2015 Research and Monitoring Report

MINNEHAHA CREEK
WATERSHED DISTRICT
QUALITY OF WATER, QUALITY OF LIFE

2015 Research and Monitoring Report

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Minnehaha Creek below Minnehaha Falls by Ernesto Ruiz

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PREFACE

The Minnehaha Creek Watershed District is comprised of eleven major subwatersheds and the major hydrologic features of the watershed are Lake Minnetonka, Minnehaha Creek, and the Minneapolis Chain of Lakes. The waterbodies throughout the 181 square miles of the watershed have been monitored by the District since 1968. The Research and Monitoring Department is responsible for assessing the waterbodies throughout the watershed in 2015.

The Water Quality Program assesses waterbodies to establish baseline conditions as well as for determining long-term change. In the upper watershed, staff and trained volunteers monitored 34 lakes, one wetland, 36 stations on 11 streams, and 20 bays on Lake Minnetonka. In the lower watershed, which begins at the Grays Bay Dam and extends to the Minnehaha Falls, 6 lakes, 1 wetland, and 10 stations on Minnehaha Creek were monitored. The Water Quality Program collaborates with several agencies who also monitor lakes within the Watershed District. Minneapolis Parks and Recreation Board, Three Rivers Parks District, and Metropolitan Council Environmental Services' Citizen-Assisted Monitoring Program collected the data for an additional 5 upper watershed lakes, 12 lower watershed lakes, and 1 lower watershed wetland in 2015. The data is summarized in this report.

In 2015, the Aquatic Invasive Species (AIS) Program monitored the distribution and abundance of invasive species in 40 different lakes across the District, and used this data to assess the impacts AIS are having on the ecological community of those lakes. Annual early detection monitoring occurred on 16 lakes by the District and its partners. These are usually on lakes with a public access, high-use and developed shorelines. AIS baseline assessments were also conducted on 20 lakes, which inventoried AIS in District waterbodies to determine presence/absence of AIS. These surveys focus on waterbodies where data gaps exist. The data is summarized in this report.

Research projects conducted in 2015 include Six Mile Marsh Subwatershed Carp Assessment, Lake Minnetonka Zebra Mussel Study, Hybrid Milfoil Study and Lake Nokomis Biomanipulation project. The progress and/or results for each project are summarized in this report. The Christmas Lake zebra mussel rapid response also wrapped up in 2015, and lessons learned from that response are also summarized in this report.

The 2015 research and monitoring report presents results in three sections: Executive Summary, Subwatershed Summaries, and Research Project Summaries. There are three appendices that detail additional analyses, programs' methods, and basin station information.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT.)

FIGURES AND TABLES

FIGURES

FIGURES

FIGURES

FIGURES

TABLES

TABLES

ACRONYMS

303 (d) List	Minnesota Pollution Control Agency's List of Impaired Waters under the Clean Water Act
CAMP	Citizen Assisted Monitoring Program
CFS	Cubic feet per seconds
CFU/100 mL	Colony forming units per 100 milliliters
CPR	Citizen Precipitation Recorders
DO	Dissolved oxygen
CHLA	Chlorophyll-*a*
CLP	Curly-leaf Pondweed
Cl	Chloride
EPA	Environmental Protection Agency
EQuIS	Environmental Quality Information System
EWM	Eurasian Watermilfoil
GPS	Global Positioning System
lbs	Pounds
LID	Low Impact Development
LMCD	Lake Minnetonka Conservation District
MCES	Metropolitan Council Environmental Services
MCWD	Minnehaha Creek Watershed District
mg/L (ppm)	Milligrams per liter, parts per million
µg/L (ppb)	Micrograms per liter, parts per billion
µS/cm	Micro Siemens per centimeter
MnDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MPRB	Minneapolis Park and Recreation Board
MSP	Minneapolis – St Paul International Airport
NCHF	North Central Hardwood Forest (Ecoregion)
NOAA	National Oceanic and Atmospheric Administration
OHW	Ordinary high water (level)
OP	Ortho-phosphate
NWS	National Weather Service
QA/QC	Quality Assurance/Quality Control
SECC	Secchi depth
TMDL	Total Maximum Daily Load
TN	Total nitrogen
TP	Total phosphorus
TRPD	Three Rivers Park District
TSI	Trophic Status Index
TSS	Total suspended solid

GLOSSARY

Chloride: a compound of chlorine with another element or group, like a salt of the anion Cl^-. The concentration of chloride found in surface water often correlates with the proportion of impervious surfaces in a watershed. Once road salt is applied, chloride remains in a waterbody, and therefore, the watershed until it is flushed downstream.

Chlorophyll-a: Chlorophyll-*a* concentration is a proxy for phytoplankton (algae) biomass in the water.

Dissolved Oxygen: The amount of oxygen present in in the water which can indicate the ability of that waterbody to support aquatic life.

Ecoregion: The geomorphic and chemical properties of lakes and streams that vary across the state. These differences are the reasons for dividing the state into seven different ecoregions. Each ecoregion contains a geographically distinct collection of plants, animals, natural communities and environmental conditions.

Epilimnion: Upper layer of more or less uniformly warm, circulating, and fairly turbulent water during summer stratification.

Escherichia coli (E. coli): *E. coli* are a member of the fecal coliform group of bacteria. Ingestion of water with high levels of *E. coli* may cause illness.

Eutrophication: Is excessive nutrients that accumulates in a waterbody that can support a dense growth of algae and plants. The resulting growth depletes oxygen that is needed to support aquatic life.

Grays Bay Dam: The Headwaters of Minnehaha Creek is an adjustable structure that controls Lake Minnetonka levels and discharge into Minnehaha Creek. Staff in the Project Maintenance and Land Management Program operate the dam in accordance with operating procedures approved by the MnDNR.

Hydraulic: The scientific study of liquid in motion and the forces and pressures associated with them.

Hydrology: Waters of the earth, their movement and occurrences on the surface and underground, and how it cycles as evaporation, precipitation, and flow to waterbodies.

***Hypolimnion*:** The lowest stratum during summer stratification, which changes very little in temperature

Internal Loading: Release of phosphorus from lake sediments during oxygen-depleted conditions. Depending on the overall nutrient budget for a lake, internal loading can be a major source of in-lake phosphorus annually and can contribute to eutrophication.

Macrophyte: A relatively large aquatic plant. Examples include floating-leaved (e.g., water lilies), submerged (e.g., coontail), and emergent (e.g., cattail).

Metalimnion: The layer between the epilimnion and hypolimnion that exhibits a marked thermal discontinuity.

Nitrogen: Algae and other plants require N as a primary nutrient. Ammonia and nitrate N are the chief forms susceptible to algal and plant uptake, but certain dissolved organic forms can also be assimilated. Measurement of N provides insight into the total potential for algal and plant growth.

Nitrate: Nitrate-N is nitrogen dissolved as nitrate ion (NO_3^-). Elevated nitrate levels usually indicate bacterial nitrification, which is typical of sewage-contaminated waters.

Tailwater: Refers to waters located immediately downstream from a hydraulic structure, such as a dam

Total Kjeldahl-Nitrogen: Total Kjeldahl-Nitrogen (TKN) measures the total of all N in the form of either organic-N or ammonia-N. Organic-N includes particulate forms (such as cell matter from algae or bacteria, and sewage solids) and dissolved forms (such as proteins and peptides).

pH: pH measures the concentration of hydrogen ion (H^+) in water. Surface waters in the metropolitan area are usually basic (pH greater than 7.0), due to plant and algal photosynthesis and geologic characteristics.

Phosphorus: Total phosphorus (TP) measures the sum of all forms. Settling of solids, algal and bacterial cell matter, as well as uptake by rooted plants, removes P from the water. TP measurements show the maximum potential for algal growth and can be used to classify the trophic status of a lake.

Soluble Reactive Phosphorus: Soluble reactive phosphorus (SRP) or orthophosphate measurements show the amount of P immediately available for algae and plant life.

Secchi Depth: The Secchi depth provides a physical measurement of water clarity by observation of the Secchi disc at the maximum visual depth in the water column. Secchi depth is an indicator of algal population density and turbidity, and can be utilized to classify the trophic status of the lake.

Specific Conductance: Specific conductance is a measure of the water's ability to act as a conductor. High conductivity is an indicator of low water quality and implies high concentrations of chlorides or other dissolved solids.

Subwatershed: Part of a larger watershed, a subwatershed is the land that drains to a specific waterbody.

Trophic State: The trophic state of a lake is a *qualitative* description of biological productivity. Common terms include eutrophic, mesotrophic, and oligotrophic

Watershed: A watershed is the area of land that drains to a common lake, wetland, stream or river.

EXECUTIVE SUMMARY

The Minnehaha Creek Watershed District (MCWD) monitors lakes and streams within its watershed boundaries on a seasonal basis for water quality indicators linked to recreational, aesthetic, and biological conditions. There are eleven major subwatersheds within the Minnehaha Creek watershed (Figure 1). Highlights and findings from 2015 are summarized below by subwatershed.

Christmas Lake Subwatershed

There has been an increase in phosphorus loading from the lake's inlet on the south side since 2012. This increase can be connected to increased precipitation events and flow, however, other factors, such as development, construction, and/or eroding stream banks may also be a factor in the increased phosphorus contribution. The amount of loading is not considerable when compared to other lakes within the District and at this time, it is not having any ecological impacts to the lake.

Zebra mussels were found in the lake in 2014. Based on the historic algae levels in Christmas Lake, the population is not predicted to be very abundant. Current algae conditions may be just enough for a quick rise in population, but should not sustain an abundant population for very long.

Dutch Lake Subwatershed

While Dutch Lake's water quality has remained poor, the District explored the stormwater influence on the lake with the help of a local volunteer. Samples were collected at three storm pipes that empty into the lake after storm events, and results showed total phosphorus ranging from 116 ug/L to 959 ug/L. Road/culvert construction was occurring at this time during 2015. The combination of these two sources plus internal loading has left Dutch Lake impaired for excessive nutrients.

Gleason Lake Subwatershed

The loading at the Gleason Lake inlet was comparable to the 10-year average, though Gleason Lake creek inlet is on the impaired list for chloride and aquatic life. The settling pond which the inlet flows into prior to reaching Gleason Lake, recently underwent maintenance in the winter of 2015.

Lake Minnetonka Subwatershed

There are trends showing significant changes to water quality in many of the eastern bays of Lake Minnetonka. These changes in water quality seem to correlate with high densities of zebra mussels in this part of the lake. As the density has increased in these bays, algae is becoming more limited and clarity is increasing. Total Phosphorus is declining as well, and further investigation is ongoing to assess the relationship between zebra mussels and phosphorus. While these changes may seem positive, production is changing in these bays from pelagic (open water) to benthic (bottom). This can result in more benthic algae blooms, possible blue-green algae blooms, and reduced food sources for certain organisms, and eventual shifts in fish composition to favor benthic organisms.

Long term trends are also indicating increases in water clarity for Crystal Bay and Spring Park Bay, decreasing chlorophyll-a concentrations for Black lake, and decreasing phosphorus concentrations for Spring Park Bay. Zebra mussels are present in several of these bays, and the population is continuing to rise due a to sufficient food base for them. It's unknown at this time if the decline of chlorophyll-a concentrations in Black Lake is due to zebra mussels or other factors.

