.51*	*3,004*	*21.93*
*Storm**			*2,140*	*2.613*	*12/28/2019 14:00*	*12/29/2019 8:00*	*874,800*	*20.09*	*116,866*	*142.70*
*Base**			*10*	*0.073*	*12/29/2019 8:00*	*1/1/2020 0:00*	*1,152,000*	*26.46*	*719*	*5.25*
Snowmelt Average			104	0.404						
Storm Average			2,140	2.613						
Base Average			10	0.073						
All Average			954	1.307						
Total							**112,468,888**	**2,583**	**2,707,186**	**3,598**
Brown's Creek Major Subwatershed Total Acres							3,855			
Total TSS/TP(lb/ac/yr)									702.25	0.933
Total TSS/TP (kg/ha/yr)									787.11	1.046

Italics indicate estimated concentrations based on average base and storm flow concentrations.
*Interval volumes were estimated using similar flow conditions.
[Y]TSS result excluded from averages.

Table 4. Brown's Creek Diversion Structure Drainage 2019 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	3/14/2019 11:20	3/14/2019 11:20	135	32	3.90	0.585	0.224							131.0	<0.03	0.62	0.90	
Snowmelt Grab	3/28/2019 9:05	3/28/2019 9:05	73	10	1.30	0.222	0.084	0.00320	0.00220	0.00130	0.00790	<0.000200	0.00210	76.3	<0.03	0.16	0.31	42
Storm Composite	5/8/2019 15:52	5/9/2019 8:32	2,900	725	18.00	3.280	0.068	0.02910	0.03340	0.02910	0.11400	0.001000	0.02950	64.2	<0.06	0.51	~0.03	94
Storm Composite	5/19/2019 6:03	5/19/2019 23:39	7,960	1,650	20.00	3.850	0.064	0.02970	0.03030	0.02770	0.10500	0.000950	0.02970	60.2	0.07	0.39	~0.05	174
Storm Composite	5/21/2019 22:47	5/22/2019 8:24	2,600	615	13.00	3.020	~0.046	0.02440	0.02640	0.02820	0.09300	0.000620	0.03000	82.4	0.12	<0.20	~0.04	67
Storm Composite	5/27/2019 14:36	5/28/2019 4:19	1,380	265	8.30	2.370	0.134	0.02320	0.02570	0.02470	0.08490	0.000610	0.02930	52.2	0.09	<0.20	~0.04	85
Storm Composite	7/1/2019 20:45	7/2/2019 7:58	1,510	344	8.40	2.890	0.072	0.01950	0.02270	0.01750	0.07610	0.000630	0.02040	46.7	<0.06	0.32	<0.02	86
Storm Composite	7/20/2019 9:49	7/20/2019 19:09	977	217	5.30	1.220	0.063							76.7	<0.06	<0.20	~0.03	
Storm Composite	8/13/2019 18:13	8/13/2019 22:37	2,750	725	13.00	2.900	0.075	0.02440	0.02830	0.02190	0.09530	0.000920	0.02600	2.80	0.07	0.34	<0.02	119
Storm Composite	9/12/2019 8:00	9/12/2019 12:49	2,860	548	5.70	1.370	0.089	0.00980	0.01060	0.00850	0.03600	~0.000230	0.01150	33.4	<0.06	0.30	<0.02	101
Base Grab	4/29/2019 13:55	4/29/2019 13:55	7	3	0.55	~0.044	<0.020	~0.00070	0.00058	~0.00050	<0.00120	<0.000063	0.00036	121.8	<0.06	0.27	~0.05	75
Base Grab	5/30/2019 14:02	5/30/2019 14:02	15	4	0.69	0.090	<0.020	~0.00080	0.00063	~0.00029	<0.00120	<0.000063	~0.00047	144.1	<0.06	<0.20	<0.02	38
Base Grab	6/25/2019 9:35	6/25/2019 9:35	16	6	0.59	0.130	~0.041	0.00110	0.00240	~0.00037	~0.00420	~0.000110	0.00072	86.3	<0.06	0.31	0.15	142
Base Grab	7/23/2019 14:53	7/23/2019 14:53	16	5	0.74	0.088	~0.039	~0.00057	0.00066	<0.00026	0.01180	<0.000063	~0.00042	131.1	<0.06	<0.20	~0.03	60
Base Grab	8/26/2019 13:31	8/26/2019 13:31	6	3	0.74	0.063	~0.034	~0.00040	~0.00044	<0.00026	<0.00120	<0.000063	~0.00027	95.1	<0.06	<0.20	~0.04	78
Base Grab	9/23/2019 13:47	9/23/2019 13:47	4	~2	0.54	~0.046	<0.020	<0.00034	0.00096	<0.00026	<0.00120	<0.000063	~0.00026	55.9	<0.06	0.57	~0.03	98
Base Grab	10/24/2019 8:50	10/24/2019 8:50	8	3	0.52	0.051	~0.028	~0.00040	~0.00044	<0.00026	<0.00120	<0.000063	~0.00023	47.8	<0.06	<0.02	<0.02	40

