BROWN'S CREEK WATERSHED DISTRICT

2018 WATER MONITORING SUMMARY

Prepared for:

Brown's Creek Watershed District
Preserving the integrity of the watershed for future generations

Prepared by:

Washington Conservation District

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

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

Bi-weekly	Every two weeks
CaCO3	Calcium Carbonate
CAMP	Citizen-Assisted Lake Monitoring Program
cfs	cubic feet per second
Chl-α	Chlorophyll-α
BCWD	Brown's Creek Watershed District
COD	Total Chemical Oxygen Demand
DO	Dissolved Oxygen
EIMS	Environmental Information Management System
E. coli	*Escherichia coli*
FAV	Final Acute Value
IESF	Iron Enhanced Sand Filter
MCES	Metropolitan Council Environmental Services
mg/L	milligrams per liter
MN DNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MPN	most probable number
NTU	nephelometric turbidity units
OHWL	Ordinary High Water Level
Ortho-P	Ortho-phosphorus
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
TP	Total Phosphorus
TSI	Trophic State Index
TSMP	Trout Stream Mitigation Project/Diversion Structure
TSS	Total Suspended Solids
µg/L	micrograms per liter
µm	micrometers
µmhos/cm	micromhos per centimeter
VSS	Volatile Suspended Solids
WCD	Washington Conservation District

2018 Brown's Creek Watershed District Baseline Water Quality Monitoring

MONITORING SUMMARY

This report focuses on the summary of lake and stream water quality data collected by the Washington Conservation District (WCD) in 2018. Additional information on the natural and cultural resources, improvement projects, and challenges related to water resources within the Brown's Creek Watershed District (BCWD) can be found in the BCWD 2017-2026 Watershed Management Plan, the 2010 Brown's Creek Biota TMDL, and past monitoring reports.

Conditions observed in the watershed in 2018 were slightly drier than recent years, but closer to the long term average in terms of total precipitation and storm intensity. Locally, 28.65 inches of precipitation was recorded at the National Weather Service (NWS) weather station in Stillwater, MN, which is roughly five inches below the long-term average. Well below average temperatures in March and April allowed ice to remain on lakes until very late April or early May, delaying the start of the growing season and algal production. However, a major snowfall in mid April and subsequent melting period heightened runoff in area drainages. Summer air temperatures tended to be warmer than recent years, as were temperatures recorded in the creek, but recent wet years provided cool groundwater recharge to minimize warming of the creek.

Lake Monitoring

BCWD monitored eighteen basins for nutrients, chlorophyll-α, Secchi disk transparency, temperature and dissolved oxygen profiles, elevation, and user perception rankings. Bass Lake East, Bass Lake West, Benz Lake, Goggins Lake, Jackson WMA Pond, Kismet Basin, Long Lake, Lynch Lake South, Masterman Lake, Plaisted Lake, South School Section Lake, and Woodpile Lake were monitored bi-weekly, while Brewer's Pond, Heifort's Pond, July Avenue Wetland, Lynch Lake North, North School Section Lake, and Pat Lake were monitored every four weeks.

Most lakes experienced an improvement in water quality as measured by lake grade, or maintained water quality from the previous year. Four lakes experienced a slight decline in overall lake grade. Long Lake and Jackson WMA Pond continued to improve from F+ grades in 2016 to B and B- grades, respectively, in 2018. The current grades for each lake are consistent with the last ten years of data. No definitive explanation as to why the lakes experienced such a drastic shift in water quality was able to be determined, and is assumed to be an anomaly.

Of the eighteen lakes monitored, Brewer's Pond, Heifort's Pond, July Avenue Wetland, and South School Section Lake summer averages exceeded (were poorer than) state impairment

thresholds for total phosphorus, chlorophyll-α, and Secchi disk transparency. Lynch Lake North exceeded the impairment threshold for total phosphorus only, while North School Section Lake exceeded the impairment threshold for chlorophyll-α only.

Due to frequent heavy rains late summer, most lakes peaked in elevation in late September or early October. Six lakes either met, surpassed, or maintained elevations above their Ordinary High Water levels (OHW), a result of above average precipitation for several of the most recent years. Most lakes in the watershed remain well below their OHW due to drought conditions in the 2000's and early 2010's.

Stream and Stormwater Monitoring

Brown's Creek

Consistent with past years, Brown's Creek was monitored at four locations; Highway 15, McKusick Road, Stonebridge, and the Outlet. Automated storm composite and manual grab samples during storm and base flow conditions were collected at all sites and analyzed for nutrients, sediment, metals, and *Escherichia coli* (*E.coli*). Continuous (15 minute) stage, discharge, temperature, dissolved oxygen, turbidity, and specific conductivity were collected at all four stations, although the period of record is limited at the Outlet due to suspected vandalism of the logger.

Nutrients & Discharge

The total discharge to the St. Croix River in 2018 was 267,105,859 cubic feet of water, as recorded at the Outlet. The total phosphorus (TP) and total suspended solids (TSS) loads to the St. Croix River at the Outlet were 2,315 pounds of phosphorus (0.501 lbs/ac) and 400,729 pounds of sediment (86.66 lbs/ac), as calculated by Metropolitan Council Environmental Services (MCES). The sampling strategy at the Outlet was changed by MCES in 2017 to a manual grab collected on the same day every other week, and composite samples collected in major storm events. This change in sampling technique will result in an apparent shift in annual loads, as the strategy is not biased towards runoff events as it was in the past, and the method used to calculate annual loads was altered to comply with MCES standard operating procedures. The creek exceeded the state standard of 0.100 mg/L of TP for most summer months, and was below the standard during winter months. The creek met the TMDL goal of 23 mg/L of TSS during base flow, but exceeded the state standard of 10 mg/L from April 1 to September 30 for all months except August and September. Improvements should continue to be made in the watershed to mitigate nutrient and sediment loading under storm conditions and bring sediment loading down to the TMDL goal of 74 pounds per acre. Loading and conditions at individual sites are discussed in greater detail later in this summary.

Metals

Concentrations of metals exceeding the state standards were more severe in 2018 compared to recent years. The final acute value for copper was exceeded by a storm sample collected July 12, which has not happened at any site since 2007. One maximum standard exceedance of copper was recorded at McKusick Road, and one for zinc at Stonebridge. A chronic standard exceedance of lead was recorded at Highway 15, McKusick Road, and Stonebridge. No standards were exceeded for any samples taken at the Outlet.

Bacteria

Samples taken during base flow at each station were above state standards for *E.coli*. Based on long term monitoring, bacteria concentrations at all stations are above the standard May through September. Sufficient data has not been collected at Highway 15, McKusick Road, or Stonebridge to compare to the standard in April.

Temperature & Dissolved Oxygen

Temperature and dissolved oxygen regimes continued to be most suitable for trout survival at Stonebridge and the Outlet. Although the threat level threshold of 18.3 ºC was exceeded 66 and 19 days as measured by daily average temperature, respectively, the critical level threshold at which trout could not survive of 23.9 ºC was never exceeded at any site. The number of threat level exceedances at all sites was near the average when compared to the last ten years. Dissolved oxygen concentrations were also favorable at Stonebridge and the Outlet, and were above (better than) the 7 mg/L as a daily minimum standard under most conditions except during major storms. Highway 15 and McKusick Road are not suitable for trout during summer months due to low dissolved oxygen and warm temperatures. The upper reaches of the creek have also been found to contain invasive curly leaf pondweed, which will hinder trout suitability by slowing the water, allowing for warmer temperatures and sediment deposition over spawning gravel.

Turbidity

Continuous turbidity and specific conductivity were monitored at each of the four stations on the creek. Average daily turbidity exceeding the TMDL goal of 10 NTU ranged from ten to fifty percent of the days monitored, although equipment fouling and loss at some sites undermined the analysis. Specific conductivity data are not discussed, but are available upon request.

Biology

The MN DNR stocked 500 yearling brown trout at the Outlet and another 500 distributed from the McKusick Road area upstream to Brown's Creek Park. Due to difficulties of raising brown trout at state hatcheries to stock-able size, the agency will shift to stocking rainbow trout in 2019. Stillwater Area High School has also raised and released trout into the creek, and will make the

same adjustment. The rainbow trout thrive in similar conditions as brown trout, but grow faster and will provide better recreational opportunities to anglers.

Diversion Drainage

The diversion drainage was again monitored at the Trout Stream Mitigation Project (TSMP) Diversion Structure for nutrients, sediment, and metals, as well as continuous stage and discharge. A secondary level logger installed at the diversion weir shows no water overtopped the weir, although a very small volume of water directly discharges via a small hole in the base of the structure designed to allow groundwater base flow to flow to Brown's Creek. Total discharge to McKusick Lake was 45,453,990 cubic feet of water. The TP load was 964 pounds (0.250 lbs/ac) and the TSS load was 505,314 pounds (131.08 lbs/ac). The site is meeting the state standard for 2B waters for TSS, and often for TP with some exceptions at base flow, but has an extremely high storm loading rate. The head cut identified as a major source of nutrients in prior monitoring summaries was repaired in late November, and is expected to significantly reduce nutrient loads in the drainage.

High concentrations of heavy metals were sampled at the site in 2018. Copper continues to be an issue; one sample exceeded the final acute value and one sample exceeded the maximum standard. One sample exceeded the maximum standard for zinc, and several chronic standard exceedances of copper, lead, and zinc were recorded. No bacteria samples were collected at the site in 2018. However, calculation of the *E.coli* standard uses the latest ten years of data to assess impairment status. As such the drainage remains impaired June through September based on prior data.

Noted in the 2017 monitoring summary, a number of events spaced at regular, near daily intervals that appeared to be drawdown by pumping of the creek or groundwater were observed, occurring at least as far back as 2010. The pattern was again recorded in 2018, but no causes were found via aerial image review or field investigation.

Long Lake Drainages

The Tributary to Long Lake at Marketplace Pond was monitored for nutrients, sediment, metals, and continuous stage and discharge, while the Tributary to Long Lake at 62nd Street was monitored for stage only. The total discharge to Long Lake at Marketplace Pond was 16,492,464 cubic feet, while the discharge at 62nd Street was estimated based on prior data at 957,234 cubic feet during the monitoring period. The tributary at Marketplace Pond contributed 70 pounds of phosphorus (0.170 lbs/ac) and 16,473 pounds of sediment (40.18 lbs/ac). Although not classified as a 2B water, state standards for TP and TSS are being met at the Marketplace Pond for all samples at base flow.

Storm events at the tributary at Marketplace Pond exceeded the final acute standard for copper twice, the maximum standard twice, and the chronic standard three times. The maximum standard for copper was also exceeded once during base flow. The maximum standard for lead was exceeded once, and the chronic standard was exceeded by six out of thirteen samples. The final acute standard for zinc was exceeded once, and the maximum standard was exceeded once. One chronic standard exceedance of cadmium and three chronic standard exceedances of chloride were also recorded.

McKusick Wetland Outlet

McKusick Wetland Outlet was added to the monitoring network in 2017. The outlet was monitored at its discharge point to Brown's Creek 100 feet upstream of the McKusick Road site for continuous stage, discharge, and temperature, as well as nutrients, sediment, and metals. Discharge to Brown's Creek during the period of monitoring was calculated at 8,319,145 cubic feet. The TP load for this period contributed 138.5 pounds of phosphorus, while the TSS load contributed 5,072 pounds of sediment. Although not a 2B water, when compared to state standards for TP and TSS the site meets the standard for TSS, but was well above the TP standard for eight out of eleven samples collected.

Continuous temperature data collected at the site show water discharged to the creek exceeded the TMDL threat level threshold 64.9% of the monitored period, and the critical level threshold 7.9% of the period. This is characteristic of a wetland warmed by solar radiation, and likely negatively impacts the suitability of this reach of Brown's Creek for cold water species like trout.

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I. INTRODUCTION

Knowledge of the changes to water quality and quantity of our water resources through monitoring guides when, where, and how management activities should be implemented to protect or restore those resources. The Brown's Creek Watershed District (BCWD) utilizes monitoring and the data collected to make such decisions as outlined in its watershed management plan. In 2018 BCWD monitored eighteen lakes, four stations on Brown's Creek, a tributary to Brown's Creek, two stations in the Long Lake subwatershed, and one station in the diversion drainage at the Diversion Structure. A summary of monitoring locations and monitored parameters can be found in Table 1 and Figure 1.

The Washington Conservation District (WCD) also conducted special project monitoring at several locations including the Iron Enhanced Sand Filter (IESF), Brown's Creek Rock Crib, Countryside Auto sediment chamber, and the McKusick Road sediment chambers. Comparable levels of data collection versus baseline sites occurred at each project, such as collection of continuous stage, discharge, and temperature, and measurement of sediment depths in complex monitoring situations. As this report focuses on baseline monitoring data, special project monitoring will not specifically be discussed, although the locations of several projects are described. Individual monitoring summaries for each project will be prepared and made available in separate reports.

Table 1. Monitoring Site Location, Description, and Parameter(s) Monitored

Site Description	Map Site ID#	Site Name	General Site Location	Monitored Parameters
Stream Monitoring	**1**	Brown's Creek at Hwy 15	Hwy 15	Discharge and Water Quality Composite/Grab Samples
Stream Monitoring	**2**	Brown's Creek at McKusick Road	McKusick Road	Discharge and Water Quality Composite/Grab Samples
Stream Monitoring	**3**	Brown's Creek at Stonebridge Trail	Stonebridge Trail	Discharge and Water Quality Composite/Grab Samples
Stream Monitoring	**4**	Brown's Creek Outlet	Hwy 95 & 96	Discharge and Water Quality Composite/Grab Samples
Stream Monitoring	**5**	Brown's Creek Diversion	Neal Ave.	Discharge and Water Quality Composite/Grab Samples
Stream Monitoring	**6**	Tributary to Long Lake at 62nd St.	62nd St.	Stage
Stream Monitoring	**7**	Tributary to Long Lake at Marketplace Pond	Market Dr.	Discharge and Water Quality Composite/Grab Samples
Stream Monitoring	**8**	Iron Enhanced Sand Filter (IESF)-1 Inlet	Morgan Ave. N.	Discharge and Water Quality Composite/Grab Samples
Stream Monitoring	**9**	Iron Enhanced Sand Filter (IESF)-1 Outlet	Morgan Ave. N.	Discharge and Water Quality Composite/Grab Samples
Stream Monitoring	**10**	Iron Enhanced Sand Filter Harvest Pond	Morgan Ave. N.	*E.coli*
Stream Monitoring	**11**	McKusick Wetland Outlet	McKusick Road	Discharge and Water Quality Grab Samples
Stream Monitoring	**12**	Brown's Creek Rock Crib Upstream	Neal Ave.	Continuous Temperature
Stream Monitoring	**13**	Brown's Creek Rock Crib Downstream	Neal Ave.	Continuous Temperature
Stream Monitoring	**14**	Brown's Creek Rock Crib Internal (5 Temp Loggers and Outlet Discharge)	Neal Ave.	Continuous Temperature, Discharge
			DNR ID	
Lake Monitoring	**15**	Kismet Basin	82-033400	Surface Water Quality Samples, Elevation
Lake Monitoring	**16**	Long Lake (North Basin)	82-002100	Surface Water Quality Samples, Elevation
Lake Monitoring	**17**	Goggins Lake	82-007700	Surface Water Quality Samples, Elevation
Lake Monitoring	**18**	South School Section Lake	82-015100	Surface Water Quality Samples, Elevation
Lake Monitoring	**19**	Benz Lake	82-012000	Surface Water Quality Samples, Elevation
Lake Monitoring	**20**	Masterman Lake	82-012600	Surface Water Quality Samples, Elevation
Lake Monitoring	**21**	Woodpile Lake	82-013200	Surface Water Quality Samples, Elevation
Lake Monitoring	**22**	Lynch Lake (North Basin)	82-004200	Surface Water Quality Samples, Elevation
Lake Monitoring	**23**	Lynch Lake (South Basin)	82-004202	Surface Water Quality Samples, Elevation
Lake Monitoring	**24**	Bass Lake (West)	82-012300	Surface Water Quality Samples, Elevation
Lake Monitoring	**25**	Bass Lake (East)	82-012400	Surface Water Quality Samples, Elevation
Lake Monitoring	**26**	July Avenue Pond	82-031800	Surface Water Quality Samples, Elevation
Lake Monitoring	**27**	Pat Lake	82-012500	Surface Water Quality Samples, Elevation
Lake Monitoring	**28**	Plaisted Lake	82-014800	Surface Water Quality Samples, Elevation
Lake Monitoring	**29**	Jackson Wildlife Management Area Pond	82-030500	Surface Water Quality Samples, Elevation
Lake Monitoring	**30**	Brewer's Pond	82-002200	Surface Water Quality Samples, Elevation
Lake Monitoring	**31**	Heifort's Pond	82-048500	Surface Water Quality Samples, Elevation
Lake Monitoring	**32**	North School Section	82-014900	Surface Water Quality Samples, Elevation
Lake Monitoring	**33**	Highway 12 & Kimbro Pond	82-034900	Elevation
Lake Monitoring	**34**	Brown's Creek at Gateway Trail	82-030300	Elevation
Lake Monitoring	**35**	55th St. Pond	82-031600	Elevation
Lake Monitoring	**36**	Vanzwol Pond	82-012800	Elevation

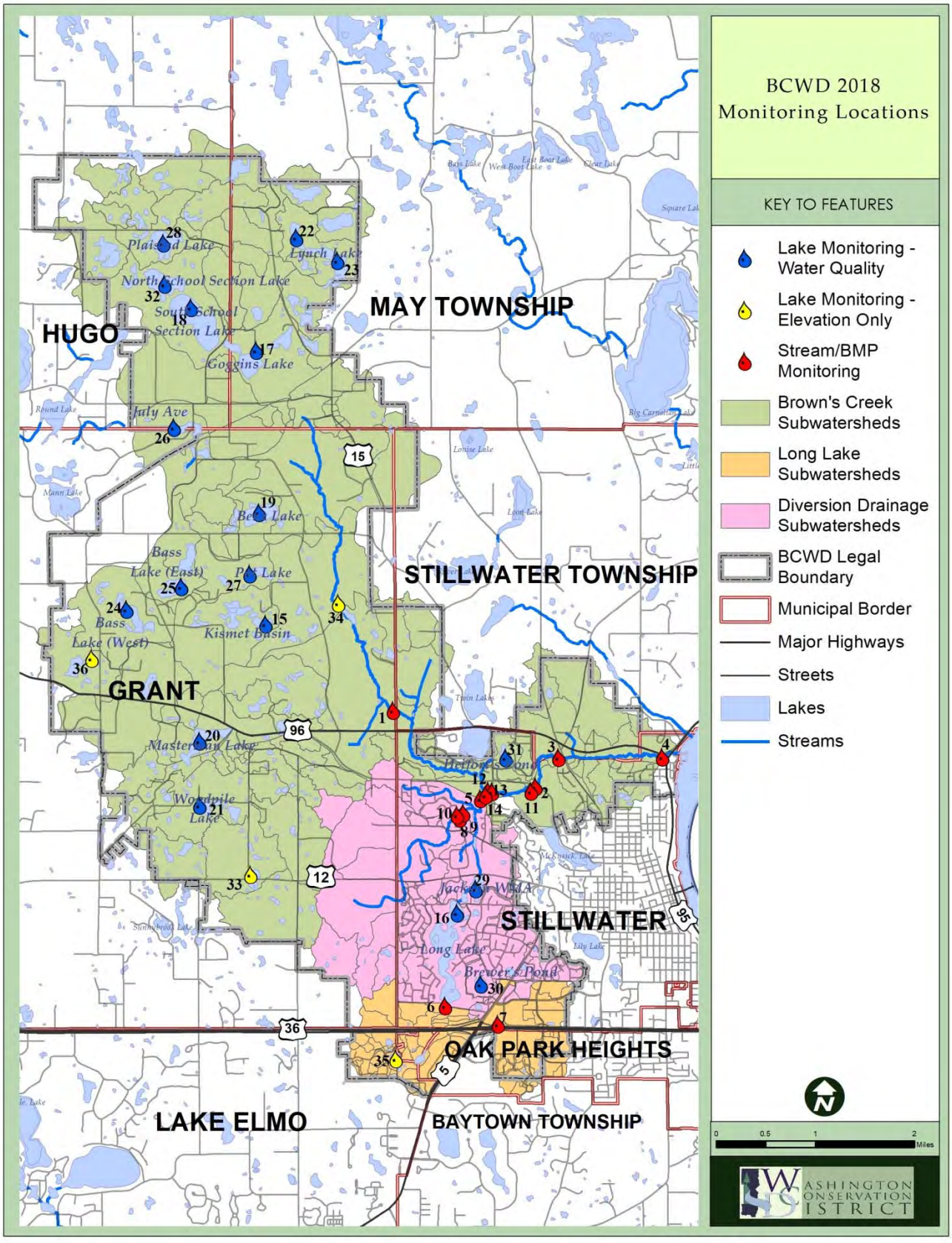


Figure 1. Brown's Creek Watershed District 2018 Sampling Locations

II. PURPOSE AND GOALS

The BCWD uses a monitoring network to assess the quality of its water resources and maintains partnerships with the Minnesota Department of Natural Resources (MN DNR), Metropolitan Council, Washington Conservation District (WCD), Stillwater Area High School, and volunteers to collect and manage data. The general purpose of the baseline water monitoring program is to collect long term data to identify issues within the watershed and track changes towards meeting water quality goals described in the 2017-2026 Watershed Management Plan and the Brown's Creek TMDL Implementation Plan. The goals specific to this monitoring report include the collection of useful data about the water resources of the District, production of an annual assessment of monitoring data, and the use of that data to determine the performance of District programs and regulations. Additional policies, goals, and implementation strategies related to monitoring data are more fully described in the watershed management plan.

III. LAKE MONITORING

III.A. Locations and Parameters

In 2018 water quality data were collected by the WCD on eighteen basins (Table 1 and Figure 1). Each lake was sampled for total phosphorus (TP), total Kjeldahl nitrogen (TKN), chlorophyll-α, and Secchi disk transparency. A complete listing of nutrient and Secchi data by lake is available in Appendix A. One meter increment temperature and dissolved oxygen profiles as well as a user perception ranking (physical and recreational suitability) were also recorded. These data are available via request or on the Metropolitan Council's Environmental Information Management System (EIMS) Water Quality Database website (http://es.metc.state.mn.us/eims).

III.B. Methods

Each basin was sampled over six consecutive months (May-October) using a two-meter (6.56 feet) integrated surface water column sampler from a watercraft. Due to extremely late ice out conditions no samples were able to be collected in April as they had been in previous monitoring seasons. Bass Lake East, Bass Lake West, Benz Lake, Goggins Lake, Jackson WMA Pond, Kismet Basin, Long Lake, Lynch Lake South, Masterman Lake, Plaisted Lake, South School Section Lake, and Woodpile Lake were monitored bi-weekly, while Brewer's Pond, Heifort's Pond, July Avenue Wetland, Lynch Lake North, North School Section Lake, and Pat Lake were monitored every four weeks. Chlorophyll-α samples were obtained by filtering water from the integrated sample through a 1.5 µm fiberglass filter using a hand pump. Samples collected for TP, TKN, and chlorophyll-α were analyzed by the Metropolitan Council Environmental Services Lab. Measurements obtained during the sampling season were averaged to allow comparison of individual lake dynamics from year to year. Trend analysis for long term Secchi disk transparency, TP, and chlorophyll-α (corrected for pheophytin) trends were completed using a Kendall's Tau statistical test, presented in Appendix A, and only data collected by professional agencies were used to assess for trends. All other data were quality assured, quality controlled,

and reviewed by Washington Conservation District staff. Detailed standard operating procedures used by WCD for water sampling, monitoring, and data management are available on the WCD website (http://www.mnwcd.org/water-quality-water-monitoring/).

III.C. Results and Discussion

III.C.1. Lake Grades

The lake water quality grading system was developed following the 1989 sampling season by Metropolitan Council. This grading system ranks water quality characteristics by comparing summer averages to those of other lakes specific to the metro area. The grading curve represents percentile ranges for the May through September averages of total phosphorus concentration, uncorrected trichromatic chlorophyll-α concentration, and Secchi disk transparency for 119 lakes sampled from 1980 to 1988, and the ranges were re-confirmed in 2000 using more recent data. Percentile ranges for each parameter can be found in Table 2. A benefit of the lake grade system is that it was developed specifically for lakes in the metro area, and serves as a convenient way to compare water quality between lakes. Current grades for each lake can be found in Figure 2, and the latest ten years of grades for each lake can be found in Appendix A. In addition, comparison of June through September water quality averages (total phosphorus concentration, pheophytin-corrected chlorophyll-α, and Secchi disk transparency) will be made to state eutrophication standards for each lake as the Minnesota Pollution Control Agency (MPCA) uses this timeframe to assess impairment status. A table of June through September averages and impairment thresholds can be found in Table 3.

Table 2. Lake Grade Ranges

Grade	Percentile	TP (µg/L)	Chl-α (µg/L)	Secchi (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	0.7-1.2
F	>90	>152	>77	<0.7

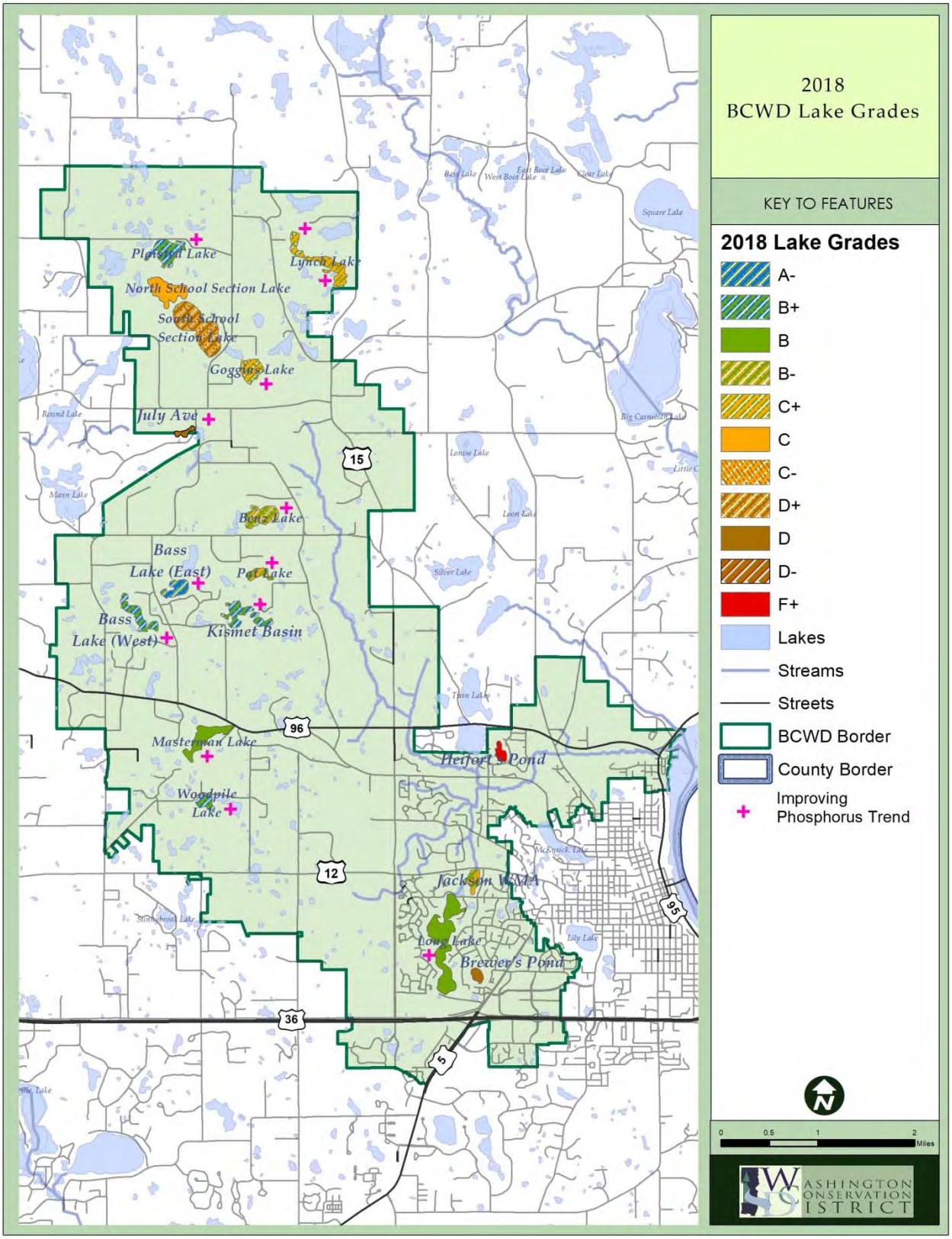


Figure 2. Brown's Creek Watershed District 2018 Lake Grades

Table 3. Impairment Thresholds and June Through September Average 2018 Parameters

Lake	Total Phosphorus (mg/L)	Pheophytin Corrected Chlorophyll-α (µg/L)	Secchi (meters)	Total Kjeldahl Nitrogen (mg/L)
Impairment Threshold- Shallow	*0.060*	*20.0*	*1.00*	*N/A*
Impairment Threshold- Deep	*0.040*	*14.0*	*1.50*	*N/A*
Bass East	0.020	6.1	2.71	0.69
Bass West	0.025	4.0	2.88	0.73
Benz	0.036	7.7	1.34	0.76
Brewer's	0.062	52.4	0.32	2.54
Goggins	0.047	18.1	1.79	1.33
Heifort's	0.114	88.6	0.30	3.14
Jackson WMA	0.046	8.3	1.88	0.74
July Ave	0.090	79.2	0.40	2.80
Kismet	0.017	5.4	1.54	0.60
Long	0.032	6.0	2.30	0.71
Lynch North	0.066	11.4	1.40	0.92
Lynch South	0.036	15.6	1.66	1.17
Masterman	0.029	8.9	1.91	0.72
North School Section	0.046	30.6	1.19	1.34
Pat	0.039	10.5	2.04	0.79
Plaisted	0.019	4.9	1.93	0.59
South School Section*	0.057	66.7	0.91	1.81
Woodpile*	0.026	5.4	2.91	0.83

Exceeds impairment threshold

*Indicates deep lake. All others are classified as shallow.

In 2018 continued improvement of water quality as measured by lake grade was observed in both Long Lake and Jackson WMA Pond. The 2016 monitoring season recorded the degradation of both lakes to an F+ rating, which rebounded to C ratings in 2017, and a B rating for Long Lake and a B- rating for Jackson WMA Pond in 2018. The shift in water quality appears to have been an anomaly, most likely caused by nutrient inputs from excessive precipitation in 2016.

Lake grade also improved significantly in Lynch Lake North, driven primarily by increasing clarity and declining algal concentrations. Field staff have noted increasing plant growth from almost no aquatic vegetation in previous years to healthy growth in the basin, especially near shore. This helps stabilize sediments and nutrients, making them less available for algal production. The MN DNR also stocked the basin with 70,000 walleye fry in late May. It is expected that, once reaching adequate size, the walleye enhance clarity by feeding on the small bullheads present in the lake that increase nutrient cycling by uprooting vegetation and disturbing sediments. No walleye recovery efforts were made in 2018, meaning all fish that were stocked into the basin and able to survive the 2018 winter will likely be preying on bullheads in 2019.

Most lakes monitored in 2018 slightly improved in lake grade or maintained their grade from the year prior. Only Bass Lake West, July Avenue Wetland, Pat Lake, and South School Section Lake declined slightly in water quality as measured by lake grade. Bass Lake East, Heifort's

Pond, Kismet Basin, North School Section Lake, Plaisted Lake, and Woodpile Lake experienced no change. Precipitation in 2018 tended to be below average during the warmest months, limiting nutrient contributions during periods when they would readily be taken up by algae. Most lakes also likely continued to experience a delayed benefit of nutrient dilution via recharge from excess precipitation during recent years.

South School Section Lake was treated in 2017 to reduce the abundance of invasive curly-leaf pondweed. The continued decline in lake grade is primarily due to a reduction in transparency, which may have been a temporary result of the first round of treatment. Removal of curly-leaf pondweed may temporarily increase availability of nutrients to organisms like algae, as well as reduce transparency since there are less rooted plants to stabilize lake bottom sediments. Treatment was scheduled to occur again in 2018, but was cancelled. The first treatment was enhanced by heavy snow and a late ice out in April, sufficiently preventing regrowth of the invasive plants. Water quality is expected to improve as native plants reclaim formerly infested areas over time. In addition, a resident noted water was flowing from Goggins Lake into South School Section Lake in August. Goggins Lake typically has poorer water quality than South School Section Lake, and the additional input of nutrients from Goggins Lake may have further degraded water quality in South School Section Lake.

III.C.2. Total Phosphorus

Phosphorus is a major nutrient involved in eutrophication and is generally associated with the growth of aquatic plants and algal blooms. Common sources of phosphorus include runoff from agricultural fields, livestock areas, urban areas, lakeshore lawns and improperly operating septic systems. In most lakes in this region, phosphorus is the least available nutrient; therefore, its abundance or scarcity controls the extent of algal growth. Algal growth in turn affects the clarity of the water and light penetration, and can control the extent of aquatic vegetation by shading out plants. The phosphorus flow path through the watershed can be found in Appendix C.

The state impairment threshold for total phosphorus (TP) is 0.060 mg/L in shallow lakes (generally greater than 50 acres and less than 15 feet deep, or more than 80% littoral area) and 0.040 mg/L in deeper lakes. In 2018 Brewer's Pond, Heifort's Pond, July Avenue Wetland, Lynch Lake North, and South School Section Lake summer average TP concentrations exceeded impairment standards (Table 3). Of note is the continued rebound of Jackson WMA Pond and Long Lake to lower TP concentrations, which were elevated in 2016 (Appendix A).

Trend analyses were completed on lakes where eight or more years of TP measurements had been collected to determine if lakes are improving, declining, or stable in terms of average summer TP. A two-tailed Kendall's Tau statistical test was completed using a p-value of <0.05 to determine statistical significance of the trend. Bass Lake East, Bass Lake West, Benz Lake, Goggins Lake, July Avenue Wetland, Kismet Basin, Long Lake, Lynch Lake North, Lynch Lake

South, Masterman Lake, Pat Lake, Plaisted Lake, and Woodpile Lake have improving trends for TP, meaning the average summer TP concentration is decreasing (Figure 2 and Appendix A). No trends (stable TP concentrations) exist on Jackson WMA Pond or South School Section Lake. Brewer's Pond, Heifort's Pond, and North School Section Lake do not have enough years of data to calculate trends.

III.C.3. Chlorophyll-α

Chlorophyll-α is a photosynthetic compound found in algae and aquatic plants, and is a direct indicator of algal productivity. Lakes with high chlorophyll-α concentrations are often eutrophic or hypereutrophic. These lakes tend to have excessive algal growth, shading out rooted plants. Lakes with low chlorophyll-α concentrations can be mesotrophic or even oligotrophic, and tend to have more rooted plants to take up phosphorus, rather than phosphorus being used by algae within the water column which produces more chlorophyll-α.

The impairment threshold for chlorophyll-α is 20 µg/L in shallow lakes and 14 µg/L in deeper lakes. Brewer's Pond, Heifort's Pond, July Avenue Wetland, North School Section, and South School Section Lake summer average concentrations exceeded the impairment threshold (Table 3).

Trend analyses were completed on lakes where eight or more years of chlorophyll-α measurements had been collected to determine if lakes are improving, declining, or stable in terms of algal productivity. A two-tailed Kendall's Tau statistical test was completed using a p-value of <0.05 to determine statistical significance of the trend. Bass Lake East, Bass Lake West, Benz Lake, Goggins Lake, Kismet Basin, Long Lake, Lynch Lake North, Lynch Lake South, Masterman Lake, Plaisted Lake, and Woodpile Lake show statistically significant long term trends for improving chlorophyll-α concentrations, meaning less algae is being produced (Appendix A). No significant trends were present on July Avenue Wetland, Jackson WMA Pond, Pat Lake, or South School Section Lake. No lakes show an increasing trend for chlorophyll-α concentration in 2018. There are not enough years of collected data to calculate trends on Brewer's Pond, Heifort's Pond, and North School Section Lake.

III.C.4. Transparency

The measurement of depth of light penetration using a Secchi disk provides a simple measure of water transparency, or clarity. It can also serve as a proxy for turbidity in the water, as well as an indication of the trophic state of the lake. A reduction in water transparency is usually the result of turbidity composed of suspended sediments, organic matter and/or phytoplankton (algae). Several lakes in the district, such as Benz Lake and Masterman Lake, are clearer than they are deep, meaning an accurate measure of transparency cannot be achieved because the disk rests on the lake bottom or is obscured by vegetation instead of reaching a depth where it is no longer visible. This can give the false appearance of low water clarity when viewing average

transparency, when in reality the true Secchi depth is much higher. Lakes which experience this phenomenon are noted in the summary points sections of Appendix A.

The impairment threshold for Secchi disk transparency is 1.00 meters in shallow lakes and 1.50 meters in deep lakes. Brewer's Pond, Heifort's Pond, July Avenue Wetland, and South School Section Lake summer average transparencies were poorer than the state standard (Table 3).

Trend analyses were completed on lakes where eight or more years of Secchi disk measurements had been collected to determine if lakes are improving, declining, or stable in terms of average summer clarity. A two-tailed Kendall's Tau statistical test was completed using a p-value of <0.05 to determine statistical significance of the trend. Long Lake, Lynch Lake North, Lynch Lake South, and Woodpile Lake show statistically significant long term trends for improving water clarity (Appendix A). No significant trends have been observed on Goggins Lake or Pat Lake. Bass Lake East, Bass Lake West, Benz Lake, Kismet Basin, Masterman Lake, and Plaisted Lake are too shallow to determine an accurate trend, since the lakes are often clearer than they are deep. There are statistically significant declining trends for clarity on Jackson WMA Pond, July Avenue Wetland, and South School Section Lake. There are not enough years of collected data to calculate trends on Brewer's Pond, Heifort's Pond, and North School Section Lake. The declining trends on July Avenue Wetland and South School Section Lake are new for 2018.

III.C.5. Total Kjeldahl Nitrogen

Total Kjeldahl nitrogen (TKN) measures the sum of ammonia and organic nitrogen present in the water column. An abundance of this nutrient can lead to excess plant growth and increase the rate of eutrophication, especially if it is the limiting nutrient in a lake. Sources of TKN are similar to those of TP. Although eutrophication standards do not exist at this time for TKN, June through September averages can be compared to the North Central Hardwood Forest ecoregion to assess if lakes may have excessive amounts of nitrogen. The ecoregion range for TKN is 0.60-1.20 mg/L. Brewer's Pond, Goggins Lake, Heifort's Pond, July Avenue Wetland, North School Section Lake, and South School Section Lake were poorer than the ecoregion range, while Bass Lake East, Bass Lake West, Benz Lake, Jackson WMA Pond, Kismet Basin, Long Lake, Lynch Lake North, Lynch Lake South, Masterman Lake, Pat Lake, and Woodpile Lake were within the ecoregion range (Table 3). Plaisted Lake was the only lake better than the ecoregion range.

III.C.6. Temperature and Dissolved Oxygen

In addition to surface water measurements, temperature and dissolved oxygen data were recorded at each lake during each sampling event. Temperature and dissolved oxygen were recorded at one-meter increments from the surface to the lake bottom. The data collected from these profiles are housed by the WCD and are available upon request, or are available via the MPCA website (https://cf.pca.state.mn.us/water/watershedweb/wdip/search_more.cfm).

These data show the extent of summer stratification and are useful in identifying the thermocline (the layer of water in which the temperature rapidly declines), if one exists. As a lake stratifies, the water column becomes more stable and mixing is less likely to occur. If mixing occurs during the growing season, bottom nutrients become available and can result in increased algal production. As a rule of thumb, shallow lakes are constantly mixed by wind, wave action, and precipitation, while lakes deeper than 20 feet often stratify. Shallow lakes can loosely stratify if they are protected from wind, during calm weather periods, or if enough algae exists near the surface to block out solar radiation near the bottom.

In 2018 Bass Lake East, Bass Lake West, Brewer's Pond, Goggins Lake, Long Lake, Lynch Lake South, Pat Lake, South School Section Lake, and Woodpile Lake stratified to some degree during the monitoring season. These lakes may have benefited from limited internal loading due to the lack of mixing of waters near the bottom rich in nutrients. Details on the depth of the thermocline for each lake that stratified can be found in Appendix A. The other ten lakes in the district did not stratify in 2018, meaning nutrients from internal loading were available for algal growth during the entire growing season.

III.C.7. Elevations

Most lakes in the district peaked in late September or early October following heavy precipitation from several storm systems that moved through the region. Several lakes met, surpassed, or remained above their OHW: Goggins Lake, Lynch Lake North, Lynch Lake South, North School Section Lake, Plaisted Lake, and South School Section Lake. Several seasons of above average summer precipitation have brought low lakes up to elevations not seen for many years. Elevation charts for each lake monitored can be found in Appendix A or using the MN DNR's Lake Finder (http://www.dnr.state.mn.us/lakefind/index.html).

IV. STREAM AND STORMWATER MONITORING

IV.A. Locations and Parameters

In 2018, the BCWD monitored four stations on Brown's Creek, two stations in the Long Lake subwatershed, one station at the Diversion Structure in the diversion drainage, and one tributary to Brown's Creek (Table 1 and Figure 1). The stations on Brown's Creek were located at Manning Avenue (Highway 15), McKusick Road, Stonebridge Trail (Stonebridge), and the intersection of Minnesota State Highways 95 & 96 (the Outlet). The two tributaries to Long Lake were monitored at 62nd Street and the Marketplace Pond. The tributary to Brown's Creek (McKusick Wetland Outlet) was monitored approximately 100 feet upstream of the McKusick Road station.

The four stations on Brown's Creek were monitored for continuous (15 minute) stage and discharge, total phosphorus (TP), dissolved phosphorus, total Kjeldahl nitrogen (TKN), total

suspended solids (TSS), volatile suspended solids (VSS), copper, nickel, lead, zinc, cadmium, chromium, chloride, nitrate, nitrite, ammonia, hardness, and *Escherichia coli* (*E.coli*). These sites were also monitored for continuous temperature, dissolved oxygen, specific conductivity, and turbidity. The Outlet was additionally sampled for total organic carbon (TOC), sulfate, alkalinity, and ortho-phosphorus. The Tributary to Long Lake at Marketplace Pond was monitored for continuous stage and discharge, TP, dissolved phosphorus, TKN, TSS, VSS, copper, nickel, lead, zinc, cadmium, chromium, chloride, nitrate, nitrite, ammonia, and hardness. The Tributary to Long Lake at 62nd Street was monitored for continuous stage only. The station at the Diversion Structure was monitored for continuous stage and discharge, TP, dissolved phosphorus, TKN, TSS, VSS, copper, nickel, lead, zinc, cadmium, chromium, chloride, nitrate, nitrite, ammonia, and hardness. An additional level logger was placed at the base of the diversion structure weir itself to determine if water overtopped it to be discharged directly to Brown's Creek. The tributary to Brown's Creek, McKusick Wetland Outlet, was monitored for continuous stage, discharge, and temperature, and TP, dissolved phosphorus, TKN, TSS, VSS, copper, nickel, lead, zinc, cadmium, chromium, chloride, nitrate, nitrite, ammonia, *E.coli,* and hardness. Continuous precipitation was monitored at Highway 15, the Outlet, and the tributary to Long Lake at Marketplace Pond.