Many of the western bays of Minnetonka continue to have nutrient impairments. There were significant trends indicating degrading water quality for Peavey Lake and increasing phosphorus concentrations for Peavey and Priests Bay. Zebra mussels are present in many of these western bays, but remain at a very low abundance due to a poor food source, dominated by blue-green algae. Aquatic plant life is also relatively sparse in these bays, as they tend to be more algae dominated.

Lake Virginia Subwatershed

Significant trends indicated declining water quality in Lake Virginia. Nutrient loading into Lake Virginia may be underestimated, and in 2016, MCWD will be monitoring a station closer to the inlet of Lake Virginia. Zebra mussels are present in Virginia, but remain at a low density and do not seem to be impacting water quality at this time. Tamarack, a smaller deep lake within the watershed that is on the States impaired list for nutrients, met all three water quality standards in 2015 and has shown significant improvement in water clarity. Re-evaluation of Tamarack may be needed for delisting in the coming years.

Langdon Lake Subwatershed

Phosphorus loading from the Langdon Lake inlet in 2015 was comparable to its 10-year loading average of 32 pounds. The lake was historically a receiving water for a wastewater treatment plant and the remnant of phosphorus concentrations are continuing to contribute to the internal loading problems.

Long Lake Subwatershed

Despite the decline in recent secchi disk averages, long term trends still show a slight improvement in water clarity for Long Lake. In 2015 Long Lake received only half the pounds of phosphorous that it historically does from the north inlet. However, downstream of Long Lake, the inlet to Tanager had slightly higher phosphorous loading than average. Tanager had the highest concentrations of algae within the entire subwatershed

Minnehaha Creek Subwatershed

A biomanipulation project occurred from 2010 – 2013 in Lake Nokomis. Long term trends now indicate a significant improvement in phosphorus and chlorophyll-a concentrations. In addition to the water quality improvements in Nokomis, aquatic plant diversity is also increasing. However, common carp are still thought to be impacting water quality and aquatic plants in Nokomis, and a carp study led by the MPRB is in development.

Long term trends on Lake Harriet show an increase in phosphorus concentrations, however, the mean concentration is still low enough that it is not yet exceeding the eutrophication standards.

Long term trends show Cedar Lake had a significant decline in water clarity, while Lake of the Isles had a significant improvement in chlorophyll-a concentrations.

Excessive nutrient and chloride loading continue to be an issue for Minnehaha Creek. In 2015, the largest phosphorus loads occurred at 21st Ave and Hiawatha Ave in Minneapolis. On average, the largest phosphorus and chloride loading occurs between Edina and Minneapolis.

Painter Creek Subwatershed

Even though phosphorus loading was below average in 2015 in the creek, it is still the highest contributor of phosphorus to Lake Minnetonka. Out of the five stations monitored on Painter Creek, the outlet of Painter Marsh near Co Rd 26, contributed the greatest amount of phosphorus to the Creek.

Schutz Lake Subwatershed

For the first time since 2002, Schutz Lake failed to meet all three of the eutrophication standards. Long term trends show chlorophyll-a concentrations have significantly increased over time. Schutz Lake creek inlet had above average phosphorus loads in 2015 which may have contributed to the increased lake nutrient concentrations.

Six Mile Marsh Subwatershed

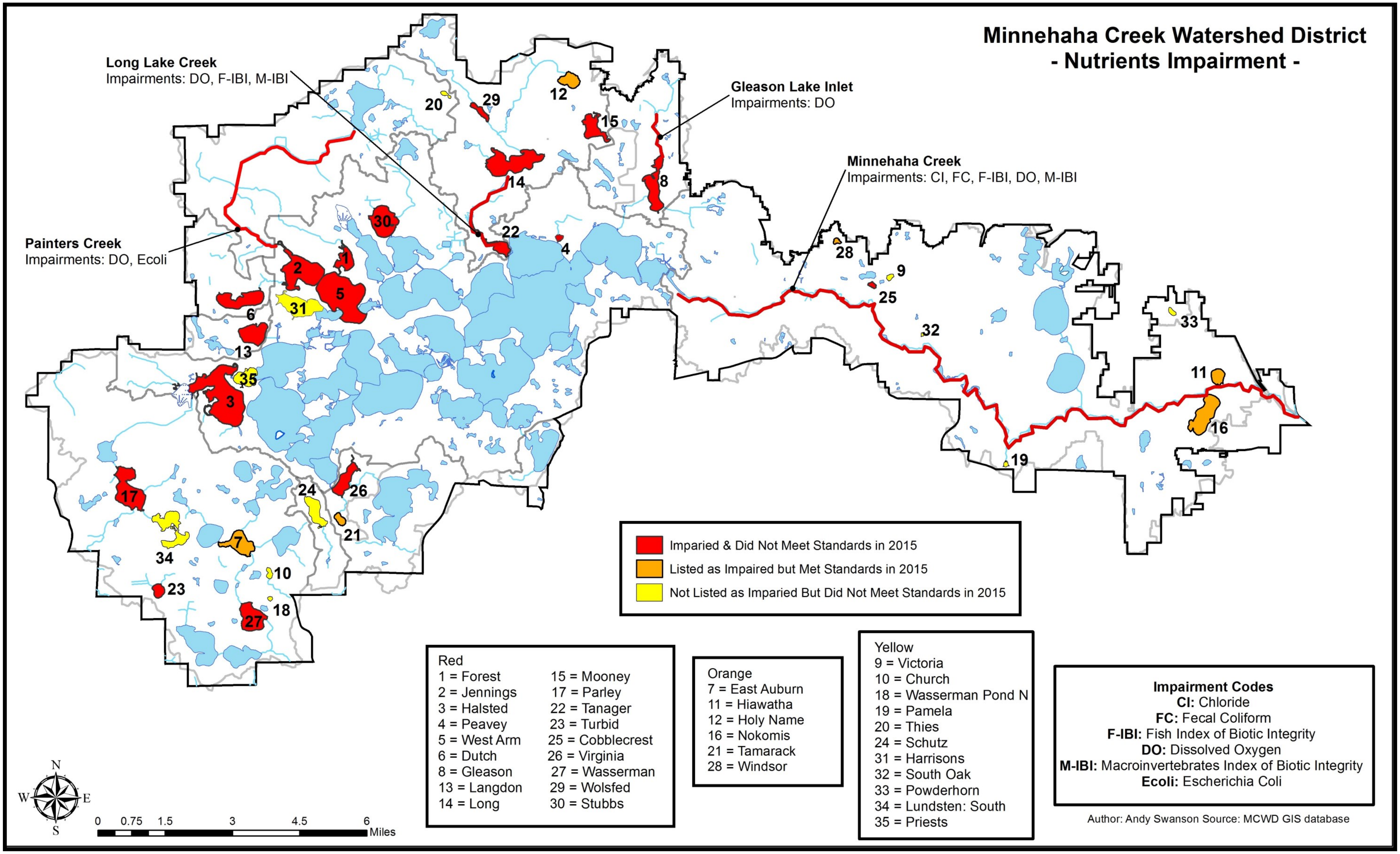
Six Mile Marsh is a complex system with many contributing factors such as a large abundance of carp, intermittent stream systems driven by precipitation, and many wetlands that could be acting as a source or sink for phosphorus. For example, diagnostic monitoring showed that the wetland between Turbid Lake and Lundsten South is most likely acting as a source of phosphorus.

Common carp are a contributor to poor water quality and poor aquatic plant communities. The District is wrapping up a study in 2017 that is assessing carp movement, abundance and recruitment areas throughout the entire subwatershed. More information can be found in the research section of this report.

Most stream stations within the subwatershed have intermittent flow with many locations with dry or no flow conditions during the summer months. Precipitation is a driver of loading in the Six Mile Creek. Dissolved oxygen concentrations are often less than 5 mg/L at most stations monitored.

The Parley-Mud-Halsted area is one of the more degraded sections in the subwatershed. Mud Lake received more pounds of phosphorous from its NW inlet than Parley Lake received from all three of the lake's inlets combined. Investigational monitoring is occurring in 2016 upstream of this inlet. Downstream of Mud Lake, the highest phosphorous loading and concentrations in the subwatershed occur before entering Halsted Bay. This section also has some of the highest carp densities in the subwatershed.

Despite heavy land use changes through much of the watershed and a strong carp influence, some waterbodies are holding steady and even improving. Zumbra, Stone, and Steiger had long term trends indicating increased water clarity, and a decrease in chlorophyll-a and phosphorous concentrations. Stone Lake is listed on the impaired waters list but has not exceeded the eutrophication standards since 2007 and should be re-evaluated for delisting.



Nutrient Impairments throughout Minnehaha Creek Watershed District.

INTRODUCTION

1.1 Minnehaha Creek Watershed District

The Minnehaha Creek Watershed District (MCWD) was established in 1967, and is responsible for managing and protecting the water resources of the Minnehaha Creek watershed drainage basin. The drainage basin extends for 181 square miles draining into the Minnehaha Creek and ultimately into the Mississippi River. The watershed district encompasses 11 subwatersheds which drains 12 creeks, 129 lakes, and thousands of wetlands throughout two counties, 27 cities, and two townships.

The watershed of Minnehaha Creek includes approximately 151 square miles in Hennepin County and 30 square miles in Carver County. The upper watershed includes Lake Minnetonka (est. 14,101 acres) and the land that drains into Lake Minnetonka. The lower watershed includes Minnehaha Creek (22 miles) and the land that drains into the Minnehaha Creek east of Lake Minnetonka. The Lake Minnetonka outlet is located at Gray's Bay Dam, the headwaters of Minnehaha Creek (Figure 1). Each watershed feature provides unique recreational opportunities and aesthetic resources.