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 2019, as in prior years, 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 recorded discharge to Lily Lake in 2019 was 8,557,064 cubic feet which was the highest recorded at the site. The volume was more than double what was recorded in 2018 even though the 2019 recorded date range had twenty-three fewer days. All discharge data from 2019 can be found in Table 5. Additionally, grab samples were collected and analyzed for the following water quality parameters: Total Phosphorus (TP), Total Kjeldahl 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 2019 were similar to results in prior years. The Greeley Street catchment base flow grab samples had low levels of TP and TSS. The 2019 average TP was 0.077 mg/L, which was slightly higher than the 2018 average (0.066 mg/L). The 2019 average TSS concentration was 2 mg/L, which was slightly less than the 4 mg/L seen in 2018 (Table 5 and Table 6). One storm event sample was collected in 2019, which followed previous years' observations with concentrations much higher than base samples. The TP concentration for the storm sample was 0.110 mg/L. This concentration was lower than the 2018 storm concentration of 0.316 mg/L, but much closer to the 2017 storm average (0.104 mg/L). The TSS storm concentration in 2019 was 8 mg/L which is lower than the 2018 storm concentration (518 mg/L) and the 2017 average

storm concentration (35 mg/L). Storm sample comparisons between 2019 and previous years are restricted because of the small sample size. The TP load to Lily Lake from Greeley Street was 41.1 lbs., higher than the load of 14.4 lbs. in 2018 (Table 5 and Figure 8). The TSS load was 978 lbs., higher than the 846 lbs. in 2018 (Table 5 and Figure 9).

Similar to previous years, storm sampling in 2019 was limited by the nature of the site as storm events at the Greeley Street Inlet are flashy. Storm events occur quickly as urban runoff is transported swiftly and this makes capturing a sample more difficult during these periods.

Table 5. Greeley Street 2019 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	5/15 - 10/28*^	8,557,064	196.55	0.077	0.046-0.134	2	1-3	41.1	978

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

^9/12 results excluded from averages and ranges

Table 6. Greeley Street 2019 Water Quality Results

Date	Greeley Street			
	Sample Type	TP (mg/L)	TSS (mg/L)	TKN (mg/L)
5/30/2019	Base	0.079	~1	0.5
6/24/2019	Base	0.134	~2	0.97
7/25/2019	Base	0.095	~1	0.73
8/28/2019	Base	0.058	3	0.57
9/12/2019*	Storm	0.110	8	0.42
9/23/2019	Base	~0.046	~2	0.5
10/23/2019	Base	0.050	~2	0.41