IV.B. Methods

The Highway 15, McKusick Road, Stonebridge, Outlet, Marketplace Pond, and Diversion Structure monitoring stations utilized automated water quality samplers consisting of a stage/velocity sensor, data logger, bottle carousel containing 24 sample bottles, strainer, intake tubing, solar panel, deep cycle marine battery, and steel enclosure. Discharge was calculated using a rating curve based on permanent staff gauges at Highway 15, McKusick Road, Stonebridge, and the Outlet, while discharge at Marketplace Pond and the Diversion Structure was calculated using an area-velocity relationship. Continuous precipitation data were collected at Highway 15, the Outlet, and the Marketplace Pond using tipping bucket rain gauges to assist in loading calculations, but are not discussed in this summary. The samplers were programmed to collect automated flow weighted storm composite samples triggered by a rise in stage. Manual grab samples were taken during storm conditions if it was determined the automated sampler had malfunctioned or had not yet been installed. Monthly manual grab samples during base flow conditions were attempted at these sites, although the Tributary to Long Lake at Marketplace Pond is often dry or stagnant during non-event periods. *E.coli* samples were collected at the time of the base grab samples when possible. Continuous temperature, dissolved oxygen, specific conductivity, and turbidity at the four stations on Brown's Creek were collected using long term deployed sondes, and secondary temperature loggers were deployed to fill gaps created by malfunctions of the primary sonde.

It must be noted the sampling strategy at the Outlet, at the direction of Metropolitan Council Environmental Services's (MCES) Watershed Outlet Monitoring Program (WOMP), was

changed to a manual grab sample on the same day every other week regardless of flow conditions, and the composite sampler was to be programmed to capture only major events. MCES attempted to install a new data logger and refrigerated sampler in 2018, but were unsuccessful due to a number of technical challenges. As such, only one storm composite was able to be collected in 2018. Analytes such as metals, TOC, sulfate, ortho phosphorus, alkalinity, and hardness were changed to be analyzed quarterly. The goal of this strategy is to create a more robust dataset that is better suited for long term statistical trend analysis and impairment assessment. However, the change in technique will cause an apparent shift in nutrient loading totals due to differences in load calculation methods as well as the timing of samples with respect to precipitation events. A limitation of grab sampling is the sample occurs at a discrete point in time and often misses the peak load which is most likely to occur on the rising limb or at the peak flow of a storm. This can lead to artificially low loading estimates, whereas composite sampling captures multiple samples throughout the storm and can provide more accurate data for loading calculations.

The Tributary to Long Lake at 62nd Street station was monitored using a stage sensor only, and discharge during the monitoring period was estimated based on stage and discharge data collected in previous years. The McKusick Wetland Outlet station was monitored using a stage/velocity sensor, and discharge was calculated using an area-velocity relationship. Similar to other stations, monthly manual grab samples were collected, and grab samples were attempted during storm events.

All samples collected were analyzed by the MCES Lab and reviewed by WCD staff. All continuous data were quality assured, quality controlled, and analyzed by WCD staff, with the exception of the Outlet stage, discharge, and loading, which were reviewed and analyzed by MCES. More detailed standard operating procedures used by WCD and MCES for water sampling, monitoring, and data management are available online (http://www.mnwcd.org/water-quality-water-monitoring/ and https://eims.metc.state.mn.us/Documents).

IV.C. Results and Discussion

IV.C.1. Brown's Creek

Brown's Creek is classified as a 2A water by the State of Minnesota, meaning it is designated for aquatic life and recreation, and should support a cold water fishery, aquatic life, and their habitats. The creek is listed as impaired by the MPCA due to a lack of cold water fish assemblages and low scores for indices of biological integrity (IBI) as described in the 2010 Brown's Creek Biota TMDL, and two reaches are impaired for *E.coli*. The stressors identified which contribute to these conditions are high total suspended solids (TSS), high temperature, low dissolved oxygen, high copper concentrations, and high nitrate-nitrite concentrations. The lower reaches of the creek where groundwater inputs help to cool the stream do support a trout fishery

and is annually stocked by the MN DNR. The following sections will make comparisons between the parameters monitored and state standards for 2A waters as described in the Minnesota Administrative Rules Part 7050.0222, as well as recommendations and goals set forth in the TMDL study. A summary of the standards and goals can be found in Table 4.

Table 4. State Standards for 2A and 2B Waters and Brown's Creek Biota TMDL Goals

Parameter	Class 2A Waters	Class 2B Waters	TMDL Goal
Total Phosphorus (TP)	0.100 mg/L	0.100 mg/L	N/A
Total Suspended Solids (TSS)	10 mg/L (Apr 1 to Sept 30)	30 mg/L (Apr 1 to Sept 30)	23 mg/L (10 NTU equivalent)
Chloride (Chronic)	>230 mg/L	>230 mg/L	N/A
Dissolved Oxygen (Daily Minimum)	7 mg/L	5 mg/L	7 mg/L
pH	<6.5 or >8.5	<6.5 or >8.5	N/A
Temperature	N/A	N/A	18.3 ºC (Threat), 23.9 ºC (Critical)

1a. Discharge

Total discharge decreased slightly from the year prior at each station on Brown's Creek. The total amount of water discharged to the St. Croix River as measured at the Outlet was 267,105,859 cubic feet. Calculated discharge for each site can be seen in Table 9.

According to the National Weather Service (NWS) station in Stillwater the total precipitation for 2018 was 28.65 inches; 5.69 inches below the thirty year average. The below average precipitation in the spring after the heavy April snowfall and August contributed to the decrease in discharge at most sites. July and October were the wettest months with several major precipitation events.

A phenomenon noted in past years is the occasional decrease in calculated discharge from the McKusick Road site to the downstream Stonebridge site. This can be explained by a groundwater elevation study completed by Emmons & Olivier Resources, Inc. (EOR) indicating this stretch of stream has the potential to be a losing stream, meaning there may be a net loss of discharge to the groundwater depending on available storage in the aquifer. This study was repeated in 2018, and the results will be available in a separate report prepared by EOR. Physical alterations made to the equipment at the site and development of a new rating curve described in past monitoring summaries supports this theory. In 2018 the annual discharge at Stonebridge was higher than McKusick Road, and it appears this reach acted as a gaining stream, contributing water to the creek rather than discharging to the groundwater.

1b. Phosphorus & Sediment

The total phosphorus (TP) load increased from the year prior at Highway 15 and the Outlet, and decreased at McKusick Road and Stonebridge, while the total suspended solids load increased at Highway 15 and decreased at the other three sites (Table 9, Figure 3, and

Figure 4). The TP load discharged to the St. Croix River was 2,315 pounds, which equates to 0.501 pounds per acre of watershed land. The state standard for TP is 0.100 mg/L, which was surpassed at all sites at various points through the summer during base flow conditions, particularly from May through July. Nutrient water chemistry results for each site and sample can be found in Table 5-Table 8.

The TSS load exported to the St. Croix River was 400,729 pounds, or 86.66 pounds per acre of watershed land. The TMDL goal for the creek is 74 pounds per acre, which is not being met under current conditions. While the state standard for TSS is 10 mg/L from April 1 to September 30, the target concentration identified in the TMDL is 23 mg/L. The target concentration specific to Brown's Creek of 23 mg/L correlates to the former state standard for turbidity of 10 NTU, but has since been replaced by the river eutrophication standards which use TSS concentration to assess impairment status. The state TSS standard was exceeded by all sites during the monitoring season, but the TMDL goal is generally being met under base flow conditions. Highway 15 exceeded the state standard in April and June, McKusick Road in April through June and September, and Stonebridge April through June and September. The Outlet exceeded the standard for the months of April through July and September. Site and sample specific results can be found in Table 5-Table 8.

A summary of site specific total loads and loading per acre of watershed area can be found in Table 9 and detailed loading tables describing hourly intervals for the year can be found in Appendix B. Discrete measurements of dissolved oxygen, temperature, pH, specific conductivity, and transparency can also be found in Appendix B. TP concentrations and loads moving on flow paths through the watershed can be seen in Appendix C.

Table 5. Brown's Creek at Highway 15 2018 Chemistry Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved P (mg/L)	*E. coli* (mpn/100 mL)	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 8:23	4/23/2018 8:23	57	35	2.10	0.257	0.059								12.4	<0.03	0.85	0.33	
Storm Composite	5/25/2018 12:46	5/26/2018 5:19	22	12	1.10	0.155	0.061		0.00340	0.00076	~0.00042	0.00790	<0.00020	0.00044	16.4	<0.03	0.26	~0.05	125
Storm Composite	6/16/2018 20:48	6/17/2018 9:15	81	47	2.50	0.370	0.069		0.00290	0.00130	0.00140	0.01190	<0.00020	0.00200	12.3	0.03	0.17	0.08	106
Storm Composite	6/18/2018 0:43	6/18/2018 14:10	89	52	2.80	0.385	0.164		0.00250	0.00130	0.00150	0.01000	<0.00020	0.00210	11.0	<0.03	0.08	~0.05	96
Storm Composite	6/26/2018 7:03	6/26/2018 14:31	144	77	3.20	0.515	0.072		0.00160	0.00140	0.00190	0.00910	<0.00020	0.00250	9.8	<0.03	0.18	<0.02	123
Storm Grab	6/27/2018 7:57	6/27/2018 7:57	26	16	1.20	0.209	0.062	308							10.6	<0.03	0.17	~0.02	
Storm Composite	7/1/2018 14:02	7/2/2018 9:36	57	32	2.00	0.350	0.084		0.00130	0.00096	0.00100	<0.01000	<0.00020	0.00140	11.5	0.03	0.34	~0.02	98
Storm Composite	7/12/2018 18:33	7/13/2018 7:37	182	112	5.00	0.728	0.093		0.00220	0.00180	0.00270	0.01440	<0.00020	0.00340	9.8	<0.03	0.23	0.11	80
Storm Composite	8/24/2018 12:36	8/26/2018 9:15	55	32	1.80	0.256	0.101								13.4	<0.03	0.07	~0.03	
Storm Composite	9/4/2018 16:34	9/5/2018 13:05	59	36	2.00	0.288	0.079		0.00068	0.00085	0.00110	0.00530	<0.00020	0.00130	12.1	<0.03	0.07	<0.02	119
Storm Grab	10/10/2018 13:48	10/10/2018 13:48	14	8	0.78	0.080	~0.041		~0.00047	~0.00053	~0.00032	<0.00500	<0.00020	0.00052	13.7	<0.03	0.10	~0.03	79
Base Grab	5/30/2018 9:30	5/30/2018 9:30	5	4	0.76	0.128	~0.049	285							14.8	0.04	0.47	0.13	
Base Grab	7/25/2018 9:04	7/25/2018 9:04	7	4	0.67	0.162	~0.047	88							13.9	<0.03	0.77	0.07	
Base Grab	8/22/2018 10:15	8/22/2018 10:15	5	3	0.59	0.121	~0.042	276							13.7	<0.03	0.57	0.10	
Base Grab	9/27/2018 8:13	9/27/2018 8:13	6	4	0.68	0.075	~0.031	228							16.6	<0.03	0.37	~0.04	
Base Grab	10/18/2018 15:04	10/18/2018 15:04	4	~2	0.44	~0.047	~0.022	17							17.3	<0.03	0.71	<0.02	

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

Table 6. Brown's Creek at McKusick Road 2018 Chemistry Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved P (mg/L)	*E. coli* (mpn/100 mL)	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 8:40	4/23/2018 8:40	76	29	2.20	0.293	0.057								14.7	<0.03	0.17	0.36	
Storm Grab	5/30/2018 9:55	5/30/2018 9:55	28	13	1.00	0.177	0.080	407							23.2	0.03	0.49	0.08	
Storm Composite	6/17/2018 23:45	6/18/2018 12:36	169	49	2.70	0.610	0.072								20.7	<0.03	0.17	~0.05	
Storm Grab	6/27/2018 8:14	6/27/2018 8:14	45	21	1.40	0.246	0.088	435							14.2	<0.03	0.13	<0.02	
Storm Composite	7/12/2018 17:57	7/12/2018 20:05	1,120	171	6.70	1.240	0.095		0.01100	0.00780	0.00860	0.04090	~0.00022	0.01120	8.2	0.05	0.50	0.1	33
Storm Composite	9/4/2018 17:33	9/5/2018 4:27	161	58	2.90	0.502	0.099		0.00300	0.00260	0.00260	0.01210	<0.0002	0.00410	27.0	<0.03	0.26	~0.03	126
Storm Composite	10/9/2018 18:23	10/9/2018 21:16	68	23	1.40	0.198	0.054		0.00170	0.00140	0.00120	0.00510	<0.0002	0.00180	22.3	<0.03	0.26	~0.04	116
Base Grab	7/25/2018 9:28	7/25/2018 9:28	7	4	0.54	0.136	0.082	649							24.8	<0.03	0.63	~0.02	
Base Grab	8/22/2018 8:55	8/22/2018 8:55	4	~2	0.26	0.093	~0.039	411							24.4	<0.03	0.54	~0.05	
Base Grab	9/27/2018 8:38	9/27/2018 8:38	11	5	0.84	0.081	~0.036	185							23.2	<0.03	0.34	~0.03	
Base Grab	10/18/2018 14:17	10/18/2018 14:17	4	~2	0.46	~0.047	~0.041	31							30.0	<0.03	0.50	<0.02	

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

Table 7. Brown's Creek at Stonebridge 2018 Chemistry Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved P (mg/L)	*E. coli* (mpn/100 mL)	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 8:54	4/23/2018 8:54	134	40	2.30	0.313	0.066								15.4	<0.03	0.18	0.34	
Storm Grab	5/30/2018 9:15	5/30/2018 9:15	27	13	0.98	0.181	0.067	517							24.5	0.03	0.54	0.06	
Storm Composite	6/16/2018 9:28	6/16/2018 13:36	197	69	4.20	0.651	0.095								24.5	0.08	0.45	0.55	
Storm Grab	6/27/2018 8:37	6/27/2018 8:37	46	21	1.50	0.266	0.106	365							14.0	<0.03	0.13	0.08	
Storm Composite	7/12/2018 18:07	7/12/2018 19:49	2,080	168	6.30	1.480	0.105		0.01250	0.00790	0.00840	0.04140	~0.00027	0.01140	7.8	0.04	0.47	0.12	27
Storm Grab	9/5/2018 14:02	9/5/2018 14:02	48	22	1.60	0.237	0.079		0.00071	0.00110	0.00100	<0.00500	<0.00020	0.00140	18.4	<0.03	0.08	<0.02	116
Storm Grab	10/10/2018 14:59	10/10/2018 14:59	137	35	1.40	0.277	~0.044		0.00240	0.00360	0.00210	0.00690	<0.00020	0.00310	89.8	<0.03	0.22	~0.02	117
Base Grab	7/25/2018 9:49	7/25/2018 9:49	6	3	0.53	0.127	0.069	411							25.1	<0.03	0.55	<0.02	
Base Grab	8/22/2018 9:25	8/22/2018 9:25	5	~2	0.37	0.081	~0.033	214							53.0	<0.03	0.94	~0.05	
Base Grab	9/27/2018 9:02	9/27/2018 9:02	10	5	0.73	0.089	~0.029	248							22.2	<0.03	0.35	~0.03	
Base Grab	10/18/2018 14:46	10/18/2018 14:46	4	~2	0.52	0.061	~0.023	31							30.9	<0.03	0.57	<0.02	

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

Table 8. Brown's Creek Outlet 2018 Primary Chemistry Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved P (mg/L)	TOC (mg/L)	Sulfate (mg/L)	Ortho P (mg/L as P)	Alkalinity (mg/L_CaCO3)	*E. coli* (mpn/100 mL)
Scheduled Grab	1/10/2018 10:55	1/10/2018 10:55	13	5	0.47	0.079	~0.026			0.019		105
Scheduled Grab	1/24/2018 9:10	1/24/2018 9:10	13	7	0.53	0.081	<0.020			0.016		44
Scheduled Grab	2/7/2018 12:00	2/7/2018 12:00	9	4	0.76	0.051	<0.020			0.017		16
Scheduled Grab	2/21/2018 10:21	2/21/2018 10:21	23	9	0.63	0.106	~0.023			0.025		14
Scheduled Grab	3/7/2018 8:24	3/7/2018 8:24	9	4	0.50	0.062	<0.020	2.7	10.40	0.015	191	49
Scheduled Grab	3/21/2018 10:24	3/21/2018 10:24	11	5	0.67	0.094	~0.025			0.027		10
Scheduled Grab	4/5/2018 9:35	4/5/2018 9:35	21	7	0.65	0.079	0.058			0.017		11
Scheduled Grab	4/18/2018 8:47	4/18/2018 8:47	18	8	0.84	0.130	~0.028			0.023		34
Scheduled Grab	5/2/2018 9:40	5/2/2018 9:40	13	6	0.94	0.116	~0.048			0.025		115
Scheduled Grab	5/16/2018 9:30	5/16/2018 9:30	14	6	0.72	0.103	~0.039			0.029		210
Scheduled Grab	5/30/2018 8:55	5/30/2018 8:55	32	14	0.92	0.171	0.062			0.043		435
Scheduled Grab	6/13/2018 15:08	6/13/2018 15:08	12	6	0.52	0.125	0.058	5.3	7.30	0.047	197	127
Storm Composite	6/18/2018 1:06	6/18/2018 12:21	256	92	4.00	0.614	0.065			0.062		
Scheduled Grab	6/27/2018 9:03	6/27/2018 9:03	42	19	1.30	0.234	0.081			0.072		387
Scheduled Grab	7/11/2018 9:10	7/11/2018 9:10	12	6	0.48	0.114	~0.036			0.041		236
Scheduled Grab (Duplicate)	7/11/2018 9:10	7/11/2018 9:10	11	5	0.47	0.110	~0.024			0.047		224
Scheduled Grab	7/25/2018 10:13	7/25/2018 10:13	5	~2	0.38	0.107	~0.038			0.040		387
Scheduled Grab	8/8/2018 8:59	8/8/2018 8:59	4	~2	0.34	0.076	~0.046			0.043		147
Scheduled Grab	8/22/2018 9:37	8/22/2018 9:37	~2	~1	0.21	0.076	~0.037			0.042		272
Scheduled Grab	9/5/2018 8:28	9/5/2018 8:28	47	20	1.60	0.255	0.065	12.6	4.17	0.079	139	>2420
Scheduled Grab	9/19/2018 8:47	9/19/2018 8:47	4	~2	0.33	0.065	~0.036			0.041		248
Scheduled Grab	10/3/2018 8:16	10/3/2018 8:16	8	4	0.50	0.071	~0.043			0.023		236
Scheduled Grab	10/17/2018 9:01	10/17/2018 9:01	5	~2	0.51	~0.048	~0.027			0.031		42
Scheduled Grab	10/31/2018 9:02	10/31/2018 9:02	4	3	0.45	0.068	~0.037			0.018		8
Scheduled Grab	11/14/2018 15:00	11/14/2018 15:00	5	~2	0.34	~0.042	<0.020			0.020		37
Scheduled Grab	11/28/2018 9:33	11/28/2018 9:33	4	4	0.18	~0.047	~0.028			0.015		13
Scheduled Grab	12/13/2018 11:00	12/13/2018 11:00	3	~2	0.22	~0.041	<0.020	2.8	9.34	0.019	186	18
Scheduled Grab (Duplicate)	12/13/2018 11:00	12/13/2018 11:00	3	~2	0.29	~0.040	<0.020	2.6	9.29	0.019	182	18
Scheduled Grab	12/26/2018 9:28	12/26/2018 9:28	4	3	0.28	~0.045	~0.024			0.022		16

Exceeds Water Quality Standard

Table 9. Brown's Creek Historic Loading- Latest Ten Years

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Brown's Creek at Highway 15										
Discharge (cf)	79,814,166	97,611,702	159,363,563	73,010,032	84,243,848	160,221,727	97,159,132	152,081,358	135,660,983	129,764,024
Total pounds of Phosphorus exported	672	833	1,838	815	658	1,210	1,450	1,736	831	1,182
TP (lbs/ac/yr)	0.210	0.261	0.575	0.231	0.186	0.343	0.410	0.492	0.235	0.335
Total pounds of TSS exported	62,160	78,762	108,296	50,132	37,105	245,954	211,364	239,237	105,900	132,765
TSS (lbs/ac/yr)	19.46	24.65	33.90	14.19	10.51	69.64	59.84	67.73	29.98	37.59
Brown's Creek at McKusick Road										
Discharge (cf)	92,884,028	85,721,155	237,861,774	97,789,599	119,479,669	282,264,777	152,913,065	229,482,654	192,485,489	179,429,476
Total pounds of Phosphorus exported	985	787	3,225	854	1,292	2,460	2,248	3,059	1,766	1,602
TP (lbs/ac/yr)	0.246	0.197	0.806	0.213	0.323	0.615	0.562	0.765	0.442	0.401
Total pounds of TSS exported	375,461	157,616	493,795	284,634	701,242	1,464,447	728,640	1,646,798	638,650	404,296
TSS (lbs/ac/yr)	93.89	39.41	123.48	71.18	175.35	366.20	182.21	411.80	159.70	101.10
Brown's Creek at Stonebridge										
Discharge (cf)	123,669,192	103,170,269	272,255,720	93,936,151	136,723,177	203,037,716	Not Calculated	224,138,246	232,701,338	225,604,711
Total pounds of Phosphorus exported	1,405	796	2,802	797	1,297	1,978	Not Calculated	2,778	2,229	1,946
TP (lbs/ac/yr)	0.335	0.190	0.669	0.190	0.310	0.472	Not Calculated	0.663	0.532	0.465
Total pounds of TSS exported	251,770	83,856	268,821	226,857	604,065	1,419,775	Not Calculated	1,187,547	718,290	515,386
TSS (lbs/ac/yr)	60.10	20.02	64.17	54.16	144.20	338.93	Not Calculated	283.49	171.47	123.03
Brown's Creek Outlet										
Discharge (cf)	175,097,177	176,755,632	282,050,178	161,856,099	202,719,259	303,513,260	241,784,443	284,583,206	278,020,037	267,105,859
Total pounds of Phosphorus exported	2,448	1,126	2,094	1,244	1,755	2,233	3,156	3,514	2,275*	2,315*
TP (lbs/ac/yr)	0.529	0.277	0.453	0.269	0.380	0.483	0.683	0.760	0.492	0.501
Total pounds of TSS exported	988,987	202,744	634,243	480,193	454,456	1,123,783	1,119,632	1,114,674	498,032*	400,729*
TSS (lbs/ac/yr)	213.88	49.89	137.16	103.85	98.28	243.03	242.13	241.06	107.71	86.66
	*Sampling regime and load estimation method changed									

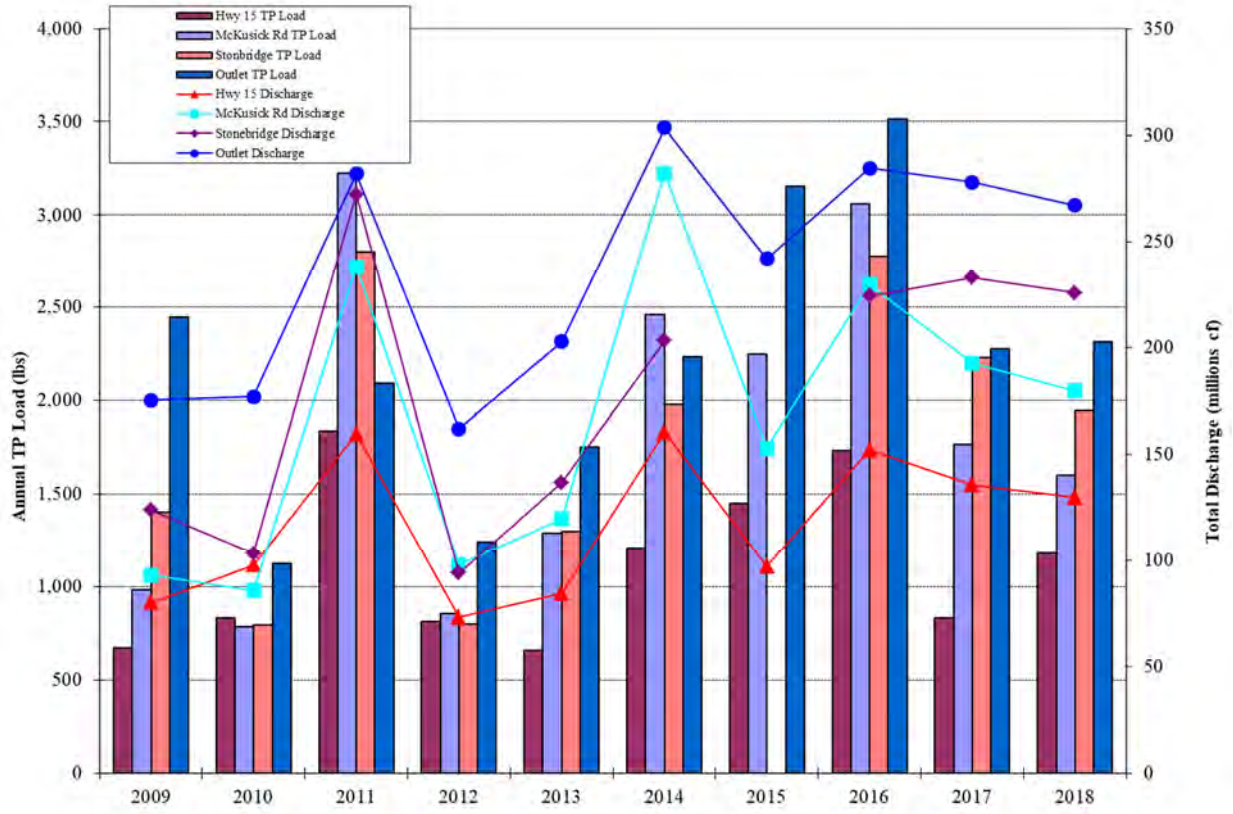


Figure 3. Brown's Creek Phosphorus Loading- Latest Ten Years

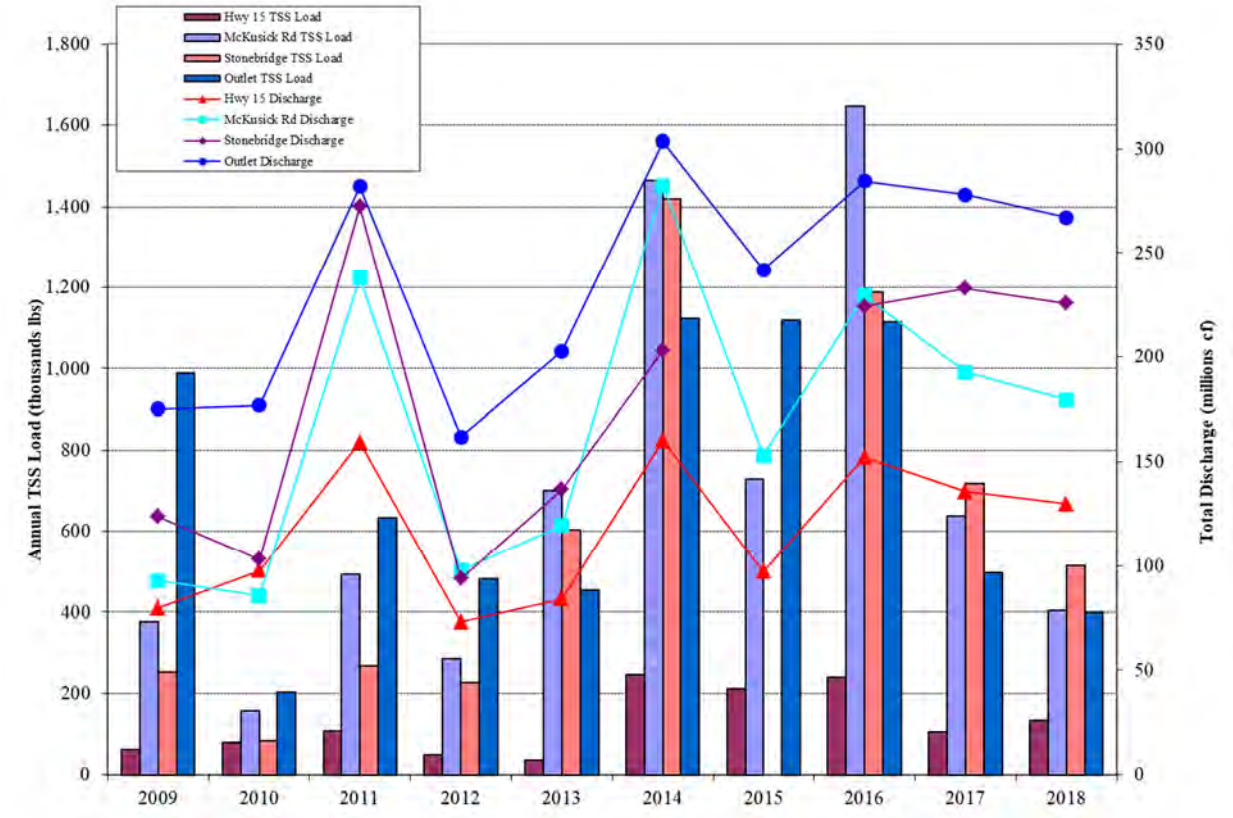


Figure 4. Brown's Creek Sediment Loading- Latest Ten Years

1c. Metals

One of the stressors identified in the TMDL study is high concentrations of copper, which are harmful to aquatic life. Additionally, other metals such as lead and zinc can be toxic to aquatic organisms. Standards for such metals are variable based on the hardness of the water which affects the level of toxicity a given concentration has. Under soft water (low hardness) conditions metals are more readily taken up by aquatic organisms, increasing the toxicity of the concentrations of metals in the water. Calculation of metals 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.

Heavy metals exceedances for each site and sample can be found in Table 5 through Table 7, and Table 10. One chronic standard exceedance of lead was recorded at Highway 15, McKusick Road, and Stonebridge. A maximum standard exceedance of copper was recorded at McKusick Road, and a maximum standard exceedance of zinc was recorded at Stonebridge. A final acute value (FAV) exceedance of copper was recorded at Stonebridge. For reference, an FAV exceedance of copper has not been recorded at any site since 2007. No exceedances were detected at the Outlet, but it is important to note the change in sampling strategy with less composite sampling at the Outlet may not capture some events which may exceed metals standards.

Table 10. Brown's Creek Outlet 2018 Secondary Chemistry Results

Sample Type	Start	End	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)
Scheduled Grab	1/10/2018 10:55	1/10/2018 10:55							26.7	<0.03	1.11	0.11	
Scheduled Grab	1/24/2018 9:10	1/24/2018 9:10							33.2	<0.03	1.19	0.08	
Scheduled Grab	2/7/2018 12:00	2/7/2018 12:00							27.7	<0.03	1.29	~0.05	
Scheduled Grab	2/21/2018 10:21	2/21/2018 10:21							28.8	<0.03	1.33	0.08	
Scheduled Grab	3/7/2018 8:24	3/7/2018 8:24	~0.00031	~0.00040	~0.00027	<0.00500	<0.00020	0.00061	31.4	<0.03	1.35	0.14	184
Scheduled Grab	3/21/2018 10:24	3/21/2018 10:24							28.2	<0.03	1.04	0.19	
Scheduled Grab	4/5/2018 9:35	4/5/2018 9:35							32.2	<0.03	1.00	0.12	
Scheduled Grab	4/18/2018 8:47	4/18/2018 8:47							36.4	<0.03	0.93	0.12	
Scheduled Grab	5/2/2018 9:40	5/2/2018 9:40							25.0	<0.03	0.46	0.07	
Scheduled Grab	5/16/2018 9:30	5/16/2018 9:30							26.8	<0.03	0.67	0.07	
Scheduled Grab	5/30/2018 8:55	5/30/2018 8:55							27.8	<0.03	0.82	<0.02	
Scheduled Grab	6/13/2018 15:08	6/13/2018 15:08	~0.00050	~0.00053	~0.00023	0.00190	<0.00020	0.00080	27.6	<0.03	0.52	0.11	205
Storm Composite	6/18/2018 1:06	6/18/2018 12:21	0.00560	0.00340	0.00330	0.01980	<0.00020	0.00520	24.0	0.03	0.31	0.57	115
Scheduled Grab	6/27/2018 9:03	6/27/2018 9:03							18.5	<0.03	0.31	<0.02	
Scheduled Grab	7/11/2018 9:10	7/11/2018 9:10							28.2	<0.03	0.95	~0.03	
Scheduled Grab (Duplicate)	7/11/2018 9:10	7/11/2018 9:10							27.8	<0.03	0.92	~0.02	
Scheduled Grab	7/25/2018 10:13	7/25/2018 10:13							29.2	<0.03	0.91	<0.02	
Scheduled Grab	8/8/2018 8:59	8/8/2018 8:59							28.1	<0.03	0.80	<0.02	
Scheduled Grab	8/22/2018 9:37	8/22/2018 9:37							28.6	<0.03	0.82	~0.04	
Scheduled Grab	9/5/2018 8:28	9/5/2018 8:28	0.00170	0.00140	0.00110	<0.00500	<0.00020	0.00170	20.8	<0.03	0.21	~0.04	151
Scheduled Grab	9/19/2018 8:47	9/19/2018 8:47							29.1	<0.03	0.93	<0.02	
Scheduled Grab	10/3/2018 8:16	10/3/2018 8:16							27.5	<0.03	0.69	~0.02	
Scheduled Grab	10/17/2018 9:01	10/17/2018 9:01							33.7	<0.03	0.67	<0.02	
Scheduled Grab	10/31/2018 9:02	10/31/2018 9:02							28.8	<0.03	0.72	~0.02	
Scheduled Grab	11/14/2018 15:00	11/14/2018 15:00							29.0	<0.03	1.15	~0.04	
Scheduled Grab	11/28/2018 9:33	11/28/2018 9:33							29.9	<0.03	1.42	~0.05	
Scheduled Grab	12/13/2018 11:00	12/13/2018 11:00	<0.00500	~0.00036	~0.00017	<0.00500	<0.00020	0.00083	26.8	<0.03	1.34	~0.05	200
Scheduled Grab (Duplicate)	12/13/2018 11:00	12/13/2018 11:00	<0.00500	~0.00031	<0.00010	<0.00500	<0.00020	0.00066	27.0	<0.03	1.34	~0.06	191
Scheduled Grab	12/26/2018 9:28	12/26/2018 9:28							28.5	<0.03	1.11	<0.02	

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

1d. Bacteria (*E.coli*)

The sites on Brown's Creek are not meeting the state standard for *E.coli* for nearly all months regulated by the standard, and two reaches of the creek have been listed as impaired for bacteria. A summary table by month and site can be found in Table 11. The standard is defined as follows, and is based on the latest ten years of data as per 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. Monthly Geometric Means of *E.coli*- Latest Ten Years

Site	April	May	June	July	August	September	October
Highway 15	Insufficient Data	155	258	294	272	144	70
McKusick Road	Insufficient Data	183	517	511	287	289	45
Stonebridge	Insufficient Data	260	494	408	242	249	58
Brown's Creek Outlet	23	154	442	340	179	173	54
Diversion	Insufficient Data	82	251	317	228	174	Insufficient Data
Trib at 62nd St	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)

Lower concentrations of bacteria observed at the Outlet are most likely due to groundwater dilution. The 2016 Bacterial Source Assessment, completed by Emmons & Olivier, Inc. has excluded human borne *E.coli* as a significant source of bacteria, indicating failing septic systems and illegal straight pipes are not contributing to the high levels of bacteria. Likely sources of bacteria include large congregations of geese around the McKusick Road area, as well as beavers and muskrat in the upper reaches of the creek. Further studies will focus on species of wildlife and livestock to determine sources of bacteria.

1e. Temperature & Dissolved Oxygen

The 2010 Brown's Creek Biota TMDL indicates a threat level temperature of 18.3 ºC and a critical level temperature of 23.9 ºC for trout survivability. The threat level impact as defined as physiological stress, reduced growth, and egg mortality. The critical level impact is defined as the point at which direct mortality can be expected. For the purposes of this report, daily average temperatures are used to determine if impact levels have been reached.

In 2018, multi-parameter sondes were deployed at all four stations on the creek. Due to battery and logger malfunctions in years prior secondary temperature loggers were deployed to minimize gaps in the temperature data created by the primary loggers. However, these gaps still exist in the dissolved oxygen period of record, as no secondary

dissolved oxygen sensors were available. Unfortunately, a major gap exists in the dissolved oxygen record of the Outlet from June 16 through August 8 due to suspected vandalism and loss of the logger. A new sonde was purchased and deployed, but unfamiliarity with the logger software created another gap from August 15 through September 15.

In terms of rank within the last ten years of data, the number of daily average threat level temperature exceedances in the creek in 2018 were around fifth coolest depending on the station, indicating temperatures in the creek were neither especially hot nor cool (Table 12). At no site did the daily average temperature exceed the critical level temperature. Cool groundwater inputs to the creek due to plentiful groundwater recharge from the wet summers of 2014 through 2016 likely minimized the number of threat and critical level exceedances as the summer air temperatures were particularly warm. According to the NWS station in Stillwater air temperatures were in excess of 90 ^{o}F six days of the season, beginning as early as May 27. Precipitation was also below average during the hottest months, and without adequate groundwater inputs to maintain baseflow the creek would likely have been considerably warmer.

The Riparian Shading Study, conducted by a graduate student working with the District's engineer, was completed in 2018 and describes the relationship of thermal loading via solar radiation and shade producing objects along the stream corridor. The study identified the least shaded (less than 60% shaded) reaches of the creek as immediately downstream of Highway 15, immediately west of Millbrook Park, a reach between Millbrook Park and McKusick Road, and the reach flowing through Oak Glen Golf Course north of McKusick Road. This indicates the buffer strip installations within the golf course have not reached full maturity, but are expected to provide up to 80% shade coverage when the final growth is achieved. The remaining three poorly shaded reaches are being targeted for shade restoration projects that will provide shade to approximately three miles of stream corridor. Work on two projects to shade 2,400 linear feet of the creek is scheduled to begin in 2019. The full Riparian Shading Study report is available on the District's website.

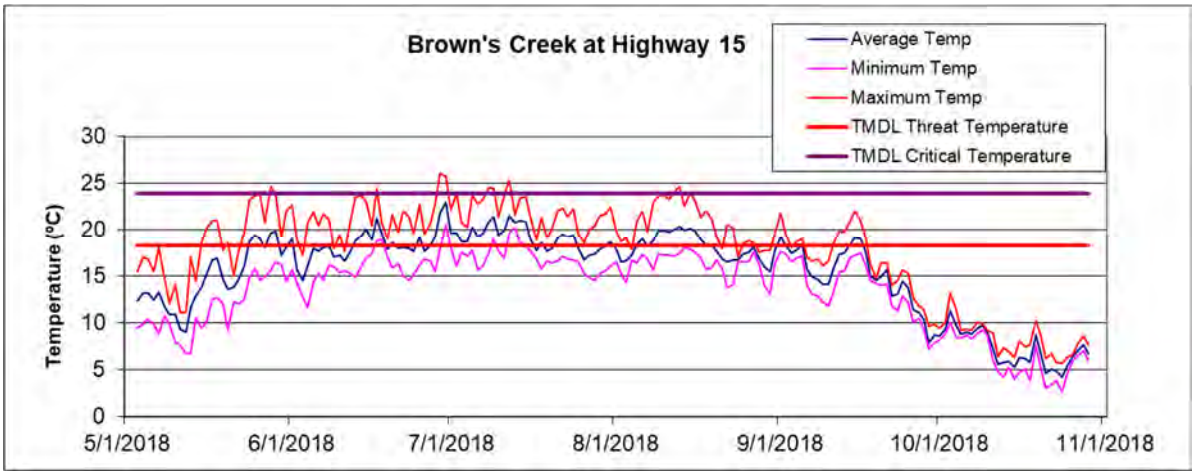


Figure 5. Brown's Creek at Highway 15 2018 Daily Temperature Summary

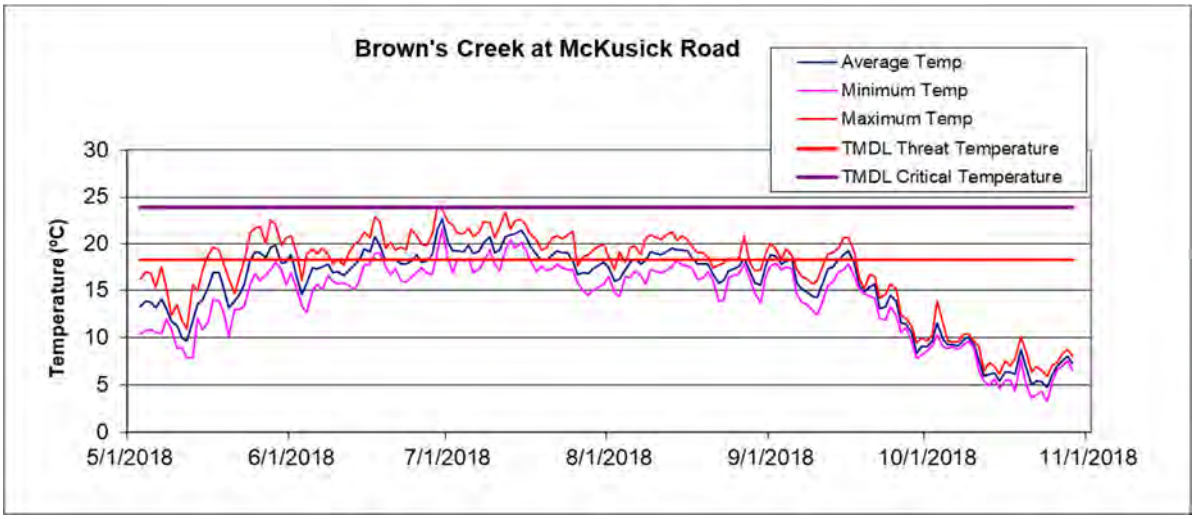


Figure 6. Brown's Creek at McKusick Road 2018 Daily Temperature Summary

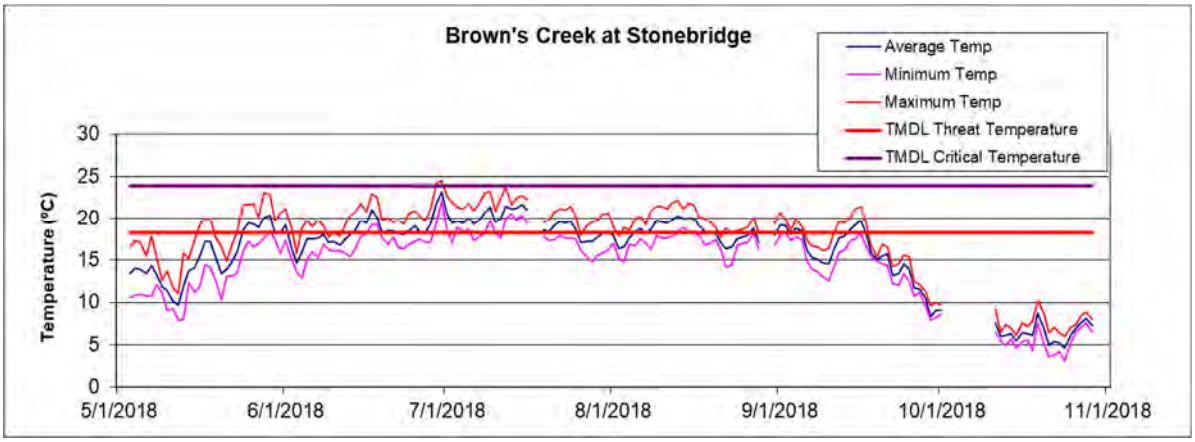


Figure 7. Brown's Creek at Stonebridge 2018 Daily Temperature Summary

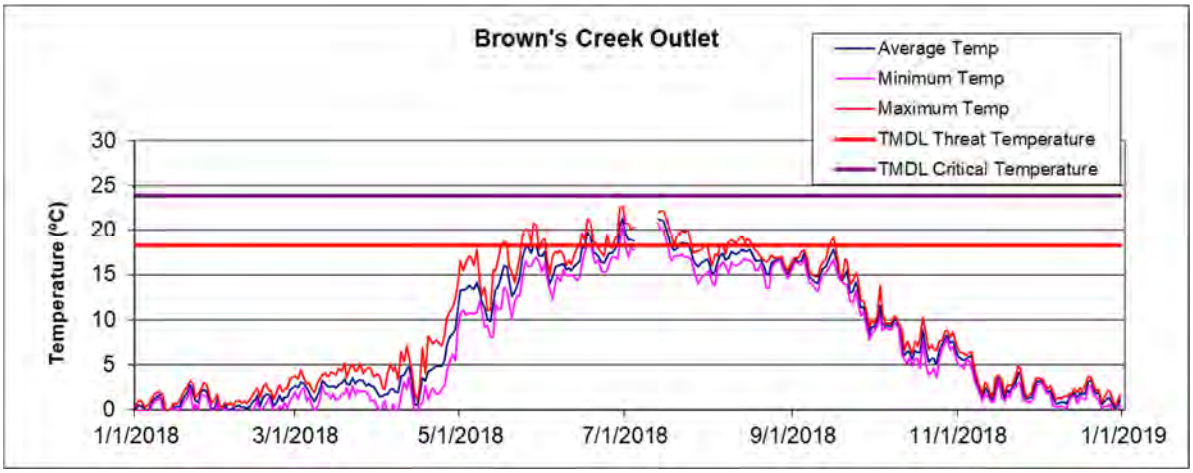


Figure 8. Brown's Creek Outlet 2018 Daily Temperature Summary

Table 12. Annual Occurrences of Brown's Creek Daily Average Temperature Greater than Threat and Critical Level Thresholds

	Exceedances at Highway 15		Exceedances at McKusick		Exceedances at Stonebridge		Exceedances at Outlet	
Year	18.3°C	23.9°C	18.3°C	23.9°C	18.3°C	23.9°C	18.3°C	23.9°C
2009	41	0	26	0	37	0	5	0
2010	78	0	62	0	71	0	17	0
2011	64	4	48	3	60	3	35	0
2012	84	6	65	2	77	5	34	0
2013	69	3	57	1	62	1	25	0
2014	54	0	46	0	59	0	17	0
2015	28*	0*	65	0	26*	0*	22	0
2016	14*	0*	17*	0*	71	0	35	0
2017	54	0	43	0	48	0	8	0
2018	61	0	54	0	66	0	19	0

* Based on severely limited period of record

The state standard for dissolved oxygen in 2A waters is 7 mg/L as a daily minimum. Logger malfunctions were minimized in 2018, with the exception of the Outlet due to suspected vandalism, and as such Highway 15, McKusick Road, and Stonebridge have records of 88% completeness or greater (percentage as the number of days successfully logged versus the number of days the longest deployed logger was physically in the stream, Table 13). Oxygen concentrations at Highway 15 were below the state standard 94.3% of the days monitored, and are unsuitable for trout survival (Table 13, Figure 9). The data collected show daily swings high above 7 mg/L at Highway 15 due to intense macrophyte growth, but drops well below the threshold at night. Dissolved oxygen levels at McKusick Road tend to be higher, but were lower than the standard nearly a quarter of the days monitored. Additionally, dissolved oxygen concentrations at McKusick Road are influenced by warm, oxygen poor water discharged to the creek at the McKusick Wetland Outlet site approximately 100 feet upstream. The data collected at the McKusick Wetland Outlet site are discussed later in this summary.