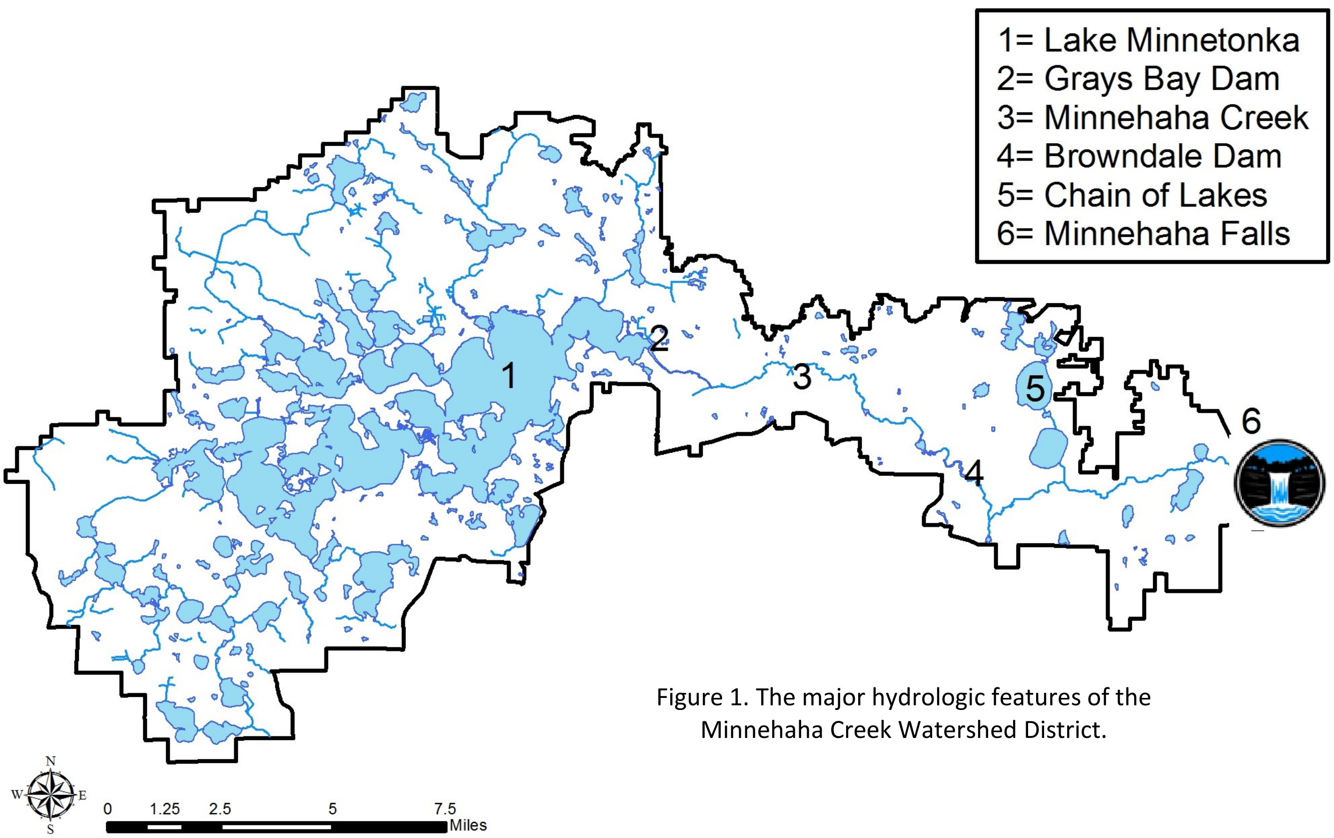


Figure 1. The major hydrologic features of the Minnehaha Creek Watershed District.

The MCWD seeks to conserve the natural resources of Minnehaha Creek watershed through efforts in monitoring, protecting, restoring, education and communication. Through monitoring and analysis of the waterbodies, MCWD has identified areas of water quality degradation and flooding. MCWD has then used this knowledge to develop and implement solutions that improve or maintain the water quality throughout the watershed.

Waterbodies throughout the Watershed District have been monitored since 1968. The monitoring program was managed by consultants until 2004, when the program management was brought in-house.

1.2 The Research and Monitoring Department

Since 2004, the monitoring program has grown into a department and has continued to evolve with the monitoring and research efforts over the years. Since 2014, the Research and Monitoring Department became comprised of three programs: Water Quality, Aquatic Invasive Species, and Ecosystem Evaluation. The mission of the Research and Monitoring Department is to assess and report on the health/function of the aquatic ecosystems throughout the Watershed District. Data collection, collaboration with partners, and informing/empowering communities are inherent among the three programs.

The Research and Monitoring Department conducts monitoring and research to understand the present condition/function of the landscape types throughout the Watershed District, often with the assistance of partners. Minneapolis Park and Recreation Board (MPRB), Three Rivers Park District (TRPD), Lake Minnetonka Conservation District (LMCD), Metropolitan Council Environmental Services (MCES) and its Citizen-Assisted Monitoring Program (CAMP), United States Geographical Survey (USGS), Minnesota Pollution Control Agency (MPCA), and Minnesota Department of Natural Resources (MnDNR) are just to list a few.

Annual research and monitoring reports can be found at www.minnehahacreek.org. Past reports as well as raw data is available upon request. Raw monitoring data can also be found at MPCA's webpage - https://www.pca.state.mn.us/data/surface-water-and-stormwater-data.

1.3 The Water Quality Program

The Water Quality Program assesses waterbodies to establish baseline conditions as well as for determining long-term change. Precipitation, water level, discharge, and stream and lake water quality data is collected and analyzed. The data is used by the Watershed District for the following purposes:

- Conduct statistical analysis
    - Identify long-term trends
    - Identify changes in loading yields
    - Maximize efficiencies in monitoring frequencies, locations and events
- Identify waterbodies not meeting the established standards as set by MPCA
- Conduct investigational monitoring to identify issues and/or new areas of concern
- Calibrate models
- Report results to bring awareness about the health/function of the waterbodies

1.4 The Aquatic Invasive Species Program

The Aquatic Invasive Species (AIS) Program was established in response to the zebra mussel infestation in Lake Minnetonka in 2010. The AIS program seeks to prevent the establishment and spread of AIS across the District, monitor current populations of AIS and assesses their impact on water quality and native biological communities, and perform research to better understand the impacts AIS have on different types of water-bodies and evaluate new control measures to manage AIS. The biological data collected is used by the Watershed District for the following purposes:

- Conduct statistical analysis
    - Identify changes in the waterbodies pre/post AIS infestation
    - Measure success of prevention and/or treatment efforts
- Empower communities to take personal responsibility to reduce the spread of AIS
- Report results to
    - Promote AIS awareness and education
    - Identify issues and/or new AIS of concern

1.5 The Ecosystem Evaluation (E-Grade) Program

The Ecosystem Evaluation (E-Grade) Program is a new program that began development in 2014 and is projected to be implemented in 2018. Its purpose is to provide a tool that allows the District to evaluate and grade the function/health of the entire watershed from a more holistic approach. The new system will continue to evaluate/grade deep lakes, but will also evaluate/grade additional landscape types, such as shallow lakes, streams, wetlands, uplands, and groundwater. Each of the landscape types will be assessed for the following functions: flood control, nutrient cycling, biodiversity, habitat diversity, recreation, and groundwater supply.

The E-Grade tool is being tested during development on data collected from the following subwatersheds: Six Mile Marsh, Schutz Lake, and Minnehaha Creek. The remaining subwatersheds will be evaluated and graded on a three-year rotation, with the E-Grade reports to be released following the scheduled displayed in Table 1, Figure 2.

Table 1. E-Grade Report Schedule by Subwatershed

2018	2021	Summer 2024	Fall 2024
Minnehaha Creek Schutz Lake Six Mile Marsh	Dutch Lake Langdon Lake Long Lake Creek Painter Creek	Christmas Lake Gleason Lake Lake Minnetonka Lake Virginia	Entire Watershed

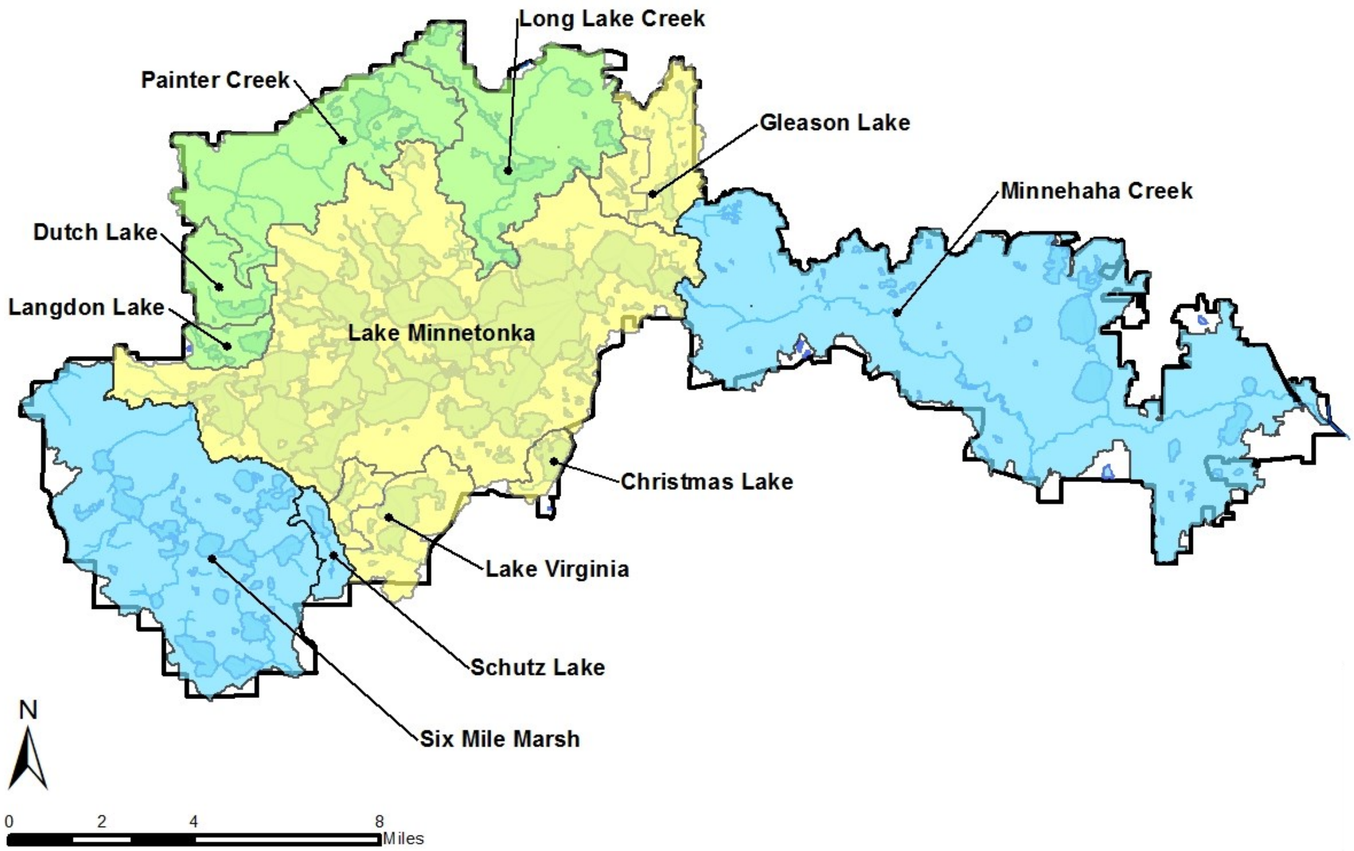


Figure 2. MCWD Subwatershed Map

2. GUIDELINES, STANDARDS, and ANALYSES

The Minnesota Pollution Control Agency (MPCA) has determined that lakes and streams have unique physical and chemical properties depending on where they are located in the state. Waterbodies within the MCWD reside within the North Central Hardwood Forest Ecoregion (NCHF). This is the transitional area in central Minnesota where the southeastern agricultural area meets the northeastern forested area. This ecoregion is comprised of upland wooded areas, as well as small plains that are used for agriculture. Much of this area has been developed for residential, recreational, urban and agricultural land use. The MPCA has established guidelines and standards specific to the NCHF ecoregion for both lakes and streams. At this time, there are no NCHF guidelines and standards for wetlands.

2.1 Ecoregion Guidelines: The MPCA provides guidelines based on median water quality data that is characteristic for the lakes and streams within the NCHF ecoregion (Table 2).