*Result excluded from averages

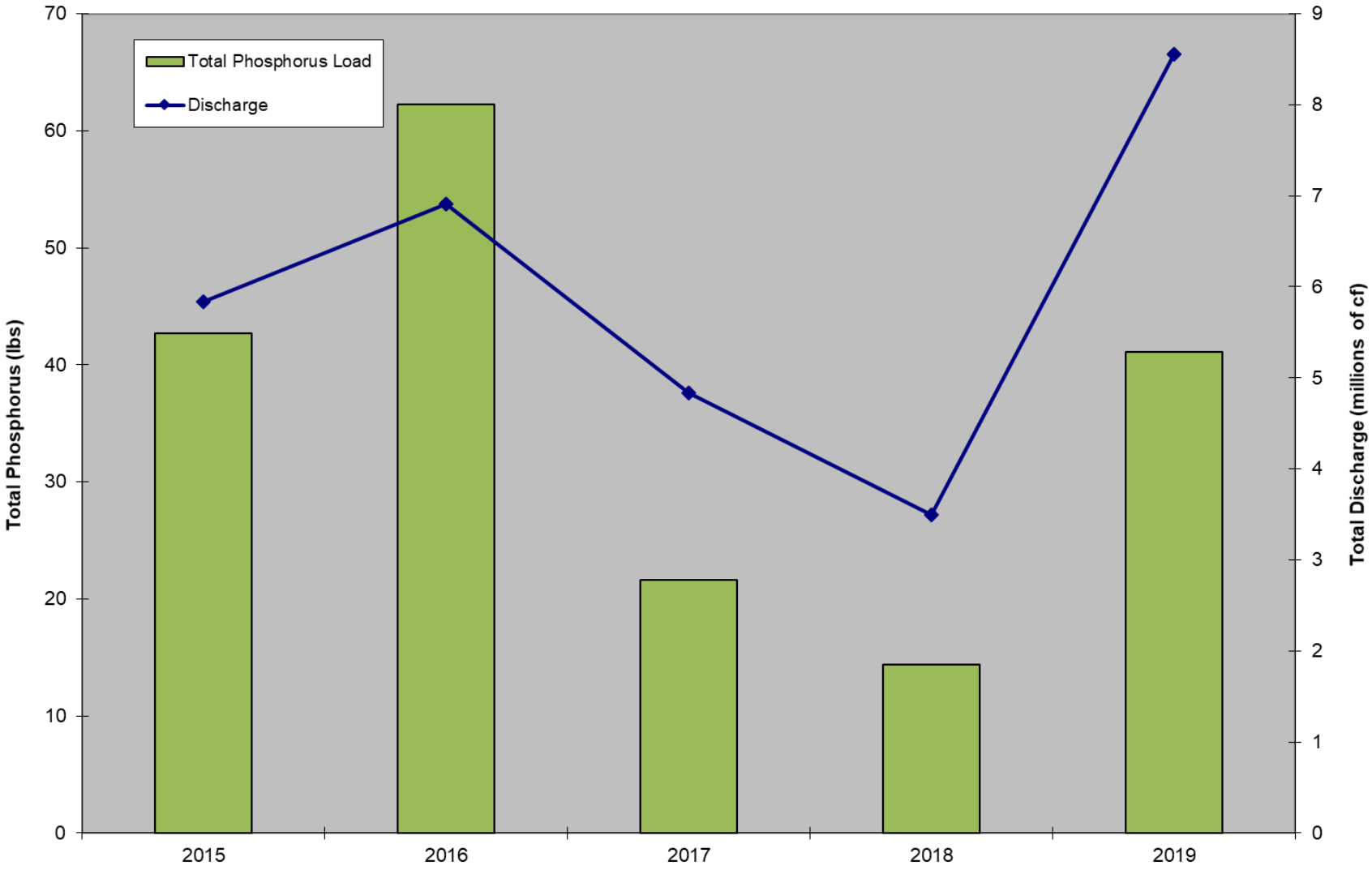

Figure 8. Greeley Street Annual Discharge and Total Phosphorus Load

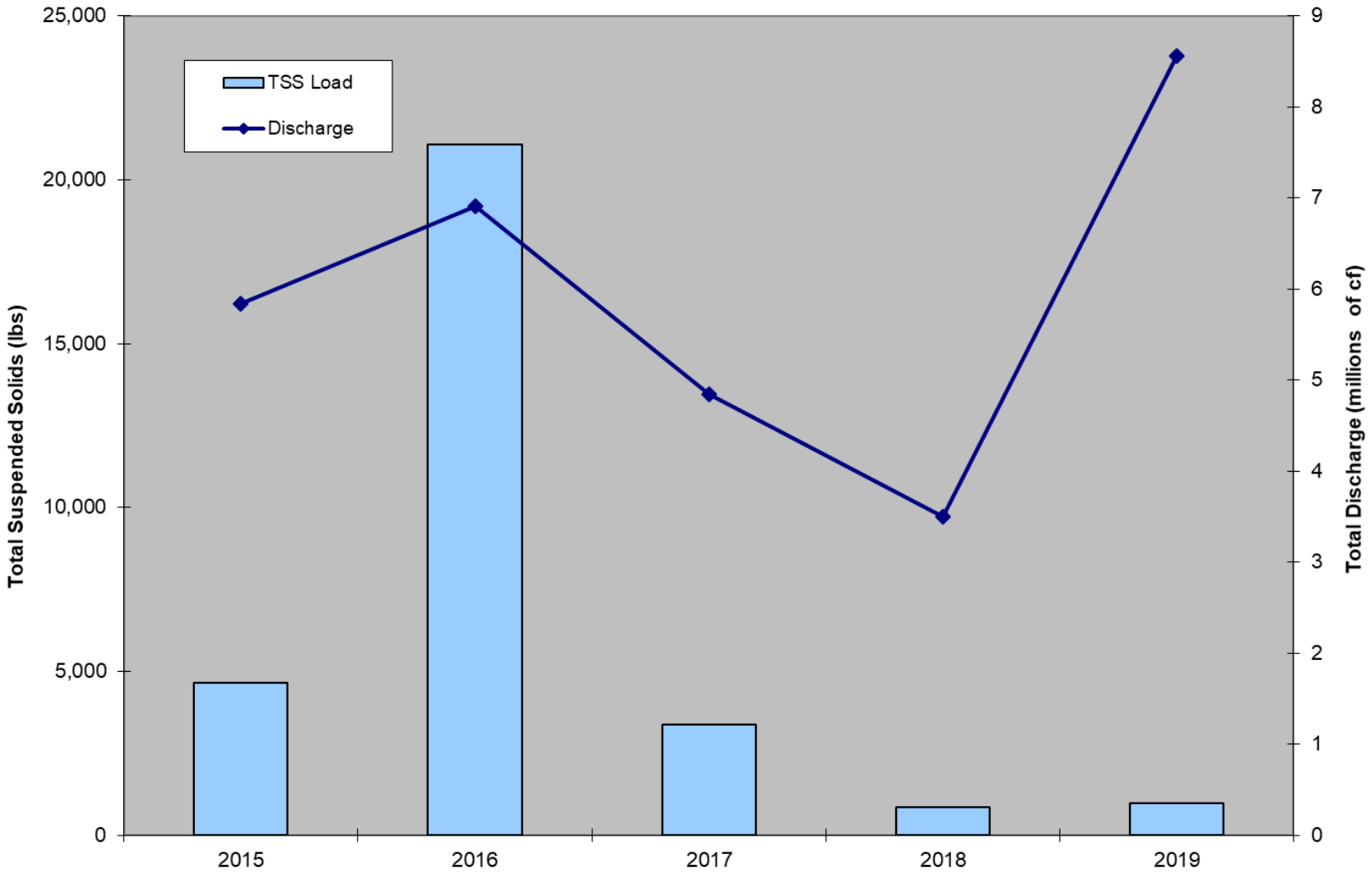

Figure 9. Greeley Street Annual Discharge and Total Suspended Solids Load

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 and 2019 to further refine previous observations. In 2019, as 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 Kjeldahl 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.