Dissolved oxygen concentrations and temperatures at the Stonebridge site have historically lent themselves better to trout survival. This holds true for dissolved oxygen in 2018, with only 4.8% of the days monitored, mostly during major storm events, below the state standard. However, temperatures at Stonebridge were above the threat level twelve days more than McKusick Road, indicating trout may have had adequate oxygen to survive, but would have been stressed by warm temperatures (Table 12 and Figure 7). Increased shading in the Oak Glen Golf Course buffer area will help to cool the water upstream of the Stonebridge site as well as increase oxygen levels.

Table 13. Daily Minimum Dissolved Oxygen Exceedances

Site	Days Monitored	Dissolved Oxygen Daily Minimum Below 7 mg/L	Percent of Days Exceeded	Record Completeness
Highway 15	159	150	94.3%	88.3%
McKusick Road	167	41	24.6%	92.8%
Stonebridge	165	8	4.8%	91.7%
Outlet	97	0	0.0%	53.9%

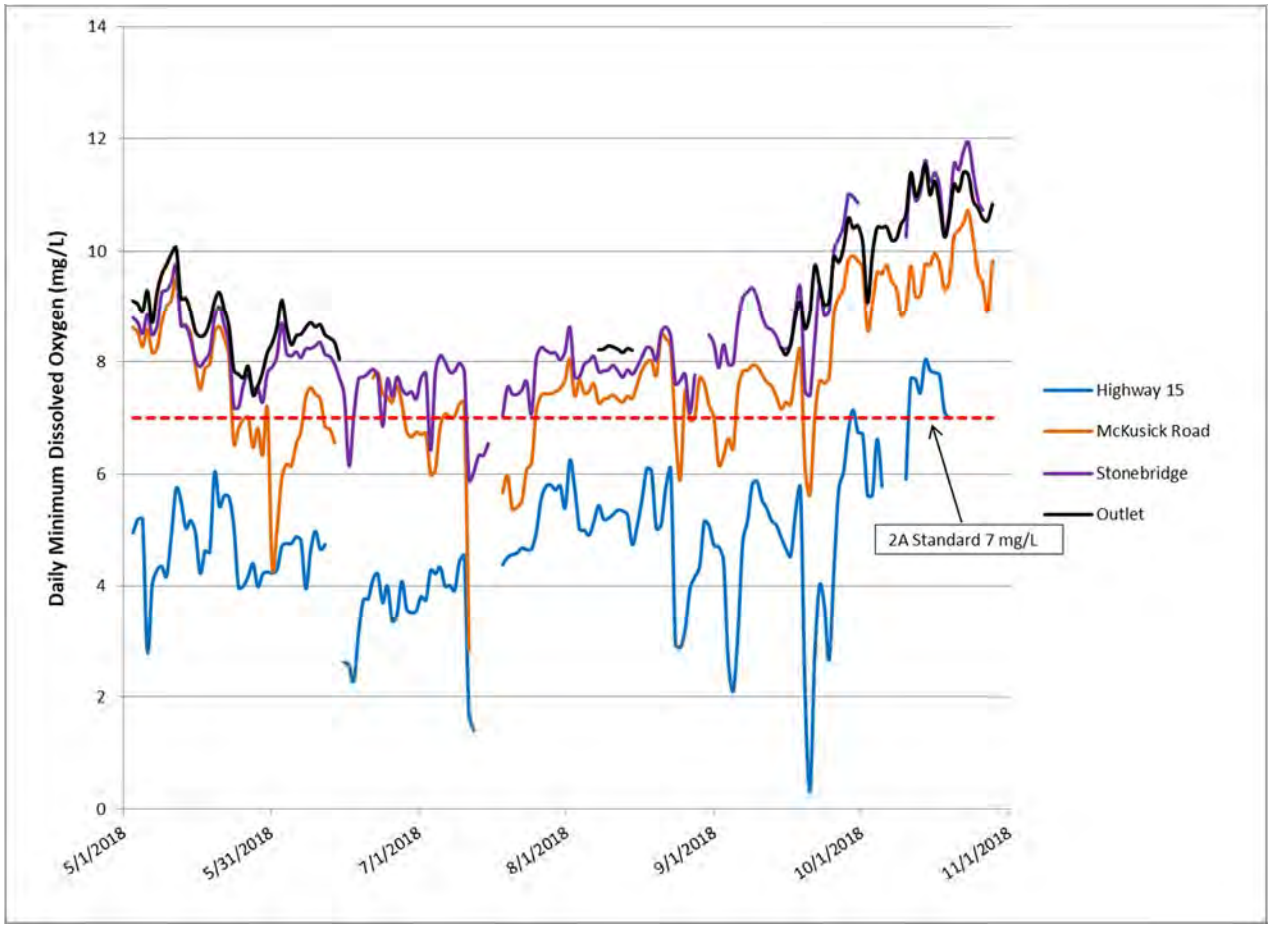


Figure 9. Daily Minimum Dissolved Oxygen in Brown's Creek

The Outlet continues to be the best location on Brown's Creek for trout survival. The average daily temperature exceeded threat level threshold only 19 days during the season, which is the fifth lowest number of exceedances in the last ten years (Table 12). This is due to cold groundwater inputs in the gorge upstream of the Outlet and a robust tree canopy to shade the stream. Despite much of the record missing during the warmest parts of the monitoring season due to suspected vandalism of the logger, it is assumed based on previous data and bi-weekly discrete measurements daily minimum oxygen concentrations were suitable for trout for nearly the entire season (Figure 9 and Appendix B).

1f. Turbidity & Specific Conductivity

Turbidity and specific conductivity can be helpful for determining the amount of particles and dissolved materials in a stream. Turbidity measures the amount of light scattered by particles such as suspended sediment, phytoplankton, and bacteria while specific conductivity measures electrical conductance of the water and is influenced by the amount of dissolved ions in the water. Excess turbidity can be detrimental to trout, since they are primarily sight feeders, as well as indicate a high sediment load which can clog gills and cover spawning areas.

Continuous turbidity and specific conductivity were monitored at all four stations on Brown's Creek. Similar to dissolved oxygen data, a limited record exists for the Outlet. Turbidity sensors on the multi-parameter sondes have the tendency to be covered by bedload sediment during storm events and be fouled by algae growth on the sensor itself, and as such gaps in the record exist at all sites. To account for fouling continuous turbidity data were converted to a daily average where at least three quarters of a day was successfully logged for comparison to a 10 NTU threshold which correlates to the TMDL goal of 23 mg/L of TSS. Specific conductivity data are not discussed in this report as they do not directly apply to state standards or TMDL goals, but will be made available upon request. A summary of days successfully monitored for turbidity at each site can be found in Table 14 and average daily turbidity can be viewed in Figure 10.

Table 14. Brown's Creek Turbidity Standard Exceedances

Site	Days Monitored	Days Over 10 NTU	Percent of Days Exceeded	Record Completeness
Highway 15	148	14	9.5%	82.2%
McKusick Road	173	70	40.5%	96.1%
Stonebridge	142	74	52.1%	78.9%
Outlet	97	29	29.9%	53.9%

It is worth noting the creek tends to be meeting the 10 NTU goal during nearly all periods of base flow, indicating sediment and other sources of turbidity are being contributed

during storm events. The highest daily average turbidity at Highway 15, McKusick Road, Stonebridge, and the Outlet were recorded during storms on September 20 (23 NTU), September 20 (65 NTU), June 18 (47 NTU), and September 20 (46 NTU), respectively.

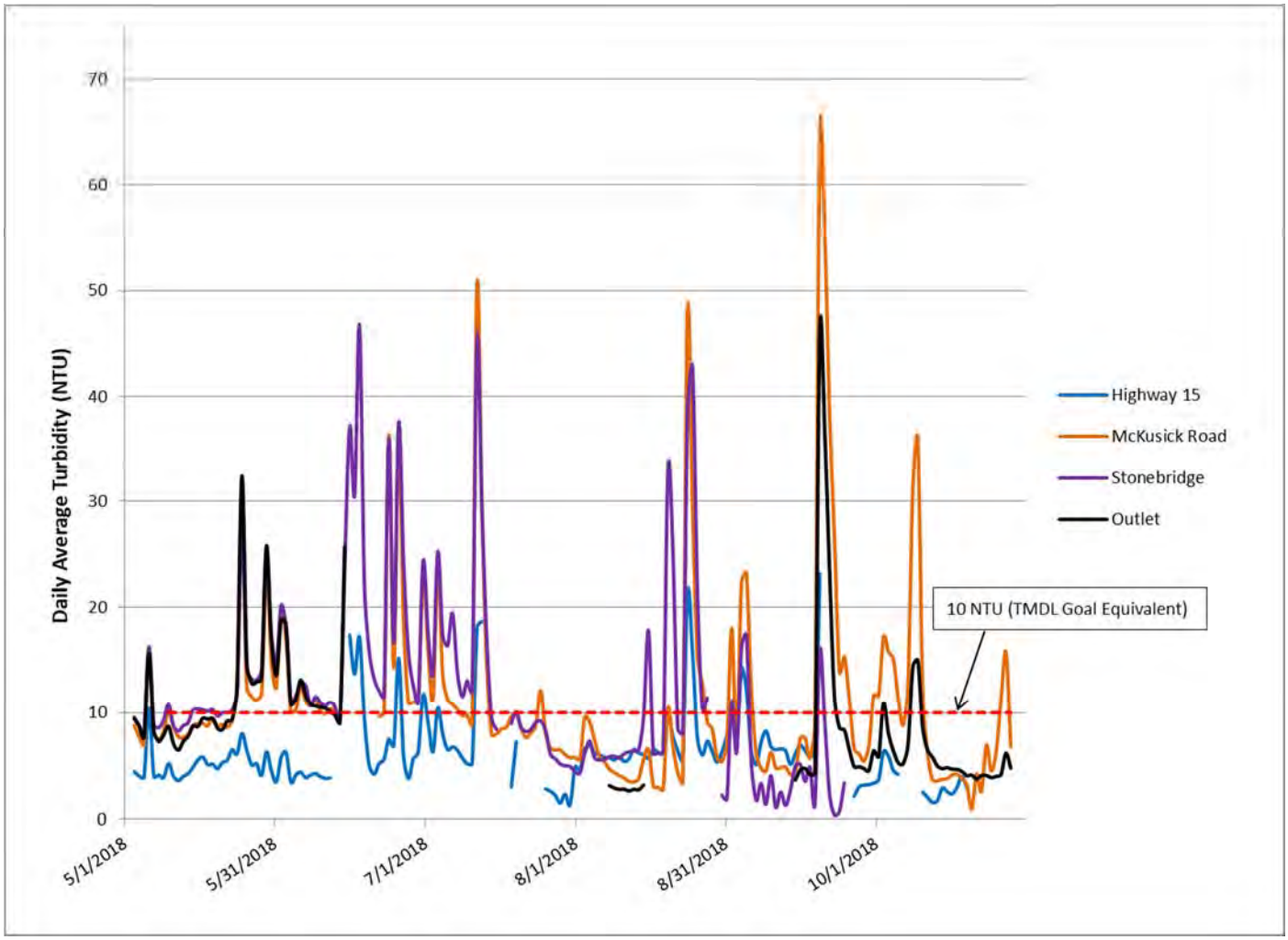


Figure 10. Brown's Creek Daily Average Turbidity

1g. Fisheries & Aquatic Invasive Species

Brown's Creek currently supports a brown trout fishery dependent upon stocking in the lower reaches of the creek. On April 12 the MN DNR stocked the creek with 1,000 yearling brown trout with half stocked at the Outlet, and the other half distributed between Oak Glen Golf Course and Brown's Creek Park. Due to difficulties of state hatcheries producing stock-able brown trout the MN DNR intends to switch from stocking brown trout to stocking rainbow trout in 2019. Stillwater Area High School (SAHS) has also raised and stocked brown trout as an educational experience for students, and will also be changing to produce rainbow trout. Rainbow trout are easier to produce, tend to grow faster, and can be stocked at a larger size to provide better recreational opportunity for

anglers. They thrive in similar conditions to brown trout and are not expected to impact the creek in any negative way.

Fish and macroinvertebrate sampling conducted by the District's engineer and SAHS have identified many varieties of organisms present in the creek that need high quality, well oxygenated water to survive, such as rainbow darters. Results of fish and macroinvertebrate samplings can be found on the District's website or are available upon request.

During the course of the monitoring season, field staff observed heavy growth of invasive curly-leaf pondweed in the upper reaches of the creek at Highway 15 and above McKusick Road. Dense mats of vegetation can alter flow rates, nutrient transport in the stream, hinder efforts to make stream improvements by slowing the water, and create conditions for warmer temperatures and increased sediment deposition on potential spawning areas. The BCWD should continue to work with partners to limit or prevent the spread of curly leaf pondweed downstream.

IV.C.2. Diversion Drainage

The Trout Stream Mitigation Project (TSMP), also known as the Diversion Structure, has been functioning since 2003 to divert warm water flows away from Brown's Creek through McKusick Lake to the St. Croix River (Table 1 and Figure 1). Diverting the water away from the creek protects it from additional thermal and sediment loads, improving conditions for trout and other cold water organisms. However, the water diverted away from the creek impacts its receiving waters: McKusick Lake and the wetland complex at the inlet to the lake. Therefore, monitoring is important to determine the load of pollutants discharged to the lake.

2a. Discharge

Discharge increased slighly from the year prior to a total volume of 45,453,990 cubic feet exported to McKusick Lake (Table 16). Similar to recent years, throughout the summer a number of non-precipitation related events occurred at the Diversion Structure. It is assumed based on the timing, shape of the hydrograph, and duration of the events that these events are due to manipulation of the outlet at the upstream Jackson WMA Pond, likely through clearing of brush from the outlet or dewatering of other basins near Boutwell Road. Some events may also be due to clearing of brush from a grate that was installed on the culvert inlet at the Diversion Structure immediately in front of the area-velocity sensor in November 2016.

The suspected pumping identified by drawdown of the creek at regular, scheduled intervals was observed again in 2018, although the pattern was not as obvious. Review of historic and current aerial photographs, as well as a limited field investigation did not identify any potential causes of drawdown, and further investigation will be necessary. A more detailed

description of the events can be found in the 2017 monitoring summary, available on the District's website.

2b. Phosphorus & Sediment

The TP load to McKusick Lake was 964 pounds, or 0.250 pounds of phosphorus per acre of watershed land (Table 16); an increase from 2017. Generally, water flowing through the site is meeting the 2B phosphorus standard at base flow (Table 15).

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 16). The state standard for 2B waters is 30 mg/L of TSS from April 1 to September 30. Water flowing through the site during this period is meeting the standard during base flow conditions, but has extraordinarily high concentrations during storm events (Table 15).

A source of the high TP and TSS loads in the diversion drainage, described more fully in previous monitoring summaries, was an eroding head cut north of Boutwell Road, upstream of the monitoring location. BCWD funded a project to repair the erosion including installation of rock vanes, which was completed in November of 2018. The restoration is estimated to remove 22 tons of sediment and 24 pounds of phosphorus annually. The Iron Enhanced Sand Filter (IESF) upstream of the monitoring site also continues to operate to reduce TP loads in the drainage. Monitoring data from the IESF will be analyzed by Emmons & Olivier, Inc. in a separate report.

Table 15. Brown's Creek Diversion 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

Table 16. Brown's Creek Diversion Historic Loading- Latest Ten Years

	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

2c. Metals

Heavy metals exceedances at the Diversion site can be seen in Table 15. The export of water high in metals to McKusick Lake and its wetland complex are particularly concerning due to the potential to kill aquatic life in a short period of time, as opposed to nutrient or sediment loading which typically degrades habitat and populations of aquatic life over time. The chronic standards for copper, lead, and cadmium were exceeded by four, nine, and one samples, respectively. The maximum standards for copper and zinc were exceeded by one sample each, and the final acute value for copper was exceeded by one sample. The number and severity of exceedances of metals standards in the drainage in 2018 were near the average when compared to the last ten years of samples. Sources of metals in this drainage may include improperly disposed waste, such as deep cycle batteries. The combination and concentration of metals observed over time appear to point to this as a possible source.

2d. Bacteria (*E.coli*)

Similar to the creek itself, the diversion drainage is not meeting the standard for *E.coli* from June through September (Table 11). The bacterial source assessment excluded anthropogenic sources of *E.coli* in the drainage, meaning wildlife and livestock are the likely culprits of the high levels of bacteria. No bacteria samples were collected in 2018.

IV.C.3. Long Lake Drainage

The tributaries to Long Lake at 62nd St. and Marketplace Pond drain a high percentage of impervious surface and developed areas upstream of Long Lake (Table 1 and Figure 1). For the purposes of this report, the Tributary to Long Lake at Marketplace Pond will be compared to 2B water quality standards. The tributary at Marketplace Pond is not classified as a 2B water, although its receiving water, Long Lake, is. The tributary at 62nd Street will not be compared to state standards as water chemistry sampling at the site ceased in 2017; only stage has been recorded since. The water discharged to Long Lake directly affects the quality of the lake, which has significant issues caused by excess nutrients. Water from Long Lake makes its way downstream to Jackson WMA Pond, the diversion drainage, McKusick Lake and its wetland complex, and eventually to the St. Croix River. Monitoring subwatershed contributions to Long Lake can help determine locations for targeted management as well as track improvements made upstream.

3a. Discharge

Annual discharge to Long Lake from the tributary at Marketplace Pond was 16,492,464 cubic feet. Only stage data was collected at the tributary at 62nd Street, and discharge was estimated during the period of logged data based on stage and discharge data from 2014. Data from 2014 was used because it covered the widest range of observed stages and was representative of the average of other years of data collection. Discharge outside of logged

data was not estimated, although the total volume outside of the period of record is likely negligible as the site freezes in the winter. Discharge to Long Lake from the tributary at 62nd Street was estimated at 957,234 cubic feet (Table 18). Flow in both systems is almost entirely event based, and flow often ceases during dry or winter conditions.

3b. Phosphorus & Sediment

The TP load at Marketplace Pond was 0.170 pounds per acre for a total of 70 pounds of phosphorus, and the TSS load was 40.18 pounds per acre for a total of 16,473 pounds of sediment (Table 18). It appears the tributary at Marketplace Pond is meeting the standards of 30 mg/L of TSS and 0.100 mg/L during base flow (Table 17). Although storm composite samples are generally not compared to state standards, the concentrations of nutrients were below both standards for many of the samples collected. It should be noted the tributary at Marketplace Pond flows through several small settling ponds before discharging to Long Lake, and some additional settling of sediment and uptake of nutrients likely occurs. Sampling of the tributary at 62nd Street ceased after the 2016 monitoring season.

3c. Metals

Heavy metal exceedances for the tributary at Marketplace Pond can be found in Table 17. The FAV for copper and zinc were exceeded by two and one samples, respectively. The maximum standards for copper, lead, and zinc were exceeded by three, one, and one samples, respectively. The chronic standards for copper, lead, and cadmium were exceeded by three, six, and one samples, respectively. The chronic standard for chloride was also exceeded by three samples in spring, caused by road salt from parking lots and streets in the drainage. Metals exceedances at this site tended to be higher than average in terms of both frequency and severity when compared to the last ten years of samples. The amount of heavy metals in the subwatershed is influenced by development and impervious surfaces, such as parking lots and Highway 36 where materials from vehicle leaks and brake dust tend to collect. Metals contributed from this subwatershed have the potential to degrade or destroy aquatic life near the outfall to Long Lake before the discharged water is fully integrated into the lake.

Table 17. Tributary to Long Lake at Marketplace Pond 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 9:40	4/23/2018 9:40	5	~2	0.97	0.063	~0.026	0.00370	0.00087	0.00054	0.01320	<0.00020	0.00110	415.8	<0.03	0.14	0.11	30
Storm Composite	5/25/2018 3:58	5/25/2018 7:29	49	14	1.30	0.123	0.060	0.00790	0.00210	0.00150	0.02660	<0.00020	0.00230	638.4	0.08	0.27	0.25	43
Storm Grab	5/30/2018 10:25	5/30/2018 10:25	11	5	1.40	0.089	~0.032	0.00450	0.00110	~0.00046	0.00970	<0.00020	0.00097	382.8	0.03	0.30	0.20	51
Storm Composite	6/17/2018 23:39	6/18/2018 7:29	18	5	0.86	0.082	<0.020	0.00490	0.00130	0.00069	0.01570	<0.00020	0.00140	189.6	<0.03	0.20	0.08	31
Storm Composite	6/26/2018 2:59	6/26/2018 13:45	16	5	0.96	0.128	0.055	0.00420	0.00150	0.00069	0.01670	<0.00020	0.00140	211.8	<0.03	0.12	~0.05	33
Storm Composite	7/1/2018 10:38	7/1/2018 20:02	11	4	0.95	0.098	~0.024	0.00380	0.00120	0.00053	0.01040	<0.00020	0.00130	152.1	<0.03	0.13	<0.02	26
Storm Composite	7/4/2018 10:34	7/4/2018 16:55	20	8	0.95	0.101	~0.027	0.00510	0.00150	0.00085	0.01640	~0.00030	0.00140	138.8	<0.03	0.17	0.10	27
Storm Composite	7/12/2018 17:54	7/12/2018 18:52	97	20	1.00	0.180	~0.029	0.00970	0.00260	0.00210	0.04460	<0.00020	0.01190	31.0	<0.03	0.30	0.17	<8
Storm Composite	8/24/2018 11:33	8/24/2018 20:51	34	10	1.10	0.163	0.062	0.00550	0.00210	0.00160	0.02220	<0.00020	0.00350	73.4	0.03	0.22	0.17	~13
Storm Composite	9/4/2018 17:38	9/5/2018 1:31	11	5	0.63	0.082	~0.030	0.00440	0.00190	0.00068	0.01140	~0.00021	0.00200	29.3	<0.03	0.11	~0.02	~14
Storm Composite	9/20/2018 11:22	9/20/2018 17:44	24	8	0.69	0.098	~0.024	0.00430	0.00120	0.00084	0.01440	<0.00020	0.00310	24.4	<0.03	0.17	0.10	~19
Storm Composite	10/9/2018 19:05	10/10/2018 0:53	24	10	0.44	0.055	~0.033							14.4	<0.03	0.15	<0.02	
Base Grab	10/4/2018 11:17	10/4/2018 11:17	8	4	0.62	~0.047	<0.020	0.00350	0.0008	~0.00049	<0.00500	<0.00020	0.00100	21.0	<0.03	0.15	0.07	~10
Base Grab	10/18/2018 13:08	10/18/2018 13:08	~1	~1	0.28	<0.020	<0.020	0.00240	~0.00043	<0.00010	0.00370	<0.00020	<0.00050	17.3	<0.03	0.11	<0.02	~16

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

Table 18. Long Lake Drainage Historic Loading- Latest Ten Years

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Tributary to Long Lake at Marketplace Pond										
Discharge (cf)	25,597,268	29,863,356	26,344,111	15,175,332	18,276,274	7,444,468	22,983,609	23,534,188	15,250,645	15,970,846
Total pounds of Phosphorus exported	165	172	195	78	85	70	137	137	77	66
TP (lbs/ac/yr)	0.403	0.419	0.476	0.189	0.208	0.172	0.335	0.333	0.187	0.162
Total pounds of TSS exported	18,315	9,514	41,505	36,288	10,825	6,622	15,797	18,278	15,162	15,577
TSS (lbs/ac/yr)	46.67	23.21	101.23	88.51	26.40	16.15	38.53	44.58	36.98	37.99
Tributary to Long Lake at 62nd Street										
Discharge (cf)	1,526,291	2,215,192	3,270,239	468,704	2,922,109	3,687,553	1,413,178	2,824,017	1,811,811*	957,234*
Total pounds of Phosphorus exported	42	61	92	8	36	57	32	49	NA	NA
TP (lbs/ac/yr)	0.073	0.107	0.159	0.014	0.063	0.100	0.056	0.086	NA	NA
Total pounds of TSS exported	5,898	11,131	24,904	4,560	4,202	15,227	6,115	20,956	NA	NA
TSS (lbs/ac/yr)	10.26	19.36	43.31	7.93	7.31	26.48	10.63	36.45	NA	NA
	*Flow not estimated outside of logged data									

IV.C.4. McKusick Wetland Outlet

The tributary to Brown's Creek at McKusick Wetland Outlet discharges water through a pipe approximately 100 feet upstream of the McKusick Road monitoring station from a wetland complex at the headwaters of McKusick Lake. Based on aerial photo evidence it may also provide a "short circuit" for warm, nutrient rich water diverted by the Diversion Structure to be introduced into Brown's Creek after flowing through the wetland complex at the headwaters of McKusick Lake. Although not classified as a 2B water, for the purposes of this summary, the data collected will be compared to 2B TP and TSS standards.

4a. Discharge

Discharge at McKusick Wetland Outlet was calculated using an area velocity relationship during the period of recorded data. Periods of flow outside of recorded data were not estimated due to unfamiliarity with the off-season flow conditions of the site, and the fact that the wetland freezes in the winter and flow ceases. The recorded discharge to Brown's Creek was 8,319,145 cubic feet (Table 20). Throughout the season several plugs of debris and vegetation were forced through the pipe and dammed the downstream rip rap apron, causing water to back up into the station and negatively influence accurate discharge calculation. The stage and velocity sensor was also pulled from its mounting location by debris several times throughout the season, causing gaps in the data and discharge to be underestimated. As the pipe is constructed of plastic, more robust mounting options are limited. Velocity in excess of eight feet per second has been recorded at the site, and plugs of debris driven by high velocity water exert enough force to pull screws from the plastic. The pipe walls are also very smooth and often algae covered, and would likely make scissor rings or other manufactured retainers designed to hold sensors ineffective. Strategies for preventing data gaps in 2019 will include additional strapping and hardware, as well as more frequent site visits.

4b. Phosphorus & Sediment

The TP load during recorded data was estimated at 138.5 pounds of phosphorus, while the estimated TSS load was 5,072 pounds of sediment (Table 20). The concentrations of TSS and TP were not precipitation or stage dependent, indicating the wetland complex "pulses" nutrients, as opposed to a typical stream channel which receives nutrient contributions based on precipitation events in addition to internal stream processes. As such, TP and TSS loads were calculated by averaging samples with similar concentrations based on seasonality, and applying the average concentration to the recorded discharge for the time period. This is consistent with the load calculation method used in 2017. Regressions of discharge and phosphorus and sediment concentrations using results from both years of data produced similar results, within 14% for TSS and 7% for TP. As such, the method of applying average concentrations to seasonal periods was used again for simplicity and consistency between years. It is important to note the characteristics of the site and

sampling strategy do not allow for load calculations as precise as other monitored sites, i.e. composite sampling, and a high degree of variability exists even between samples taken in similar time periods.

Samples collected show the site meets the 2B standard of 30 mg/L of TSS for all months, but exceeds the standard of 0.100 mg/L of TP for nearly all months (Table 19). The water discharging from the wetland is low in suspended sediment and other materials, but quite high in phosphorus, a large fraction of which is dissolved phosphorus. This is typical of wetlands, which break down organic materials while filtering particulate matter, but can have negative effects on receiving waters such as Brown's Creek by contributing large amounts of nutrients readily available to organisms like algae.

Table 19. McKusick Wetland Outlet 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)	*E. coli* (mpn/100 mL)
Snowmelt Grab	4/23/2018 8:43	4/23/2018 8:43	~3	~3	0.67	0.093	~0.029	0.00130	~0.00041	~0.00027	<0.00500	<0.00020	~0.00014	24.9	<0.03	0.06	0.16	80	
Base Grab	5/30/2018 10:05	5/30/2018 10:05	14	~9	1.00	0.465	0.099	<0.00030	~0.00057	~0.00027	0.00230	<0.00020	0.00020	35.4	<0.03	<0.05	0.10	173	162
Storm Grab	6/18/2018 13:34	6/18/2018 13:34	12	~7	1.00	0.380	0.161	~0.00035	~0.00053	~0.00014	~0.00150	<0.00020	0.00032	31.4	<0.03	<0.05	0.08	132	
Base Grab	6/27/2018 8:24	6/27/2018 8:24	12	~7	0.83	0.403	0.119	<0.00030	<0.00030	~0.00018	~0.00100	<0.00020	0.00021	21.7	<0.03	<0.05	0.10	134	
Storm Grab	7/13/2018 9:11	7/13/2018 9:11	6	~4	1.10	0.198	0.075	~0.00047	0.00078	~0.00020	0.00230	<0.00020	0.00027	14.8	<0.03	<0.05	<0.02	61	
Base Grab	7/25/2018 9:37	7/25/2018 9:37	13	~7	0.97	0.396	0.163	<0.00030	~0.00042	~0.00013	<0.00500	<0.00020	0.00032	44.4	<0.03	<0.05	0.09	145	
Base Grab	8/22/2018 9:05	8/22/2018 9:05	19	8	1.10	0.385	0.064	<0.00030	0.00061	~0.00035	0.00200	<0.00020	0.00037	44.7	<0.03	<0.05	0.11	157	
Storm Grab	9/5/2018 13:35	9/5/2018 13:35	7	5	0.92	0.213	0.097	~0.00031	~0.00056	<0.00100	<0.00500	<0.00020	0.00023	29.4	<0.03	<0.05	~0.04	103	
Storm Grab	9/20/2018 9:14	9/20/2018 9:14	18	~9	0.97	0.321	0.060	<0.00500	~0.00049	~0.00037	<0.01000	<0.00020	0.00044	35.0	<0.03	<0.05	0.13	173	
Base Grab	9/27/2018 8:44	9/27/2018 8:44	4	~2	0.54	0.097	~0.038	<0.00030	~0.00035	~0.00018	<0.00500	<0.00020	0.00019	37.3	<0.03	<0.05	~0.04	128	
Base Grab	10/18/2018 14:29	10/18/2018 14:29	~1	~1	0.38	~0.025	<0.020	<0.00030	<0.00030	<0.00010	<0.00080	<0.00020	<0.00050	75.2	<0.03	<0.05	<0.02	98	

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

Table 20. McKusick Wetland Outlet 2018 Discharge and Loading Estimates

Period	Total Flow (cf)	Total Flow (ac-ft)	Average TP Concentration (mg/L)	TP Range (mg/L)	Average TSS Concentration (mg/L)	TSS Range (mg/L)	TP Load (lbs.)	TSS Load (lbs.)
4/26-5/1	482,027	11.07	0.093	N/A	3	N/A	2.8	90
5/1-6/27	2,304,640	52.93	0.416	0.380-0.465	13	12-14	59.8	1,870
7/11-7/13, 7/25-9/3, 9/5-10/1	4,430,938	101.77	0.268	0.097-0.396	11	4-19	74.1	3,043
10/1-10/11	1,101,540	25.30	0.025	N/A	1	N/A	1.7	69
Total	**8,319,145**	**191.08**					**138.5**	**5,072**

4c. Temperature

Thermal data recorded at McKusick Wetland Outlet show temperatures for the period of recorded data roughly 2.5 ºC higher, on average, than those recorded at McKusick Road when compared to the same period. The wetland is warmed by solar radiation and can reach high temperatures when precipitation events are not frequent enough to continuously flush cooler water through. Although the wetland outlet is not intended to be suitable for trout, when compared to TMDL thresholds of 18.3 ºC (threat level) and 23.9 ºC (critical level), water temperatures exceeded the thresholds 64.9% and 7.9%, respectively, of the monitoring period. It is important to compare temperatures to these thresholds because they directly influence temperatures in Brown's Creek when discharged upstream of the McKusick Road site. Comparing continuous temperature data of both sites, when temperatures in Brown's Creek at McKusick Road exceeded the threat level threshold the water discharged from McKusick Wetland Outlet was also over the threat level threshold 100% of the time, meaning at no time during stressful periods for trout does the wetland contribute cooler water to the creek. Trout have been observed and stocked in the reach of Brown's Creek the wetland outlet discharges to, but only during spring and fall when water temperatures are cooler. Managing or eliminating thermal inputs to Brown's Creek from the wetland would likely improve conditions for trout survival during the warmest periods of the year. The District is considering a project with the Oak Glen Golf Course to divert the water from the wetland to a holding pond which will then be used for irrigation, effectively eliminating the direct discharge from the wetland.

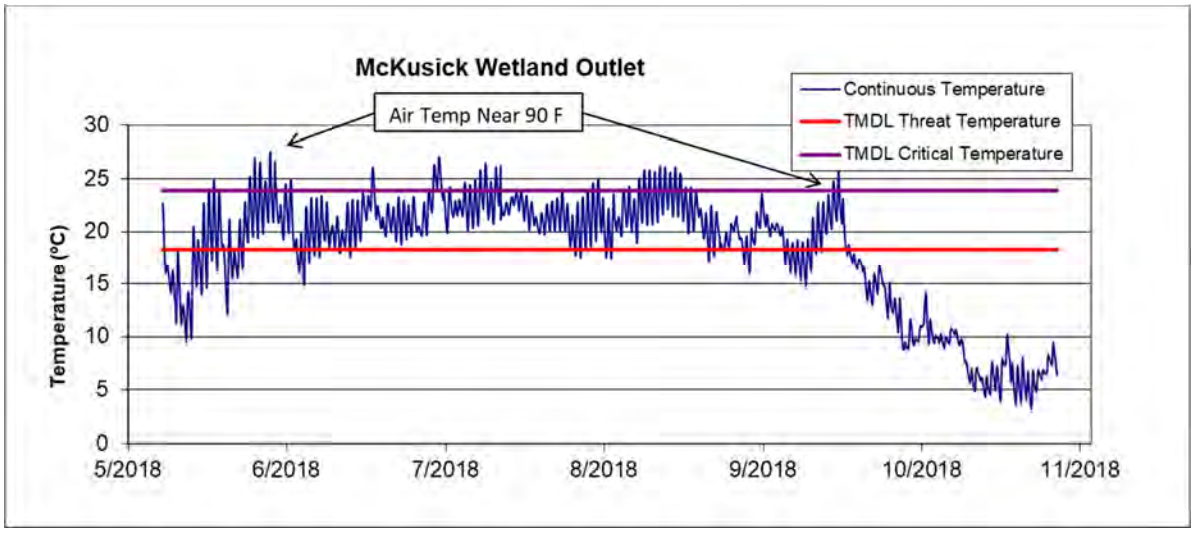


Figure 11. McKusick Wetland Outlet 2018 Continuous Temperature

V. RECOMMENDATIONS

- Expand monitoring on Benz Lake according to the Benz Lake Management Plan, including monitoring the inlet of Benz Lake and collecting winter temperature and dissolved oxygen data.
- Expand monitoring on Masterman Lake according to the Masterman Lake Management Plan including conducting bi-annual macrophyte surveys.
- Perform macrophyte surveys on lakes that are lacking data.
- Continue collecting water quality and continuous discharge data at existing monitoring stations to determine long term trends.
- Install a stage sensor near the Jackson WMA Pond outlet to differentiate hydrograph anomalies at the Diversion Structure.
- Continue investigation to identify possible causes of the anomalies observed in the diversion drainage.
- Investigate alternative mounting locations and strategies at McKusick Wetland Outlet to eliminate data gaps.
- Consider modifying sampling on Brown's Creek to match Metropolitan Council's WOMP program using unbiased sampling regimes as opposed to storm/event based sampling to allow for more rigorous statistical trend analysis.

APPENDIX A - WATER QUALITY DATA – BY LAKE

Brown's Creek Watershed Lakes: Bass East, Bass West, Benz, Brewer's Pond, Goggins, Heifort's Pond, Jackson WMA, July Avenue, Kismet, Long (North Basin), Lynch North, Lynch South, Masterman, North School Section, Pat, Plaisted, South School Section, and Woodpile

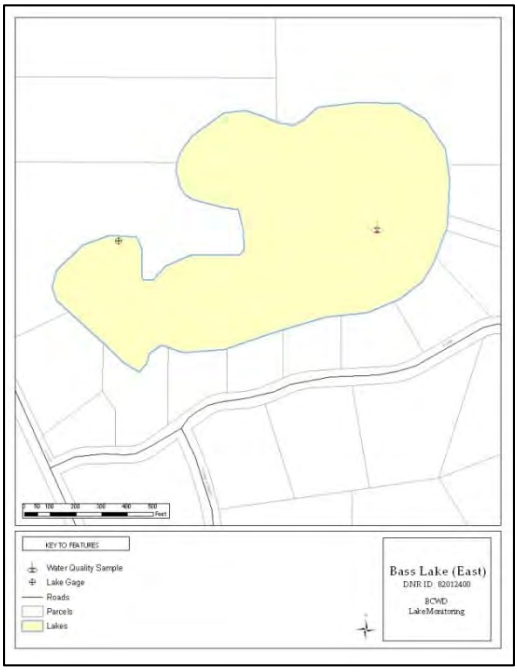
Lake grades are assessed using the Metropolitan Council's lake grade system. Grades are determined based on May through September averages of total phosphorus concentration, uncorrected trichromatic chlorophyll-α concentration, and Secchi disk transparency.

The Minnesota Pollution Control Agency uses the June through September average to assess impairment status of a lake based on total phosphorus concentration, pheophytin-corrected chlorophyll-α concentration, and Secchi disk transparency.

Bass Lake (East)

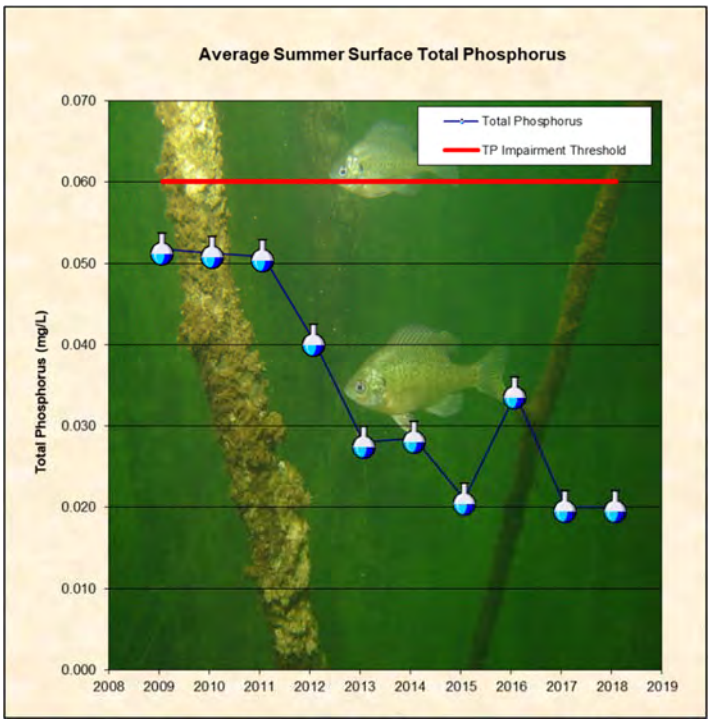
2018 Lake Grade: A-

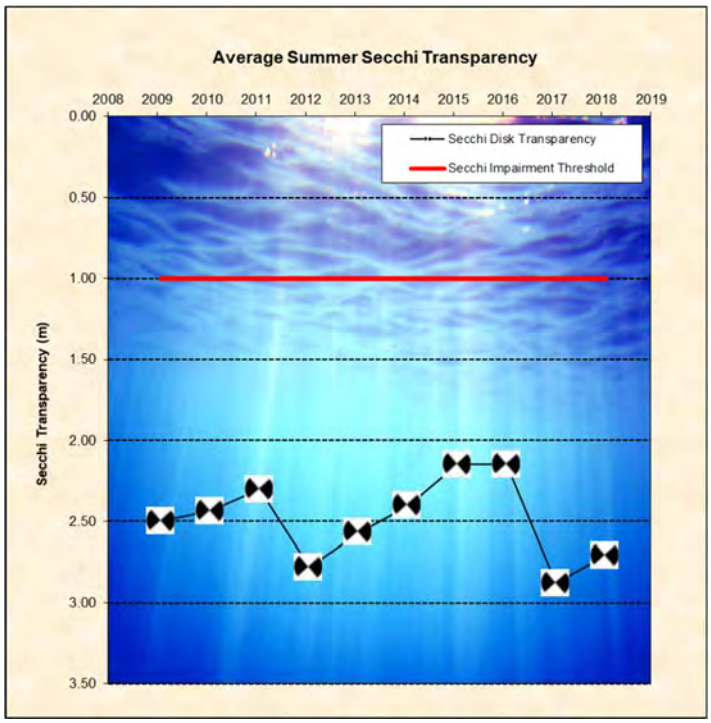
- DNR ID #: 820124
- Municipality: City of Grant
- Location: Section 10, T30N-R21W
- Lake Size: 29 Acres
- Maximum Depth (2018): 18.5 ft
- Ordinary High Water Mark: 960.20 ft
- 100-Year High Water Level: 960.40 ft
- 99% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as mesotrophic according the Carlson Trophic State Index.
- Using the Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for average total phosphorus and average chlorophyll-α, and the trend for the average Secchi transparency is skewed due to vegetation limiting the transparency.
- The major land use is rural/agricultural.
- The lake stratified in 2018 with a thermocline around 3 meters.
- This lake is categorized as shallow according to the Minnesota Pollution Control Agency's standards.