Table 2. North Central Hardwood Forest Ecoregion Water Quality Guidelines for Lakes and Streams

North Central Hardwood Forest Ecoregion	Water Quality Guidelines (25^{th} – 75^{th} percentile)		
	Units	Lakes	Streams
Secchi Depth (SECC)	m	1.5 - 3.2	
Chlorophyll-*a* (CHLA)	µg/L	5 - 22	
NOx	mg/L	< 0.01	0.04 - 0.26
Temperature	°C		2 - 21
Total Kjeldahl Nitrogen (TKN)	mg/L	< 0.60 - 1.2	
Total Phosphorus (TP)	µg/L	23 - 50	60 - 150
Total Suspended Solids (TSS)	mg/L	2 - 6	4.8 - 16
pH	N/A	8.6 - 8.8	7.9 - 8.3

2.2 Lake Standards

Ecoregion Eutrophication Standards: Ecoregion lake eutrophication standards are used for assessing the recreational use of lakes in Minnesota. If a lake fails to meet two or more of the standards over two consecutive years, then the MPCA evaluates listing the lake as impaired for nutrient/eutrophication biological indicators. Different eutrophication standards have been established for shallow and deep lakes. Shallow lakes are defined as a having a maximum depth less than 15 feet and a littoral zone greater than 80 percent of the lake surface area. Station-specific water quality standards have been approved for Lake Hiawatha and Lake Nokomis (Table 3).

Table 3. North Central Hardwood Forest Ecoregion Eutrophication Standards for Shallow and Deep Lakes, and Station-Specific Eutrophication Standards for Lake Hiawatha and Lake Nokomis

North Central Hardwood Forest Ecoregion	Eutrophication Standards (June-Sept Means)				
	Units	Shallow Lakes	Lake Hiawatha	Lake Nokomis	Deep Lakes
Secchi Depth (SECC)	m	> 1.0	> 1.4	> 1.4	> 1.4
Chlorophyll-*a* (CHLA)	µg/L	< 20	< 14	< 20	< 14
Total Phosphorus (TP)	µg/L	< 60	< 50	< 50	< 40

Chloride Standard: The criteria for lakes to be evaluated for impairment is found in Table 4.

Table 4. North Central Hardwood Forest Ecoregion Chloride Standard for Lakes

North Central Hard-wood Forest Ecoregion	Chloride Standard	
	Chronic	Acute
	Impaired: 2 or more exceedances in 3 years	Impaired: 1 or more exceedances of the max standard
Chloride (Cl)	230 mg/L	860 mg/L

2.3 Stream Standards

Dissolved Oxygen Standard: To determine if a stream is able to support aquatic life, the dissolved oxygen (DO) standard has to be violated under the several criteria (See Appendix B). One criteria requires DO samples to be collected to 9:00 am. Although MCWD consistently monitors the stations at the same time every week, the data is not collected prior to 9:00 am.

Two factors effect DO levels in the watershed district's streams: intermittent flow and stream stretches classified as ditched. Intermittent streams tend to cease flow occasionally or seasonally. Low flow and/or no water negatively effects DO levels. The MPCA considers ditched streams as streams altered from their natural state, and will evaluate listing these stream stations for DO impairment on a case-by-case basis.

Table 5. Dissolved Oxygen Standard for Streams

DO Standards	
Dissolved Oxygen (DO)	> 5 mg/L

Chloride Standard: The criteria for streams to be evaluated for impairment is found in Table 6.

Table 6. North Central Hardwood Forest Ecoregion Chloride Standard for Streams

North Central Hard-wood Forest Ecoregion	Chloride Standard	
	Chronic	Acute
	Impaired: over a 4-day average	Impaired: over a 1-hour duration
Chloride (Cl)	230 mg/L	860 mg/L

***E. coli* Standard:** A minimum of five values per month for at least 3 months between June and September is preferred for determining violations of the *E. coli* standard (Table 7).

Table 7. *E. coli* Standard for Recreational Use in Streams

North Central Hardwood Forest Ecoregion	Chronic	Acute
	Impaired: Geometric mean of not less than 5 samples within any calendar month	Impaired: Not more than 10% of all samples taken during any calendar month individually exceed
E. coli	126 cfu/100 mL	1,260 cfu/100 mL

2.4 Analyses - Lakes

Summer Means: For each lake seasonal means are computed for each of the three parameters (surface TP, surface CHLA, and SECC). The data has to be collected from four or more monitoring events between June through September. Field duplicates are averaged together before computing the means.

Long-term Trend Analysis: Using R-studio statistical package, trends were computed using the Mann-Kendall test on SECC, surface CHLA, and surface TP on lakes with at least eight years of consecutive data. MCWD used an alpha of 0.1 to determine if the trend is significant.

2.5 Analyses - Streams

Means: For each stream station, annual means are computed for all parameters collected at that station. The data is collected on a weekly basis from thaw to freeze. Field duplicates are averaged together before computing the means.

Nutrient Loading: For each stream station, flow and nutrient concentrations are measured. Nutrient loads are then calculated for TP, SRP, TN, TSS and Cl.

3. SUBWATERSHED SUMMARIES

3.1 Precipitation throughout MCWD

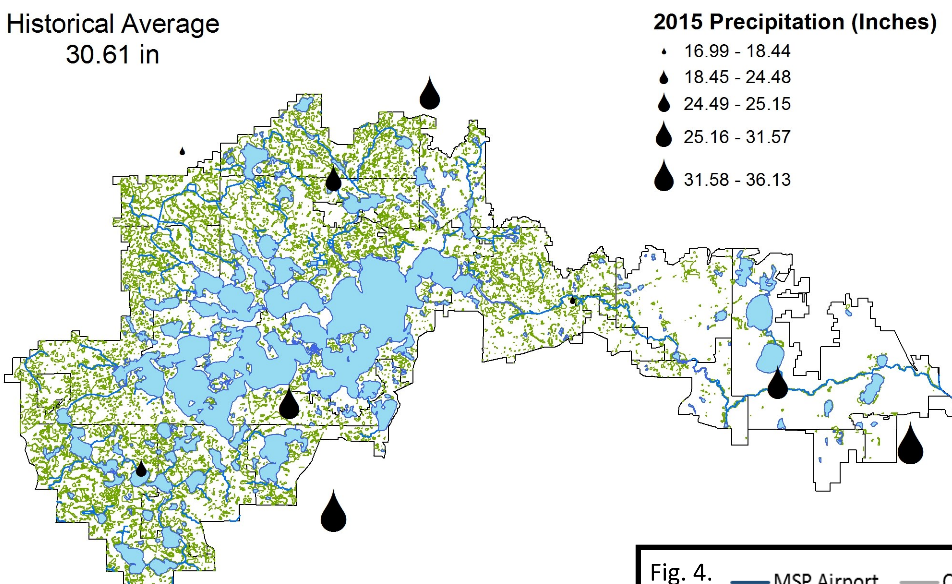
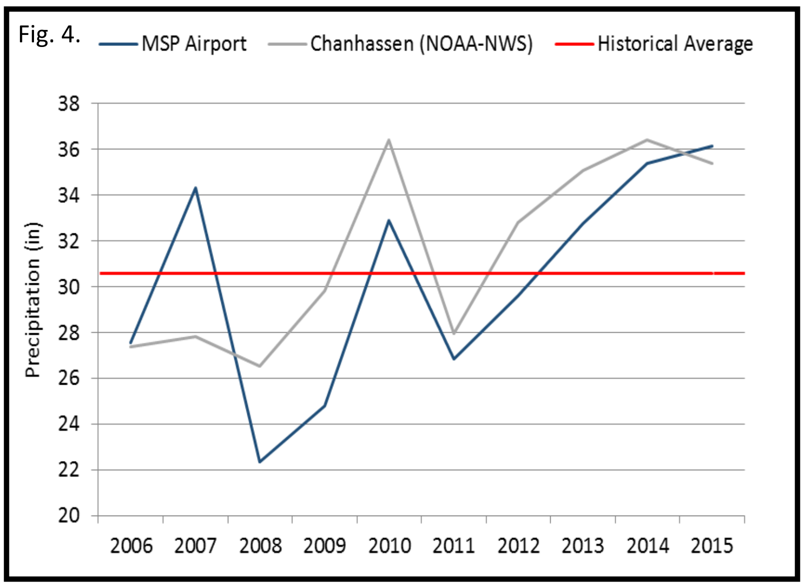
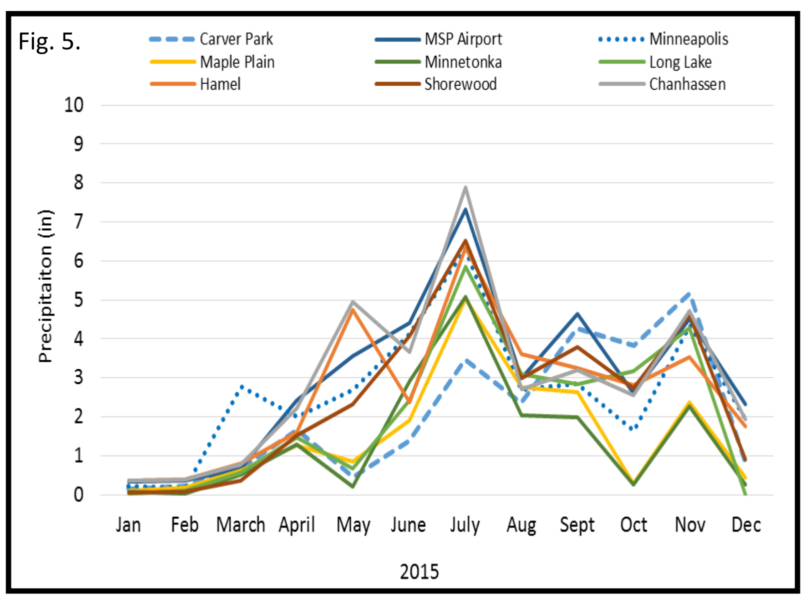


Figure 3. 2015 precipitation totals throughout MCWD.

Figure 4. Annual precipitation totals compared to historical average.

Figure 5. Monthly precipitation totals at all stations throughout MCWD.





Although MCWD records precipitation throughout the watershed, MSP Airport and Chanhassen (NOAA-NWS) provide more reliable data records. Chanhassen and Minneapolis experienced above average precipitation, where the rest of the monitored cities received at or below average precipitation (Figure 3 and 4). Precipitation amounts varied, but the largest events occurred in the same months for most stations - July, September and November (Figure 5).

The late fall precipitation in 2015 kept the intermittent streams throughout the watershed flowing into late December, including Minnehaha Creek.

The Grays Bay Dam is outlet of Lake Minnetonka and the headwaters of Minnehaha Creek. The Grays Bay Dam had stopped discharging for a week in late October in preparation for ice-in; however, November precipitation events raised Lake Minnetonka's water levels to 928.67 ft forcing the Dam to begin discharging again (Figure 6). Majority of the discharge in 2015 occurred during this period at 300 cfs. Grays Bay Dam did not stop discharging in 2015 until December 21st.