In 2019 Perro Creek at the Diversion Structure had higher average results than 2018. The average phosphorus concentration was 0.180 mg/L with a range of 0.021-0.597 mg/L, higher than the average phosphorus concentration in 2018 of 0.065 mg/L and range of 0.020-0.252 mg/L. The average TSS concentration was 25 mg/L, which was higher than the 9 mg/L in 2018. Perro Creek at the Diversion Structure TSS results had a range of 1-97 mg/L, which was a higher range than 1-31 mg/L in 2018 (Table 7 and Table 8).

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 9/12/2019, with eight of the ten sites at or exceeding the standard testing limit of 2,420 most probable number of organisms (MPN) per 100/ml (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). More details on how the MPCA assesses *E. coli* can be found in the footnote below Table 10.

In 2019 additional sampling occurred on Perro Creek to determine if human fecal DNA was present in the *E.coli*. Samples were collected at four locations along the creek (Perro at 9th Street, Perro at 6th Street, Perro at the Diversion Structure, and Perro Creek at 3rd Ave) and were submitted to Source Molecular Corporation in Florida to be analyzed for the presence of human fecal gene biomarkers. Samples were collected on 8/1/2019, 8/28/2019, and 10/2/2019. Human fecal DNA was detected in the samples collected on 8/1/2019 and 10/2/2019 at the Perro Creek at 3rd Ave location. All other samples tested negative for human fecal DNA (Table 11). Samples will continue to be collected in 2020 for human fecal DNA analysis at the same four locations.

Table 7. Perro Creek 2019 Total Suspended Solids (TSS) and Total Phosphorus (TP)

Site	Estimated Discharge (CFS)	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 5/6/10/23	7,181,443	164.95	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Perro at Diversion Structure Base 5/6-10/23*	26,416,703	606.76	0.9823	0.034	0.021-0.065	2	1-3	56.069	3298
Perro at Diversion Structure Storm 5/6-10/23^	477,290	10.96	0.0177	0.372	0.133-0.597	58	21-97	11.084	1728

* Excluded TP & TSS results from 6/24 base sample

^ Included TP & TSS results from 3/14 snowmelt sample

Table 8. Perro Creek 2019 Water Quality Results

Date	Perro Creek at the Diversion Structure			
	Sample Type	TP (mg/L)	TSS (mg/L)	TKN (mg/L)
3/14/2019	Snowmelt	0.504	63	3.40
5/8/2019	Storm	0.597	97	2.40
5/28/2019	Base	~0.025	~2	0.33
6/24/2019	Base	0.147	8	0.93
6/27/2019	Storm	0.252	51	2.00
7/30/2019	Base	0.065	3	0.33
8/27/2019	Base	~0.034	3	0.37
9/12/2019	Storm	0.133	21	0.35
9/26/2019	Base	~0.024	~1	0.26
10/23/2019	Base	~0.021	3	0.25

Table 9. Perro Creek 2019 *E. coli* Results

Site	*E. coli* Results				
	5/29/2019	6/24/2019	7/30/2019	8/27/2019	9/12/2019
Perro at Perro Pond Outlet	12	52	24	55	687
Perro at 5th Ave	19	50	59	68	1733
Perro at 9th Street	17	82	88	97	2420
Perro at 8th Street	12	88	50	104	>2420
Perro at 6th Street	28	365	93	82	>2420
Perro at 4th Street	46	197	129	152	>2420
Perro at St. Croix Trail Downstream	35	260	73	186	>2420
Perro at Diversion Structure	37	225	86	135	>2420
Perro at Central Ave	67	291	108	172	>2420
Perro at 3rd Ave	50	461	89	276	>2420

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	58	196	116	100	415	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.*"

Table 11. Perro Creek 2019 Human Fecal DNA Detection Results

Site	Date	DNA Analytical Results
Perro Creek @ 9th Street	8/1/2019	Not Detected
Perro Creek @ 6th Street	8/1/2019	Not Detected
Perro Creek @ Diversion Structure	8/1/2019	Not Detected
Perro Creek @ 3rd Ave	8/1/2019	Detected
Perro Creek @ 9th Street	8/28/2019	Not Detected
Perro Creek @ 6th Street	8/28/2019	Not Detected
Perro Creek @ Diversion Structure	8/28/2019	Not Detected
Perro Creek @ 3rd Ave	8/28/2019	Not Detected
Perro Creek @ 9th Street	10/2/2019	Not Detected
Perro Creek @ 6th Street	10/2/2019	Not Detected
Perro Creek @ Diversion Structure	10/2/2019	Not Detected
Perro Creek @ 3rd Ave	10/2/2019	Detected

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 2019 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 and 2019 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 occurred in 2018-2019. 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 installed at Lakeview Hospital discharging to Brick Pond in 2017, and a large gully stabilization and stormwater treatment system discharging to Brick Pond in 2018. In 2019 another raingarden was installed. The effects of these BMPs may have been seen from 2012 to 2019 monitoring seasons with the 2016-2019 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 2019 the Lily Lake Phosphorus Reductions for Delisting grant was secured. 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 2017-2019 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 2019 with low base flow discharge, low average TP concentrations (0.077 mg/L), and low average TSS concentrations (2 mg/L). The only storm event sample collected had a TP result of 0.110 mg/L and TSS result of 8 mg/L. These results confirm 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. However, more storm samples should be collected to calculate more accurate TP and TSS loadings and to better characterize storm events.