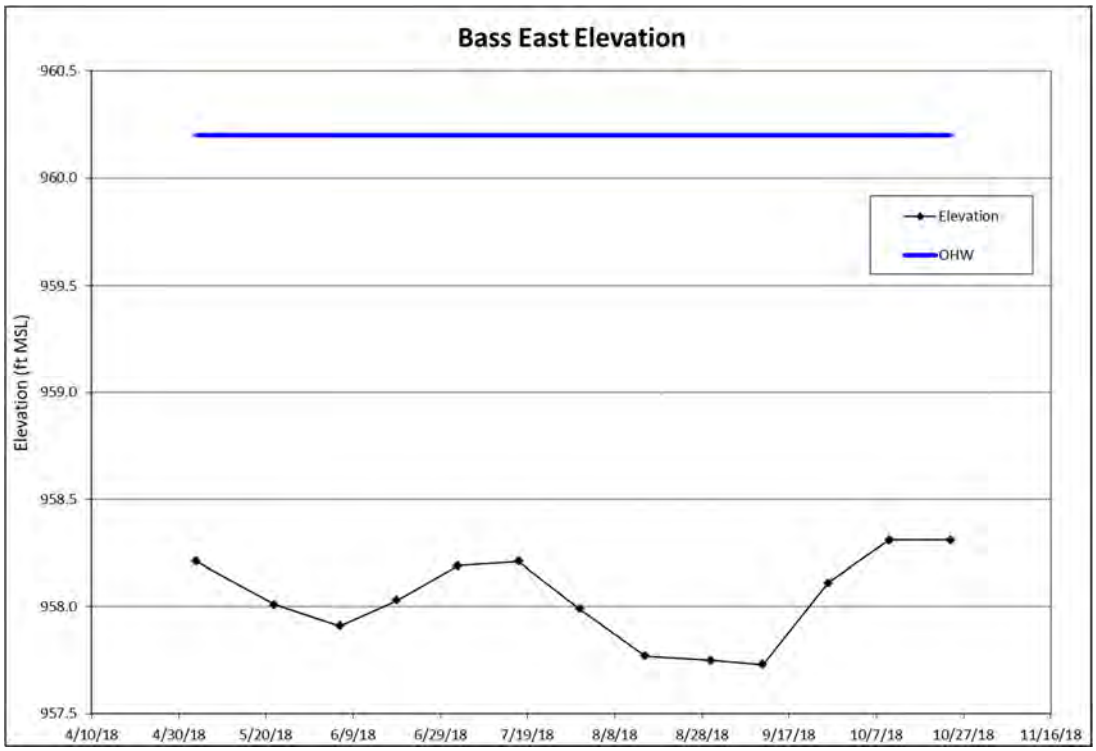
Date/Time	Total Phosphorus (mg/L)	Trichromatic Uncorrected Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/8/2018 15:21	0.020	6.0	5.3	0.60	1.83	19.8	10.09
5/22/2018 11:19	0.021	4.0	4.1	0.56	2.90	19.6	9.64
6/6/2018 11:24	0.021	2.8	2.4	0.59	3.35	22.7	9.55
6/19/2018 13:34	0.021	7.8	6.6	0.62	2.74	24.5	7.10
7/3/2018 11:34	0.024	13.0	13.0	0.69	2.44	26.4	8.76
7/17/2018 12:11	0.024	12.0	12.0	0.79	2.13	28.6	8.03
7/31/2018 9:34	0.015	5.2	4.0	0.77	2.59	26.1	7.49
8/15/2018 10:03	0.015	4.7	4.1	0.81	2.29	27.5	8.03
8/30/2018 8:54	0.027	5.5	4.4	0.77	2.90	21.7	5.09
9/11/2018 14:27	0.012	3.4	2.3	0.56	2.90	23.1	8.39
9/26/2018 10:14	0.025	7.0	6.0	0.61	3.05	17.1	5.52
10/10/2018 14:15	0.035	3.8	2.6	0.66	4.72	11.2	7.58
2018 Average	0.022	6.3	5.6	0.67	2.82	22.4	7.94
2018 Summer Average	0.020	6.8	6.1	0.69	2.71	24.2	7.55

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)	958.31	10/10/2018	957.73	9/11/2018	958.04

*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."

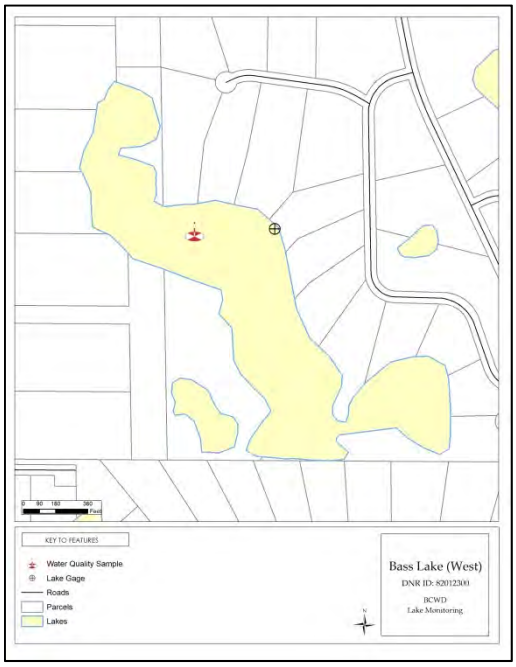


Lake Water Quality Summary										
	Lake Grades									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	A	A	C	A	B	B	C	C	C	C
Chlorophyll-*a* (ug/l)	A	A	A	A	A	A	A	B	A	B
Secchi depth (ft)	B	B	B	C	B	B	B	B	B	B
Overall	**A-**	**A-**	**B**	**B+**	**B+**	**B+**	**B**	**B-**	**B**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

Bass Lake (West)

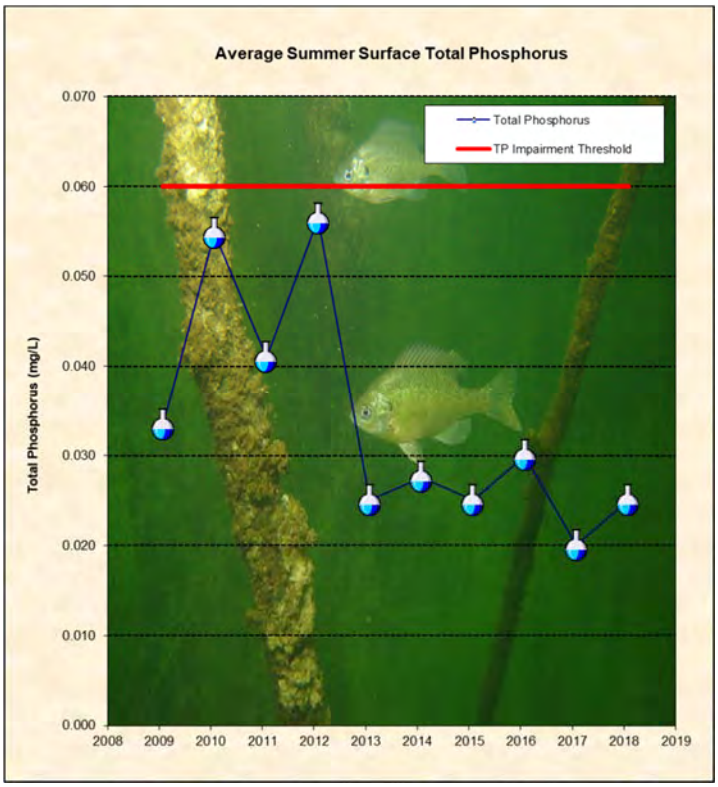
2018 Lake Grade: B+

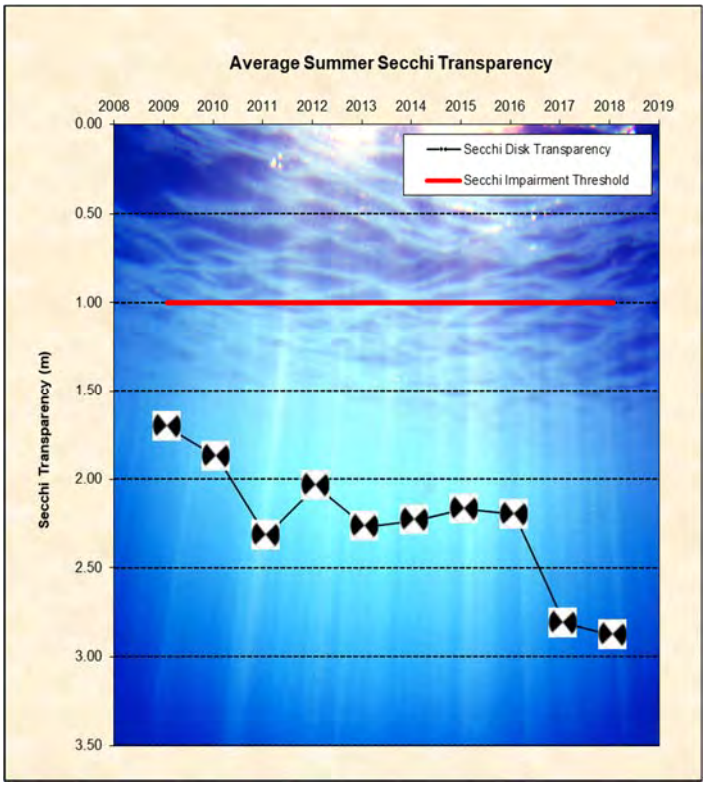
- DNR ID #: 820123
- Municipality: City of Grant
- Location: Section 10, T30N-R21W
- Lake Size: 72 Acres
- Maximum Depth (2018): 15 ft
- Ordinary High Water Mark: 952.60 ft
- 100-Year High Water Level: 955.90 ft
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as mesotrophic according the Carlson Trophic State Index.
- Using the Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for average total phosphorus and average chlorophyll-α, and the trend for the average Secchi transparency is skewed due to vegetation limiting the transparency.
- The major land use is rural/agricultural.
- The lake stratified in 2018 with a thermocline around 3 meters.
- This lake is categorized as shallow according to the Minnesota Pollution Control Agency's standards.





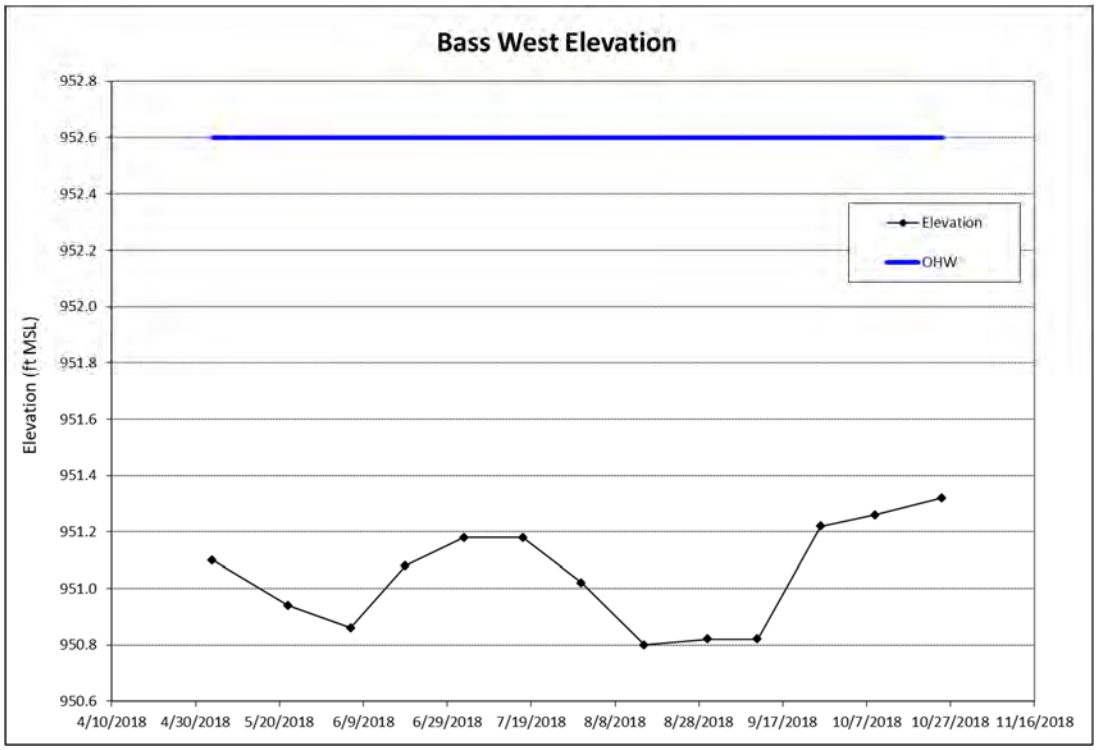
Date/Time	Total Phosphorus (mg/L)	Trichromatic Uncorrected Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/8/2018 14:54	0.022	2.9	2.5	0.75	3.05	19.1	7.83
5/22/2018 10:53	0.018	2.1	1.5	0.64	3.66	19.0	8.05
6/6/2018 11:47	0.011	5.5	4.9	0.71	3.35	22.7	7.89
6/19/2018 12:59	0.020	4.4	5.2	0.71	2.74	24.4	6.44
7/3/2018 11:11	0.067	3.4	3.3	0.71	3.05	26.3	7.70
7/17/2018 11:43	0.021	5.1	4.5	0.72	2.44	28.1	5.89
7/31/2018 9:00	0.020	2.2	1.5	0.75	2.90	25.5	6.84
8/15/2018 10:24	0.023	7.7	6.4	0.75	3.05	27.3	7.27
8/30/2018 9:22	0.024	6.2	4.2	0.73	1.98	21.5	3.47
9/11/2018 13:58	0.016	3.4	2.9	0.77	3.66	22.5	7.26
9/26/2018 10:41	0.021	4.2	3.3	0.76	2.74	17.2	4.13
10/9/2018 11:58	0.027	4.0	3.4	0.72	3.66	11.8	5.83
2018 Average	0.024	4.3	3.6	0.73	3.02	22.1	6.55
2018 Summer Average	0.025	4.7	4.0	0.73	2.88	23.9	6.32

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)	951.32	10/25/2018	950.80	8/15/2018	951.05

*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."

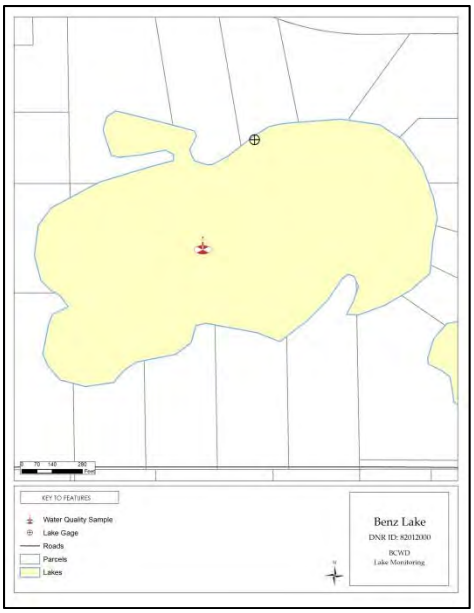


Lake Water Quality Summary										
	Lake Grades									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	B	A	B	B	B	B	C	C	C	C
Chlorophyll-*a* (ug/l)	A	A	A	A	A	A	B	A	B	B
Secchi depth (ft)	B	B	B	C	B	B	C	B	C	C
Overall	**B+**	**A-**	**B+**	**B**	**B+**	**B+**	**C+**	**B**	**C+**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

Benz Lake

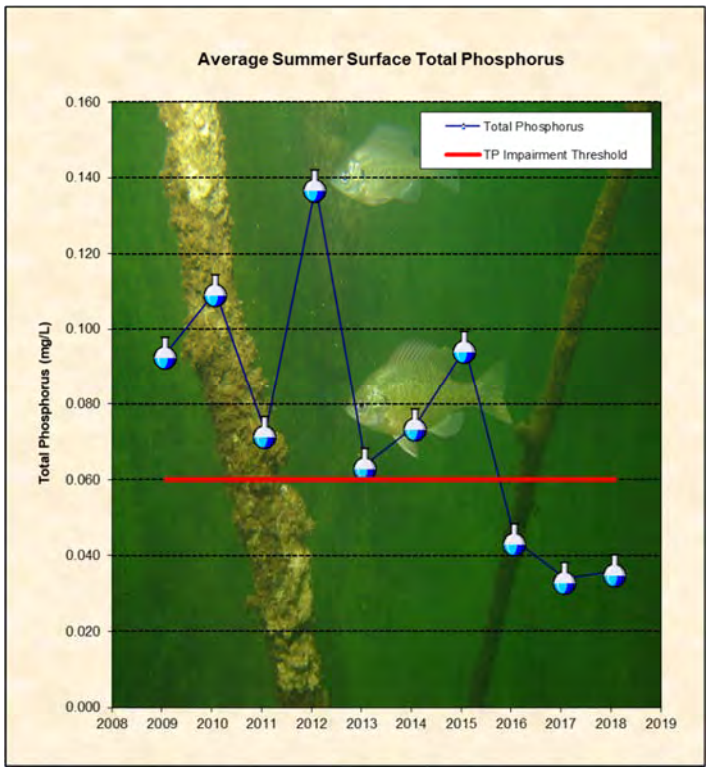
2018 Lake Grade: B-

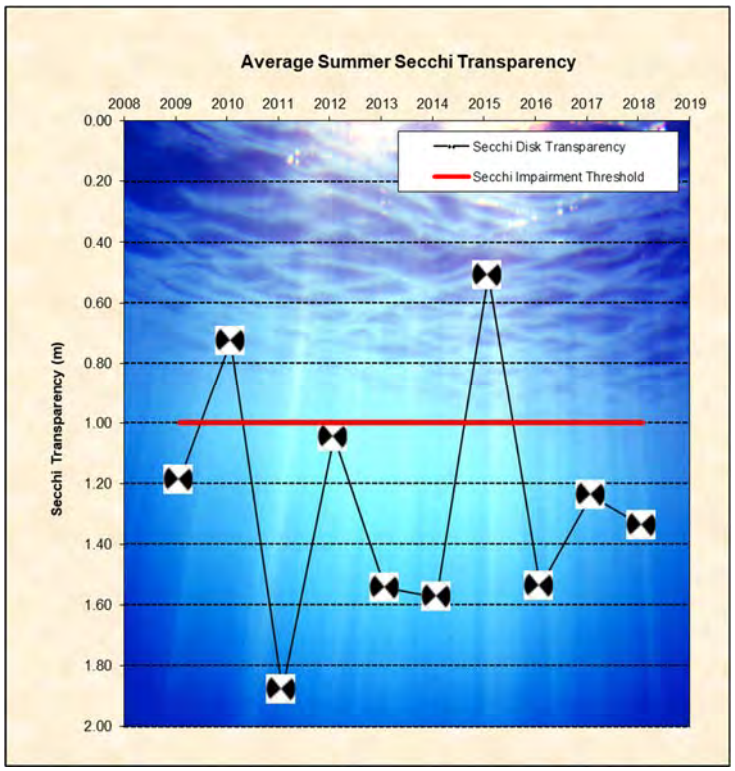
- DNR ID #: 820120
- Municipality: City of Grant
- Location: SE$^{1/4}$ Section 2, T30N-R21W
- Lake Size: 40 Acres
- Maximum Depth (2018): 8.5 ft
- Ordinary High Water Mark: 958.90 ft
- 100-Year High Water Level: 956.20 ft
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as eutrophic according the Carlson Trophic State Index.
- Using the Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for average total phosphorus and average chlorophyll-α, and the trend for the average Secchi transparency is skewed due to vegetation limiting the transparency.
- The major land use is rural/agricultural.
- The lake did not stratify in 2018.
- This lake is categorized as shallow according to the Minnesota Pollution Control Agency's standards.
- Benz Lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List.





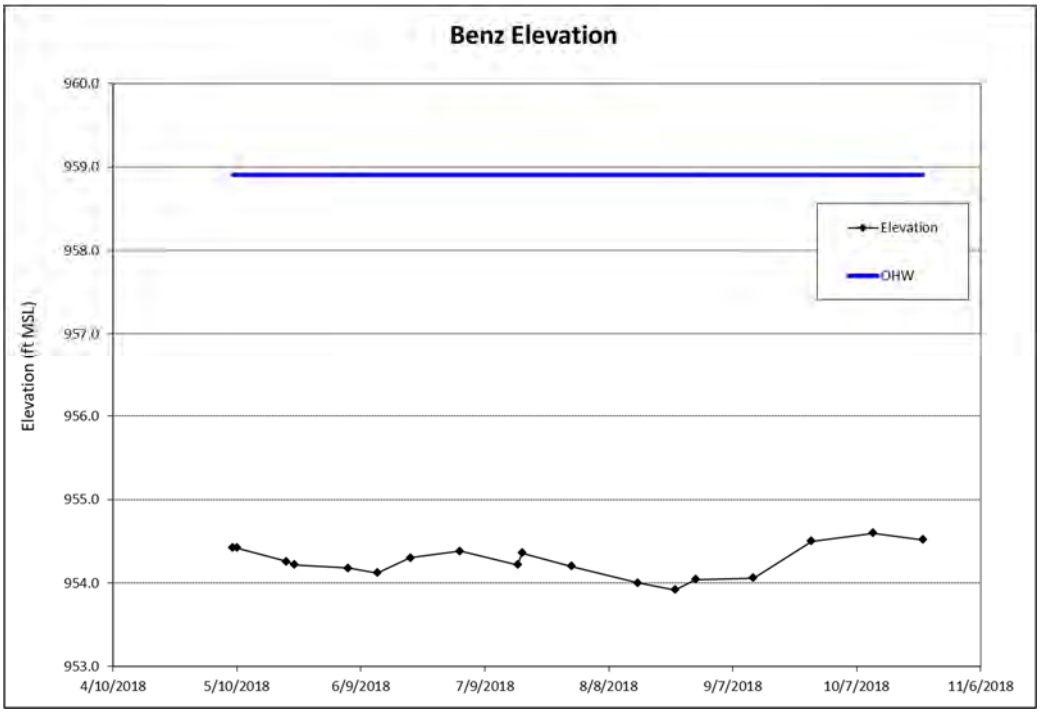
Date/Time	Total Phosphorus (mg/L)	Trichromatic Uncorrected Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/8/2018 9:29	0.037	11.0	9.9	0.71	1.83	19.8	11.48
5/22/2018 9:54	0.052	17.0	16.0	0.81	1.37	19.4	10.88
6/6/2018 13:45	0.051	22.0	21.0	1.10	0.61	22.9	12.54
6/21/2018 9:10	0.047	9.6	8.5	0.89	0.46	23.9	9.54
7/3/2018 9:51	0.030	6.1	5.6	0.69	1.52	25.8	9.70
7/18/2018 8:26	0.026	3.0	2.6	0.74	1.37	27.0	9.17
7/30/2018 14:30	0.024	4.4	4.2	0.76	1.52	27.2	9.80
8/15/2018 9:39	0.017	3.5	3.3	0.68	1.52	27.2	8.78
8/29/2018 10:13	0.050	5.5	4.1	0.69	1.52	21.8	2.89
9/12/2018 8:25	0.047	8.1	7.2	0.71	1.68	22.1	9.46
9/26/2018 8:14	0.031	14.0	13.0	0.62	1.83	16.7	6.72
10/11/2018 12:25	0.026	3.8	2.9	0.52	2.13	9.6	9.05
2018 Average	0.037	9.0	8.2	0.74	1.45	22.0	9.17
2018 Summer Average	0.036	8.5	7.7	0.76	1.34	23.8	8.73

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)	954.60	10/11/2018	953.92	8/24/2018	954.26

*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."

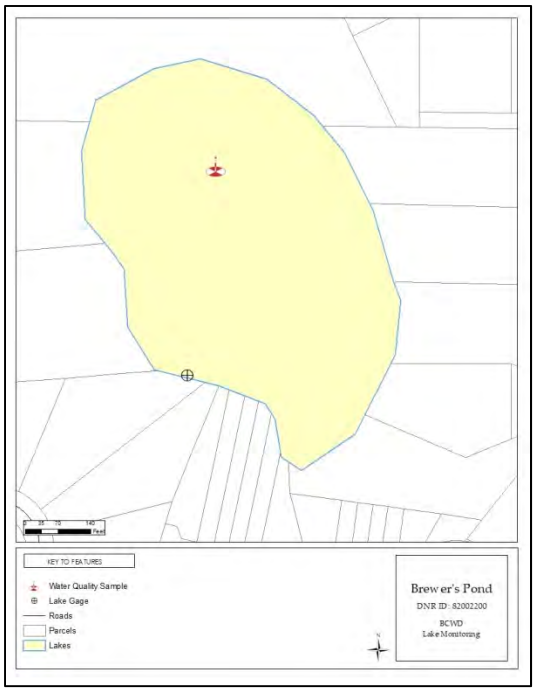


Lake Water Quality Summary										
	Lake Grades									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	C	C	C	D	D	C	D	D	D	D
Chlorophyll-*a* (ug/l)	A	A	A	D	B	B	C	B	D	C
Secchi depth (ft)	C	D	C	F	C	C	C	C	D	D
Overall	**B-**	**C+**	**B-**	**D-**	**C**	**C+**	**C-**	**C**	**D**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

Brewer's Pond

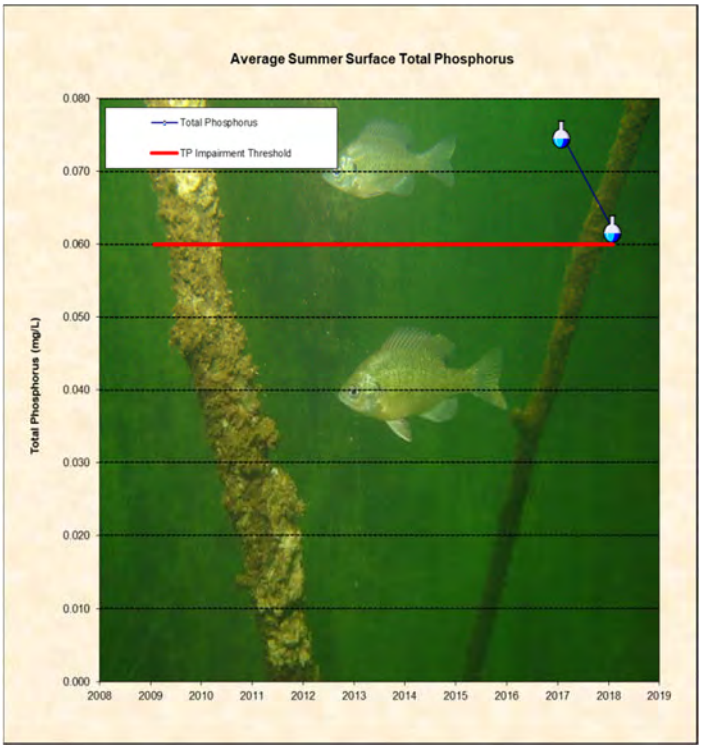
2018 Lake Grade: D

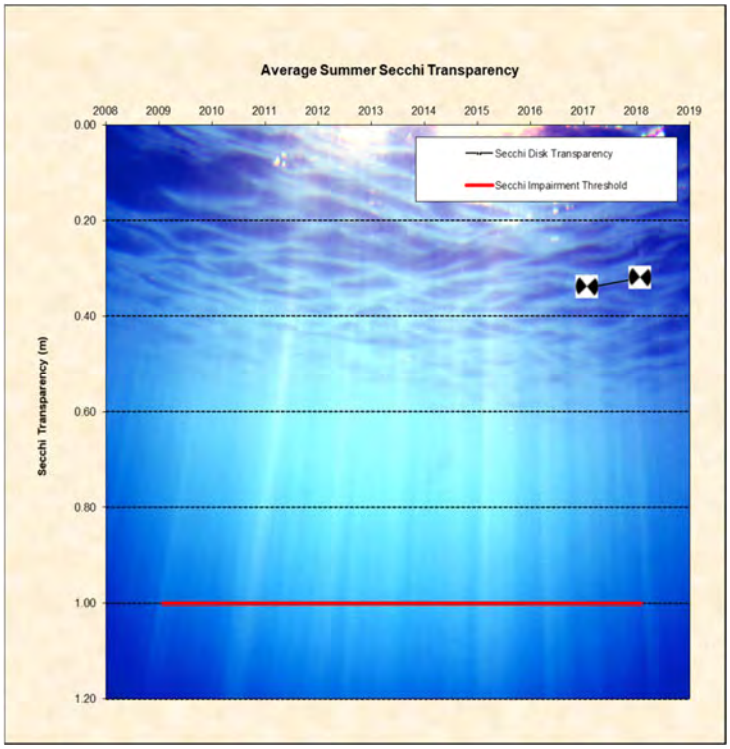
- DNR ID #: 820022
- Municipality: City of Stillwater
- Location: SE$^{1/4}$ Section 31, T30N-R20W
- Lake Size: 9 Acres
- Maximum Depth (2018): 13.5 ft
- Ordinary High Water Mark: 891.90 ft
- 100-Year High Water Level: 893.85ft
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as hypereutrophic according the Carlson Trophic State Index.
- There are an insufficient number of years of data to determine a trend for the average total phosphorus, average chlorophyll-α, and the average Secchi transparency.
- The major land use is urban/residential.
- The lake stratified in 2018 with a thermocline between 2 and 3 meters.
- This lake is categorized as shallow according to the Minnesota Pollution Control Agency's standards.





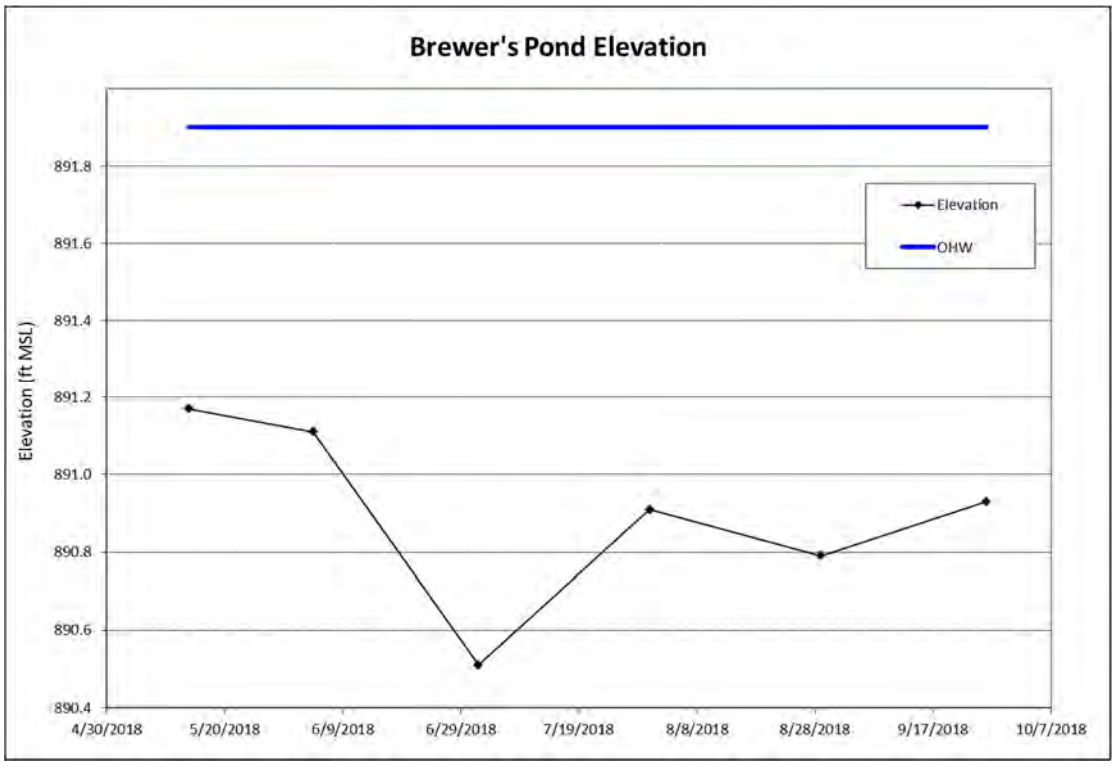
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/7/2018 14:25	0.078	66.0	64.0	2.40	0.15	20.5	15.83
6/4/2018 13:47	0.060	25.0	24.0	2.00	0.30	22.3	8.48
7/2/2018 13:29	0.069	35.0	34.0	2.30	0.15	27.3	10.30
7/31/2018 11:03	0.058	66.0	59.0	3.00	0.23	25.3	7.67
8/29/2018 13:43	0.057	78.0	74.0	2.60	0.46	22.5	5.88
9/26/2018 13:53	0.066	73.0	71.0	2.80	0.46	17.8	5.43
2018 Average	0.065	57.2	54.3	2.52	0.29	22.6	8.93
2018 Summer Average	0.062	55.4	52.4	2.54	0.32	23.0	7.55

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)	891.17	5/14/2018	890.51	7/2/2018	890.90

*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."

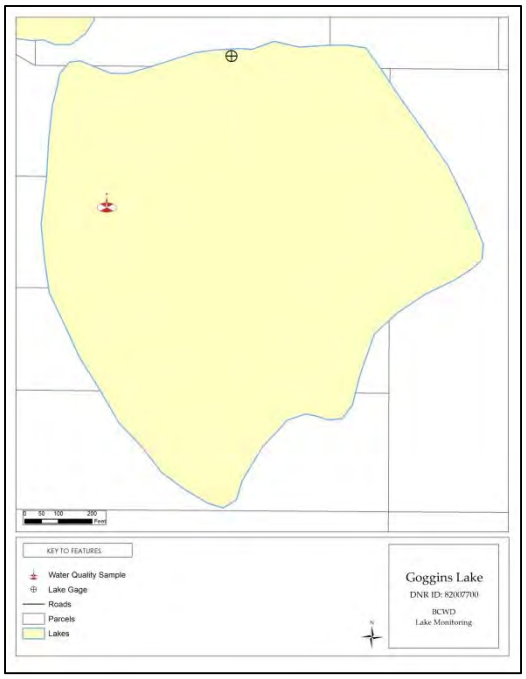


Lake Water Quality Summary										
	Lake Grades									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	C	D	NA	NA	NA	NA	NA	NA	NA	NA
Chlorophyll-*a* (ug/l)	D	D	NA	NA	NA	NA	NA	NA	NA	NA
Secchi depth (ft)	F	F	NA	NA	NA	NA	NA	NA	NA	NA
Overall	**D**	**D-**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Goggins Lake

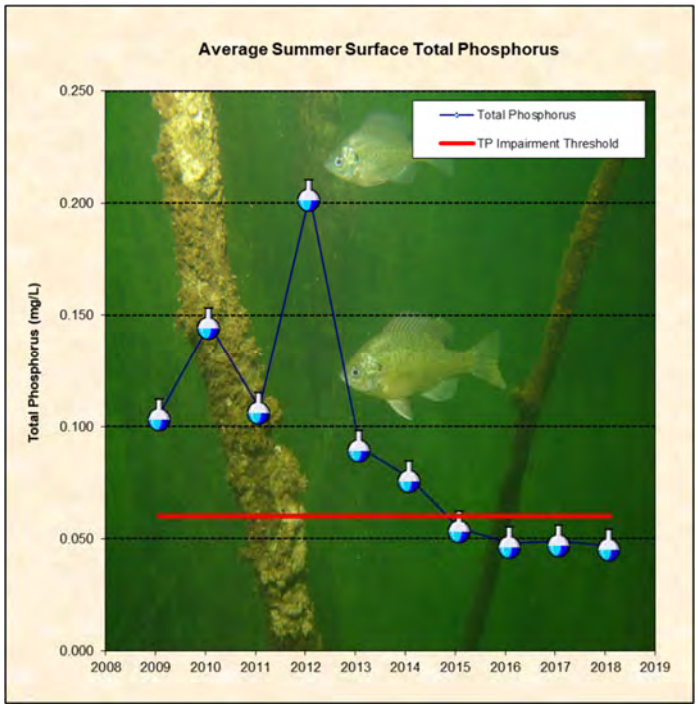
2018 Lake Grade: C+

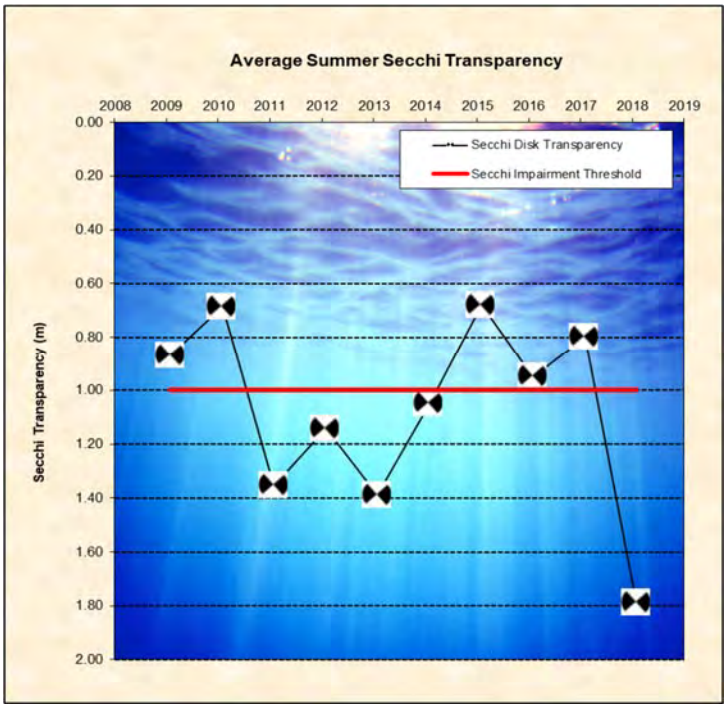
- DNR ID #: 820077
- Municipality: May Township
- Location: NW$^{1/4}$ Section 31, T31N-R20W
- Lake Size: 85 Acres
- Maximum Depth (2018): 17 ft
- Ordinary High Water Mark: 966.50 ft
- 100-Year High Water Level: 972.20 ft
- 99% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as eutrophic according to the Carlson Trophic State Index.
- Using the Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for the average total phosphorus and average chlorophyll-α, and no trend for the average Secchi transparency.
- The major land use is rural/agricultural.
- The lake stratified in 2018 with a thermocline around 3 meters.
- This lake is categorized as shallow according to the Minnesota Pollution Control Agency's standards.
- Goggins Lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List.





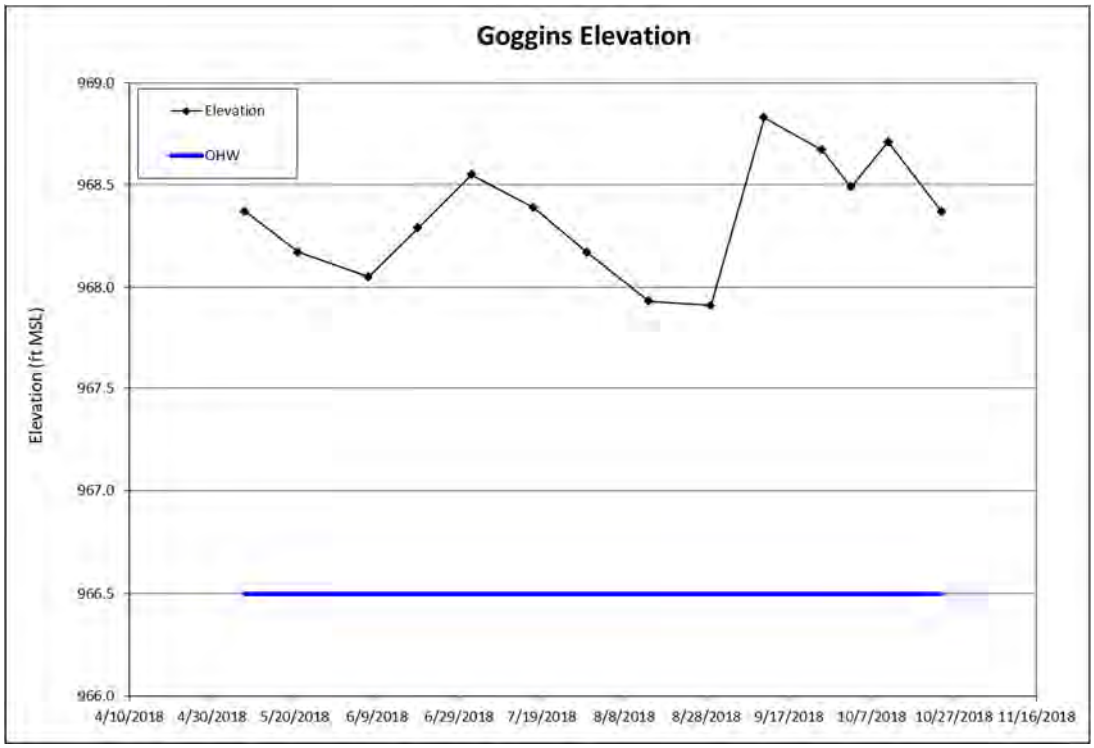
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/7/2018 10:25	0.061	34.0	31.0	1.50	0.76	18.2	12.70
5/21/2018 10:31	0.044	1.0	4.7	1.10	2.74	18.1	7.82
6/7/2018 9:51	0.038	9.0	8.4	1.20	2.59	21.8	8.52
6/19/2018 10:42	0.041	10.0	8.9	1.10	2.29	23.8	6.96
7/2/2018 10:03	0.057	23.0	21.0	1.20	1.83	25.5	6.66
7/17/2018 10:37	0.038	18.0	16.0	1.10	1.37	27.2	7.76
7/30/2018 11:31	0.048	29.0	30.0	1.50	1.07	25.6	9.55
8/14/2018 10:55	0.047	20.0	20.0	1.30	1.52	27.6	9.98
8/29/2018 8:12	0.048	22.0	19.0	1.80	1.98	21.6	4.02
9/11/2018 11:16	0.044	16.0	14.0	1.40	1.68	21.5	8.01
9/25/2018 10:27	0.059	28.0	26.0	1.40	1.83	18.1	7.33
10/11/2018 11:27	0.035	15.0	15.0	1.00	2.44	10.2	8.39
2018 Average	0.047	18.75	17.83	1.30	1.84	21.6	8.14
2018 Summer Average	0.047	19.44	18.14	1.33	1.79	23.6	7.64

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)	968.83	9/11/2018	967.91	8/29/2018	968.35

*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."