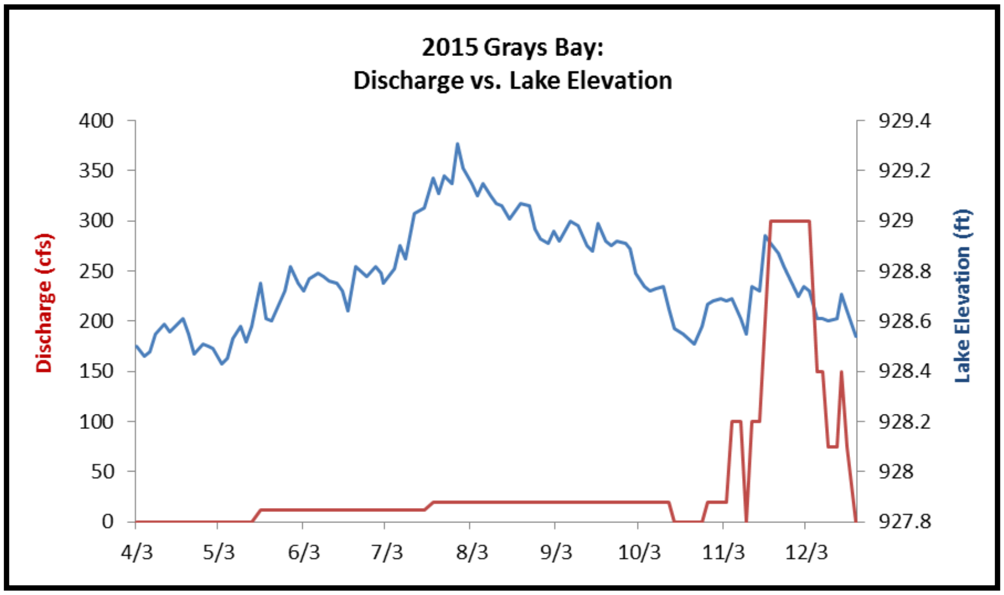


Figure 6. Discharge compared to Lake Minnetonka: Grays Bay Elevation in 2015.

View of Minnehaha Creek from Grays Bay Dam. Top left - April 2015, when the dam is closed; Bottom right - December 2015 when the dam is open to 300 cfs.

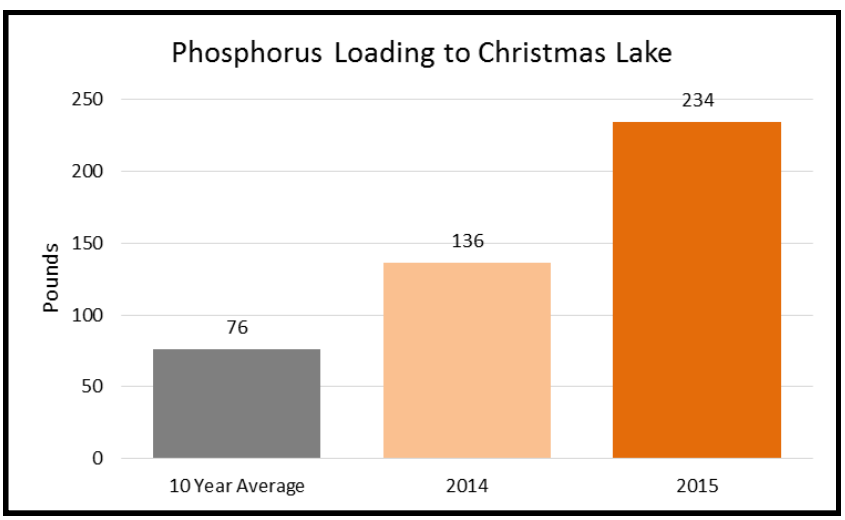
3.2 Christmas Lake Subwatershed

The Christmas Lake Subwatershed is the smallest in the watershed district. The subwatershed is dominated by a mix of residential/business and woodland/wetland land cover. The nutrient contribution to Lake Minnetonka is minimal due to the fact that Christmas Lake does not often flow into St. Alban's Bay.

In 2015, Christmas Lake never overtopped the outlet weir; however, the inlet, which is intermittent and typically dries up in August, flowed off/on into December. Late summer and fall precipitation events along with warmer air temperatures contributed to extended discharge into Christmas Lake.

Water Quality: Christmas Lake inlet was one of three creeks in the watershed that had greater loading in 2015 than 2014 (Figure 7). The loading in Christmas Lake inlet has been increasing every year since 2012 (Figure 8). The increase in pounds of phosphorus is connected to precipitation events and flow; however, other factors, such as development, construction, and/or eroding stream banks, may be driving the increase in phosphorus as well.

Figure 7. Comparison of phosphorus loading at Christmas Lake inlet (CCH02).



At this point in time, the increased phosphorus loading is currently not having any ecological impacts to Christmas Lake. There is no significant change in water quality (SECC, CHLA and TP) in Christmas Lake from 2001-2015. In 2015, the water quality in Christmas Lake was not impaired for eutrophication or excessive nutrients (Table 8).

Figure 8. Comparison of annual precipitation and loading at Christmas Lake inlet

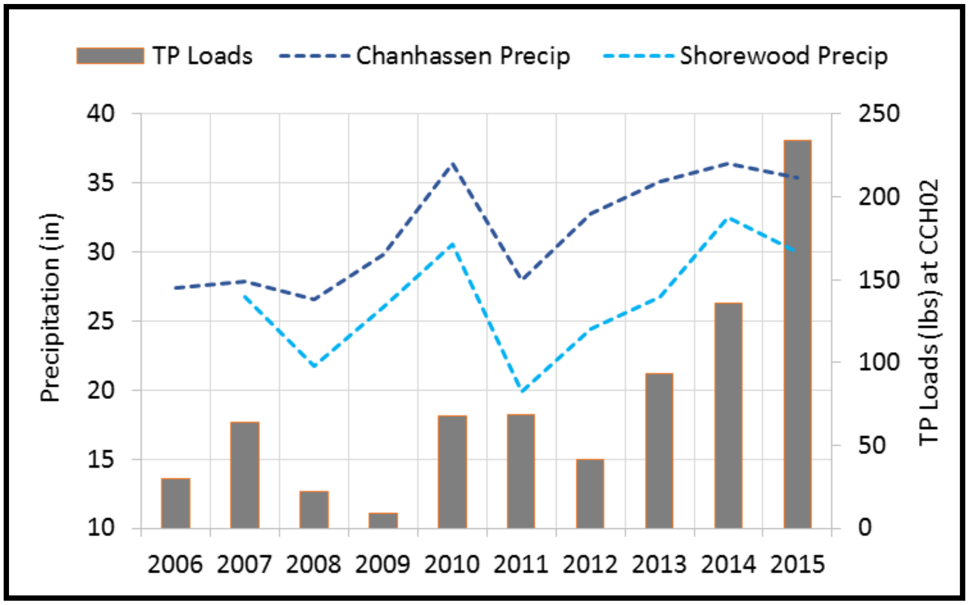


Table 8. Christmas Lake 2015 Means and List of Known Impairments

Lake	Mean SECC (m)	Mean CHLA (µg/L)	Mean TP (µg/L)	Impairment
	June-Sept 2015			
Christmas	5.96	2.75	11.50	Mercury

Christmas Lake public access

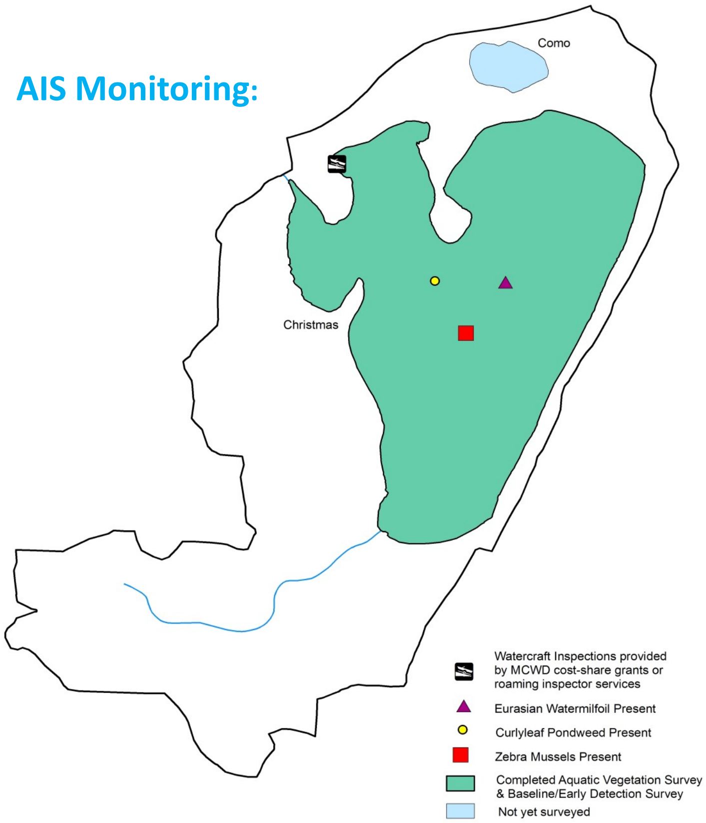
Project/Research Activities (Year Completed):

- Zebra Mussel Rapid Response (2015)
- Hybrid Milfoil Study (Active)

AIS Prevention - Watercraft Inspections: The MCWD is a cost-share partner with the City of Shorewood for the watercraft inspection program they operate at Christmas Lake.

Inspection Hours	# Inbound Inspections	# Outbound Inspections	% Compliance with MN Drain Plug Law	% Watercraft Entering with Possible AIS	# Inbound Watercraft stopped with zebra mussels attached
2,800	1,266	1,232	92.7%	2.1%	3

AIS Monitoring:



Aquatic plants - High abundance in Christmas, with a good diversity of native plants, especially compared to other lakes in the area. The most recent survey shows 98.7% of the littoral area is vegetated with 27 plant species found, which gives Christmas Lake one of the more diverse plant communities in the District. While Eurasian Watermilfoil and Curlyleaf Pondweed are present, they have not had a big impact on the native plant community (Figure 9).

Zebra mussels - Discovered in 2014 during MCWD's early detection monitoring. A multi-agency rapid response occurred with several treatments for zebra mussels conducted in the NW bay by the public boat launch (Figure 10). Zebra mussels were controlled within the treatment area, but later found in 2015 in other areas of the lake. The population is now established; however, due to very low abundance of algae in the lake it should quickly become food limited, resulting in a relatively lower abundance and hopefully less ecological impacts. MCWD will continue to monitor the population and its impacts.