It's 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.

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 2019 through monitoring at Perro Creek at the Diversion Structure. The average total phosphorus result was 0.180 mg/L, higher than the 0.065 mg/L in 2018.

As in 2018, Perro Creek *E. coli* results are low at both sites prior to the creek entering the City of Bayport and results do not increase at all sites moving downstream as expected. The *E. coli* results didn't always significantly increase after the Perro Creek at 8th Street Site as was seen in 2018. However, there is a drop in *E. coli* results near the Perro Creek at the Diversion Structure site as seen in 2018. This may indicate that a source of groundwater, or piped drinking water, could be contributing to Perro Creek upstream of this area and diluting *E. coli*. Human fecal DNA was detected on 8/1/2019 and 10/2/2019 at the Perro Creek at 3rd Ave location, which is the furthest downstream sampling location. All other samples tested negative for human fecal DNA. Samples will continue to be collected in 2020 for human fecal DNA analysis at the same four locations to expand upon the 2019 dataset.

APPENDIX A
WATER QUALITY DATA – LILY LAKE AND MCKUSICK LAKE

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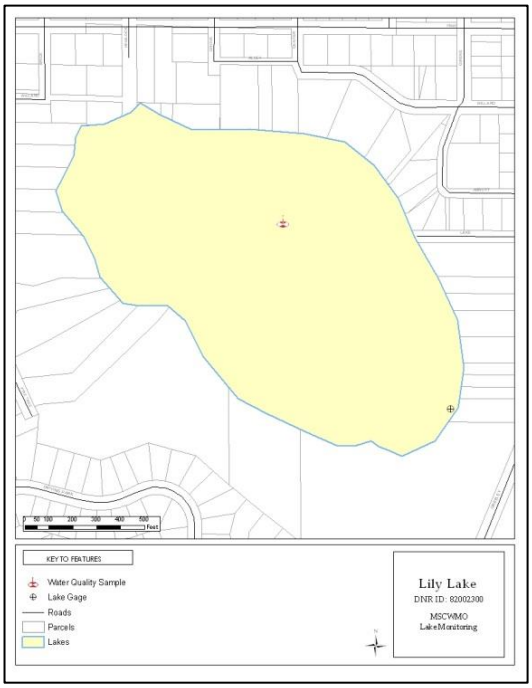
LILY LAKE