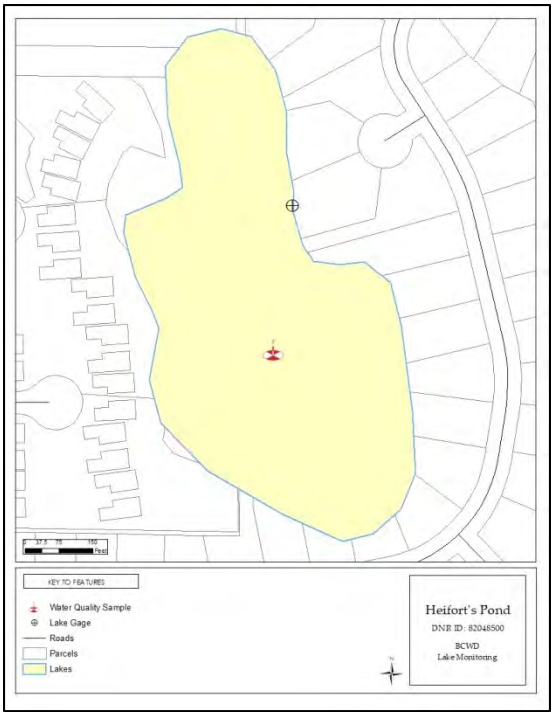


Lake Water Quality Summary										
	Lake Grades									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	C	C	C	C	D	D	F	D	D	D
Chlorophyll-*a* (ug/l)	B	C	C	C	C	C	C	C	D	C
Secchi depth (ft)	C	D	D	F	D	C	D	C	F	D
Overall	**C+**	**C-**	**C-**	**D+**	**D+**	**C-**	**D**	**C-**	**D-**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

Heifort's Pond

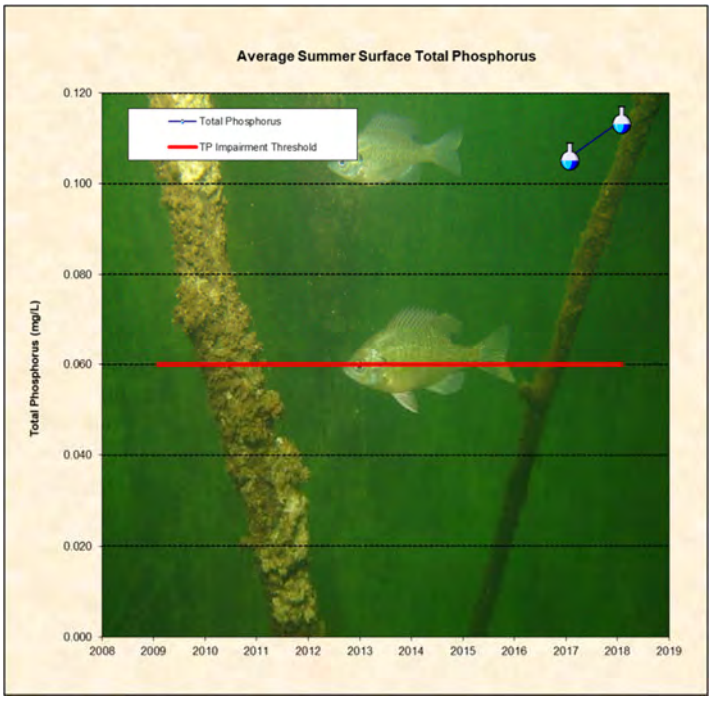
2018 Lake Grade: F+

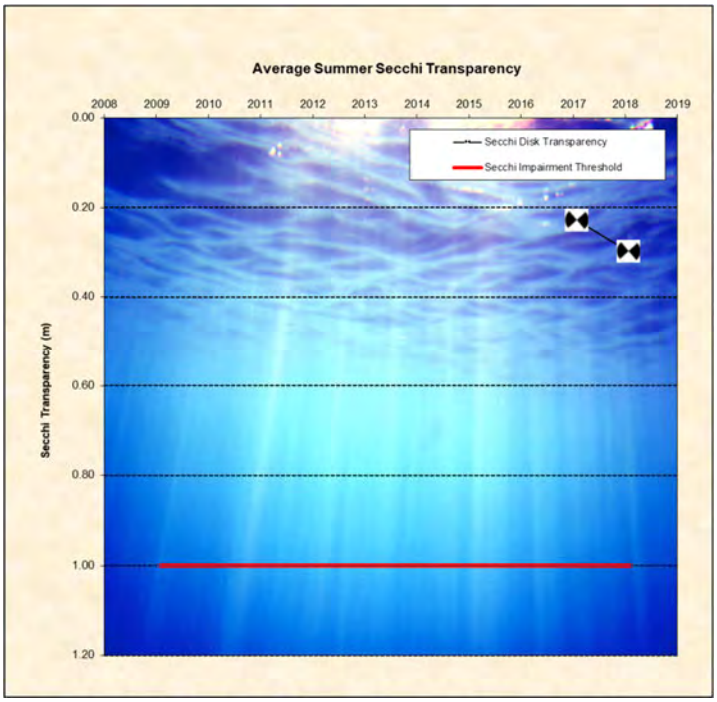
- DNR ID #: 820485
- Municipality: City of Stillwater
- Location: $NW^{1/4}$ Section 20, T30N-R20W
- Lake Size: 6 Acres
- Maximum Depth (2018): 8 ft
- Ordinary High Water Mark: 883.9 ft
- 100-Year High Water Level: 885.42 ft
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as hypereutrophic according to the Carlson Trophic State Index.
- Using the Kendall's Tau correlation test ($p<0.05$) there are an insufficient number of years of data to determine a trend for the average total phosphorus, average chlorophyll-α, and the average Secchi transparency.
- The major land use is urban/residential.
- The lake did not stratify in 2018.
- This lake is categorized as shallow according to the Minnesota Pollution Control Agency's standards.





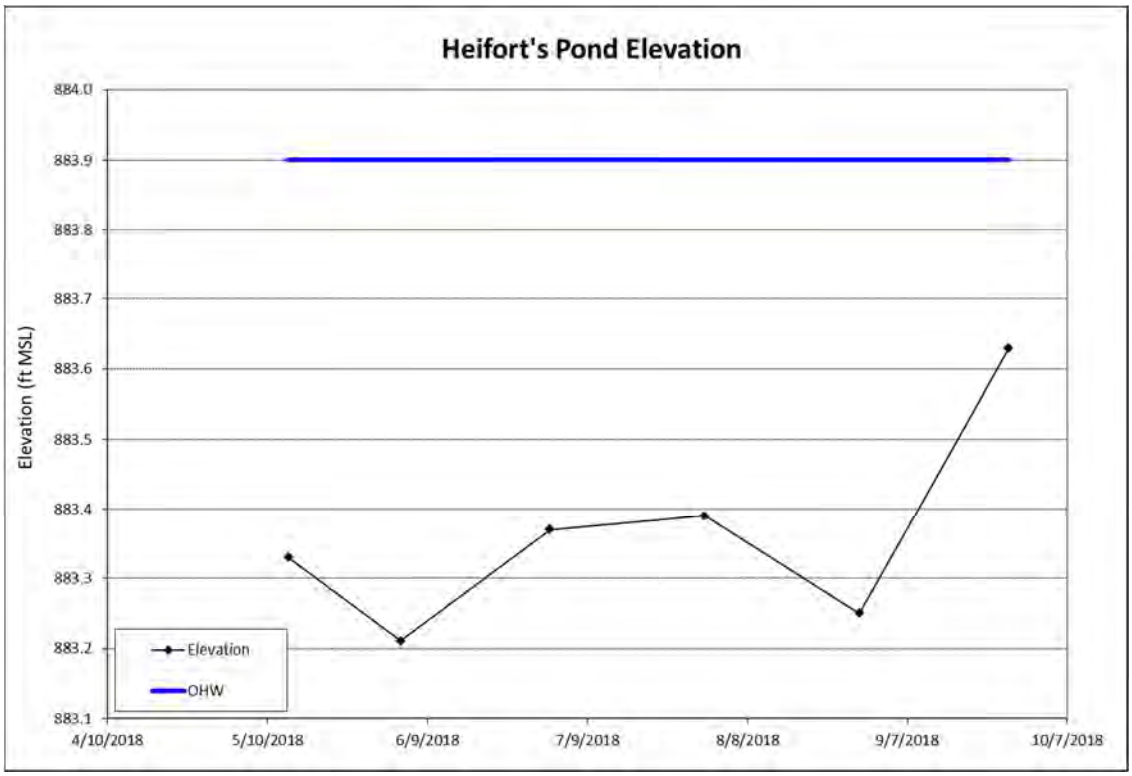
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/7/2018 13:15	0.090	50.0	48.0	2.3	0.46	21.8	11.05
6/4/2018 12:07	0.099	71.0	64.0	3	0.46	22.9	8.31
7/2/2018 11:50	0.076	80.0	75.0	2.6	0.46	26.9	7.15
7/31/2018 10:08	0.140	150.0	140.0	3.6	0.23	25.1	9.40
8/29/2018 11:45	0.091	150.0	140.0	3.4	0.23	20.9	4.61
9/26/2018 11:44	0.163	24.0	24.0	3.1	0.15	15.9	4.88
2018 Average	0.110	87.5	81.8	3.00	0.33	22.3	7.57
2018 Summer Average	0.114	95.0	88.6	3.14	0.30	22.3	6.87

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)	883.63	9/26/2018	883.21	6/4/2018	883.36

*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."

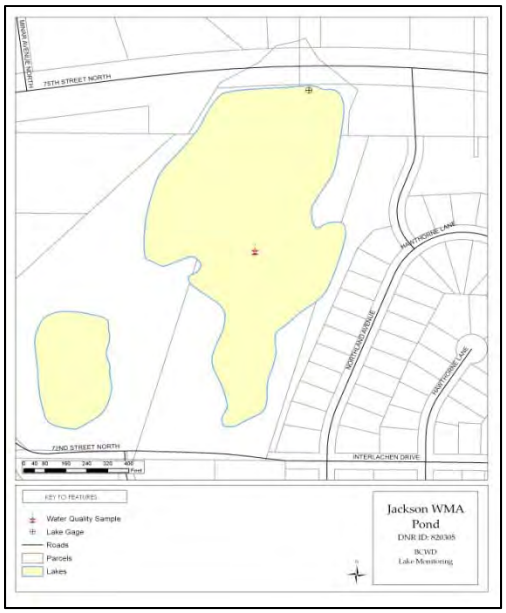


Lake Water Quality Summary										
	Lake Grades									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	D	D	NA	NA	NA	NA	NA	NA	NA	NA
Chlorophyll-*a* (ug/l)	F	F	NA	NA	NA	NA	NA	NA	NA	NA
Secchi depth (ft)	F	F	NA	NA	NA	NA	NA	NA	NA	NA
Overall	**F+**	**F+**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Jackson WMA Pond

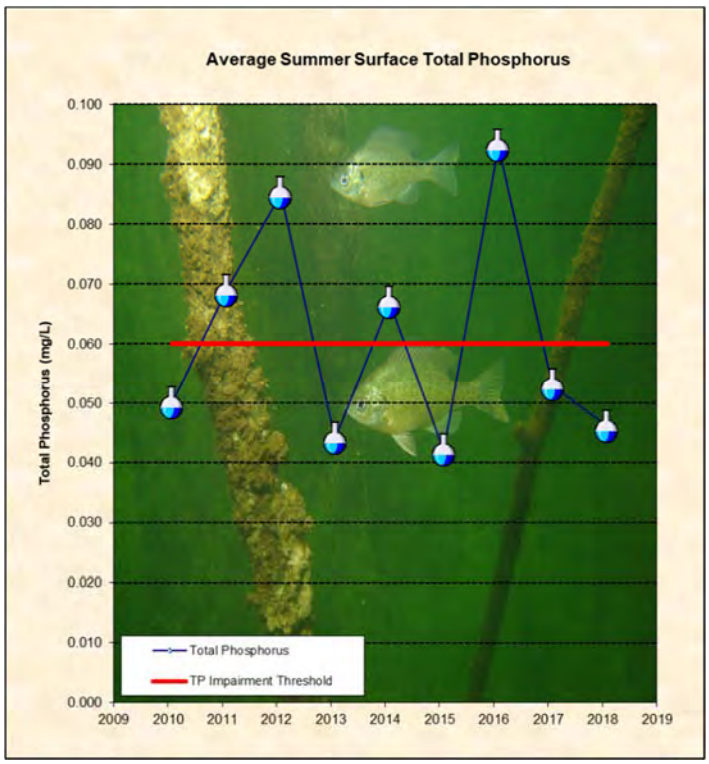
2018 Lake Grade: B-

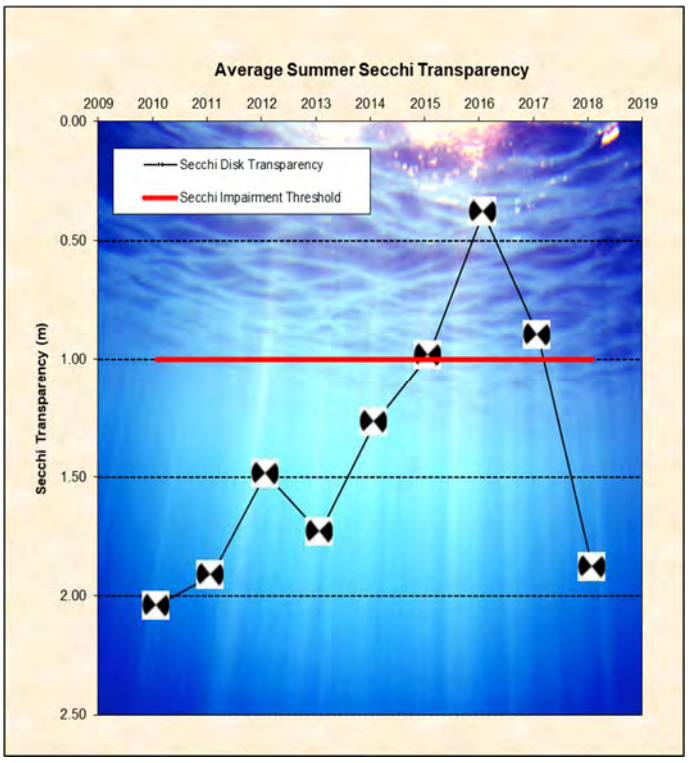
- DNR ID #: 820305
- Municipality: City of Stillwater
- Location: SE$^{1/4}$ Section 30, T30N-R20W
- Lake Size: 14.3 Acres
- Maximum Depth (2018): 9 ft
- Ordinary High Water Mark: NA
- 100-Year High Water Level: NA
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as eutrophic according to the Carlson Trophic State Index.
- Using the Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **declining** trend for the average Secchi transparency. Secchi readings during 2018 were sometimes limited by vegetation and the lake bottom. There is no trend for average total phosphorus and average chlorophyll-α.
- The major land use is urban/residential.
- The lake did not stratify in 2018.
- This lake is categorized as shallow according to the Minnesota Pollution Control Agency's standards.





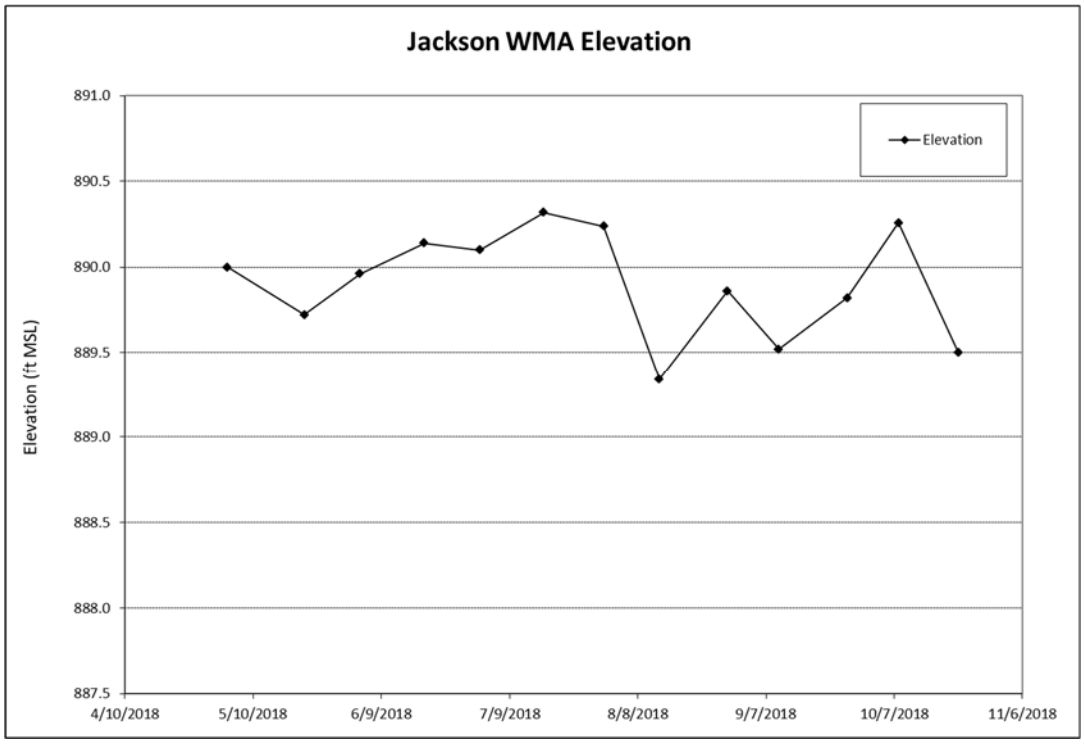
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/7/2018 15:25	0.031	5.8	4.8	0.77	1.37	21.0	9.16
5/22/2018 14:11	0.035	5.5	4.5	0.79	2.44	21.2	8.23
6/4/2018 14:39	0.032	4.8	5.1	0.77	1.83	23.8	7.25
6/19/2018 15:09	0.038	6.3	5.4	0.70	1.98	24.7	7.37
7/2/2018 14:22	0.051	8.6	7.2	0.73	1.37	27.2	6.35
7/17/2018 14:15	0.024	5.4	4.8	0.72	1.83	28.3	6.32
7/31/2018 12:03	0.161	25.0	25.0	0.95	1.98	25.9	8.08
8/13/2018 14:35	0.033	2.9	2.1	0.77	1.83	27.9	8.68
8/29/2018 14:44	0.026	11.0	8.6	0.72	1.52	22.9	5.35
9/10/2018 14:32	0.024	6.4	5.3	0.64	2.13	21.8	8.27
9/26/2018 14:42	0.023	11.0	11.0	0.66	2.44	17.4	7.34
10/8/2018 14:22	0.019	6.0	4.9	0.63	2.29	11.7	8.24
2018 Average	0.041	8.2	7.4	0.74	1.92	22.8	7.55
2018 Summer Average	0.046	9.0	8.3	0.74	1.88	24.4	7.22

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)	890.32	7/17/2018	889.34	8/13/2018	889.91

*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."

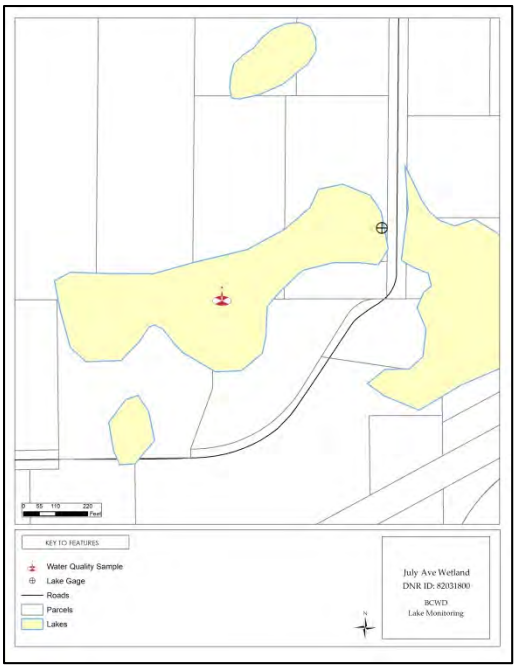


Lake Water Quality Summary										
	Lake Grades									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	C	C	D	C	C	C	D	D	C	NA
Chlorophyll-*a* (ug/l)	A	B	F	B	D	B	B	B	B	NA
Secchi depth (ft)	C	D	F	D	C	C	C	C	C	NA
Overall	**B-**	**C**	**F+**	**C**	**C-**	**C+**	**C**	**C**	**C+**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

July Ave Wetland

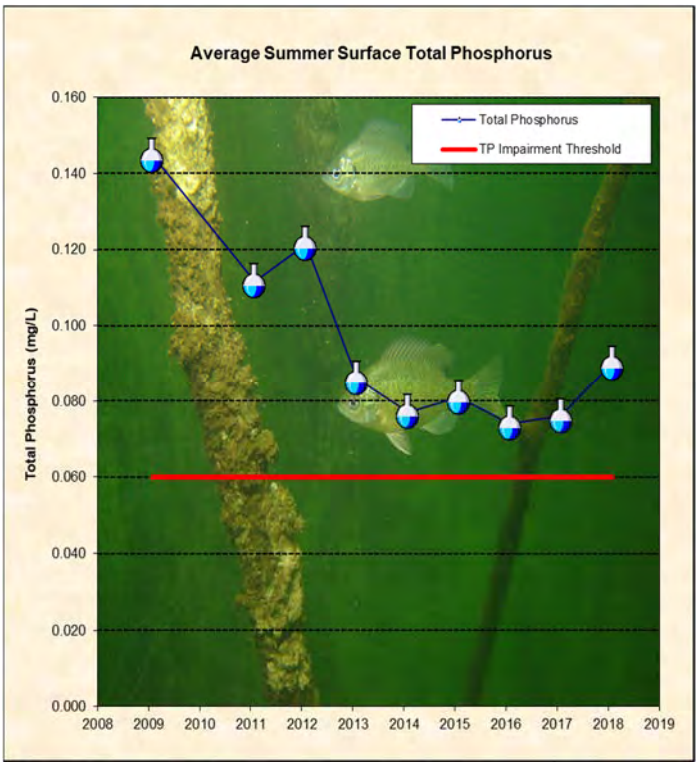
2018 Lake Grade: D-

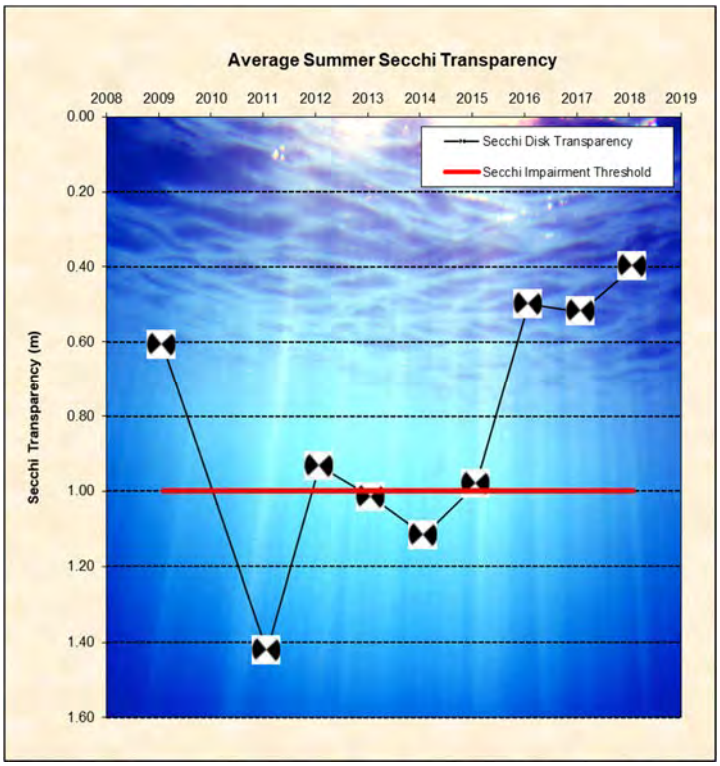
- DNR ID #: 820318
- Municipality: City of Grant
- Location: Section 3, T30N-R21W
- Lake Size: 12 Acres
- Maximum Depth (2018): 10 ft
- Ordinary High Water Mark: NA
- 100-Year High Water Level: 979.20 ft
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as hypereutrophic according to the Carlson Trophic State Index.
- Using the Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for the average total phosphorus, there is a statistically significant **declining** trend for the average Secchi transparency, and no trend for average chlorophyll-α.
- The major land use is rural/agricultural.
- The lake did not stratify in 2018.
- This lake is categorized as shallow according to the Minnesota Pollution Control Agency's standards.





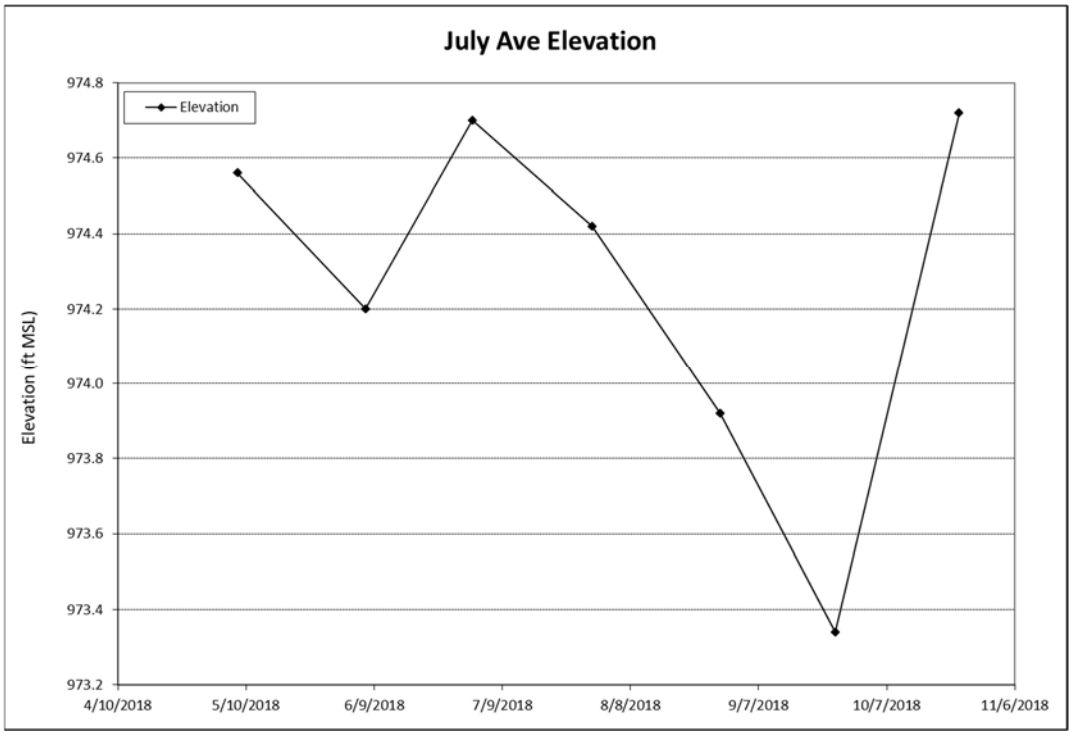
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/7/2018 10:55	0.059	22.0	17.0	1.30	1.07	19.4	9.87
6/7/2018 10:17	0.064	24.0	21.0	1.40	0.61	22.6	7.85
7/2/2018 10:28	0.087	140.0	140.0	2.70	0.15	25.4	7.78
7/30/2018 13:56	0.083	86.0	94.0	3.20	0.15	24.9	11.25
8/29/2018 8:42	0.110	93.0	85.0	3.70	0.46	20.8	1.83
9/25/2018 10:57	0.106	59.0	56.0	3.00	0.61	17.7	7.94
2018 Average	0.085	70.7	68.8	2.55	0.51	21.8	7.75
2018 Summer Average	0.090	80.4	79.2	2.80	0.40	22.3	7.33

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)	974.72	10/24/2018	973.34	9/25/2018	974.27

*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."

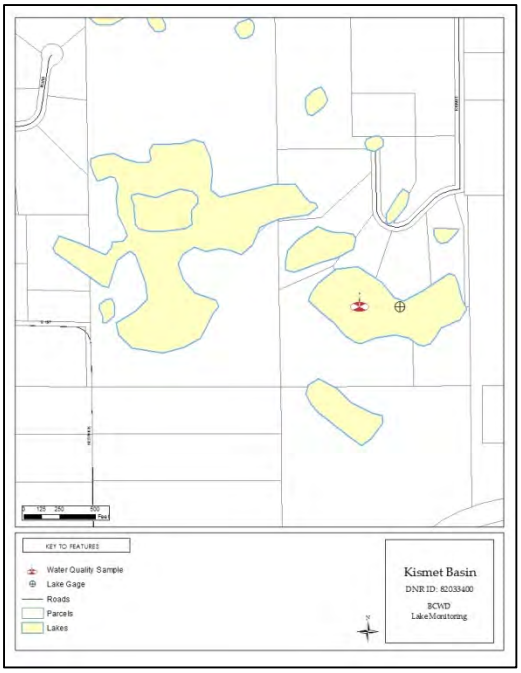


Lake Water Quality Summary										
	Lake Grades									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	D	C	D	D	D	D	D	D	NA	D
Chlorophyll-*a* (ug/l)	D	D	D	D	C	C	D	D	NA	D
Secchi depth (ft)	F	F	F	F	D	D	D	C	NA	F
Overall	**D-**	**C**	**D-**	**D-**	**D+**	**D+**	**D**	**D+**	**NA**	**D-**

Kismet Basin

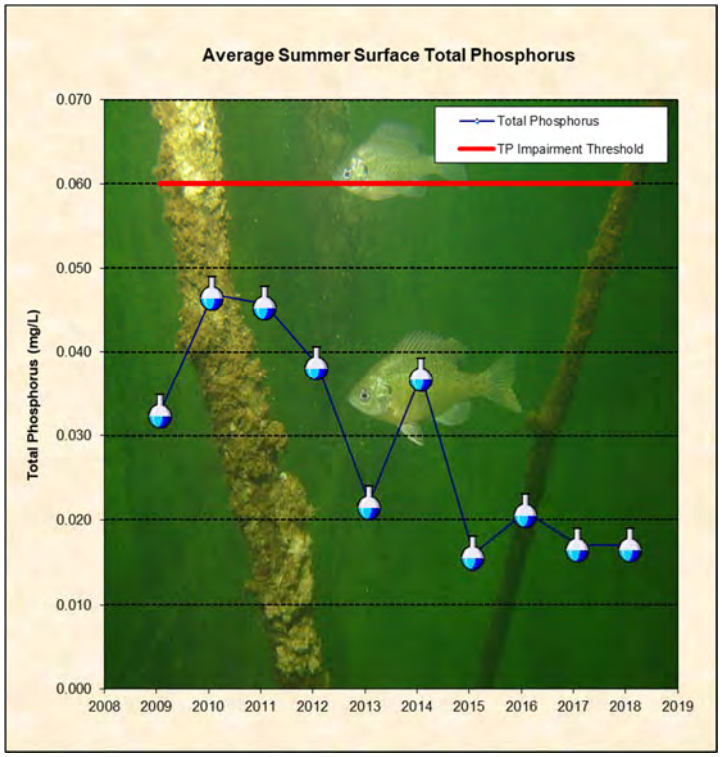
2018 Lake Grade: B+

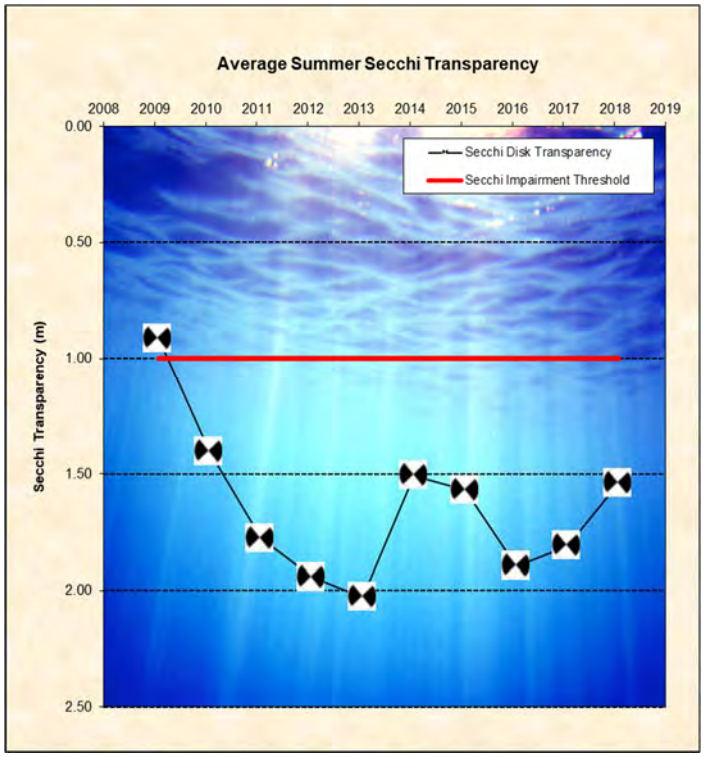
- DNR ID #: 820334
- Municipality: City of Grant
- Location: $S^{1/2}$ Section 11, T30N-R21W
- Lake Size: 70 Acres
- Maximum Depth (2018): 11 ft
- Ordinary High Water Mark: 943.50 ft
- 100-Year High Water Level: 944.90 ft
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as mesotrophic according to the Carlson Trophic State Index.
- Using the Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for the average total phosphorus and the average chlorophyll-α, and the trend for the average Secchi transparency is skewed due to vegetation limiting the transparency.
- The major land use is rural/agricultural.
- The lake did not stratify in 2018.
- This lake is categorized as shallow according to the Minnesota Pollution Control Agency's standards.





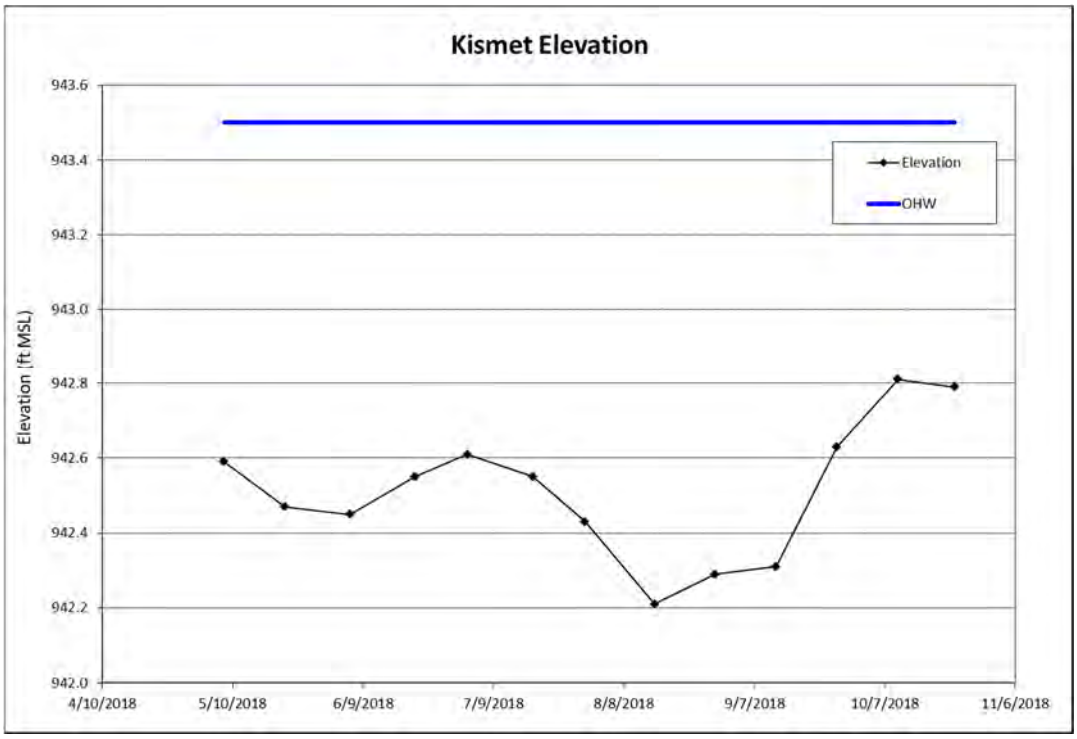
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/8/2018 10:50	0.041	5.3	4.0	0.78	2.13	20.0	8.88
5/22/2018 10:20	0.021	2.8	2.4	0.62	3.05	19.5	8.51
6/6/2018 13:20	0.015	5.2	4.5	0.60	2.13	23.0	9.08
6/21/2018 9:33	0.017	2.6	2.1	0.57	1.22	24.2	8.42
7/3/2018 10:40	0.018	3.2	2.2	0.53	1.98	25.5	7.50
7/18/2018 8:46	0.015	4.2	3.1	0.66	1.37	25.8	5.10
7/30/2018 14:56	0.022	4.9	3.8	0.62	1.37	26.9	6.02
8/15/2018 9:19	0.013	6.4	4.7	0.65	1.68	25.6	4.65
8/29/2018 11:09	0.016	6.6	5.8	0.57	1.37	20.9	1.77
9/12/2018 8:50	0.012	4.1	3.4	0.53	1.37	21.2	6.22
9/26/2018 9:09	0.029	23.0	19.0	0.66	1.37	16.1	2.45
10/10/2018 14:56	0.014	6.2	4.9	0.48	2.59	10.8	5.73
2018 Average	0.019	6.2	5.0	0.61	1.80	21.6	6.19
2018 Summer Average	0.017	6.7	5.4	0.60	1.54	23.2	5.69

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)	942.81	10/10/2018	942.21	8/15/2018	942.51

*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."

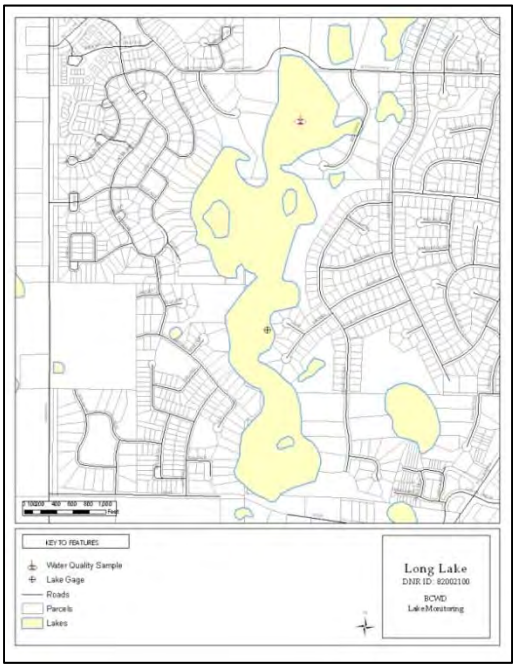


Lake Water Quality Summary										
	Lake Grades									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	A	A	B	A	C	A	C	C	C	C
Chlorophyll-*a* (ug/l)	A	A	A	B	C	A	B	B	C	A
Secchi depth (ft)	C	C	C	C	C	C	C	C	C	D
Overall	**B+**	**B+**	**B**	**B**	**C**	**B+**	**C+**	**C+**	**C**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

Long Lake

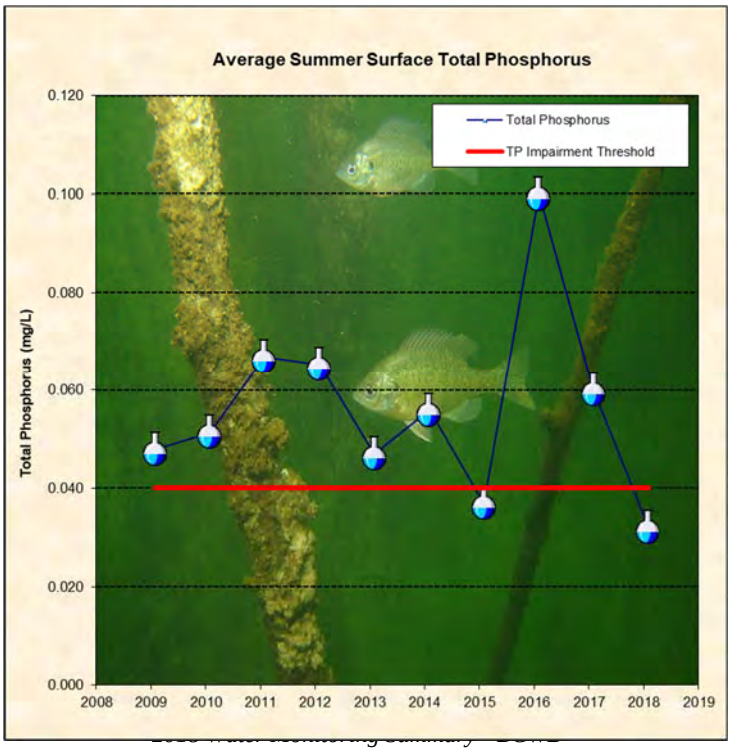
2018 Lake Grade: B

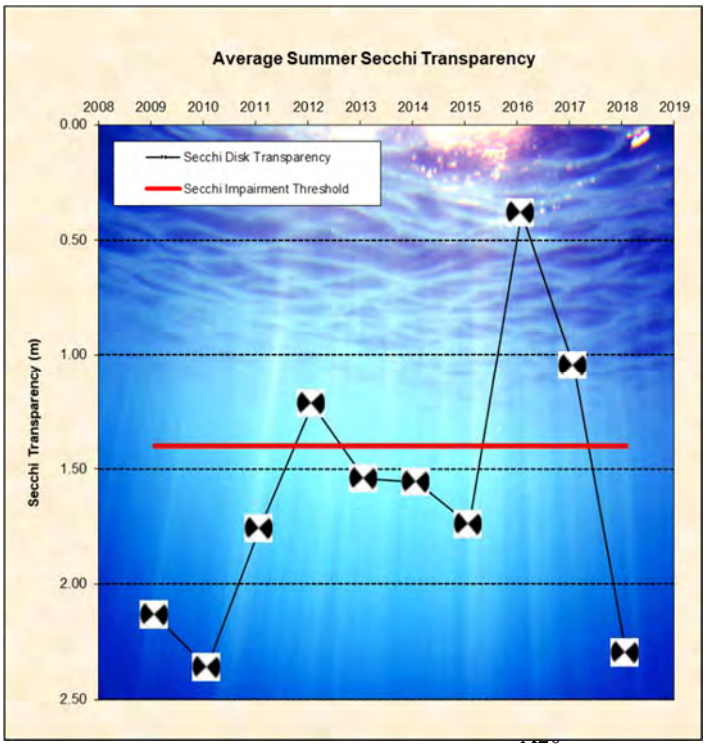
- DNR ID #: 820021
- Municipality: City of Stillwater
- Location: Section 30, T30N-R20W
- Lake Size: 110 Acres
- Maximum Basin Depth (2018): 21 ft
- Ordinary High Water Mark: 891.50 ft
- 100-Year High Water Level: 893.20 ft
- 95% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as mesotrophic according to the Carlson Trophic State Index.
- Using the Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for the average Secchi transparency, average chlorophyll-α, and average total phosphorus.
- The major land use is urban/residential.
- The lake stratified in 2018 with a thermocline around 4 meters.
- This lake is categorized as shallow according to the Minnesota Pollution Control Agency's standards.
- Long Lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List.





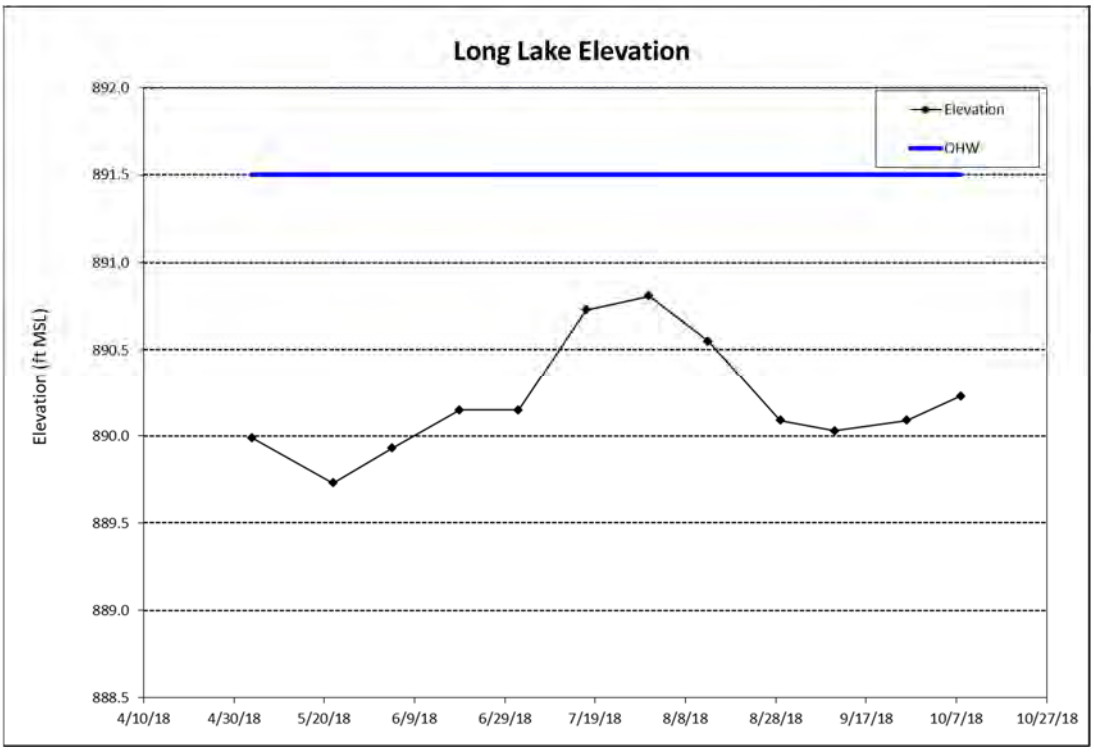
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/7/2018 15:00	0.063	5.5	4.8	1.10	1.52	20.8	8.64
5/22/2018 13:52	0.031	3.7	3.3	0.75	4.27	20.9	7.80
6/4/2018 14:18	0.036	5.0	3.1	0.72	2.29	23.5	7.10
6/19/2018 14:36	0.035	5.5	4.9	0.64	2.13	24.8	7.64
7/2/2018 13:59	0.033	6.1	5.7	0.69	2.44	26.8	6.76
7/17/2018 13:52	0.025	5.9	5.1	0.74	1.98	28.3	7.68
7/31/2018 11:36	0.023	6.3	5.7	0.80	2.29	25.8	8.37
8/13/2018 14:13	0.050	3.9	3.3	0.77	2.29	27.7	8.99
8/29/2018 14:15	0.027	9.8	8.2	0.74	2.44	22.3	5.60
9/10/2018 14:07	0.026	7.2	5.7	0.65	2.44	21.9	8.11
9/26/2018 14:21	0.030	13.0	12.0	0.66	2.44	17.7	6.45
10/8/2018 14:02	0.035	4.0	3.4	0.89	1.83	12.2	5.57
2018 Average	0.035	6.3	5.4	0.76	2.36	22.7	7.39
2018 Summer Average	0.032	7.0	6.0	0.71	2.30	24.3	7.41

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)	890.81	7/31/2018	889.73	5/22/2018	890.21

*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."