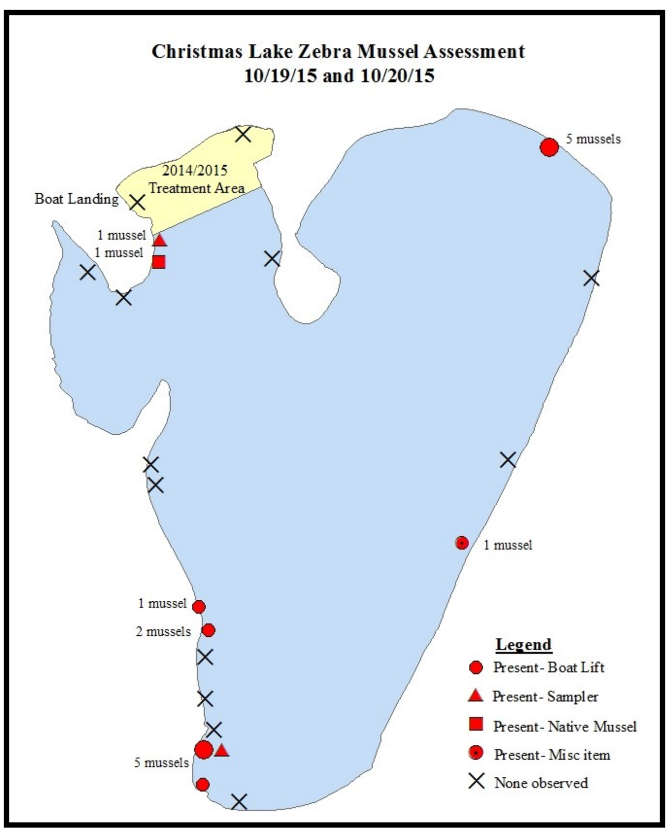
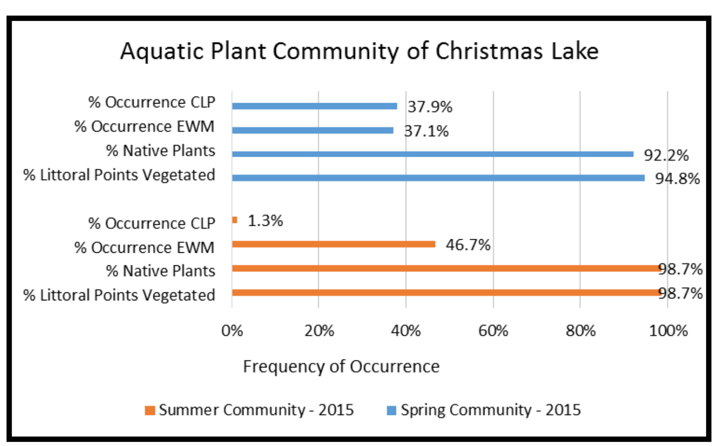
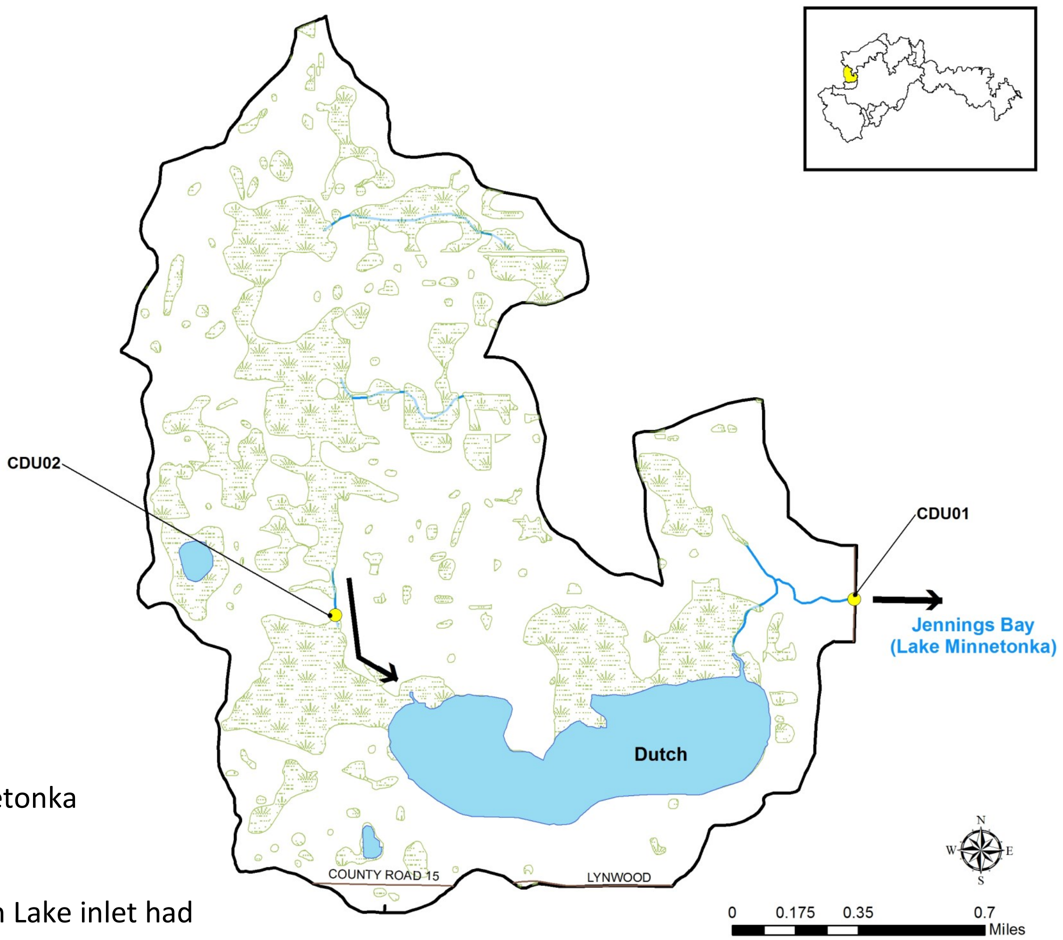


Figure 9. Aquatic Plant Community of Christmas Lake; Figure 10. Christmas Lake Zebra Mussel Assessment.



3.3 Dutch Lake Subwatershed

The Dutch Lake Subwatershed has a land cover mix of wetlands, woodlands, agriculture, horse farms and residential that surround Dutch Lake. Dutch Lake inlet (CDU02) drains the wetland to the north into Dutch Lake, and the lake outlet (CDU01) flows into Jennings Bay, Lake Minnetonka. There is an ecological impact from the Dutch Lake outlet loading nutrients into Jennings Bay, which is discussed in the Lake Minnetonka Subwatershed section.



Water Quality: The Dutch Lake inlet had slightly above average phosphorus loads in 2015 (Figure 11). Precipitation is a large driver of discharge into Dutch Lake (Figure 12). In wet years, as observed in 2014, loading into Dutch Lake can be twice the average poundage (Figure 11), but in dry years, like 2009, loading can decrease to less than 50 lbs (Figure 12).

Dutch Lake outlet (CDU01) into Jennings Bay

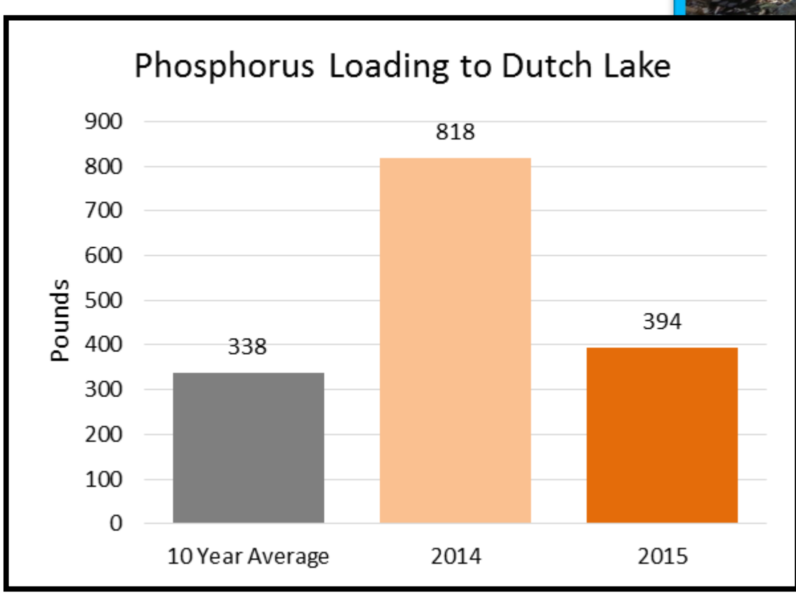


Figure 11. Comparison of phosphorus loading at Dutch Lake inlet (CDU02).

In addition to the loading from the inlet, Dutch Lake receives direct storm water from storm pipes. Investigational monitoring with assistance of volunteers was done on three storm pipes after observing blue-green algal blooms following storm events. Samples collected after storm events revealed total phosphorus ranged from 116 to 959 µg/L. Staff notified the City of Mound of the results as road/culvert construction was occurring adjacent to Dutch Lake at this time during 2015.

The combination of these two sources plus internal loading has left Dutch Lake impaired for excessive nutrients (Table 9). In 2015, the water quality in Dutch Lake continues to not meet the MPCA's eutrophication standards. Evaluating water quality (SECC, CHLA and TP) in the lake from 2001-2015 reveals no significant changes.

Figure 12. Comparison of annual precipitation and loading at Dutch Lake inlet

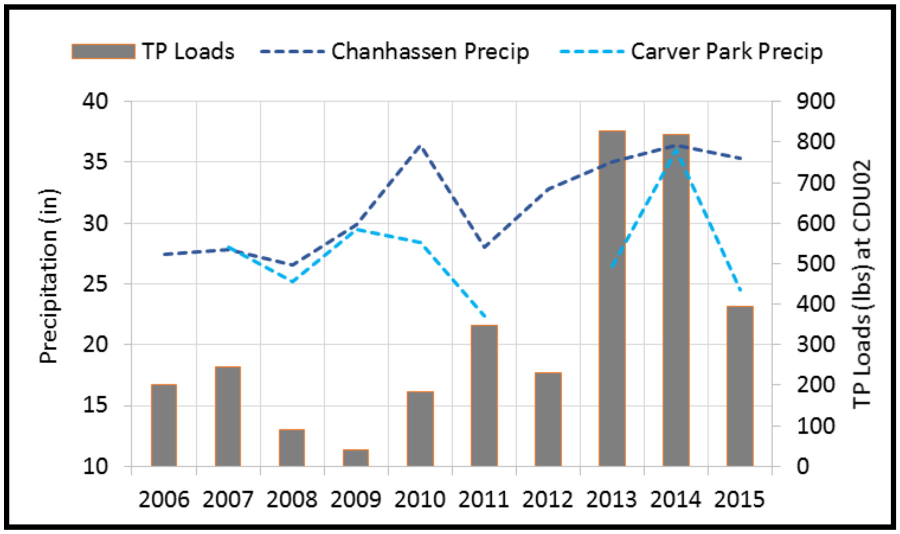


Table 9. Dutch Lake 2015 Means and List of Known Impairments

Lake	Mean SECC (m)	Mean CHLA (µg/L)	Mean TP (µg/L)	Impairment
	June-Sept 2015			
Dutch	0.69	51.25	71.00	Nutrients