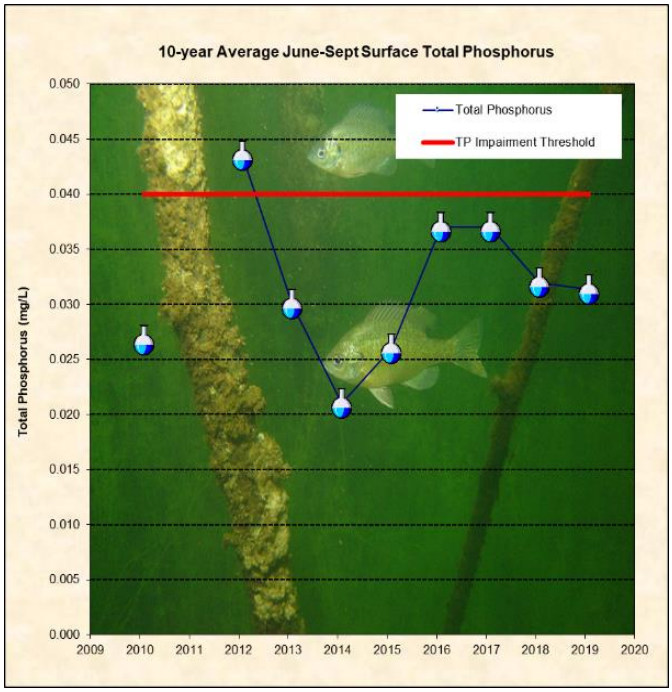
2019 Lake Grade: B-

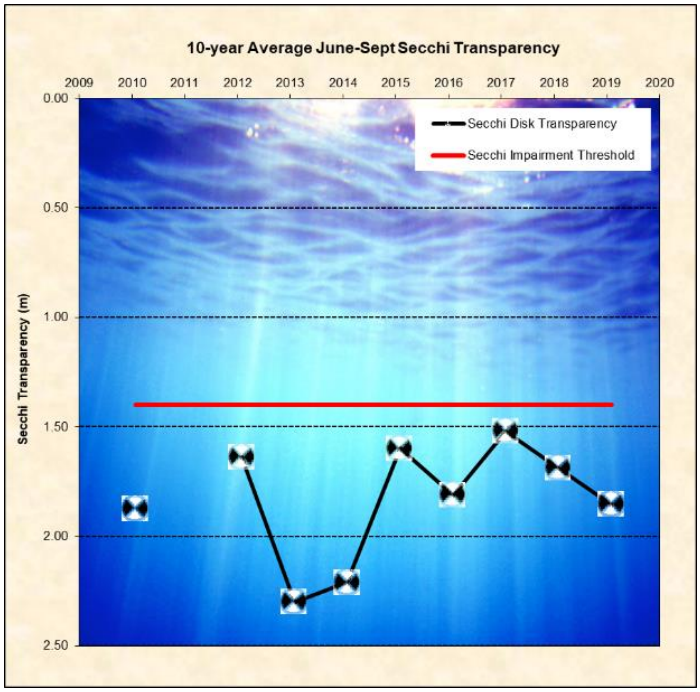
- DNR ID #: 820023
- Municipality: City of Stillwater
- Location: NE ¼ Section 32, T30N-R20W
- Lake Size: 35.90 Acres
- Maximum Depth (2019): 50.0 ft
- Ordinary High Water Mark: 844.8 ft
- 55%Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.
- Publically accessible



Summary Points

- Based on the chlorophyll-α results Lily Lake was considered eutrophic in 2019, 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 2019 with the thermocline between 4-5 meters deep.
- Lily Lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List.





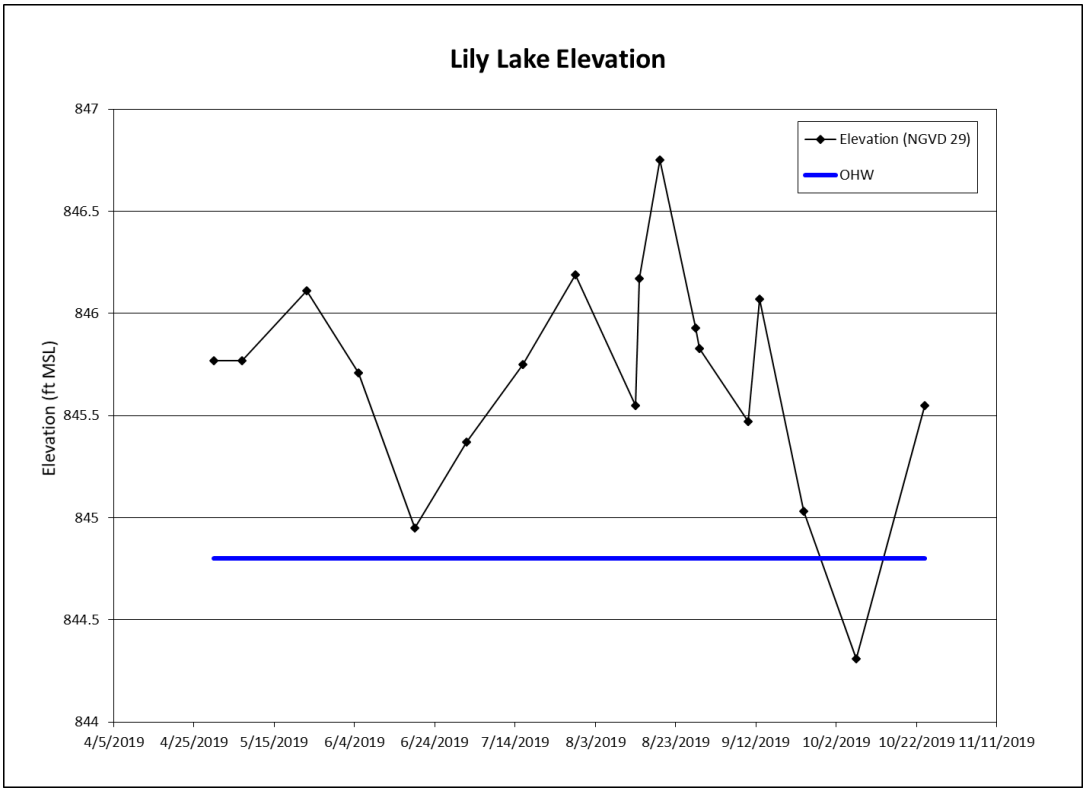
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
4/23/2019 8:07	0.041	28.0	25.0	0.82	1.37	10.4	9.49
5/7/2019 8:21	0.024	3.1	3.0	0.62	3.66	13.9	10.47
5/23/2019 12:30	0.024	2.6	1.8	0.66	3.35	14.2	8.69
6/5/2019 9:36	0.020	3.1	3.0	0.53	4.04	21.6	8.97
6/19/2019 9:20	0.034	7.1	6.4	0.68	3.51	22.2	8.06
7/2/2019 9:08	0.032	22.0	21.0	0.91	1.52	24.6	9.49
7/16/2019 11:37	0.038	14.0	12.0	0.91	1.98	28.4	6.49
7/29/2019 13:08	0.033	36.0	33.0	1.10	1.07	26.2	7.82
8/13/2019 12:07	0.039	45.0	44.0	1.20	0.76	26.0	6.57
8/28/2019 8:20	0.036	39.0	40.0	1.20	0.76	21.1	6.56
9/10/2019 12:49	0.025	21.0	21.0	0.87	1.37	20.8	6.60
9/24/2019 13:33	0.025	14.0	13.0	0.80	1.68	21.4	8.13
10/7/2019 13:18	0.020	9.1	7.7	0.74	3.05	14.3	7.59
2019 Average	0.030	18.8	17.8	0.85	2.16	20.4	8.07
2019 Summer Average	0.031	22.4	21.5	0.91	1.85	23.6	7.63

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
2019 Elevation (ft)	846.75	8/19/2019	844.31	10/7/2019	845.68

*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."