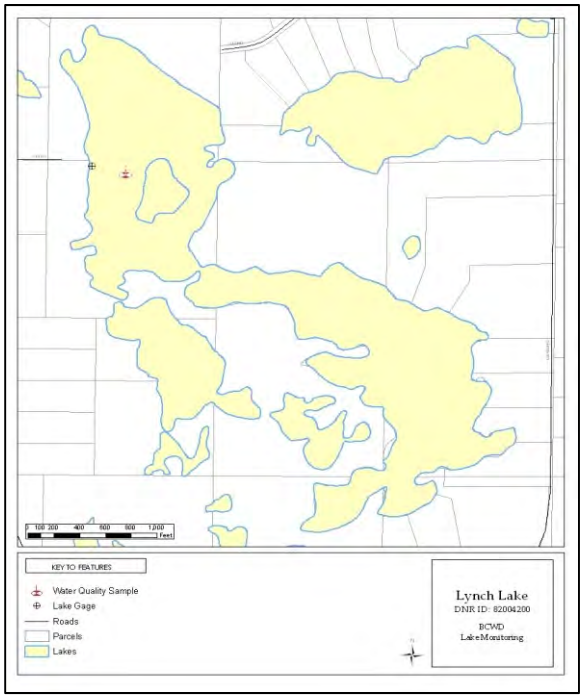


Lake Water Quality Summary										
	Lake Grades									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	C	C	D	C	C	C	C	C	C	C
Chlorophyll-*a* (ug/l)	A	B	F	B	C	B	C	C	B	B
Secchi depth (ft)	B	D	F	C	C	C	C	C	B	C
Overall	**B**	**C**	**F+**	**C+**	**C**	**C+**	**C**	**C**	**B-**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

Lynch Lake – North Basin

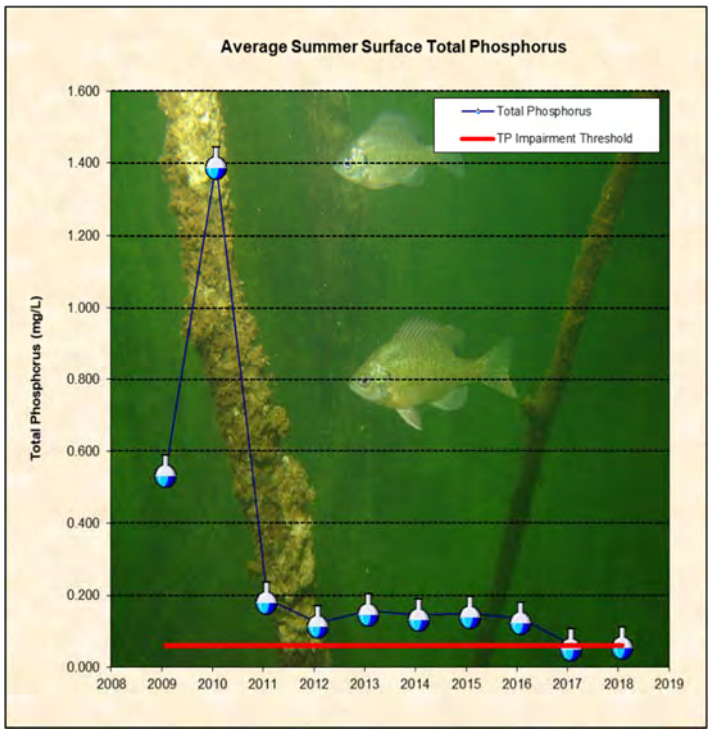
2018 Lake Grade: C+

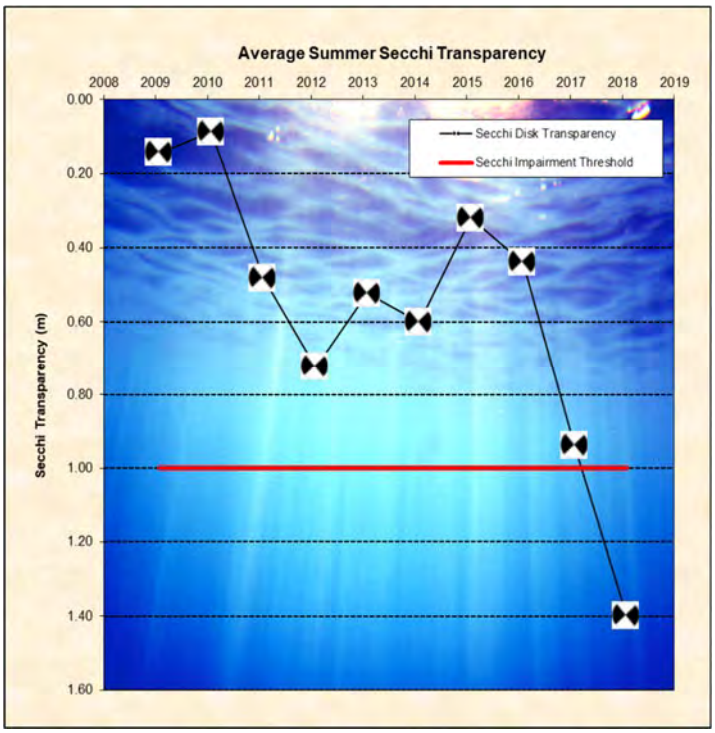
- DNR ID #: 820042
- Municipality: May Township
- Location: Section 30, T31N-R20W
- Lake Size: 87 Acres
- Maximum Depth (2018): 6 ft
- Ordinary High Water Mark: 1005.30 ft
- 100-Year High Water Level: 1008.10 ft
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as eutrophic according to the Carlson Trophic State Index.
- Using the Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for the average Secchi transparency, average chlorophyll-α, and average total phosphorus.
- The major land use is rural/agricultural.
- The lake did not stratify in 2018.
- The north and south basins were connected in 2018.
- This lake is categorized as shallow according to the Minnesota Pollution Control Agency's standards.
- Lynch Lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List.





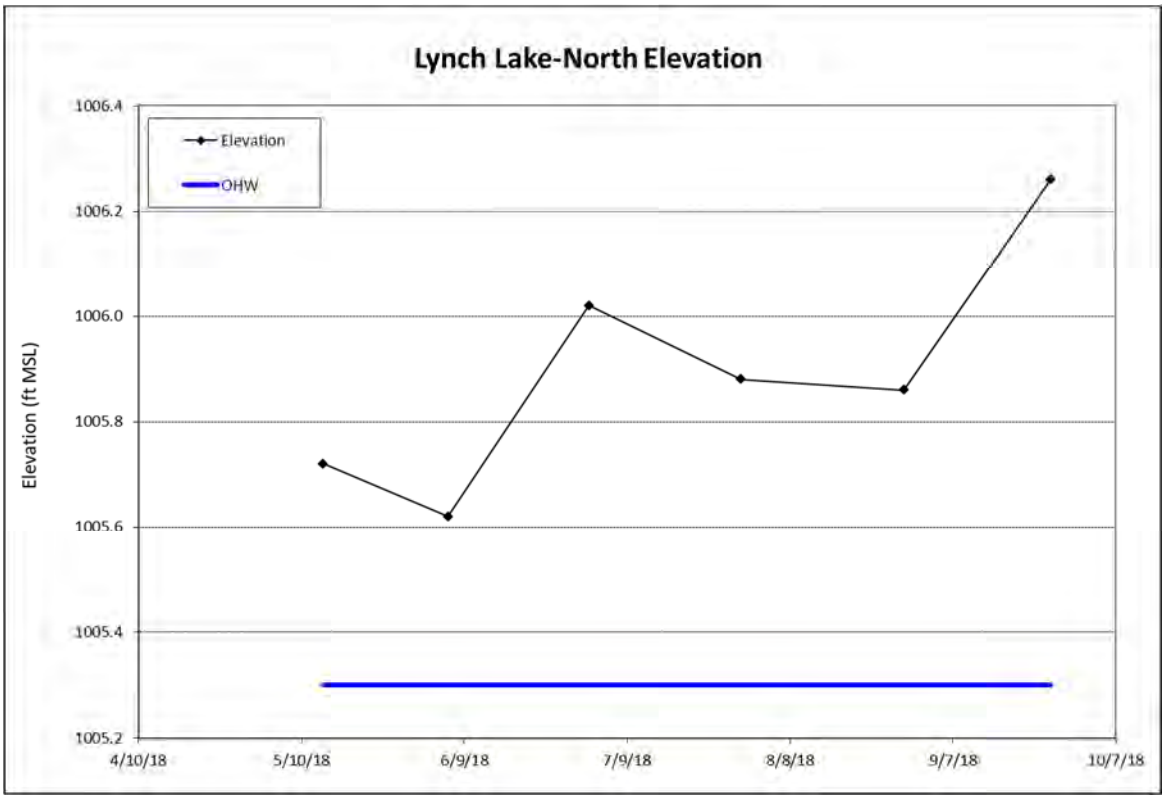
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/7/2018 11:25	0.048	13.0	9.0	0.80	1.37	18.9	7.37
6/6/2018 14:11	0.047	11.0	8.9	0.88	1.07	23.1	7.75
7/2/2018 10:53	0.102	21.0	18.0	1.00	1.07	25.6	4.40
7/30/2018 10:38	0.057	14.0	14.0	1.10	1.52	24.4	6.97
8/29/2018 9:09	0.080	13.0	11.0	0.93	1.68	20.7	1.97
9/25/2018 11:25	0.045	6.0	5.0	0.67	1.68	17.2	6.33
2018 Average	0.063	13.0	11.0	0.90	1.40	21.7	5.80
2018 Summer Average	0.066	13.0	11.4	0.92	1.40	22.2	5.48

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)	1006.26	9/25/2018	1005.62	6/6/2018	1005.89

*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."

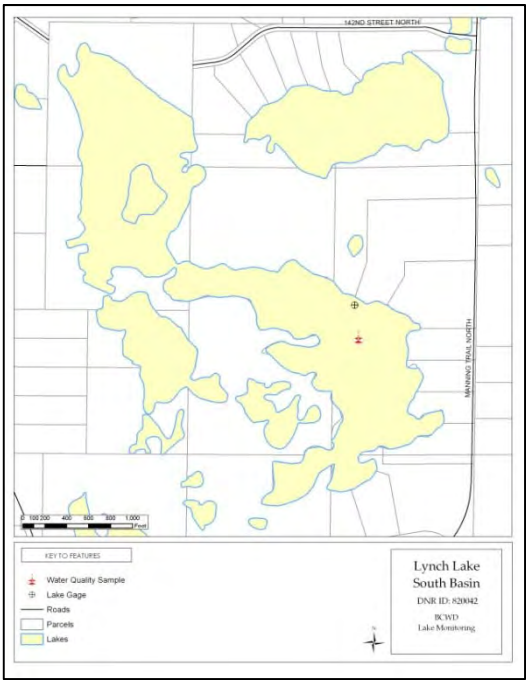


Lake Water Quality Summary										
	Lake Grades									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	C	C	D	D	D	F	D	F	F	F
Chlorophyll-*a* (ug/l)	B	C	D	F	F	F	C	D	F	F
Secchi disk (ft)	C	D	F	F	F	F	D	F	F	F
Overall	**C+**	C-	D-	F+	F+	F	D+	F+	F	F

Lynch Lake – South Basin

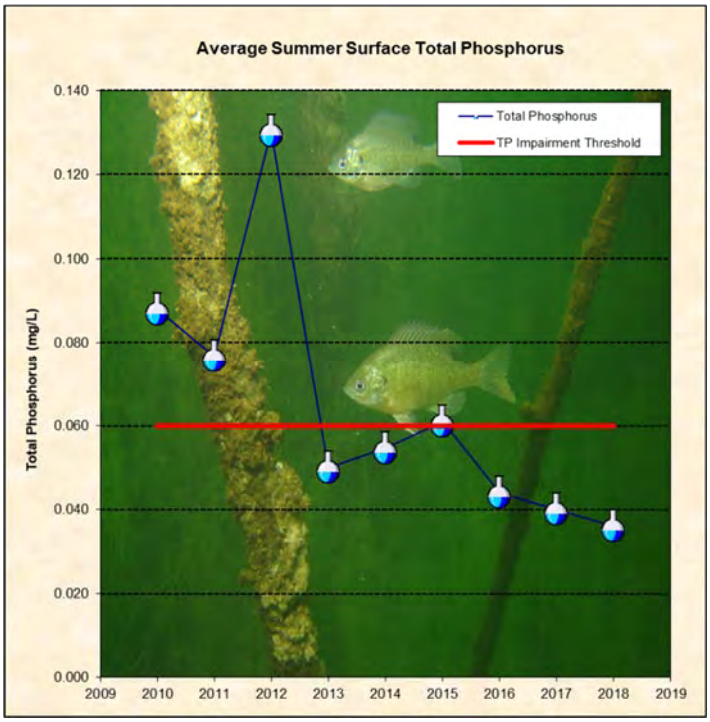
2018 Lake Grade: C+

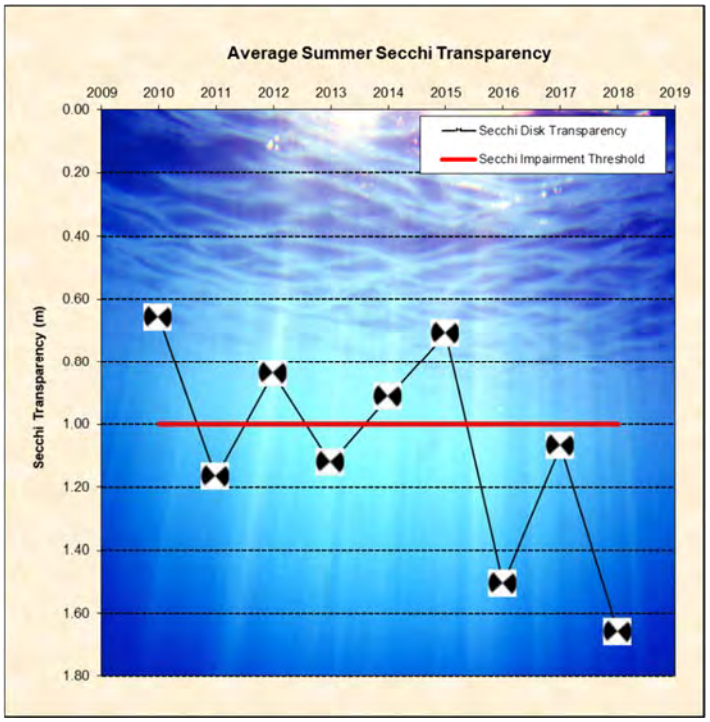
- DNR ID #: 820042
- Municipality: May Township
- Location: Section 30, T31N-R20W
- Lake Size: 87 Acres
- Maximum Depth (2018): 19.5 ft
- Ordinary High Water Mark: 1005.30 ft
- 100-Year High Water Level: 1008.10 ft
- 99% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as eutrophic according to the Carlson Trophic State Index.
- Using the Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for the average Secchi transparency, average chlorophyll-α, and average total phosphorus.
- The major land use is rural/agricultural.
- The lake stratified in 2018 with the thermocline between 3 and 4 meters.
- The north and south basins were connected in 2018.
- This lake is categorized as shallow according to the Minnesota Pollution Control Agency's standards.
- Lynch Lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired





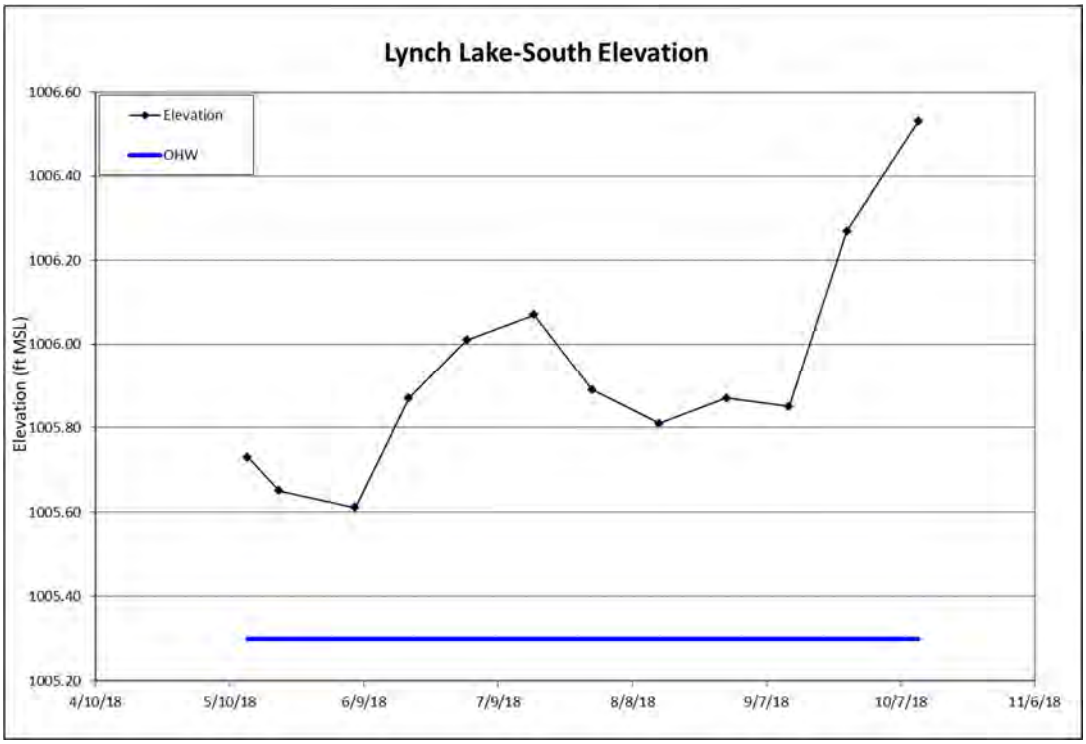
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/7/2018 11:55	0.037	22.0	19.0	1.10	1.22	18.2	9.71
5/21/2018 11:04	0.035	8.8	8.9	0.98	1.37	18.9	8.25
6/7/2018 10:49	0.025	11.0	8.7	0.98	1.98	22.5	7.70
6/19/2018 11:25	0.043	21.0	18.0	1.10	1.52	22.5	6.12
7/2/2018 11:19	0.049	11.0	9.3	0.99	2.13	26.2	6.09
7/17/2018 11:12	0.031	13.0	12.0	0.98	1.68	27.7	5.74
7/30/2018 11:02	0.025	11.0	9.4	1.00	2.59	25.6	7.75
8/14/2018 11:29	0.032	16.0	16.0	1.20	1.07	28.1	8.29
8/29/2018 9:34	0.041	37.0	33.0	1.40	0.91	21.7	4.67
9/12/2018 9:20	0.041	18.0	17.0	1.40	0.91	21.6	6.72
9/25/2018 11:52	0.041	19.0	17.0	1.50	2.13	18.2	4.02
10/11/2018 11:55	0.029	21.0	20.0	1.30	2.44	10.6	8.04
2018 Average	0.036	17.4	15.7	1.16	1.66	21.8	6.93
2018 Summer Average	0.036	17.4	15.6	1.17	1.66	23.8	6.34

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)	1006.53	10/11/2018	1005.61	6/7/2018	1005.93

*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."

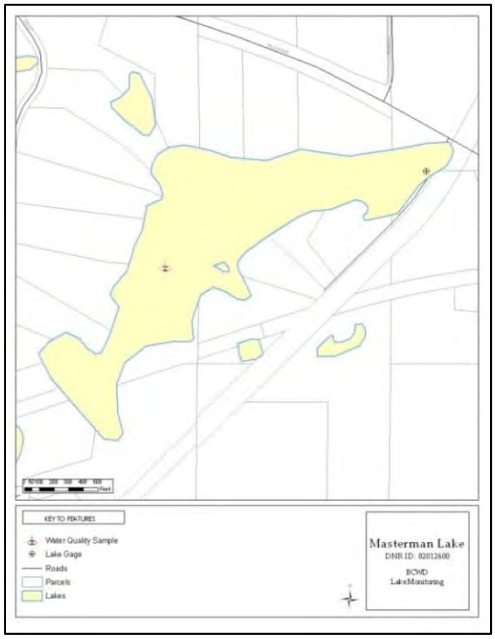


Lake Water Quality Summary										
	Lake Grades									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	C	C	C	C	C	C	D	D	D	NA
Chlorophyll-*a* (ug/l)	B	B	C	C	C	B	F	D	F	NA
Secchi depth (ft)	C	D	C	D	D	D	D	D	F	NA
Overall	**C+**	**C**	**C**	**C-**	**C-**	**C**	**D-**	**D**	**F**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

Masterman Lake

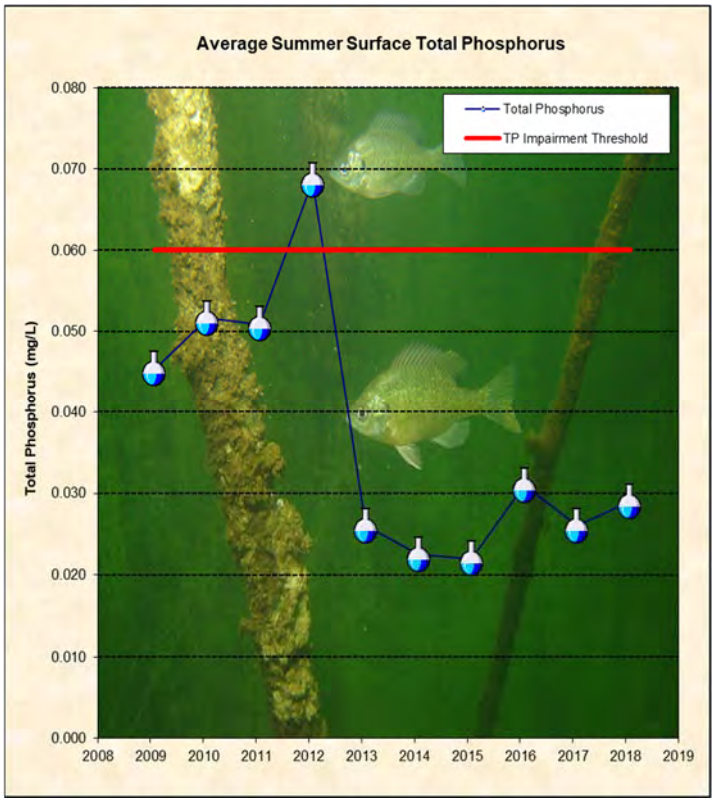
2018 Lake Grade: B

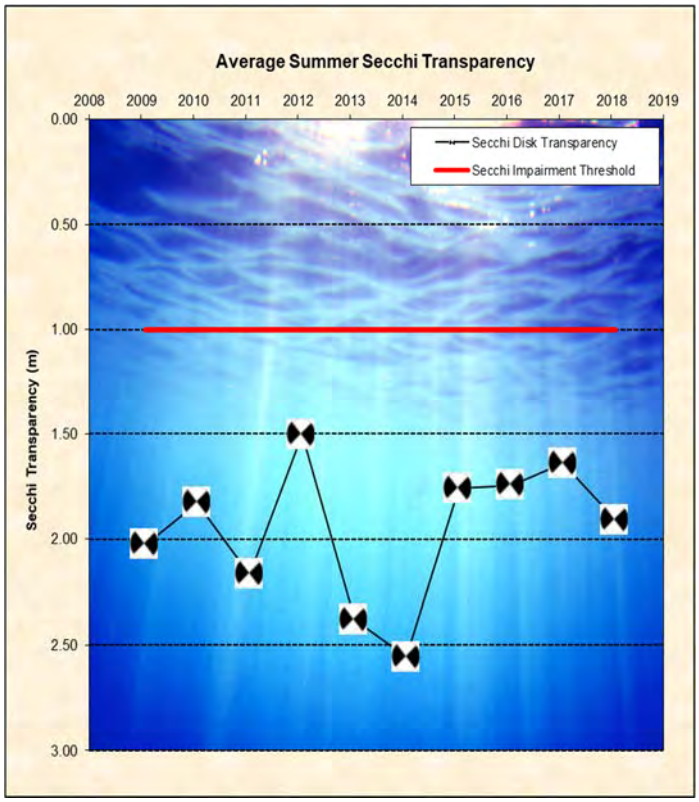
- DNR ID #: 820126
- Municipality: City of Grant
- Location: Section 23, T30N-R21W
- Lake Size: 40 Acres
- Maximum Depth (2018): 9.5 ft
- Ordinary High Water Mark: 955.70 ft
- 100-Year High Water Level: 955.90 ft
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as eutrophic according to the Carlson Trophic State Index.
- Using the Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for the average total phosphorus and average chlorophyll-α, and the trend for the average Secchi transparency is skewed due to vegetation limiting the transparency.
- The major land use is rural/agricultural.
- The lake did not stratify in 2018.
- This lake is categorized as shallow according to the Minnesota Pollution Control Agency's standards.





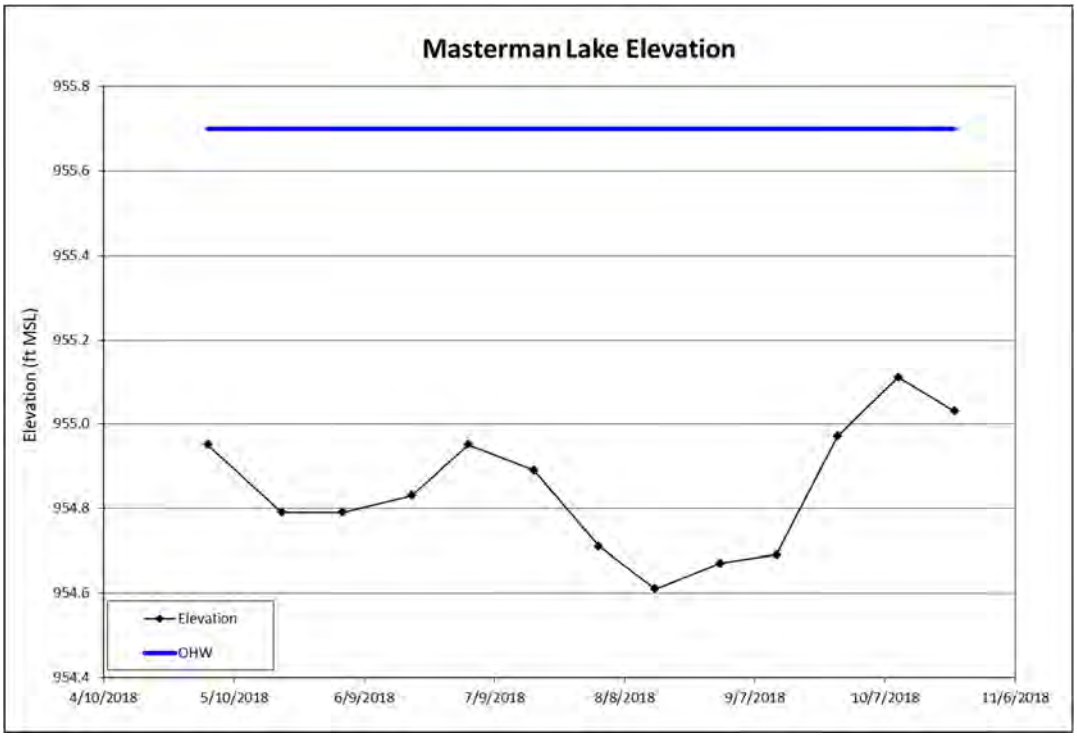
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/8/2018 14:19	0.036	8.9	8.2	0.73	2.29	19.7	9.53
5/21/2018 11:41	0.032	4.1	3.3	0.62	2.13	19.3	9.20
6/4/2018 13:13	0.030	18.0	17.0	0.79	1.83	22.9	7.76
6/20/2018 14:03	0.027	12.0	12.0	0.71	1.83	24.9	7.80
7/3/2018 12:00	0.067	22.0	21.0	0.94	1.52	26.3	8.85
7/18/2018 9:11	0.021	9.2	8.5	0.74	1.98	27.1	7.75
8/2/2018 9:09	0.023	5.1	4.3	0.83	1.83	24.2	6.42
8/15/2018 8:56	0.026	3.5	3.0	0.64	1.83	26.8	8.36
8/30/2018 8:22	0.023	4.6	3.0	0.65	2.29	21.1	3.54
9/12/2018 9:50	0.026	5.0	3.9	0.66	1.98	21.7	7.89
9/26/2018 9:44	0.015	8.0	7.0	0.53	2.13	16.6	5.58
10/10/2018 13:45	0.024	8.3	7.7	0.54	2.44	11.1	8.10
2018 Average	0.029	9.1	8.2	0.70	2.01	21.8	7.57
2018 Summer Average	0.029	9.7	8.9	0.72	1.91	23.5	7.11

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)	955.11	10/10/2018	954.61	8/15/2018	954.85

*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."

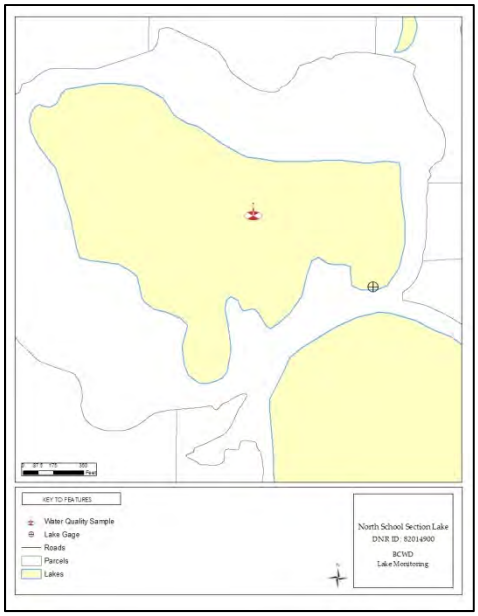


Lake Water Quality Summary										
	Lake Grades									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	B	B	B	A	A	B	C	C	C	C
Chlorophyll-*a* (ug/l)	A	B	B	A	A	A	C	B	C	B
Secchi depth (ft)	C	C	C	C	B	B	C	C	C	C
Overall	**B**	B-	B-	B+	A-	B+	C	C+	C	C+

North School Section Lake

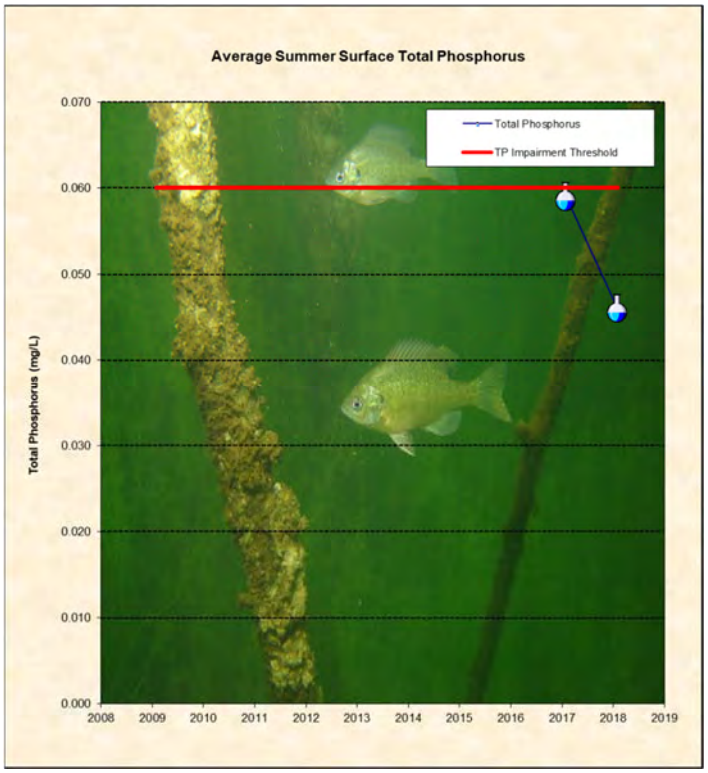
2018 Lake Grade: C

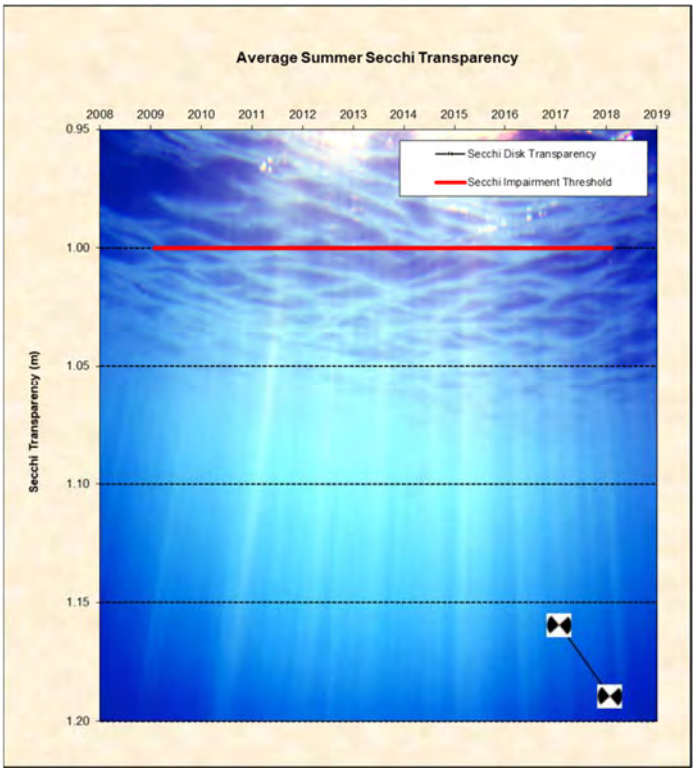
- DNR ID #: 820149
- Municipality: City of Hugo
- Location: SW ¼ Section 25, T31N-R21W
- Lake Size: 40 Acres
- Maximum Depth (2018): 12 ft
- Ordinary High Water Mark: 963.2 ft
- 100-Year High Water Level: 970.42
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as eutrophic according to the Carlson Trophic State Index.
- Using the Kendall's Tau correlation test ($p<0.05$) there are an insufficient number of years of data to determine a trend for the average total phosphorus, average chlorophyll-α, and average Secchi transparency.
- The major land use is rural/agricultural.
- The North and South School Section were connected in 2018.
- The lake did not stratify in 2018.
- This lake is categorized as shallow according to the Minnesota Pollution Control Agency's standards.





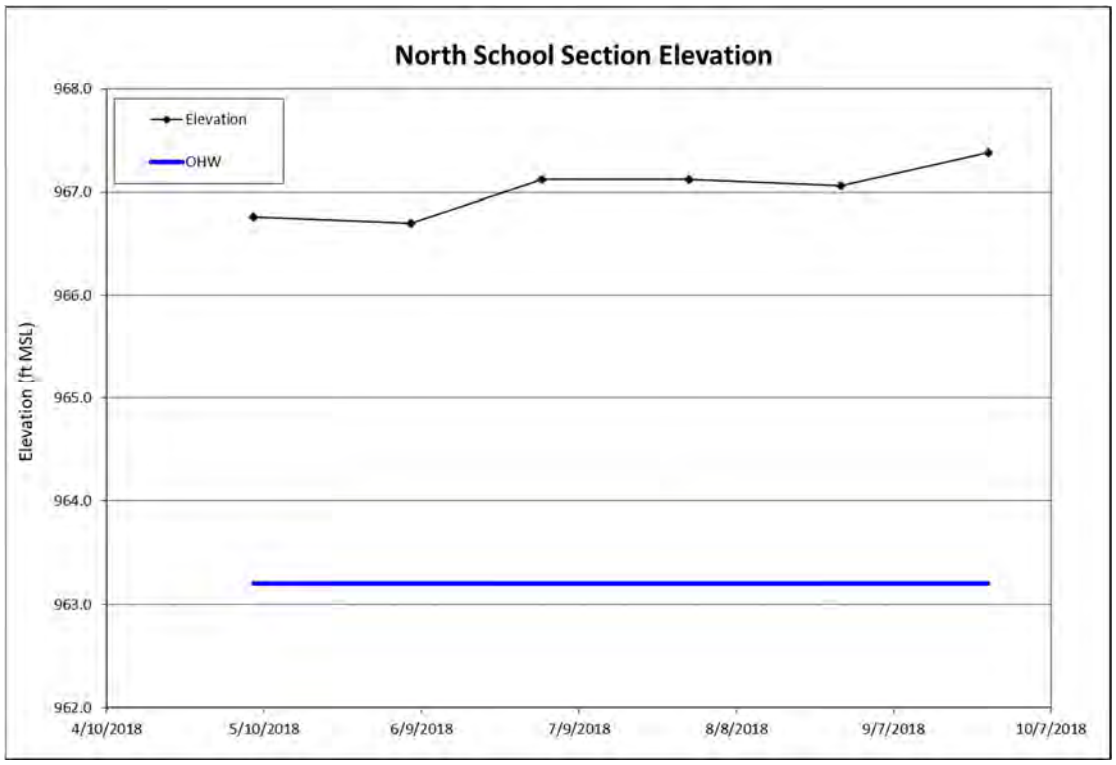
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/7/2018 9:45	0.030	10.0	8.7	0.96	1.68	17.3	9.23
6/7/2018 9:15	0.027	14.0	12.0	0.99	1.83	21.8	8.43
7/2/2018 9:31	0.055	25.0	23.0	1.10	1.37	25.2	5.84
7/30/2018 13:26	0.054	53.0	51.0	1.70	0.46	27.2	9.66
8/28/2018 9:45	0.054	41.0	39.0	1.50	0.76	22.7	4.88
9/25/2018 9:53	0.040	31.0	28.0	1.40	1.52	18.0	8.17
2018 Average	0.043	29.0	27.0	1.28	1.27	22.0	7.70
2018 Summer Average	0.046	32.8	30.6	1.34	1.19	23.0	7.40

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)	967.38	9/25/2018	966.70	6/7/2028	967.02

*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."

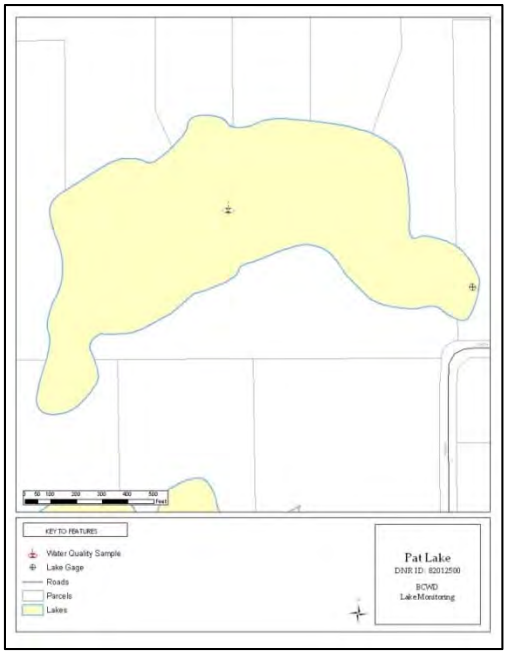


Lake Water Quality Summary										
	Lake Grades									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	C	C	NA	NA	NA	NA	NA	NA	NA	NA
Chlorophyll-*a* (ug/l)	C	C	NA	NA	NA	NA	NA	NA	NA	NA
Secchi depth (ft)	C	C	NA	NA	NA	NA	NA	NA	NA	NA
Overall	**C**	**C**	**NA**	**NA**	**NA**	**NA**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

Pat Lake

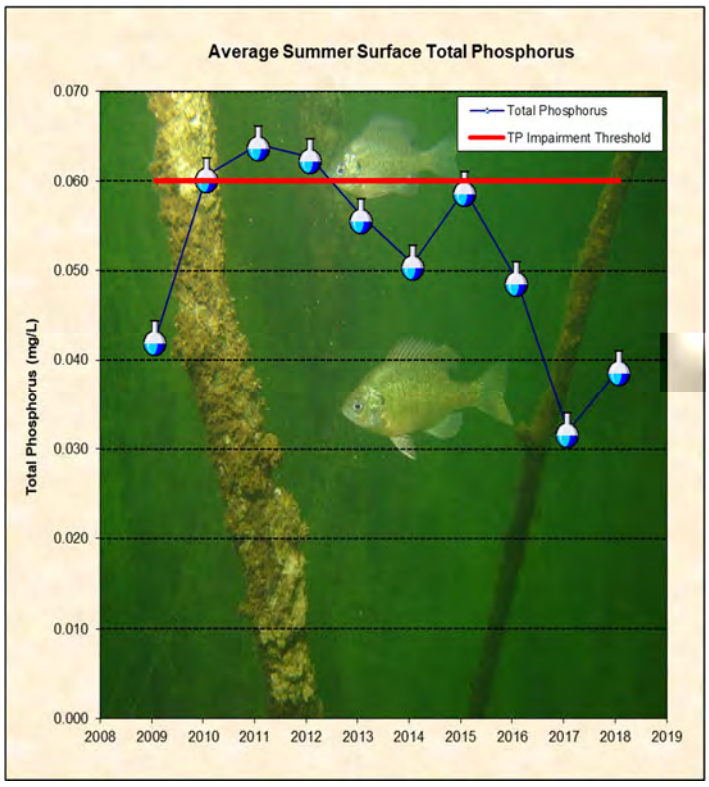
2018 Lake Grade: C+

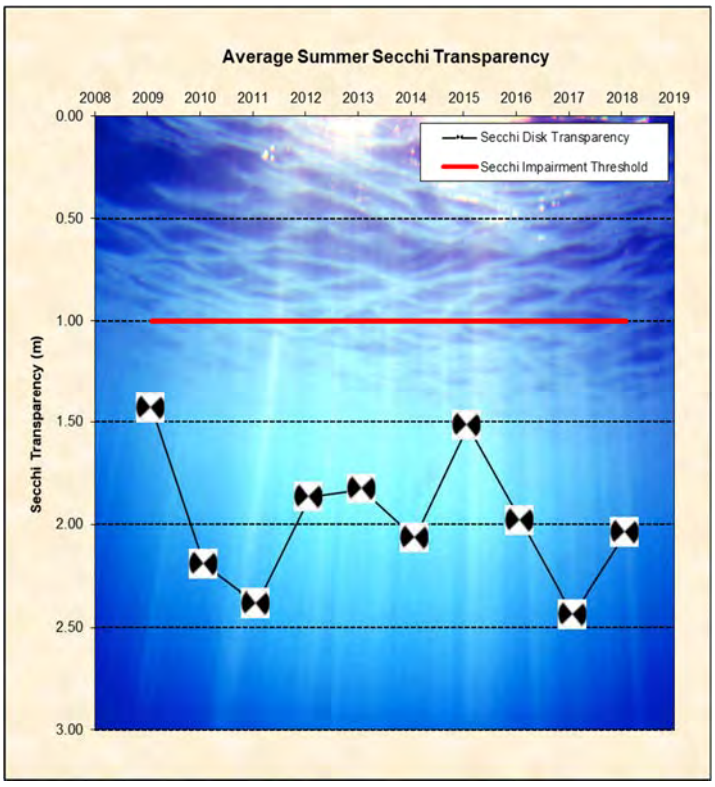
- DNR ID #: 820125
- Municipality: City of Grant
- Location: Section 11, T30N-R21W
- Lake Size: 20 Acres
- Maximum Depth (2018): 18 ft
- Ordinary High Water Mark: 941.80 ft
- 100-Year High Water Level: 949.10 ft
- 99% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as eutrophic according to the Carlson Trophic State Index.
- Using the Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for the average total phosphorus, and no trend for average chlorophyll-α or average Secchi transparency at this time.
- The major land use is rural/agricultural.
- The lake stratified in 2018 with a thermocline between 2 and 3 meters.
- This lake is categorized as shallow according to the Minnesota Pollution Control Agency's standards.