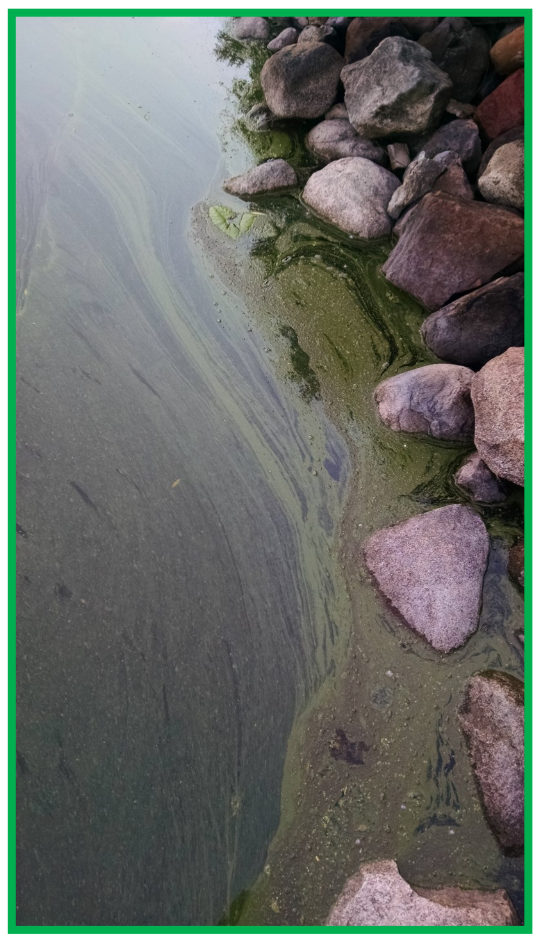
Red indicates not meeting standard

Project Activities (Year Completed):

- Dutch Lake Inlet Sand/Iron Filter (2012)

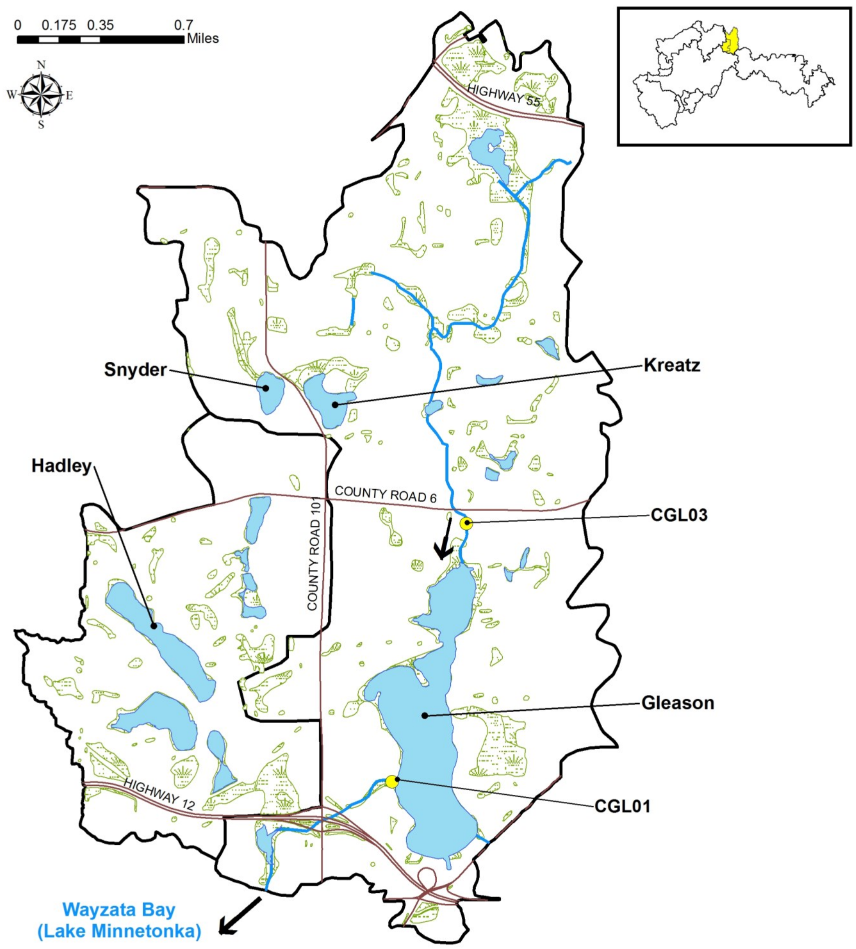
AIS Prevention and Monitoring:

Dutch lake has two small, low-use public boat launches that do not receive watercraft inspections. MCWD staff does conduct weekly early detection searches at these access points. Eurasian watermilfoil is present in Dutch Lake.



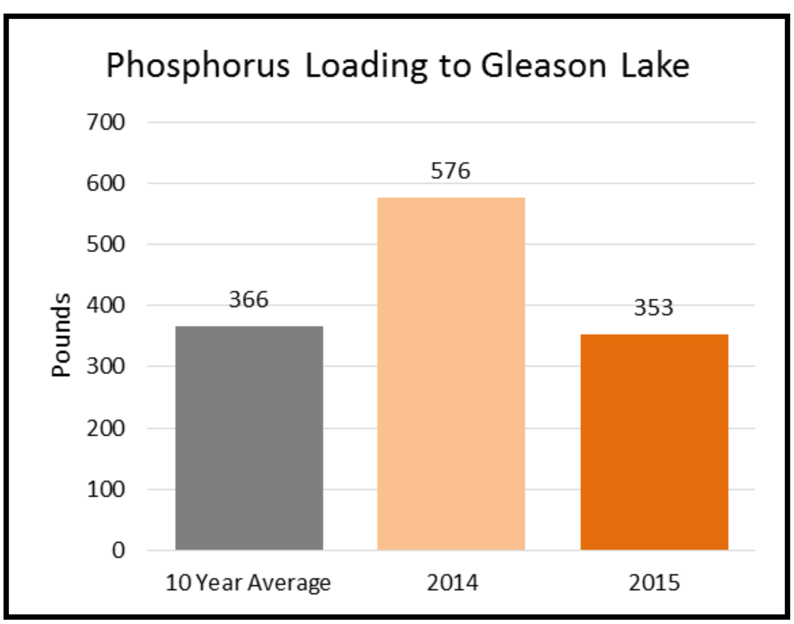
Blue-Green algal bloom along the eastern shoreline near public access on Dutch Lake

3.4 Gleason Lake Subwatershed



Gleason Lake Subwatershed is dominated by a mix of urban residential/business land cover with very little woodland and wetlands remaining. The subwatershed is drained in the west by Hadley Lake and in the east by Gleason Lake. All the water drains into Wayzata Bay, Lake Minnetonka. The nutrient loading into Wayzata Bay is not well understood. One of the outlets is piped and the other one drains into pond prior to discharging into Wayzata Bay. A 2013 Macroinvertebrate Assessment collected at stations along the creek that discharges into Wayzata Bay indicates poor water quality. MCWD plans to investigate further in 2016.

Figure 13. Comparison of phosphorus loading at Gleason Lake inlet (CGL03).



Water Quality: The 2015 phosphorus loading at Gleason Lake inlet was comparable to the 10-year loading average (Figure 13). Similar to other creeks in the watershed, Gleason Lake Creek discharge is driven by precipitation and flow (Figure 14). Curly-leaf pondweed management occurred from 2007-2012 and the settling pond north of Gleason Lake was widened in 2008. Both of these projects as well as a drought in 2009 aided in temporary lowering of the phosphorus loading into Gleason Lake (Figure 14).

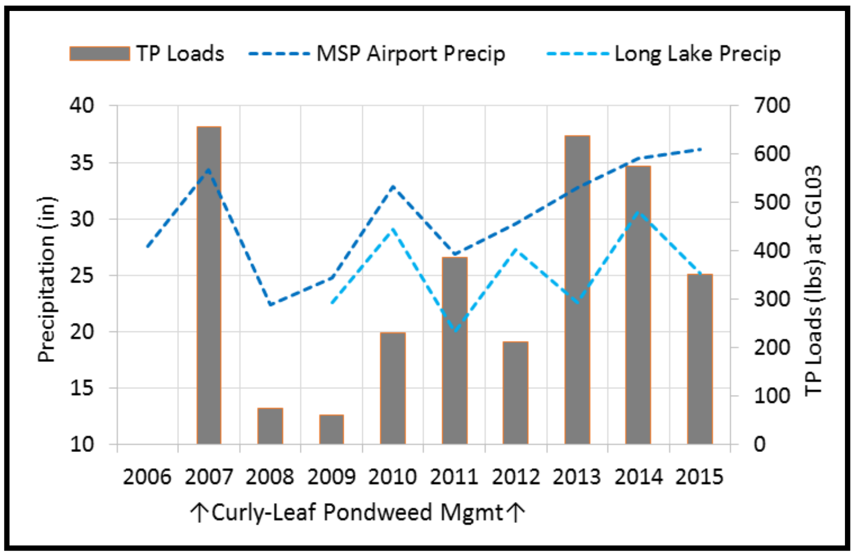
Gleason Lake is impaired for excessive nutrients, and in 2015, the water quality in the lake continued to not meet eutrophication standards for two of the three parameters (Table 10).

From 2001-2015, CHLA in Gleason Lake has decreased about 1 µg/L per year and the TP has decreased by 2.6 µg/L per year, but both those changes are not statistically significant. Snyder (west) and Kreatz (east) were also monitored by MCWD volunteers in 2015, but had insufficient data to compute means. Snyder (west) is impaired for excessive nutrients.

Project Activities
(Year Completed):

- Gleason Lake Creek Water Cleanup/Ponds Expansion (2008)
- Curly-leaf Pondweed Management Study (2012)
- Chelsea Woods/Mews Stream Restoration (2012)
- Gleason Settling Ponds Clean Out (2016)

Figure 14. Comparison of annual precipitation and loading at Gleason Lake inlet



AIS Monitoring: Gleason

Locations of Curlyleaf Pondweed in May 2014. Map below courtesy of Blue Water Science.