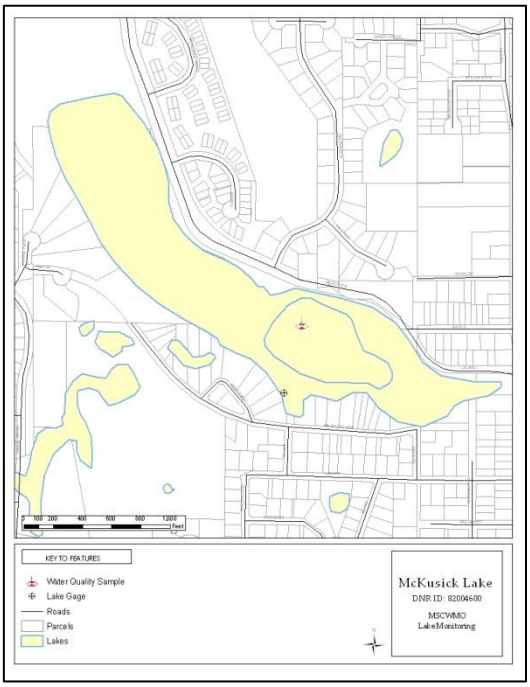
Lake Water Quality Summary										
	Summertime Lake Grades (May-Sept)									
	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010
Total Phosphorus (mg/L)	B	B	C	C	B	A	B	C	NA	B
Chlorophyll-*a* (ug/L)	B	B	B	C	C	B	B	B	NA	C
Secchi depth (ft)	C	C	C	B	C	B	B	C	NA	C
Overall	**B-**	**B-**	**C+**	**C+**	**C+**	**B+**	**B**	**C+**	**NA**	**C+**

MCKUSICK LAKE

2019 Lake Grade: B-

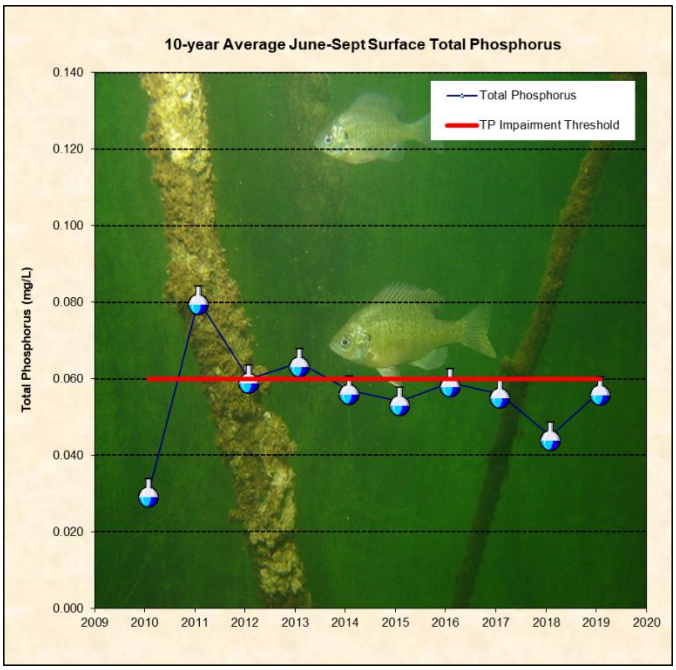
DNR ID #: 820020

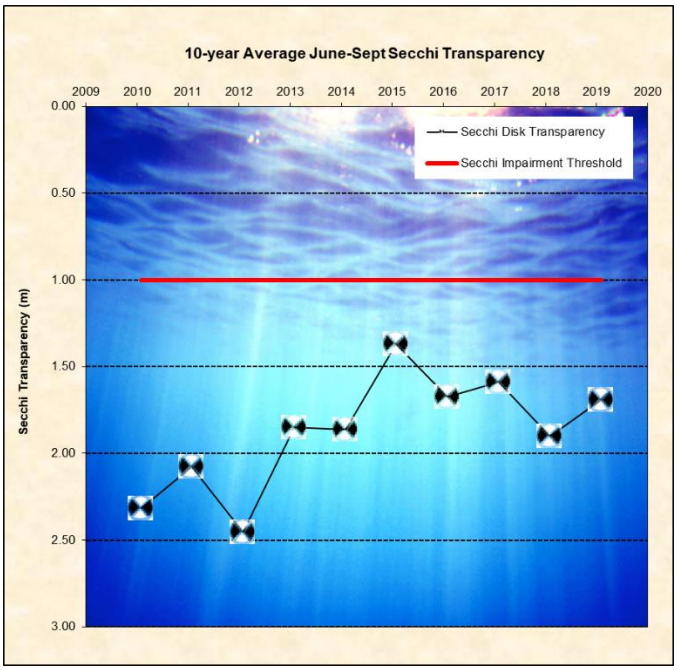
- Municipality: City of Stillwater
- Location: NE ¼ Section 29, T30N-R20W
- Lake Size: 46 Acres
- Maximum Depth (2019): 16 ft
- Ordinary High Water Mark: 851.7 ft
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on the chlorophyll-α results McKusick Lake was considered eutrophic in 2019, 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 2019 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.