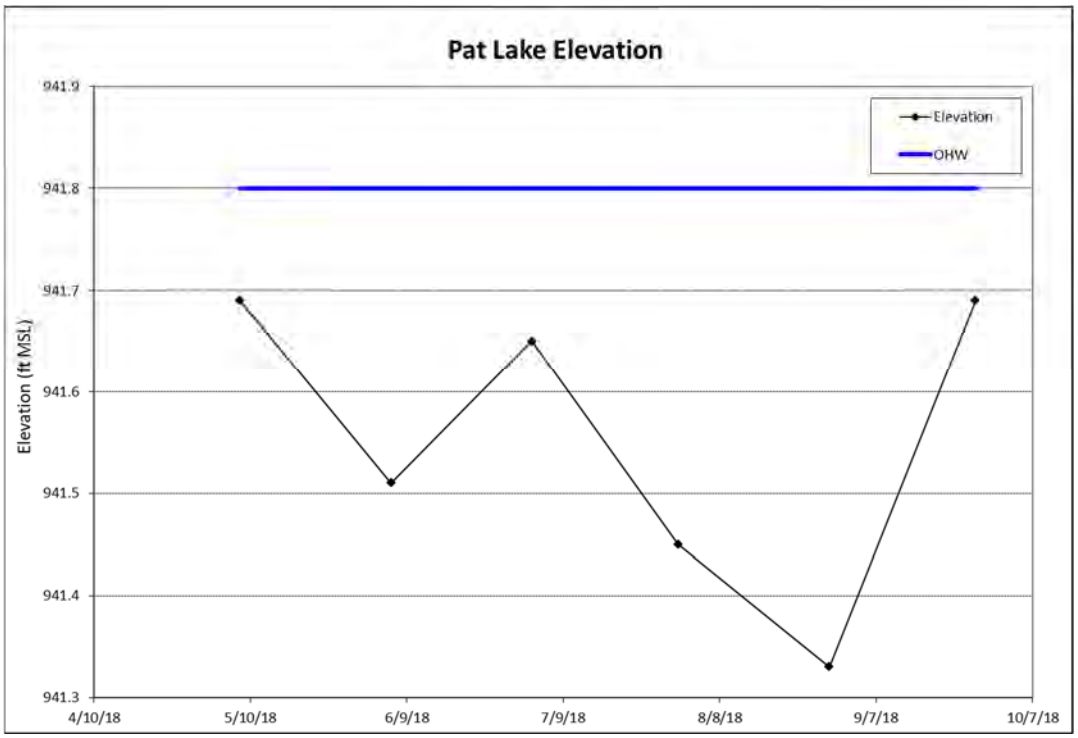
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/8/2018 10:15	0.019	3.5	2.9	0.57	2.13	19.9	9.98
6/6/2018 12:56	0.036	21.0	19.0	0.92	1.22	23.6	9.68
7/3/2018 10:16	0.054	18.0	17.0	0.91	1.68	26.4	8.74
7/31/2018 8:13	0.032	4.6	3.6	0.82	2.29	25.4	7.71
8/29/2018 10:42	0.046	15.0	12.0	0.71	2.29	22.0	3.41
9/26/2018 8:44	0.026	3.9	1.0	0.59	2.74	17.0	5.52
2018 Average	0.036	11.0	9.3	0.75	2.06	22.4	7.51
2018 Summer Average	0.039	12.5	10.5	0.79	2.04	22.9	7.01

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)	941.69	5/8/2018	941.33	8/29/2018	941.55

*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."

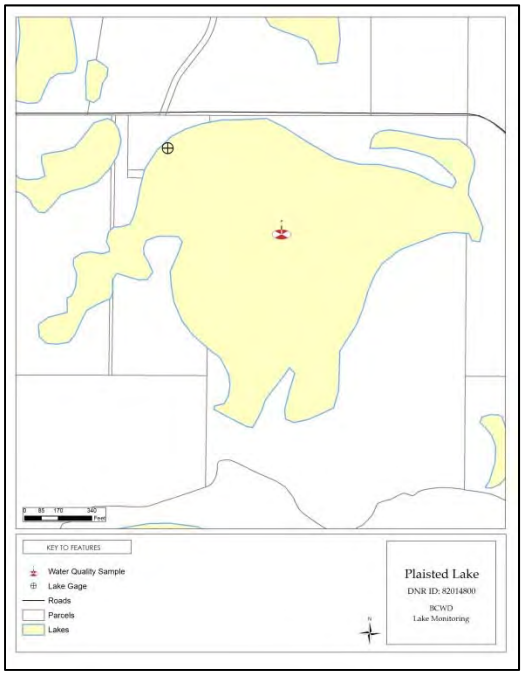


Lake Water Quality Summary										
	Lake Grades									
	2018	2107	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	C	B	C	C	C	C	C	C	C	C
Chlorophyll-*a* (ug/l)	B	A	B	C	B	B	C	B	C	B
Secchi depth (ft)	C	B	C	C	C	C	C	B	C	C
Overall	**C+**	B+	C+	C	C+	C+	C	B-	C	C+

Plaisted Lake

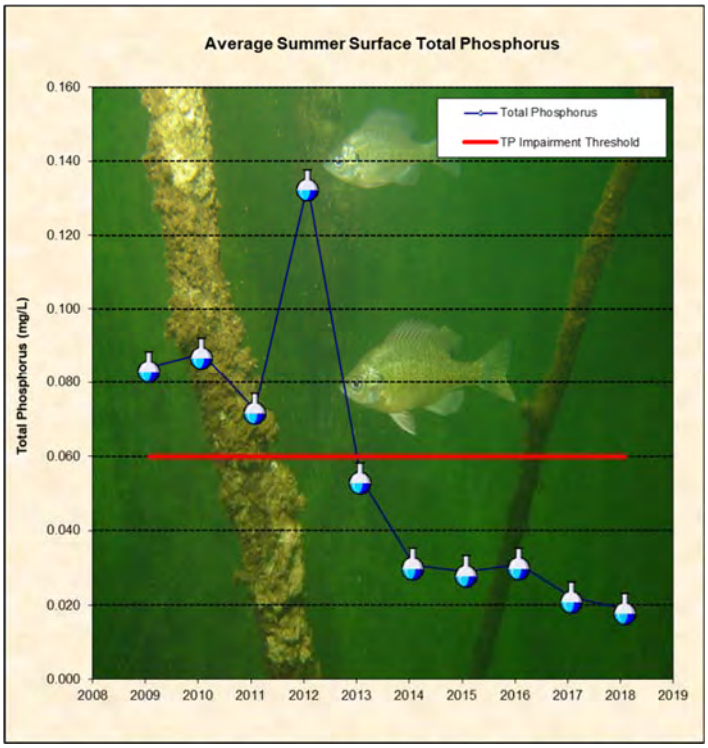
2018 Lake Grade: B+

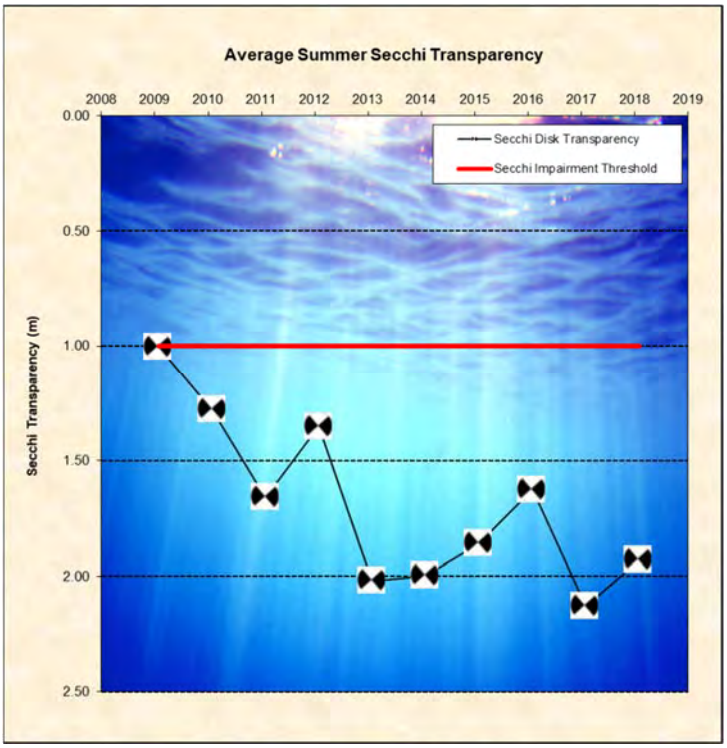
- DNR ID #: 820148
- Municipality: City of Hugo
- Location: Section 25, T31N-R21W
- Lake Size: 70 Acres
- Maximum Depth (2018): 10 ft
- Ordinary High Water Mark: 966.00 ft
- 100-Year High Water Level: NA
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as mesotrophic according to the Carlson Trophic State Index.
- Using the Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for the average total phosphorus and average chlorophyll-α, and the trend for the average Secchi transparency is skewed due to vegetation limiting the transparency.
- The major land use is rural/agricultural.
- The lake did not stratify in 2018.
- This lake is categorized as shallow according to the Minnesota Pollution Control Agency's standards.
- Plaisted Lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List.





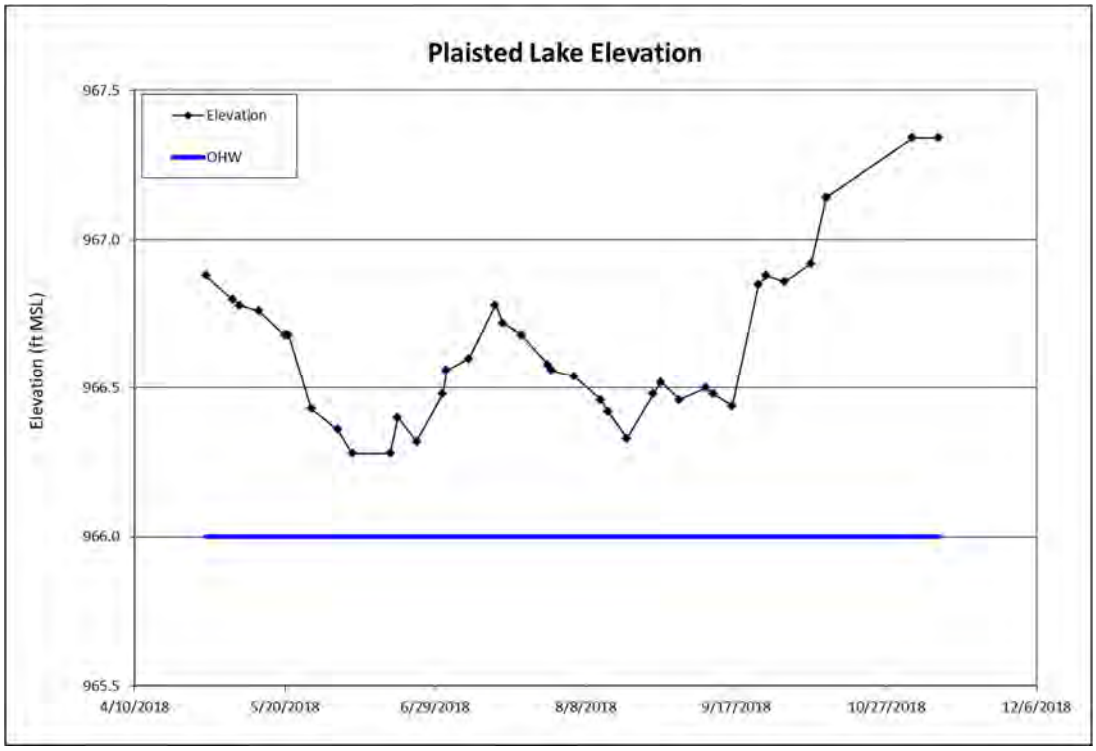
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/7/2018 9:00	0.022	3.1	2.2	0.56	2.59	18.0	9.46
5/21/2018 9:33	0.022	2.3	2.0	0.48	2.74	19.0	9.22
6/7/2018 8:33	0.022	2.8	2.3	0.54	2.13	22.6	9.73
6/19/2018 9:29	0.020	13.0	12.0	0.60	1.83	24.3	8.36
7/2/2018 8:49	0.024	8.9	8.1	0.57	2.29	25.6	6.97
7/17/2018 9:48	0.017	6.5	5.9	0.65	2.13	27.3	8.18
7/30/2018 10:13	0.012	3.8	3.6	0.59	1.22	25.0	8.31
8/14/2018 9:56	0.010	3.7	3.0	0.57	1.83	27.5	9.25
8/28/2018 9:04	0.025	5.8	4.6	0.57	1.83	22.6	5.40
9/11/2018 10:17	0.018	2.4	1.8	0.61	1.83	21.1	8.34
9/25/2018 9:09	0.022	3.5	2.6	0.60	2.29	17.9	7.27
10/11/2018 10:30	0.017	5.2	3.2	0.46	2.59	10.0	8.74
2018 Average	0.019	5.1	4.3	0.57	2.11	21.7	8.27
2018 Summer Average	0.019	5.6	4.9	0.59	1.93	23.8	7.98

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)	967.34	11/10/2018	966.28	6/17/2018	966.64

*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."

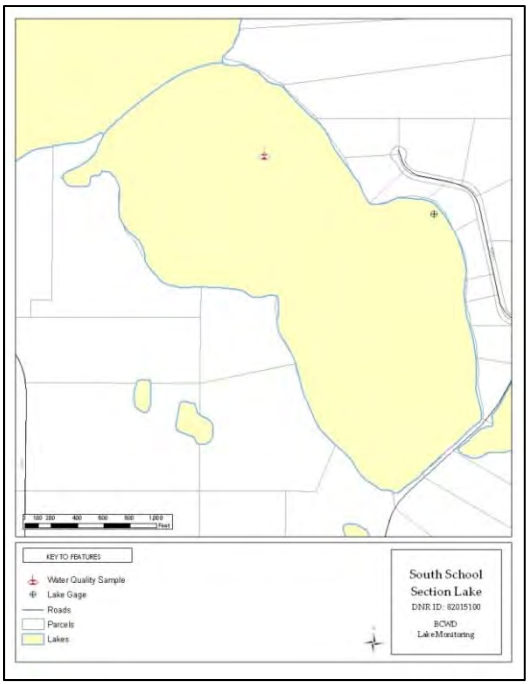


Lake Water Quality Summary										
	Lake Grades									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	A	A	B	B	B	C	D	D	D	D
Chlorophyll-*a* (ug/l)	A	A	B	A	A	C	C	C	C	C
Secchi depth (ft)	C	C	C	C	C	C	C	C	C	D
Overall	**B+**	**B+**	**B-**	**B**	**B**	**C**	**C-**	**C-**	**C-**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

South School Section Lake

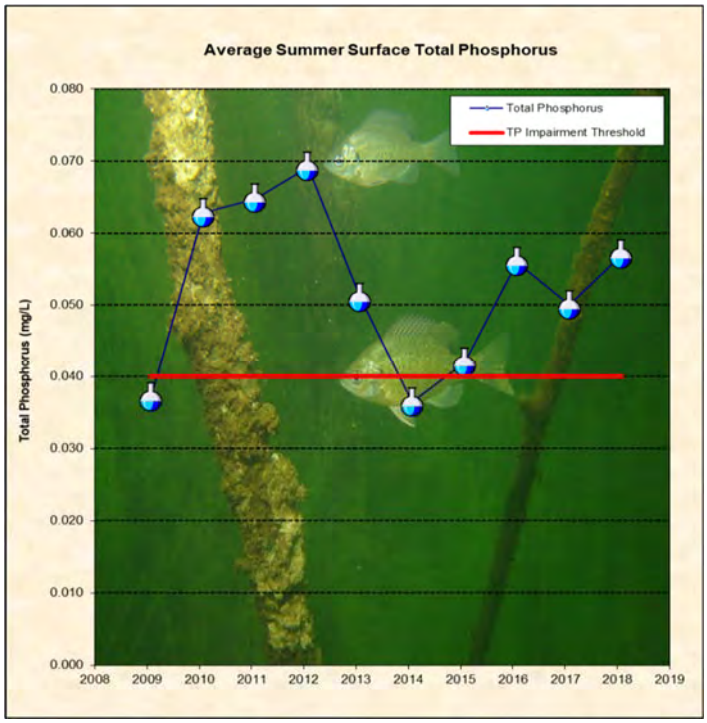
2018 Lake Grade: D+

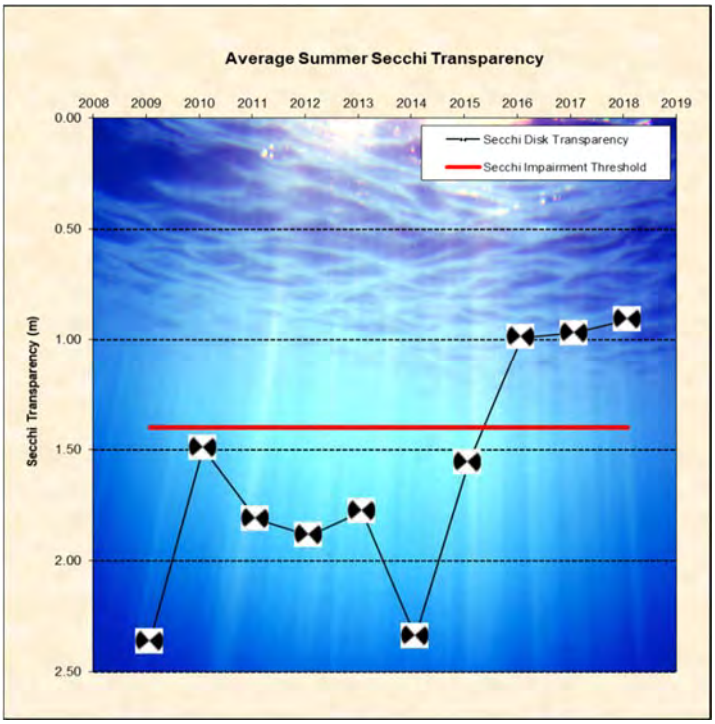
- DNR ID #: 820151
- Municipality: City of Hugo
- Location: S ½ Section 25, T31N-R21W
- Lake Size: 115 Acres
- Maximum Depth (2018): 22 ft
- Ordinary High Water Mark: 965.30 ft
- 100-Year High Water Level: 972.20 ft
- 41% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as eutrophic according to the Carlson Trophic State Index.
- Using the Kendall's Tau correlation test ($p<0.05$) there a statistically significantly **declining** trend for the average Secchi transparency and there is no trend for average total phosphorus and average chlorophyll-α.
- The major land use is rural/agricultural.
- The lake stratified in 2018 with a thermocline between 4 and 5 meters.
- The North and South School Section were connected in 2018.
- This lake is categorized as a deep lake according to the Minnesota Pollution Control Agency's standards.
- South School Section Lake is listed as impaired for nutrients on the Minnesota Pollution Control





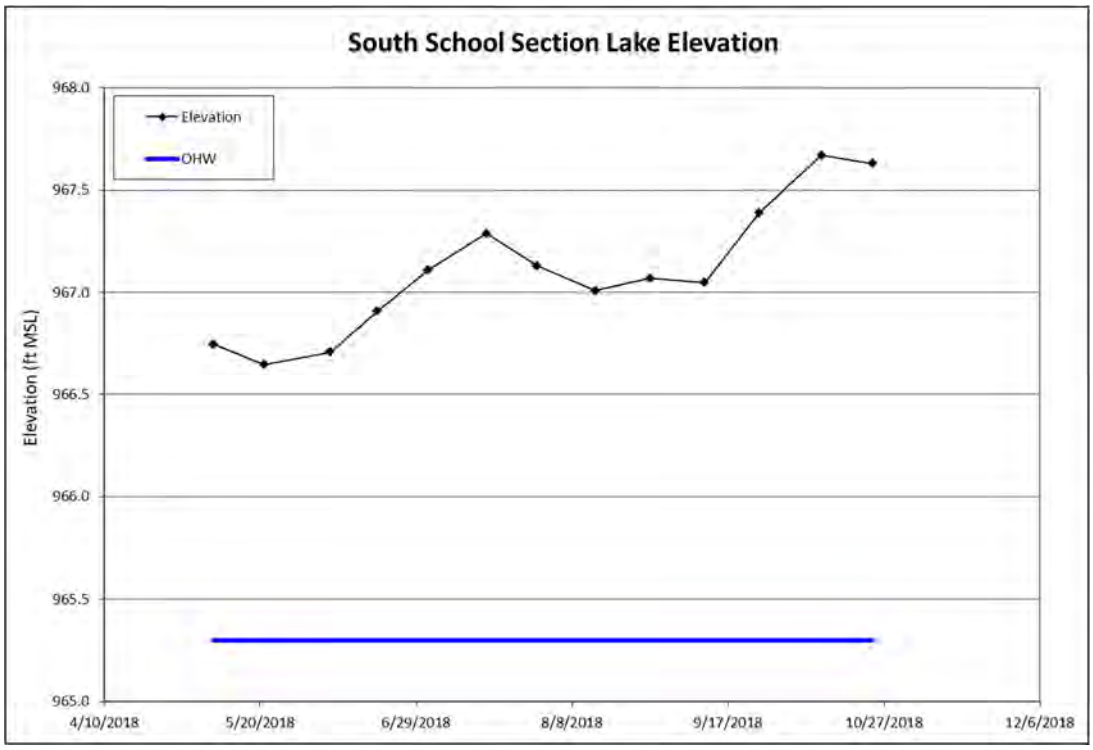
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/7/2018 9:30	0.036	12.0	11.0	1.40	1.37	14.3	10.25
5/21/2018 10:01	0.027	3.1	2.7	0.98	3.20	18.1	9.49
6/7/2018 8:59	0.024	19.0	18.0	1.10	1.68	21.6	9.91
6/19/2018 10:01	0.028	21.0	20.0	1.10	1.52	23.6	7.00
7/2/2018 9:13	0.050	47.0	44.0	1.30	0.91	25.1	7.53
7/17/2018 10:12	0.068	91.0	90.0	1.80	0.30	27.1	7.93
7/30/2018 13:10	0.071	210.0	210.0	3.00	0.12	27.7	14.08
8/14/2018 10:22	0.080	59.0	59.0	2.30	0.46	27.8	8.86
8/28/2018 9:29	0.049	62.0	59.0	1.80	0.76	22.8	5.19
9/11/2018 10:45	0.074	89.0	86.0	1.80	0.61	21.7	7.93
9/25/2018 9:37	0.068	15.0	14.0	2.10	1.83	18.5	4.22
10/11/2018 11:00	0.050	17.0	17.0	2.00	2.44	11.3	7.62
2018 Average	0.052	53.8	52.6	1.72	1.27	21.6	8.33
2018 Summer Average	0.057	68.1	66.7	1.81	0.91	24.0	8.07

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)	967.67	10/11/2018	966.65	5/21/2018	967.11

*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."

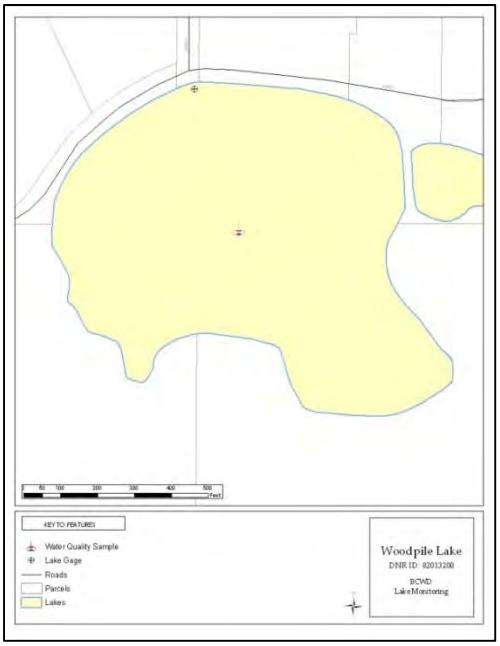


Lake Water Quality Summary										
	Lake Grades									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	C	C	C	C	C	C	C	C	C	C
Chlorophyll-*a* (ug/l)	D	C	C	C	B	C	B	C	D	B
Secchi depth (ft)	D	D	C	C	B	C	C	C	C	B
Overall	**D+**	**C-**	**C**	**C**	**B-**	**C**	**C+**	**C**	**C-**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

Woodpile Lake

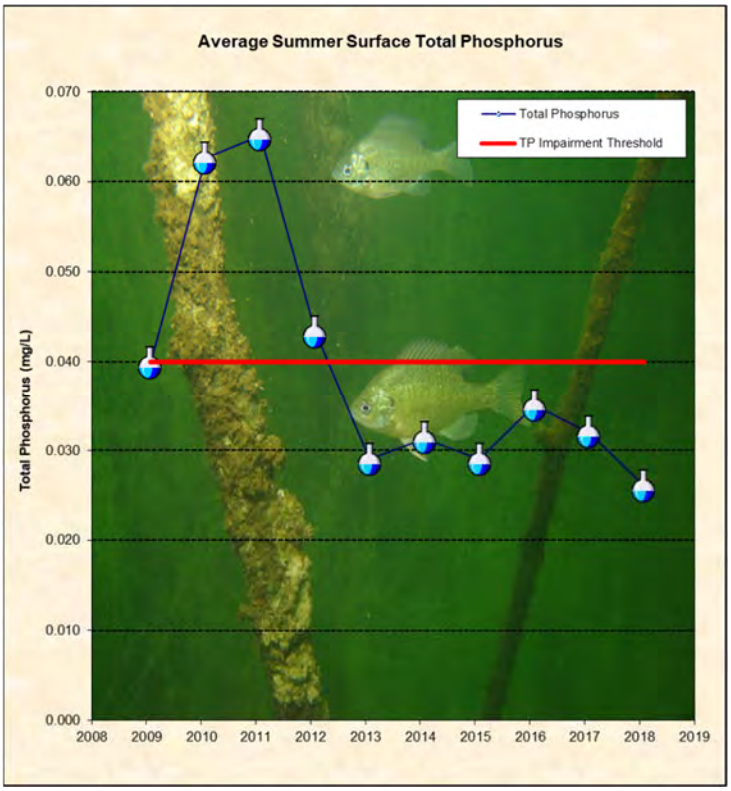
2018 Lake Grade: B+

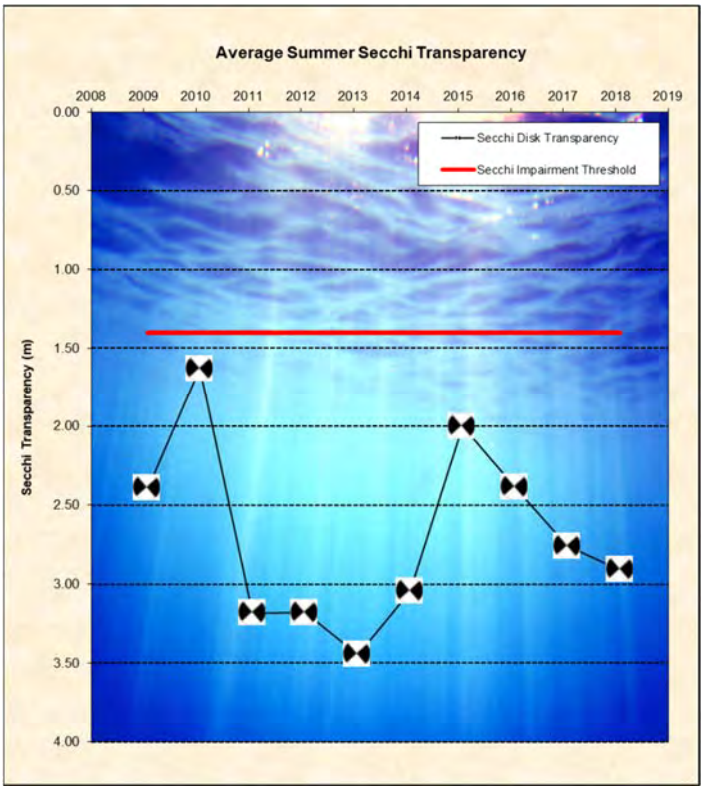
- DNR ID #: 820132
- Municipality: City of Grant
- Location: Section 23, T30N-R21W
- Lake Size: 15 Acres
- Maximum Depth (2018): 28 ft
- Ordinary High Water Mark: 968.50 ft
- 100-Year High Water Level: 971.00 ft
- 8% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

- Based on chlorophyll-α data, the lake is classified as mesotrophic according to the Carlson Trophic State Index.
- Using the Kendall's Tau correlation test ($p<0.05$) a statistically significant **improving** trend for the average Secchi transparency, average chlorophyll-α, and average total phosphorus.
- The major land use is rural/agricultural.
- The lake stratified in 2018 with a thermocline around 4 meters.
- This lake is categorized as a deep lake according to the Minnesota Pollution Control Agency's standards.





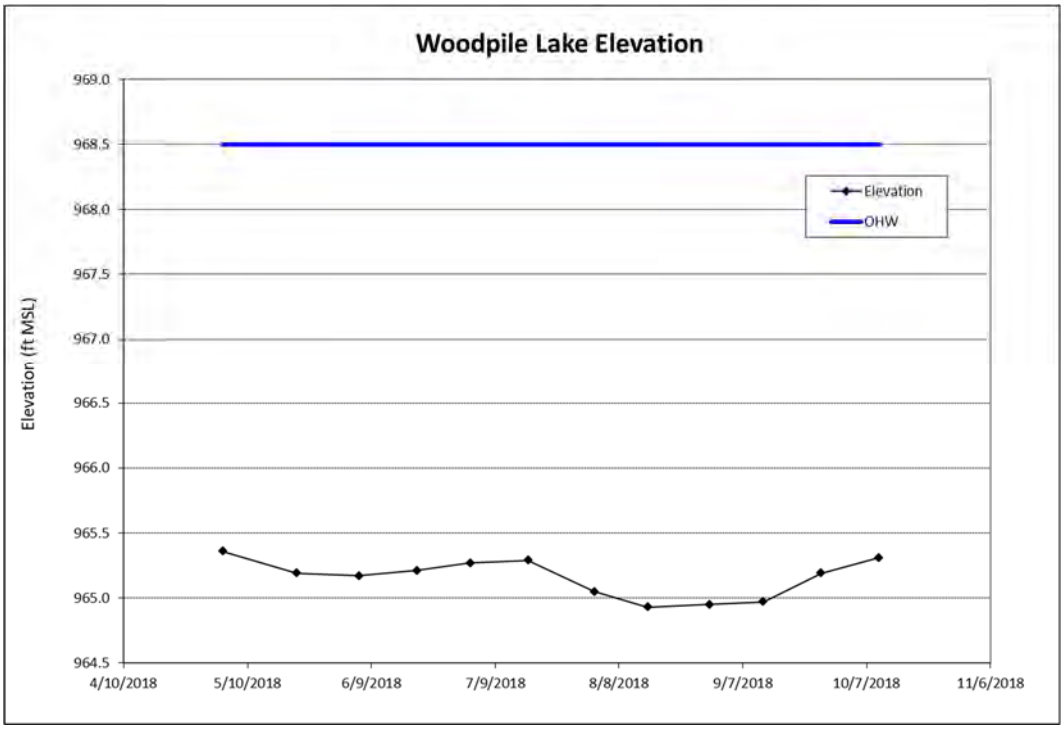
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
5/8/2018 13:51	0.069	4.0	3.6	1.10	2.90	18.9	9.31
5/22/2018 11:51	0.028	1.9	1.2	0.72	3.81	19.1	9.00
6/6/2018 10:53	0.030	5.4	4.2	0.95	3.96	22.4	8.74
6/20/2018 13:35	0.061	10.0	9.9	0.84	2.59	25.0	8.12
7/3/2018 13:03	0.026	9.2	8.1	0.79	2.59	26.1	8.45
7/17/2018 13:17	0.016	3.5	3.1	0.78	3.05	28.4	6.98
8/2/2018 8:27	0.023	5.5	4.6	1.10	3.05	24.4	6.31
8/15/2018 8:32	0.017	4.4	3.8	0.81	2.59	26.7	8.58
8/30/2018 7:54	0.027	7.3	5.6	0.82	2.74	21.8	5.50
9/12/2018 10:17	0.020	4.9	4.1	0.71	1.98	22.0	8.41
9/26/2018 11:10	0.017	6.4	4.8	0.70	3.66	17.8	7.01
10/10/2018 13:19	0.026	5.0	4.0	0.71	4.88	11.9	7.81
2018 Average	0.030	5.6	4.8	0.84	3.15	22.0	7.85
2018 Summer Average	0.026	6.3	5.4	0.83	2.91	23.8	7.57

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)	965.36	5/4/2018	964.93	8/15/2018	965.16

*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										
	Lake Grades									
	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Total Phosphorus (mg/l)	B	B	C	B	B	B	C	C	C	C
Chlorophyll-*a* (ug/l)	A	A	A	B	A	A	B	C	C	B
Secchi depth (ft)	B	B	B	C	A	A	A	B	C	B
Overall	**B+**	**B+**	**B**	**B-**	**A-**	**A-**	**B**	**C+**	**C**	**B-**

APPENDIX B –STREAM DATA

Total Phosphorus and Total Suspended Solids Loading Tables

Table 1: Brown's Creek at Highway 15 2018 Total Suspended Solids (TSS) and Total Phosphorus (TP) Loading

Table 2: Brown's Creek at McKusick Road 2018 Total Suspended Solids (TSS) and Total Phosphorus (TP) Loading

Table 3: Brown's Creek at Stonebridge Trail 2018 Total Suspended Solids (TSS) and Total Phosphorus (TP) Loading

Table 4: Tributary to Long Lake at Marketplace Pond 2018 Total Suspended Solids (TSS) and Total Phosphorus (TP) Loading

Table 5: Brown's Creek Diversion Structure Drainage 2018 Total Suspended Solids (TSS) and Total Phosphorus (TP) Loading

Field Water Quality Data Tables

Table 6: Brown's Creek at Highway 15 2018 Field Water Quality Results

Table 7: Brown's Creek at McKusick Road 2018 Field Water Quality Results

Table 8: Brown's Creek at Stonebridge Trail 2018 Field Water Quality Results

Table 9: Brown's Creek Outlet 2018 Field Water Quality Results

Table 10: Brown's Creek Diversion Structure Drainage 2018 Field Water Quality Results

Table 11: McKusick Wetland Outlet 2018 Field Water Quality Results

Table 1: Brown's Creek at Highway 15 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**			*5*	*0.137*	*1/1/2018 0:00*	*3/26/2018 14:45*	*21,932,100*	*503.76*	*7,393*	*187.57*
*Snowmelt**			*57*	*0.257*	*3/26/2018 14:45*	*3/28/2018 17:45*	*1,193,400*	*27.41*	*4,246*	*19.15*
*Base**			*5*	*0.137*	*3/28/2018 17:45*	*4/11/2018 11:45*	*3,861,000*	*88.68*	*1,302*	*33.02*
*Snowmelt**			*57*	*0.257*	*4/11/2018 11:45*	*4/12/2018 18:00*	*653,400*	*15.01*	*2,325*	*10.48*
*Base**			*5*	*0.137*	*4/12/2018 18:00*	*4/19/2018 11:15*	*1,886,625*	*43.33*	*636*	*16.14*
Snowmelt Grab*	4/23/2018 8:23	4/23/2018 8:23	57	0.257	4/19/2018 11:15	4/23/2018 19:30	3,433,995	78.87	12,219	55.09
*Base**			*5*	*0.137*	*4/23/2018 19:30*	*5/2/2018 14:15*	*3,034,800*	*69.71*	*1,023*	*25.95*
Base			*5*	*0.137*	*5/2/2018 14:15*	*5/6/2018 6:15*	*1,237,940*	*28.43*	*417*	*10.59*
Storm			*18*	*0.118*	*5/6/2018 6:15*	*5/6/2018 15:15*	*228,297*	*5.24*	*257*	*1.67*
Base			*5*	*0.137*	*5/6/2018 15:15*	*5/24/2018 20:15*	*5,034,060*	*115.63*	*1,697*	*43.05*
Storm Composite	5/25/2018 12:46	5/26/2018 5:19	22	0.155	5/24/2018 20:15	5/26/2018 5:15	470,613	10.81	646	4.55
Base Grab	5/30/2018 9:30	5/30/2018 9:30	5	0.128	5/26/2018 5:15	6/2/2018 11:15	2,454,200	56.37	766	19.61
Storm			*87*	*0.388*	*6/2/2018 11:15*	*6/3/2018 9:15*	*397,844*	*9.14*	*2,151*	*9.63*
Base			*5*	*0.137*	*6/3/2018 9:15*	*6/14/2018 23:15*	*3,956,070*	*90.87*	*1,334*	*33.83*
Storm			*87*	*0.388*	*6/14/2018 23:15*	*6/15/2018 8:15*	*217,830*	*5.00*	*1,178*	*5.27*
Base			*5*	*0.137*	*6/15/2018 8:15*	*6/16/2018 6:15*	*363,181*	*8.34*	*122*	*3.11*
Storm Composite	6/16/2018 20:48	6/17/2018 9:15	81	0.370	6/16/2018 6:15	6/17/2018 9:15	890,837	20.46	4,505	20.58
Base			*5*	*0.137*	*6/17/2018 9:15*	*6/17/2018 23:15*	*415,010*	*9.53*	*140*	*3.55*
Storm Composite	6/18/2018 0:43	6/18/2018 14:10	89	0.385	6/17/2018 23:15	6/18/2018 14:15	648,217	14.89	3,601	15.58
Base			*5*	*0.137*	*6/18/2018 14:15*	*6/24/2018 13:15*	*3,339,010*	*76.69*	*1,126*	*28.56*
Storm			*87*	*0.388*	*6/24/2018 13:15*	*6/24/2018 21:15*	*172,951*	*3.97*	*935*	*4.19*
Base			*5*	*0.137*	*6/24/2018 21:15*	*6/26/2018 2:15*	*623,969*	*14.33*	*210*	*5.34*
Storm Composite	6/26/2018 7:03	6/26/2018 14:31	144	0.515	6/26/2018 2:15	6/27/2018 2:15	956,503	21.97	8,598	30.75
Storm Grab	6/27/2018 7:57	6/27/2018 7:57	26	0.209	6/27/2018 2:15	6/28/2018 8:15	883,058	20.28	1,433	11.52
Base			*5*	*0.137*	*6/28/2018 8:15*	*7/1/2018 9:15*	*1,387,060*	*31.86*	*468*	*11.86*
Storm Composite	7/1/2018 14:02	7/2/2018 9:36	57	0.350	7/1/2018 9:15	7/2/2018 10:15	688,526	15.81	2,450	15.04
Base			*5*	*0.137*	*7/2/2018 10:15*	*7/4/2018 10:15*	*983,040*	*22.58*	*331*	*8.41*
Storm			*87*	*0.388*	*7/4/2018 10:15*	*7/4/2018 22:15*	*314,323*	*7.22*	*1,700*	*7.61*
Base			*5*	*0.137*	*7/4/2018 22:15*	*7/12/2018 17:15*	*3,254,280*	*74.75*	*1,097*	*27.83*
Storm Composite	7/12/2018 18:33	7/13/2018 7:37	182	0.728	7/12/2018 17:15	7/13/2018 19:15	1,986,760	45.63	22,573	90.29
Base			*5*	*0.137*	*7/13/2018 19:15*	*7/24/2018 9:15*	*4,925,180*	*113.13*	*1,660*	*42.12*
Base Grab	7/25/2018 9:04	7/25/2018 9:04	7	0.162	7/24/2018 9:15	7/26/2018 9:15	691,159	15.88	302	6.99
Base			*5*	*0.137*	*7/26/2018 9:15*	*8/15/2018 17:15*	*5,948,550*	*136.63*	*2,005*	*50.87*
Storm			*87*	*0.388*	*8/15/2018 17:15*	*8/15/2018 23:15*	*79,997*	*1.84*	*433*	*1.94*
Base			*5*	*0.137*	*8/15/2018 23:15*	*8/20/2018 10:15*	*1,052,950*	*24.19*	*355*	*9.01*
Storm			*87*	*0.388*	*8/20/2018 10:15*	*8/20/2018 20:15*	*130,835*	*3.01*	*708*	*3.17*
Base Grab	8/22/2018 10:15	8/22/2018 10:15	5	0.121	8/20/2018 20:15	8/24/2018 10:15	893,778	20.53	279	6.75
Storm Composite	8/24/2018 12:36	8/26/2018 9:15	55	0.256	8/24/2018 10:15	8/26/2018 9:15	1,389,210	31.91	4,770	22.20
Base			*5*	*0.137*	*8/26/2018 9:15*	*9/4/2018 12:15*	*2,742,190*	*62.98*	*924*	*23.45*
Storm Composite	9/4/2018 16:34	9/5/2018 13:05	59	0.288	9/4/2018 12:15	9/5/2018 13:15	886,269	20.36	3,264	15.93
Base			*5*	*0.061*	*9/5/2018 13:15*	*9/20/2018 6:15*	*4,178,190*	*95.97*	*1,408*	*15.91*
Storm			*87*	*0.388*	*9/20/2018 6:15*	*9/21/2018 17:15*	*2,994,320*	*68.78*	*16,192*	*72.46*
Base			*5*	*0.061*	*9/21/2018 17:15*	*9/26/2018 8:15*	*4,182,810*	*96.07*	*1,410*	*15.93*
Base Grab	9/27/2018 8:13	9/27/2018 8:13	6	0.075	9/26/2018 8:15	9/28/2018 8:15	646,445	14.85	242	3.03
Base			*5*	*0.061*	*9/28/2018 8:15*	*10/3/2018 17:15*	*1,525,800*	*35.05*	*514*	*5.81*
Storm			*18*	*0.118*	*10/3/2018 17:15*	*10/4/2018 4:15*	*184,342*	*4.23*	*207*	*1.35*
Base			*5*	*0.061*	*10/4/2018 4:15*	*10/8/2018 21:15*	*1,683,820*	*38.68*	*568*	*6.41*
Storm			*18*	*0.118*	*10/8/2018 21:15*	*10/10/2018 7:15*	*931,615*	*21.40*	*1,047*	*6.83*
Storm Composite	10/10/2018 13:48	10/10/2018 13:48	14	0.080	10/10/2018 7:15	10/10/2018 21:15	760,111	17.46	664	3.80
Base			*5*	*0.061*	*10/10/2018 21:15*	*10/17/2018 15:15*	*3,283,660*	*75.42*	*1,107*	*12.50*
Base Grab	10/18/2018 15:04	10/18/2018 15:04	4	0.047	10/17/2018 15:15	10/19/2018 15:15	671,084	15.41	168	1.97
Base			*5*	*0.061*	*10/19/2018 15:15*	*10/29/2018 10:15*	*3,653,160*	*83.91*	*1,231*	*13.91*
*Base**			*5*	*0.061*	*10/29/2018 10:15*	*12/27/2018 14:00*	*17,888,850*	*410.89*	*5,584*	*68.12*
*Storm**			*18*	*0.118*	*12/27/2018 14:00*	*12/28/2018 9:00*	*444,600*	*10.21*	*500*	*3.28*
*Base**			*5*	*0.118*	*12/28/2018 9:00*	*1/1/2019 0:00*	*1,096,200*	*25.18*	*342*	*8.07*
Storm Average (Jan-May, Oct-Dec)			18	0.118						
Storm Average (Jun-Sept)			87	0.388						
Base Average (TP: Jan-Aug)			5	0.137						
Base Average (TP: Sept-Dec)			---	0.061						
All Average			51	0.258						
Total							**129,764,024**	**2,981**	**132,765**	**1,182**
Brown's Creek Major Subwatershed Total Acres							3,532			
Total TSS/TP(lb/ac/yr)									37.59	0.335
Total TSS/TP (kg/ha/yr)									42.13	0.375

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

*Interval volumes were estimated using similar flow conditions.