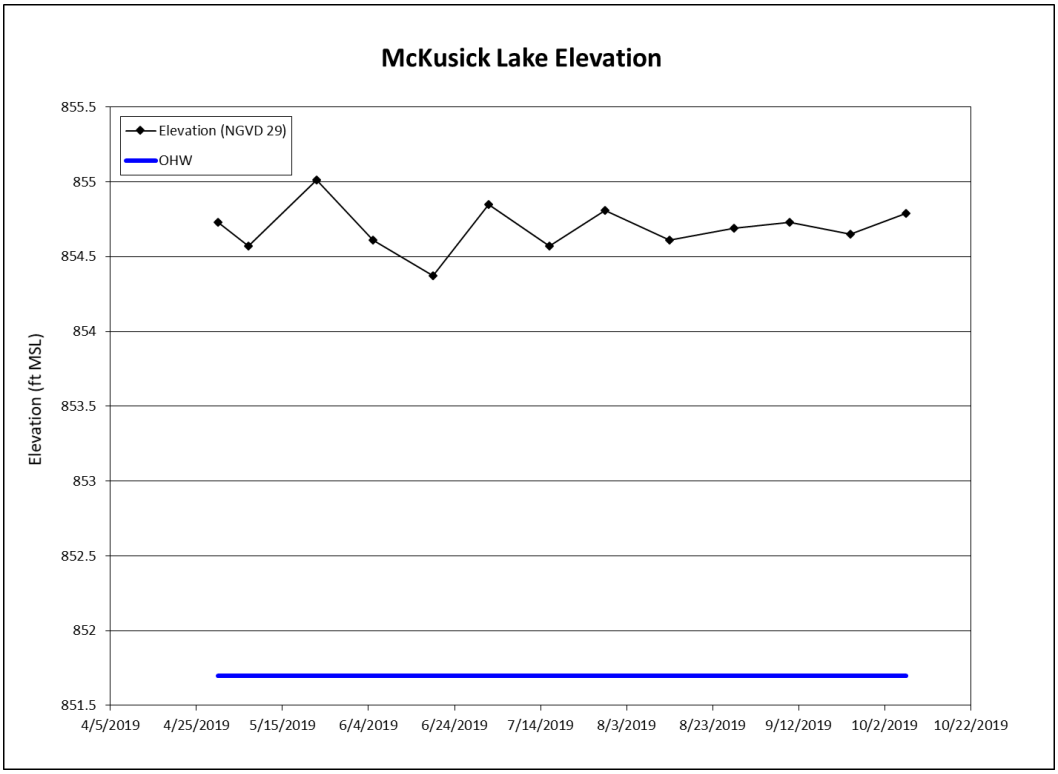
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
4/23/2019 8:53	0.062	30.0	28.0	0.82	1.22	10.7	9.49
5/7/2019 8:46	0.039	6.3	5.0	0.61	1.52	14.3	9.95
5/23/2019 12:02	0.043	5.6	5.1	0.62	2.29	13.9	8.78
6/5/2019 9:08	0.039	3.6	2.8	0.53	2.59	22.2	8.91
6/19/2019 9:52	0.055	3.3	2.9	0.64	2.74	22.2	9.26
7/2/2019 9:37	0.068	20.0	18.0	0.87	2.13	23.8	8.58
7/16/2019 11:09	0.058	11.0	9.0	0.84	1.37	26.7	3.45
7/29/2019 13:40	0.040	7.3	6.4	0.76	1.52	24.8	4.43
8/13/2019 11:35	0.069	4.2	3.7	0.71	1.37	23.5	2.64
8/28/2019 8:48	0.058	8.0	7.0	0.70	0.91	19.3	2.90
9/10/2019 11:44	0.053	17.0	15.0	0.68	1.37	18.5	4.11
9/24/2019 14:07	0.072	18.0	17.0	0.70	1.22	22.3	6.80
10/7/2019 12:47	0.047	4.1	3.4	0.57	2.29	13.2	6.76
2019 Average	0.054	10.6	9.5	0.70	1.74	19.6	6.62
2019 Summer Average	0.057	10.3	9.1	0.71	1.69	22.6	5.68

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
2019 Elevation (ft)	855.01	5/23/2019	854.37	6/19/2019	854.69

*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)									
	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010
Total Phosphorus (mg/L)	C	C	C	C	C	C	C	C	D	B
Chlorophyll-*a* (ug/L)	A	B	B	B	C	C	B	A	C	A
Secchi depth (ft)	C	C	C	C	C	C	C	B	C	B
Overall	**B-**	**C+**	**C+**	**C+**	**C**	**C**	**C+**	**B**	**C-**	**B+**