Table 2: Brown's Creek at McKusick Road 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*	*0.089*	*1/1/2018 0:00*	*3/19/2018 12:30*	*26,791,200*	*615.36*	*10,871*	*149.27*
*Snowmelt**			*76*	*0.293*	*3/19/2018 12:30*	*3/19/2018 20:45*	*148,500*	*3.41*	*705*	*2.72*
*Base**			*7*	*0.089*	*3/19/2018 20:45*	*3/26/2018 14:45*	*2,478,600*	*56.93*	*1,006*	*13.81*
*Snowmelt**			*76*	*0.293*	*3/26/2018 14:45*	*3/28/2018 17:45*	*2,019,600*	*46.39*	*9,582*	*36.94*
*Base**			*7*	*0.089*	*3/28/2018 17:45*	*4/11/2018 11:45*	*5,940,000*	*136.43*	*2,410*	*33.09*
*Snowmelt**			*76*	*0.293*	*4/11/2018 11:45*	*4/12/2018 18:00*	*1,143,450*	*26.26*	*5,425*	*20.91*
*Base**			*7*	*0.089*	*4/12/2018 18:00*	*4/19/2018 11:15*	*3,483,000*	*80.00*	*1,413*	*19.41*
Snowmelt Grab*	4/23/2018 8:40	4/23/2018 8:40	76	0.293	4/19/2018 11:15	4/23/2018 19:30	5,629,500	129.30	26,709	102.97
*Base**			*7*	*0.089*	*4/23/2018 19:30*	*5/2/2018 14:45*	*6,084,000*	*139.74*	*2,469*	*33.90*
Base			*7*	*0.089*	*5/2/2018 14:45*	*5/6/2018 8:45*	*2,640,760*	*60.66*	*1,072*	*14.71*
Storm			*94*	*0.347*	*5/6/2018 8:45*	*5/6/2018 16:45*	*316,661*	*7.27*	*1,862*	*6.85*
Base			*7*	*0.089*	*5/6/2018 16:45*	*5/24/2018 20:45*	*8,533,390*	*196.00*	*3,463*	*47.54*
Storm			*94*	*0.347*	*5/24/2018 20:45*	*5/25/2018 12:45*	*362,536*	*8.33*	*2,132*	*7.84*
Base			*7*	*0.089*	*5/25/2018 12:45*	*5/29/2018 21:45*	*1,886,300*	*43.33*	*765*	*10.51*
Storm			*94*	*0.347*	*5/29/2018 21:45*	*5/30/2018 9:45*	*208,325*	*4.78*	*1,225*	*4.51*
Storm Grab	5/30/2018 9:55	5/30/2018 9:55	28	0.177	5/30/2018 9:45	6/1/2018 6:45	1,023,550	23.51	1,789	11.31
Base			*7*	*0.089*	*6/1/2018 6:45*	*6/2/2018 10:45*	*433,049*	*9.95*	*176*	*2.41*
Storm			*94*	*0.347*	*6/2/2018 10:45*	*6/3/2018 9:45*	*592,818*	*13.62*	*3,486*	*12.83*
Base			*7*	*0.089*	*6/3/2018 9:45*	*6/15/2018 2:45*	*4,037,470*	*92.74*	*1,638*	*22.49*
Storm			*94*	*0.347*	*6/15/2018 2:45*	*6/15/2018 10:45*	*197,255*	*4.53*	*1,160*	*4.27*
Base			*7*	*0.089*	*6/15/2018 10:45*	*6/16/2018 6:45*	*294,505*	*6.76*	*120*	*1.64*
Storm			*94*	*0.347*	*6/16/2018 6:45*	*6/17/2018 7:45*	*897,146*	*20.61*	*5,276*	*19.41*
Base			*7*	*0.089*	*6/17/2018 7:45*	*6/17/2018 22:45*	*528,299*	*12.13*	*214*	*2.94*
Storm Composite	6/17/2018 23:45	6/18/2018 12:36	169	0.610	6/17/2018 22:45	6/18/2018 15:45	803,245	18.45	8,474	30.59
Base			*7*	*0.089*	*6/18/2018 15:45*	*6/24/2018 12:45*	*3,383,970*	*77.73*	*1,373*	*18.85*
Storm			*94*	*0.347*	*6/24/2018 12:45*	*6/25/2018 21:45*	*826,458*	*18.98*	*4,860*	*17.88*
Base			*7*	*0.089*	*6/25/2018 21:45*	*6/26/2018 2:45*	*91,507*	*2.10*	*37*	*0.51*
Storm			*94*	*0.347*	*6/26/2018 2:45*	*6/27/2018 2:45*	*971,084*	*22.30*	*5,711*	*21.01*
Storm Grab	6/27/2018 8:14	6/27/2018 8:14	45	0.246	6/27/2018 2:45	6/28/2018 8:45	988,598	22.71	2,777	15.18
Base			*7*	*0.089*	*6/28/2018 8:45*	*7/1/2018 9:45*	*1,228,090*	*28.21*	*498*	*6.84*
Storm			*94*	*0.347*	*7/1/2018 9:45*	*7/2/2018 10:45*	*741,183*	*17.02*	*4,359*	*16.04*
Base			*7*	*0.089*	*7/2/2018 10:45*	*7/4/2018 9:45*	*846,091*	*19.43*	*343*	*4.71*
Storm			*94*	*0.347*	*7/4/2018 9:45*	*7/4/2018 22:45*	*385,124*	*8.85*	*2,265*	*8.33*
Base			*7*	*0.089*	*7/4/2018 22:45*	*7/12/2018 17:45*	*2,537,190*	*58.28*	*1,030*	*14.14*
Storm Composite**	7/12/2018 17:57	7/12/2018 20:05	1,120	1.240	7/12/2018 17:45	7/13/2018 20:45	2,663,470	61.18	186,223	206.18
Base			*7*	*0.089*	*7/13/2018 20:45*	*7/24/2018 9:45*	*5,971,800*	*137.17*	*2,423*	*33.27*
Base Grab	7/25/2018 9:28	7/25/2018 9:28	7	0.136	7/24/2018 9:45	7/26/2018 9:45	596,851	13.71	261	5.07
Base			*7*	*0.089*	*7/26/2018 9:45*	*8/20/2018 12:45*	*6,209,190*	*142.62*	*2,520*	*34.59*
Storm			*94*	*0.347*	*8/20/2018 12:45*	*8/20/2018 20:45*	*102,329*	*2.35*	*602*	*2.21*
Base Grab	8/22/2018 8:55	8/22/2018 8:55	4	0.093	8/20/2018 20:45	8/24/2018 10:45	861,750	19.79	215	5.00
Storm			*94*	*0.347*	*8/24/2018 10:45*	*8/25/2018 23:45*	*1,592,210*	*36.57*	*9,363*	*34.45*
Base			*7*	*0.089*	*8/25/2018 23:45*	*9/2/2018 8:45*	*3,400,590*	*78.11*	*1,380*	*18.95*
Storm			*94*	*0.347*	*9/2/2018 8:45*	*9/2/2018 17:45*	*240,780*	*5.53*	*1,416*	*5.21*
Base			*7*	*0.089*	*9/2/2018 17:45*	*9/4/2018 14:45*	*764,411*	*17.56*	*310*	*4.26*
Storm Composite	9/4/2018 17:33	9/5/2018 4:27	161	0.502	9/4/2018 14:45	9/5/2018 11:45	1,153,330	26.49	11,592	36.14
Base			*7*	*0.089*	*9/5/2018 11:45*	*9/20/2018 5:45*	*5,808,330*	*133.41*	*2,357*	*32.36*
Storm			*94*	*0.347*	*9/20/2018 5:45*	*9/21/2018 21:45*	*4,024,670*	*92.44*	*23,667*	*87.08*
Base			*7*	*0.089*	*9/21/2018 21:45*	*9/26/2018 8:45*	*6,045,090*	*138.85*	*2,453*	*33.68*
Base Grab	9/27/2018 8:38	9/27/2018 8:38	11	0.081	9/26/2018 8:45	9/28/2018 8:45	1,401,480	32.19	962	7.09
Base			*7*	*0.089*	*9/28/2018 8:45*	*10/8/2018 21:45*	*6,766,330*	*155.41*	*2,746*	*37.70*
Storm Composite	10/9/2018 18:23	10/9/2018 21:16	68	0.198	10/8/2018 21:45	10/11/2018 2:45	3,841,870	88.24	16,309	47.49
Base			*7*	*0.089*	*10/11/2018 2:45*	*10/17/2018 14:45*	*6,801,410*	*156.22*	*2,760*	*37.89*
Base Grab	10/18/2018 14:17	10/18/2018 14:17	4	0.047	10/17/2018 14:45	10/19/2018 14:45	1,318,460	30.28	329	3.87
Base			*7*	*0.089*	*10/19/2018 14:45*	*10/27/2018 23:45*	*5,118,060*	*117.56*	*2,077*	*28.52*
Storm			*94*	*0.347*	*10/27/2018 23:45*	*10/28/2018 15:45*	*623,894*	*14.33*	*3,669*	*13.50*
Base			*7*	*0.089*	*10/28/2018 15:45*	*10/29/2018 11:45*	*752,667*	*17.29*	*305*	*4.19*
*Base**			*7*	*0.089*	*10/29/2018 11:45*	*12/27/2018 14:00*	*22,975,650*	*527.72*	*10,040*	*127.65*
*Storm**			*94*	*0.347*	*12/27/2018 14:00*	*12/28/2018 9:00*	*513,000*	*11.78*	*3,010*	*11.11*
*Base**			*7*	*0.089*	*12/28/2018 9:00*	*1/1/2019 0:00*	*1,409,400*	*32.37*	*616*	*7.83*
Storm Average			94	0.347						
Base Average			7	0.089						
All Average			57	0.238						
Total							**179,429,476**	**4,121**	**404,296**	**1,602**
Brown's Creek Major Subwatershed Total Acres							3,999			
Total TSS/TP (lb/ac/yr)									101.10	0.401
Total TSS/TP (kg/ha/yr)									113.32	0.449

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 3: Brown's Creek at Stonebridge Trail 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**			*6*	*0.090*	*1/1/2018 0:00*	*3/19/2018 12:30*	*30,140,100*	*692.28*	*11,760*	*168.40*
*Snowmelt**			*134*	*0.313*	*3/19/2018 12:30*	*3/19/2018 20:45*	*184,140*	*4.23*	*1,540*	*3.60*
*Base**			*6*	*0.090*	*3/19/2018 20:45*	*3/26/2018 14:45*	*3,061,800*	*70.33*	*1,195*	*17.11*
*Snowmelt**			*134*	*0.313*	*3/26/2018 14:45*	*3/28/2018 17:45*	*2,754,000*	*63.26*	*23,037*	*53.81*
*Base**			*6*	*0.090*	*3/28/2018 17:45*	*4/11/2018 11:45*	*6,534,000*	*150.08*	*2,549*	*36.51*
*Snowmelt**			*134*	*0.313*	*4/11/2018 11:45*	*4/12/2018 18:00*	*1,415,700*	*32.52*	*11,842*	*27.66*
*Base**			*6*	*0.090*	*4/12/2018 18:00*	*4/19/2018 11:15*	*3,773,250*	*86.67*	*1,472*	*21.08*
Snowmelt Grab*	4/23/2018 8:54	4/23/2018 8:54	134	0.313	4/19/2018 11:15	4/23/2018 19:30	7,506,000	172.40	62,788	146.66
*Base**			*6*	*0.090*	*4/23/2018 19:30*	*5/2/2018 15:00*	*7,233,300*	*166.14*	*2,822*	*40.41*
Base			*6*	*0.090*	*5/2/2018 15:00*	*5/6/2018 9:00*	*3,187,410*	*73.21*	*1,244*	*17.81*
Storm			*91*	*0.322*	*5/6/2018 9:00*	*5/6/2018 17:00*	*431,867*	*9.92*	*2,453*	*8.69*
Base			*6*	*0.090*	*5/6/2018 17:00*	*5/24/2018 21:00*	*9,602,260*	*220.55*	*3,746*	*53.65*
Storm			*91*	*0.322*	*5/24/2018 21:00*	*5/25/2018 17:00*	*614,993*	*14.13*	*3,494*	*12.38*
Base			*6*	*0.090*	*5/25/2018 17:00*	*5/29/2018 23:00*	*2,261,810*	*51.95*	*882*	*12.64*
Storm			*91*	*0.322*	*5/29/2018 23:00*	*5/30/2018 9:00*	*223,972*	*5.14*	*1,272*	*4.51*
Storm Grab	5/30/2018 9:15	5/30/2018 9:15	27	0.181	5/30/2018 9:00	6/1/2018 1:00	1,052,160	24.17	1,773	11.89
Base			*6*	*0.090*	*6/1/2018 1:00*	*6/2/2018 11:00*	*645,900*	*14.84*	*252*	*3.61*
Storm			*91*	*0.322*	*6/2/2018 11:00*	*6/3/2018 11:00*	*678,579*	*15.59*	*3,855*	*13.66*
Base			*6*	*0.090*	*6/3/2018 11:00*	*6/15/2018 3:00*	*4,932,720*	*113.30*	*1,925*	*27.56*
Storm			*91*	*0.322*	*6/15/2018 3:00*	*6/15/2018 11:00*	*186,231*	*4.28*	*1,058*	*3.75*
Base			*6*	*0.090*	*6/15/2018 11:00*	*6/16/2018 6:00*	*309,957*	*7.12*	*121*	*1.73*
Storm Composite	6/16/2018 9:28	6/16/2018 13:36	197	0.651	6/16/2018 6:00	6/17/2018 14:00	1,213,060	27.86	14,918	49.30
Base			*6*	*0.090*	*6/17/2018 14:00*	*6/17/2018 23:00*	*318,975*	*7.33*	*124*	*1.78*
Storm			*91*	*0.322*	*6/17/2018 23:00*	*6/18/2018 17:00*	*1,112,220*	*25.55*	*6,318*	*22.38*
Base			*6*	*0.090*	*6/18/2018 17:00*	*6/24/2018 13:00*	*3,821,620*	*87.78*	*1,491*	*21.35*
Storm			*91*	*0.322*	*6/24/2018 13:00*	*6/25/2018 4:00*	*538,705*	*12.37*	*3,060*	*10.84*
Base			*6*	*0.090*	*6/25/2018 4:00*	*6/26/2018 3:00*	*546,285*	*12.55*	*213*	*3.05*
Storm			*91*	*0.322*	*6/26/2018 3:00*	*6/27/2018 3:00*	*1,168,820*	*26.85*	*6,640*	*23.52*
Storm Grab	6/27/2018 8:37	6/27/2018 8:37	46	0.266	6/27/2018 3:00	6/28/2018 9:00	1,108,610	25.46	3,183	18.41
Base			*6*	*0.090*	*6/28/2018 9:00*	*7/1/2018 10:00*	*1,507,170*	*34.62*	*588*	*8.42*
Storm			*91*	*0.322*	*7/1/2018 10:00*	*7/2/2018 16:00*	*984,033*	*22.60*	*5,590*	*19.80*
Base			*6*	*0.090*	*7/2/2018 16:00*	*7/4/2018 10:00*	*849,278*	*19.51*	*331*	*4.75*
Storm			*91*	*0.322*	*7/4/2018 10:00*	*7/4/2018 15:00*	*196,211*	*4.51*	*1,115*	*3.95*
Base			*6*	*0.090*	*7/4/2018 15:00*	*7/12/2018 17:00*	*3,503,400*	*80.47*	*1,367*	*19.57*
Storm Composite**	7/12/2018 18:07	7/12/2018 19:49	2,080	1.480	7/12/2018 17:00	7/13/2018 2:00	1,360,540	31.25	176,661	125.70
Storm			*91*	*0.322*	*7/13/2018 2:00*	*7/14/2018 0:00*	*2,630,790*	*60.43*	*14,945*	*52.95*
Base			*6*	*0.090*	*7/14/2018 0:00*	*7/24/2018 10:00*	*8,501,190*	*195.26*	*3,317*	*47.50*
Base Grab	7/25/2018 9:49	7/25/2018 9:49	6	0.127	7/24/2018 10:00	7/26/2018 10:00	1,000,930	22.99	375	7.94
Base			*6*	*0.090*	*7/26/2018 10:00*	*8/21/2018 9:00*	*10,490,000*	*240.94*	*4,093*	*58.61*
Base Grab	8/22/2018 9:25	8/22/2018 9:25	5	0.081	8/21/2018 9:00	8/24/2018 11:00	1,230,530	28.26	384	6.22
Storm			*91*	*0.322*	*8/24/2018 11:00*	*8/25/2018 23:00*	*2,388,050*	*54.85*	*13,566*	*48.06*
Base			*6*	*0.090*	*8/25/2018 23:00*	*9/2/2018 9:00*	*5,250,910*	*120.61*	*2,049*	*29.34*
Storm			*91*	*0.322*	*9/2/2018 9:00*	*9/2/2018 21:00*	*507,661*	*11.66*	*2,884*	*10.22*
Base			*6*	*0.090*	*9/2/2018 21:00*	*9/4/2018 8:00*	*987,843*	*22.69*	*385*	*5.52*
Storm			*91*	*0.322*	*9/4/2018 8:00*	*9/5/2018 4:00*	*1,275,060*	*29.29*	*7,243*	*25.66*
Storm Grab	9/5/2018 14:02	9/5/2018 14:02	48	0.237	9/5/2018 4:00	9/6/2018 1:00	1,583,680	36.38	4,745	23.43
Base			*6*	*0.090*	*9/6/2018 1:00*	*9/20/2018 7:00*	*7,566,370*	*173.79*	*2,952*	*42.27*
Storm			*91*	*0.322*	*9/20/2018 7:00*	*9/21/2018 20:00*	*5,189,950*	*119.21*	*29,483*	*104.45*
Base			*6*	*0.090*	*9/21/2018 20:00*	*9/26/2018 9:00*	*8,452,680*	*194.15*	*3,298*	*47.23*
Base Grab	9/27/2018 9:02	9/27/2018 9:02	10	0.089	9/26/2018 9:00	9/28/2018 9:00	1,850,450	42.50	1,155	10.28
Base			*6*	*0.090*	*9/28/2018 9:00*	*10/3/2018 17:00*	*3,702,760*	*85.05*	*1,445*	*20.69*
Storm			*91*	*0.322*	*10/3/2018 17:00*	*10/4/2018 4:00*	*561,211*	*12.89*	*3,188*	*11.30*
Base			*6*	*0.090*	*10/4/2018 4:00*	*10/9/2018 14:00*	*5,841,680*	*134.18*	*2,279*	*32.64*
Storm Grab	10/10/2018 14:59	10/10/2018 14:59	137	0.277	10/9/2018 14:00	10/11/2018 5:00	3,910,210	89.81	33,442	67.62
Base			*6*	*0.090*	*10/11/2018 5:00*	*10/17/2018 15:00*	*8,782,450*	*201.72*	*3,427*	*49.07*
Base Grab	10/18/2018 14:46	10/18/2018 14:46	4	0.061	10/17/2018 15:00	10/19/2018 15:00	1,860,990	42.74	465	7.09
Base			*6*	*0.090*	*10/19/2018 15:00*	*10/24/2018 17:00*	*4,163,640*	*95.63*	*1,624*	*23.26*
*Base**			*6*	*0.090*	*10/24/2018 17:00*	*12/27/2018 14:00*	*30,353,400*	*697.18*	*11,369*	*170.54*
*Storm**			*91*	*0.322*	*12/27/2018 14:00*	*12/28/2018 9:00*	*684,000*	*15.71*	*3,886*	*13.75*
*Base**			*6*	*0.090*	*12/28/2018 9:00*	*1/1/2019 0:00*	*1,879,200*	*43.16*	*704*	*10.56*
Storm Average			91	0.322						
Base Average			6	0.090						
All Average			61	0.228						
Total							**225,604,711**	**5,182**	**515,386**	**1,946**
Brown's Creek Major Subwatershed Total Acres							4,189			
Total TSS/TP(lb/ac/yr)									123.03	0.465
Total TSS/TP (kg/ha/yr)									137.90	0.521

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: Tributary to Long Lake at Marketplace Pond 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)**
*Intermittent Flow**			*5*	*0.034*	*1/1/2018 0:00*	*3/19/2018 12:30*	*6,698*	*0.15*	*2*	*0.01*
*Snowmelt**			*5*	*0.063*	*3/19/2018 12:30*	*3/19/2018 20:45*	*22,275*	*0.51*	*7*	*0.09*
*Intermittent Flow**			*5*	*0.034*	*3/19/2018 20:45*	*3/26/2018 14:45*	*29,160*	*0.67*	*8*	*0.06*
*Snowmelt**			*5*	*0.063*	*3/26/2018 14:45*	*3/28/2018 17:45*	*183,600*	*4.22*	*57*	*0.72*
*Intermittent Flow**			*5*	*0.034*	*3/28/2018 17:45*	*4/11/2018 11:45*	*59,400*	*1.36*	*17*	*0.13*
*Snowmelt**			*5*	*0.063*	*4/11/2018 11:45*	*4/12/2018 18:00*	*54,450*	*1.25*	*17*	*0.21*
*Base**			*5*	*0.034*	*4/12/2018 18:00*	*4/19/2018 11:15*	*29,025*	*0.67*	*8*	*0.06*
Snowmelt Grab*	4/23/2018 9:40	4/23/2018 9:40	5	0.063	4/19/2018 11:15	4/23/2018 19:30	375,300	8.62	117	1.48
*Base**			*5*	*0.034*	*4/23/2018 19:30*	*4/25/2018 15:00*	*39,150*	*0.90*	*11*	*0.08*
Base			*5*	*0.034*	*4/25/2018 15:00*	*5/2/2018 0:00*	*172,616*	*3.96*	*48*	*0.37*
Storm			*29*	*0.109*	*5/2/2018 0:00*	*5/2/2018 9:00*	*37,558*	*0.86*	*67*	*0.26*
Base			*5*	*0.034*	*5/2/2018 9:00*	*5/24/2018 20:00*	*388,748*	*8.93*	*109*	*0.83*
Storm Composite	5/25/2018 3:58	5/25/2018 7:29	49	0.123	5/24/2018 20:00	5/25/2018 8:00	220,581	5.07	675	1.69
Base			*5*	*0.034*	*5/25/2018 8:00*	*5/29/2018 18:00*	*549,568*	*12.62*	*154*	*1.17*
Storm			*29*	*0.109*	*5/29/2018 18:00*	*5/30/2018 8:00*	*98,092*	*2.25*	*175*	*0.67*
Storm Grab	5/30/2018 10:25	5/30/2018 10:25	11	0.089	5/30/2018 8:00	5/30/2018 11:00	36,297	0.83	25	0.20
Storm			*29*	*0.109*	*5/30/2018 11:00*	*5/30/2018 20:00*	*180,410*	*4.14*	*323*	*1.23*
Base			*5*	*0.034*	*5/30/2018 20:00*	*6/2/2018 11:00*	*288,635*	*6.63*	*81*	*0.61*
Storm			*29*	*0.109*	*6/2/2018 11:00*	*6/2/2018 19:00*	*47,880*	*1.10*	*86*	*0.33*
Base			*5*	*0.034*	*6/2/2018 19:00*	*6/6/2018 6:00*	*153,218*	*3.52*	*43*	*0.33*
Storm			*29*	*0.109*	*6/6/2018 6:00*	*6/6/2018 15:00*	*36,000*	*0.83*	*64*	*0.24*
Base			*5*	*0.034*	*6/6/2018 15:00*	*6/16/2018 6:00*	*179,472*	*4.12*	*50*	*0.38*
Storm Composite	6/17/2018 23:39	6/18/2018 7:29	18	0.082	6/16/2018 6:00	6/16/2018 15:00	95,474	2.19	107	0.49
Base			*5*	*0.034*	*6/16/2018 15:00*	*6/17/2018 23:00*	*216,094*	*4.96*	*61*	*0.46*
Storm			*29*	*0.109*	*6/17/2018 23:00*	*6/18/2018 8:00*	*273,292*	*6.28*	*489*	*1.86*
Base			*5*	*0.034*	*6/18/2018 8:00*	*6/26/2018 1:00*	*623,662*	*14.32*	*175*	*1.32*
Storm Composite	6/26/2018 2:59	6/26/2018 13:45	16	0.128	6/26/2018 1:00	6/26/2018 14:00	159,649	3.67	159	1.28
Base			*5*	*0.034*	*6/26/2018 14:00*	*7/1/2018 9:00*	*246,646*	*5.67*	*69*	*0.52*
Storm Composite	7/1/2018 10:38	7/1/2018 20:02	11	0.098	7/1/2018 9:00	7/1/2018 21:00	189,277	4.35	130	1.16
Base			*5*	*0.034*	*7/1/2018 21:00*	*7/4/2018 10:00*	*219,511*	*5.04*	*62*	*0.47*
Storm Composite	7/4/2018 10:34	7/4/2018 16:55	20	0.101	7/4/2018 10:00	7/4/2018 17:00	257,873	5.92	322	1.63
Base			*5*	*0.034*	*7/4/2018 17:00*	*7/12/2018 17:00*	*424,739*	*9.76*	*119*	*0.90*
Storm Composite	7/12/2018 17:54	7/12/2018 18:52	97	0.180	7/12/2018 17:00	7/12/2018 23:00	510,659	11.73	3,092	5.74
Base			*5*	*0.034*	*7/12/2018 23:00*	*7/19/2018 16:00*	*977,149*	*22.44*	*274*	*2.07*
Storm			*29*	*0.109*	*7/19/2018 16:00*	*7/19/2018 20:00*	*10,104*	*0.23*	*18*	*0.07*
Base			*5*	*0.034*	*7/19/2018 20:00*	*7/25/2018 16:00*	*55,303*	*1.27*	*16*	*0.12*
Storm			*29*	*0.109*	*7/25/2018 16:00*	*7/26/2018 2:00*	*74,535*	*1.71*	*133*	*0.51*
Base			*5*	*0.034*	*7/26/2018 2:00*	*8/3/2018 9:00*	*103,825*	*2.38*	*29*	*0.22*
Storm			*29*	*0.109*	*8/3/2018 9:00*	*8/4/2018 18:00*	*159,613*	*3.67*	*285*	*1.09*
Base			*5*	*0.034*	*8/4/2018 18:00*	*8/24/2018 11:00*	*121,434*	*2.79*	*34*	*0.26*
Storm Composite	8/24/2018 11:33	8/24/2018 20:51	34	0.163	8/24/2018 11:00	8/25/2018 3:00	715,354	16.43	1,518	7.28
Base			*5*	*0.034*	*8/25/2018 3:00*	*8/27/2018 1:00*	*394,589*	*9.06*	*111*	*0.84*
Storm			*29*	*0.109*	*8/27/2018 1:00*	*8/27/2018 4:00*	*18,266*	*0.42*	*33*	*0.12*
Base			*5*	*0.034*	*8/27/2018 4:00*	*8/27/2018 17:00*	*53,717*	*1.23*	*15*	*0.11*
Storm			*29*	*0.109*	*8/27/2018 17:00*	*8/28/2018 2:00*	*349,360*	*8.02*	*625*	*2.38*
Base			*5*	*0.034*	*8/28/2018 2:00*	*9/2/2018 8:00*	*595,967*	*13.69*	*167*	*1.26*
Storm			*29*	*0.109*	*9/2/2018 8:00*	*9/2/2018 20:00*	*226,291*	*5.20*	*405*	*1.54*
Base			*5*	*0.034*	*9/2/2018 20:00*	*9/4/2018 15:00*	*227,279*	*5.22*	*64*	*0.48*
Storm Composite	9/4/2018 17:38	9/5/2018 1:31	11	0.082	9/4/2018 15:00	9/5/2018 2:00	376,755	8.65	259	1.93
Base			*5*	*0.034*	*9/5/2018 2:00*	*9/17/2018 15:00*	*630,568*	*14.48*	*177*	*1.34*
Storm			*29*	*0.109*	*9/17/2018 15:00*	*9/17/2018 21:00*	*24,802*	*0.57*	*44*	*0.17*
Base			*5*	*0.034*	*9/17/2018 21:00*	*9/20/2018 6:00*	*100,432*	*2.31*	*28*	*0.21*
Storm Composite	9/20/2018 11:22	9/20/2018 17:44	24	0.098	9/20/2018 6:00	9/21/2018 16:00	1,502,500	34.51	2,251	9.19
Base			*5*	*0.034*	*9/21/2018 16:00*	*9/24/2018 22:00*	*366,223*	*8.41*	*103*	*0.78*
Storm			*29*	*0.109*	*9/24/2018 22:00*	*9/25/2018 4:00*	*58,984*	*1.35*	*105*	*0.40*
Base			*5*	*0.034*	*9/25/2018 4:00*	*9/27/2018 22:00*	*163,969*	*3.77*	*46*	*0.35*
*Base**			*5*	*0.034*	*9/27/2018 22:00*	*10/3/2018 18:00*	*252,000*	*5.79*	*71*	*0.53*
*Storm**			*29*	*0.109*	*10/3/2018 18:00*	*10/4/2018 0:00*	*58,320*	*1.34*	*104*	*0.40*
*Base**			*5*	*0.034*	*10/4/2018 0:00*	*10/4/2018 11:30*	*20,700*	*0.48*	*6*	*0.04*
Base Grab	10/4/2018 11:17	10/4/2018 11:17	8	0.047	10/4/2018 11:30	10/8/2018 7:30	485,836	11.16	243	1.43
Storm Composite	10/9/2018 19:05	10/10/2018 0:53	24	0.055	10/8/2018 7:30	10/10/2018 6:30	883,778	20.30	1,324	3.03
Base			*5*	*0.034*	*10/10/2018 6:30*	*10/10/2018 15:30*	*248,663*	*5.71*	*70*	*0.53*
*Base**			*5*	*0.034*	*10/10/2018 15:30*	*11/15/2018 0:00*	*305,460*	*7.02*	*86*	*0.65*
*Intermittent Flow**			*5*	*0.034*	*11/15/2018 0:00*	*12/27/2018 14:00*	*3,679*	*0.08*	*1*	*0.01*
*Storm**			*29*	*0.109*	*12/27/2018 14:00*	*12/28/2018 6:00*	*489,600*	*11.25*	*886*	*3.33*
*Intermittent Flow**			*5*	*0.034*	*12/28/2018 6:00*	*1/1/2019 0:00*	*32,400*	*0.74*	*10*	*0.07*
Storm Average			29	0.109						
Base Average			5	0.034						
All Average			24	0.095						
Total							**16,492,464**	**379**	**16,473**	**70**
Brown's Creek Major Subwatershed Total Acres							410			
Total TSS/TP(lb/ac/yr)									40.18	0.170
Total TSS/TP (kg/ha/yr)									45.03	0.191

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

*Interval volumes were estimated using similar flow conditions.

Table 5: 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 6: Brown's Creek at Highway 15 2018 Field Water Quality Results

Date/Time	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (umhos/cm)	pH
5/30/2018 9:30	16.3	4.76	363	7.5
6/27/2018 7:57	16.7	4.36	287	8.0
7/25/2018 9:04	9.7	4.88	394	8.0
8/16/2018 10:07	18.5	5.92		
8/22/2018 10:15	14.3	6.67	395	7.2
9/27/2018 8:13	10.4	6.30	331	7.5
10/18/2018 15:04	7.2	9.38	341	8.0

Exceeds Water Quality Standard

Table 7: Brown's Creek at McKusick Road 2018 Field Water Quality Results

Date/Time	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (umhos/cm)	pH
5/30/2018 9:55	17.2	7.26	393	7.9
6/27/2018 8:14	17.0	8.43	299	8.0
7/25/2018 9:28	17.3	7.76	436	7.8
8/16/2018 10:27	18.1	7.75		
8/22/2018 8:55	13.8	9.42	433	7.8
9/27/2018 8:38	11.1	9.52	356	7.8
10/18/2018 14:17	6.9	10.83	382	8.3

Exceeds Water Quality Standard

Table 8: Brown's Creek at Stonebridge Trail 2018 Field Water Quality Results

Date/Time	Water Temperature (^{o}C)	Dissolved Oxygen (mg/L)	Conductivity (umhos/cm)	pH
5/30/2018 9:15	17.7	7.64	396	8.0
6/27/2018 8:37	17.1	9.13	298	8
7/25/2018 9:49	17.8	7.78	431	8.1
8/16/2018 8:58	18.2	8.18		
8/22/2018 9:25	14.2	9.95	458	7.9
9/27/2018 9:02	11.2	10.14	356	7.9
10/18/2018 14:46	7.3	11.50	383	8.4

Exceeds Water Quality Standard

Table 9: Brown's Creek Outlet 2018 Field Water Quality Results

Date/Time	Water Temperature (^{o}C)	Dissolved Oxygen (mg/L)	Conductivity (umhos/cm)	pH
1/10/2018 10:55	2.0	12.93	493	8.4
1/24/2018 9:10	0.7	13.13	541	8.4
2/7/2018 12:00	0.7	12.87	493	8.3
2/21/2018 10:21	0.0	14.15	525	8.5
3/7/2018 8:24	1.3	13.54	517	8.3
3/21/2018 10:24	2.4	12.89	479	8.4
4/5/2018 9:35	0.5	13.97	511	8.2
4/18/2018 8:47	3.0	12.67	464	8.1
5/2/2018 9:40	11.5	10.43	478	8.2
5/16/2018 9:30	12.6	10.36	410	8.2
5/30/2018 8:55	16.8	7.98	431	8.1
6/13/2018 15:08	17.8	7.64	444	8.4
6/27/2018 9:03	16.6	9.71	329	8.2
7/11/2018 9:10	16.4	10.12	464	8.7
7/25/2018 10:13	16.1	8.54	469	8.4
8/8/2018 8:59	15.2	9.06	470	8.2
8/16/2018 9:33	16.8	8.72		
8/22/2018 9:37	13.7	10.02	488	8.1
9/5/2018 8:28	18.0	9.29	332	
9/19/2018 8:47	14.0	8.30	471	
10/3/2018 8:16	10.8	10.38	392	
10/17/2018 9:01	6.0	9.90	422	8.4
10/31/2018 9:02	5.7	11.65	425	
11/14/2018 15:00	2.0	13.56	475	
11/28/2018 9:33	1.1	13.62	487	
12/13/2018 11:00	1.5	14.49	456	8.28
12/26/2018 9:28	1.1	13.60	495	

Exceeds Water Quality Standard

Table 10: Brown's Creek Diversion 2018 Field Water Quality Results

Date/Time	Water Temperature (^{o}C)	Dissolved Oxygen (mg/L)	Conductivity (umhos/cm)	pH
5/30/2018 9:45	15.8	7.20	560	8.1
6/25/2018 10:13	18.1	7.59		
7/25/2018 9:18	20.4	7.38	507	7.7
8/22/2018 8:40	11.5	10.08	598	7.81
9/27/2018 8:25	14.5	8.52	562	7.6
10/18/2018 14:07	9.0	10.87	520	8.2

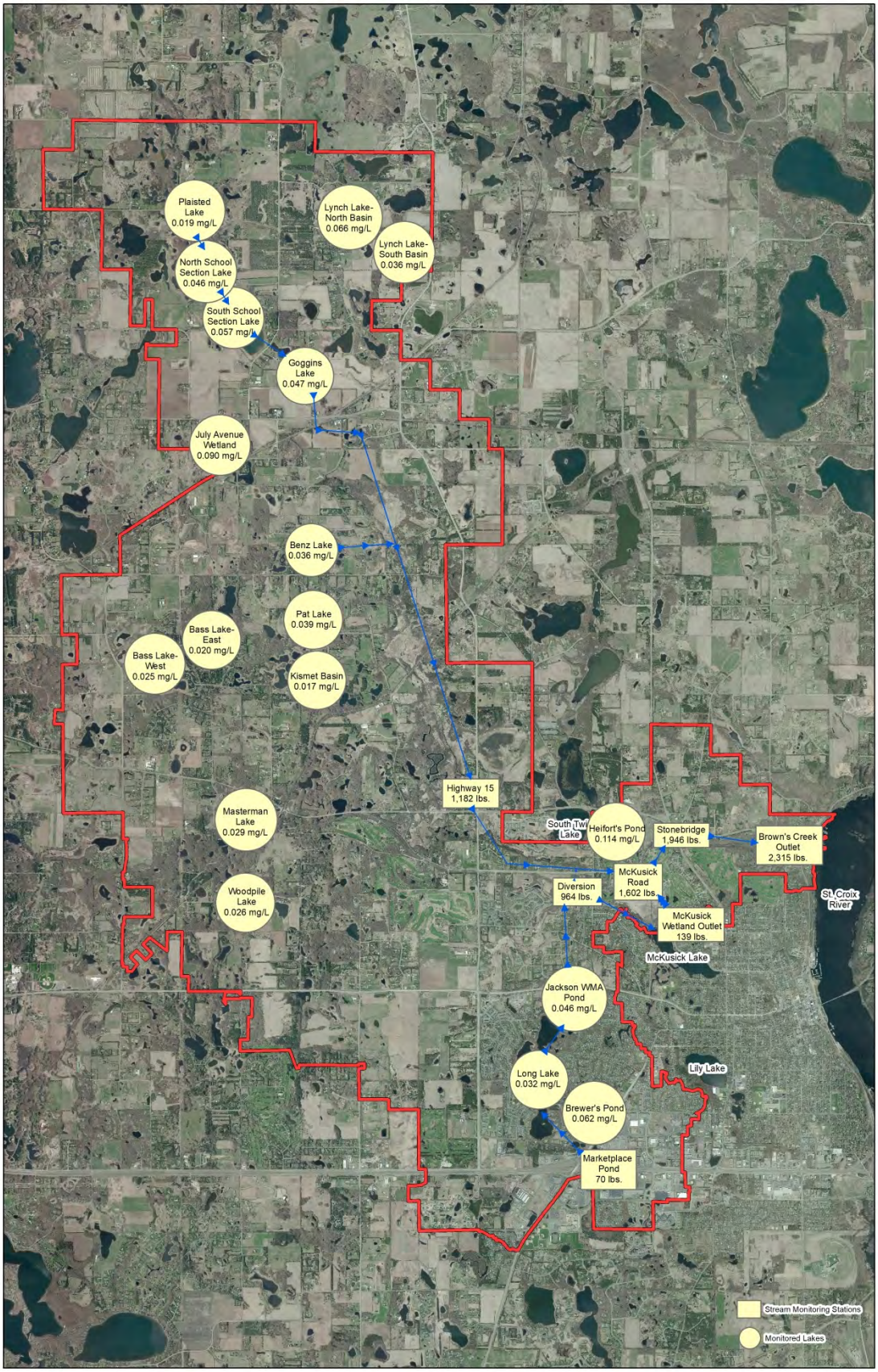
Exceeds Water Quality Standard

Table 11. McKusick Wetland Outlet 2018 Field Water Quality Results

Date/Time	Water Temperature (^{o}C)	Dissolved Oxygen (mg/L)	Conductivity (umhos/cm)	pH
5/30/2018 10:05	21	1.81	423	7.2
6/18/2018 13:34	21.5	2.17	360	6.1
6/27/2018 8:24	19.7	1.86	348	7.1
7/25/2018 9:37	20.2	1.33	435	6.8
8/22/2018 9:05	17.3	1.95	421	6.6
9/27/2018 8:44	12.3	1.97	371	6.7
10/18/2018 14:29	7.1	5.49	420	7.8

Exceeds Water Quality Standard

APPENDIX C – 2018 BROWN'S CREEK TOTAL PHOSPHORUS FLOW CHART



GLOSSARY

Anoxic- Lacking oxygen.

Best Management Practice (BMP)- Any practice or constructed feature designed to reduce pollution, erosion, or other environmental degradation such as silt fence, rain gardens, storm water pollution prevention plans, buffer strips, etc.

Biota- Living organisms such as plants, animals, and bacteria.

Chronic Standard- The highest water concentration or fish tissue concentration of a toxicant or effluent to which aquatic life, humans, or wildlife can be exposed indefinitely without causing chronic toxicity.

Composite Sample- A collection of individual samples taken over the course of a storm and combined into a single sample to represent conditions throughout the entire storm event.

Discharge- The amount of water moving past a given point in a stream, usually measured in cubic feet per second, but may also be discussed as the total volume of water that flowed through a site in a year, measured in cubic feet.

Eutrophic- Bodies of water with high levels of biological productivity characterized by high amounts of aquatic vegetation with clear water, or minimal vegetation with green water due to algal growth shading out larger plants. These waters are often shallow, have excessive nutrients, and may experience severe algal blooms resulting in anoxic conditions and potential fish kills. Most district lakes fall within this classification.

External Load- Nutrients or pollution contributed from outside a water body such as atmospheric deposition or inlets from streams or pipes.

Final Acute Value (FAV)- An estimate of the concentration of a pollutant corresponding to the cumulative probability of 0.05 in the distribution of all the acute toxicity values for the genera or species from the acceptable acute toxicity tests conducted on a pollutant. This concentration is severe enough to rapidly induce a response, normally observed in 96 hours or less. Acute mortality can be expected above this concentration.

Gaining Stream- A stream which gains water through the stream bed from groundwater.

Hypereutrophic- Bodies of water with extremely high biological productivity and nutrients which often experience severe algal blooms, very low clarity, and limited aquatic life beyond algae and vegetation. Often have the appearance of “pea soup” in mid-summer.

Impaired Waters List/303(d) List- A section of the Clean Water Act which lists water bodies impaired by one or more pollutants for which a TMDL study should be completed.

Internal Load- Nutrients or pollution cycled within a lake from sediments, vegetation, or other sources within a water body.

Littoral- The area of a lake less than 15 feet deep dominated by aquatic vegetation.

Load/Loading- The amount of nutrients or pollutants from a source, usually expressed as pounds or pounds per acre.

Losing Stream- A stream which loses water through the stream bed to the groundwater.

Maximum Standard- The highest concentration of a toxicant in water to which aquatic organisms can be exposed for a brief time with zero or slight mortality. The max standard is half of the final acute value.

Mesotrophic- Bodies of water with an intermediate amount of biological productivity. These waters are typically clear water with healthy aquatic vegetation, some algal growth, and an intermediate amount of nutrients. When stratified, these waters may become anoxic near the bottom.

Non-point Source- A source of pollution from a undefined area such as runoff from a landscape.

Nutrients- Discussed in this report as total phosphorus (TP), total suspended solids (TSS) or sediment, and total Kjeldahl nitrogen (TKN).

Ordinary High Water Level (OHWL)- The boundary of public waters and wetlands determined by a level of water maintained with enough time to leave evidence upon the landscape, such as a change in natural vegetation from terrestrial to aquatic, or the top of the bank of a channel.

Oligotrophic- Bodies of water with low biological productivity characterized by clear water, low algal growth, low nutrient concentrations, minimal aquatic vegetation, and well-oxygenated water.

Point Source- A source of pollution from a single defined outlet such as a pipe.

Shallow Lake- A lake 50 acres or greater in size and less than 15 feet deep, or has greater than 80% littoral area.

Stratification- Separation of water within a lake based on density as a result of differences in water temperature from warm water near the surface and heavy, cold water near the bottom.

Thermocline/metalimnion- The boundary between warm and cold water within a stratified lake characterized by a sudden change in temperature and dissolved oxygen.

Total Maximum Daily Load (TMDL)- Defined by the Clean Water Act as the amount of a pollutant a water body can receive and still meet water quality standards. TMDL studies will often assign a point source load, non-point source load, internal load, and a margin of safety to each pollutant to guide management activities for load reductions from each source.