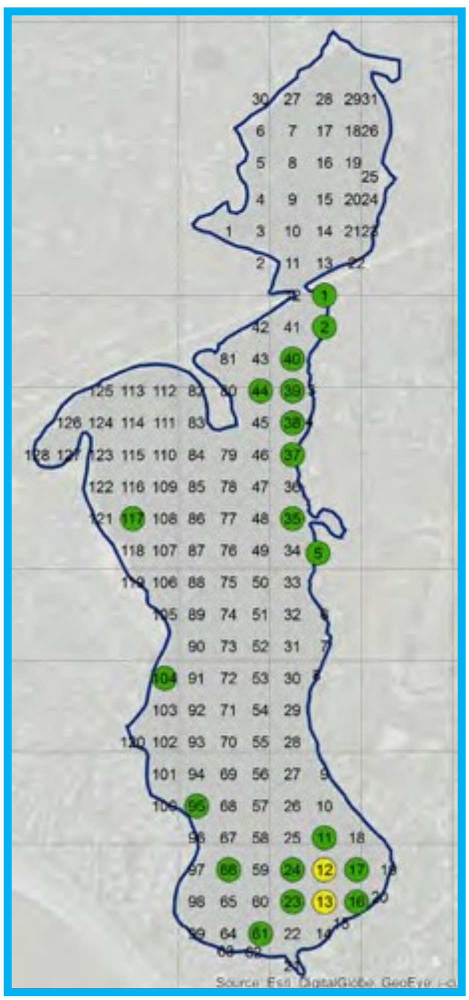


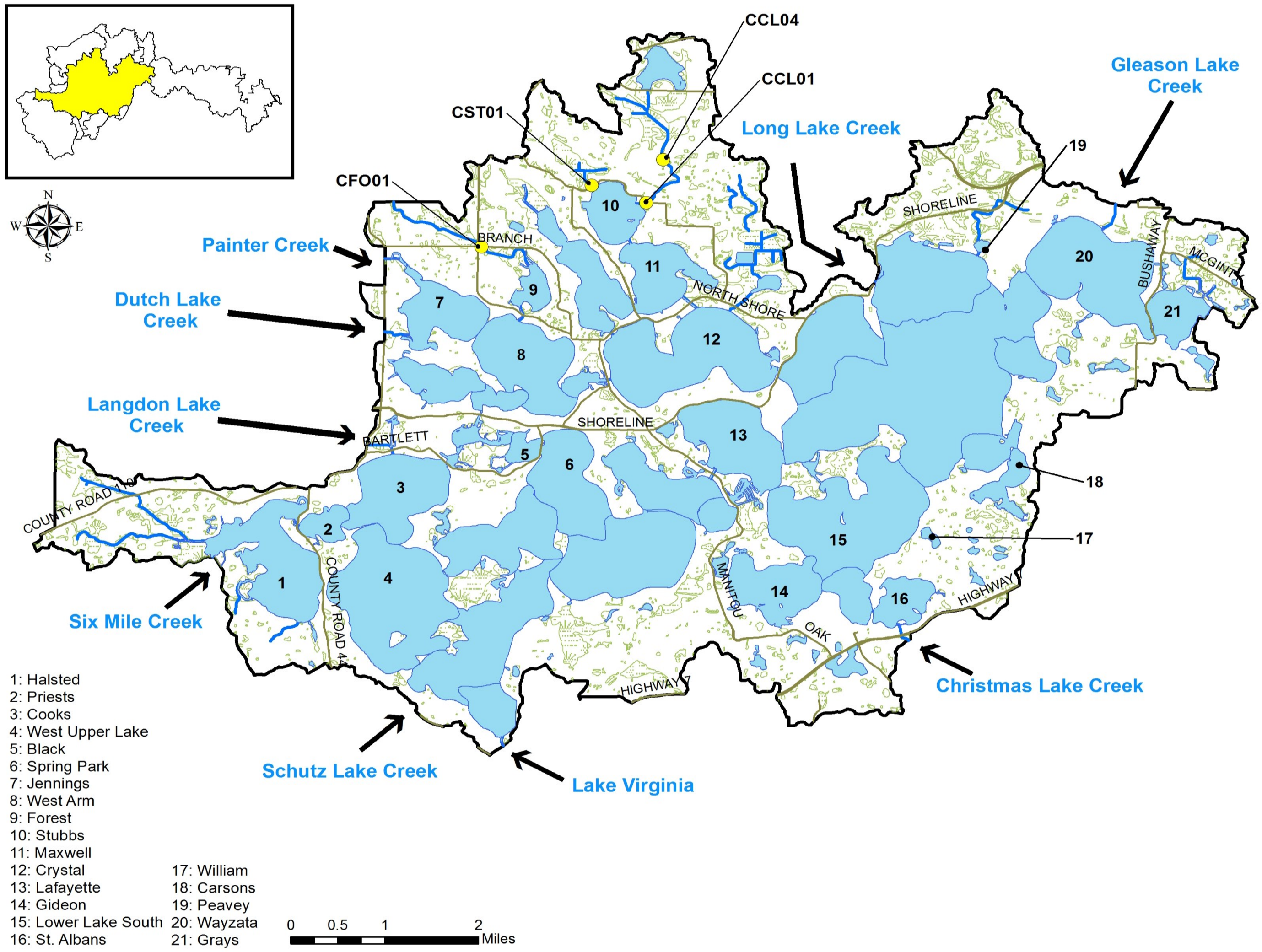
Table 10. Gleason Lake 2015 Means and List of Known Impairments

Lake	Mean SECC (m)	Mean CHLA (µg/L)	Mean TP (µg/L)	Impairment
	June-Sept 2015			
Gleason*	1.04	54.75	118.75	Nutrients

*Shallow lake; red indicates not meeting standard

Lake was recently delisted for Eurasian watermilfoil by the MN DNR. The plant has not been found in the lake for a number of years. Gleason Lake does have curlyleaf pondweed, and its distribution in 2014 is shown on the map to the left.

3.5 Lake Minnetonka Subwatershed



The land cover in the Lake Minnetonka Subwatershed is comprised of lakes, wetlands and scattered pockets of forest, woodlands and grasslands. Single-family residences, marinas, sailing schools, and restaurants are concentrated along the shorelines. Agricultural practices exist on the western boundary of the subwatershed in the vicinity of Halsted Bay, Jennings Bay, North Arm and Stubbs Bay.

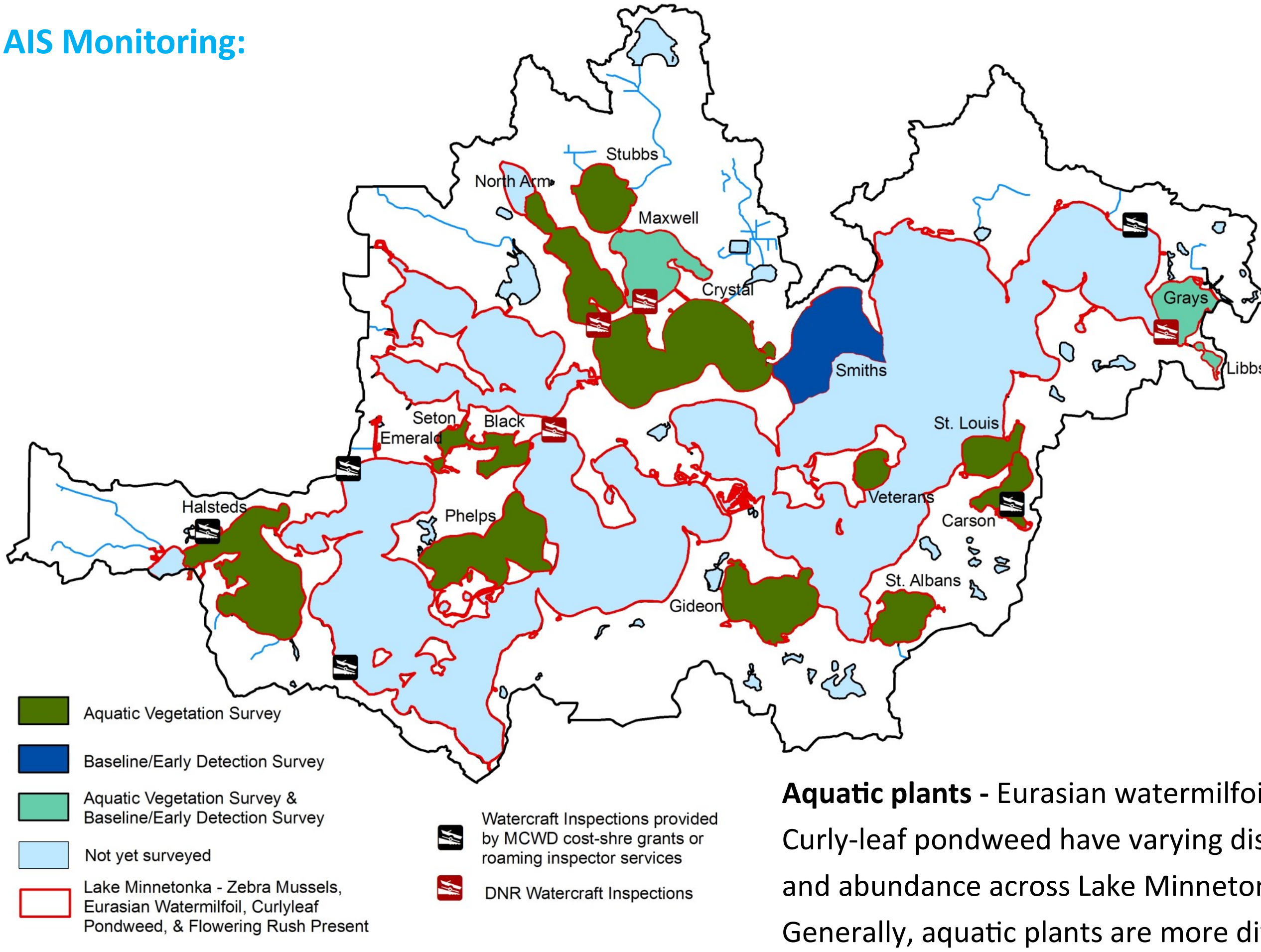
Unlike the other subwatersheds in the Minnehaha Creek Watershed District, the Lake Minnetonka Subwatershed receives direct drainage from nine major sources (See map above). The health and function of Lake Minnetonka is not only affected by these creek inlets, but also affected by aquatic invasive species. Lake Minnetonka was one of the first lakes in the Watershed District to be infested with Eurasian watermilfoil and zebra mussels.

AIS Prevention: Watercraft Inspections

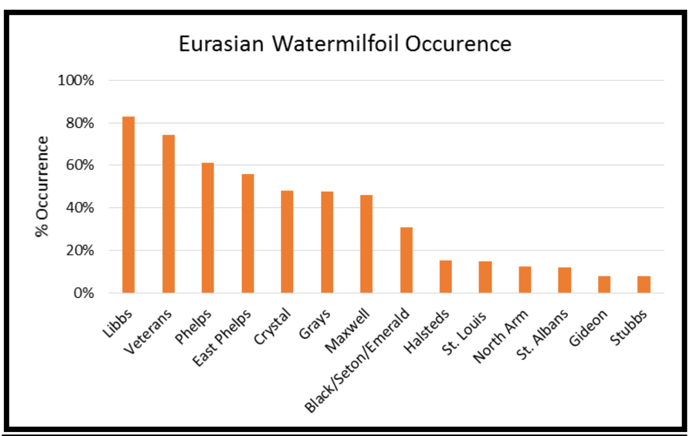
Inspection Hours	# Inbound Inspections	# Outbound Inspections	% Compliance with MN drain plug law	% Watercraft entering with possible AIS
7,830.5	21,508	14,607	95%	3.4%

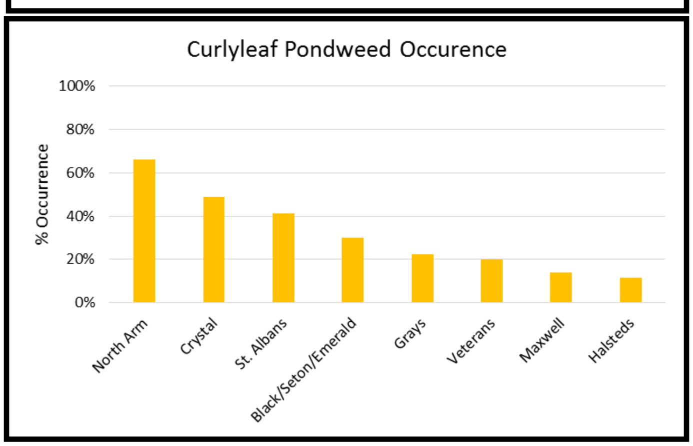
Watercraft inspections on Lake Minnetonka are performed by the MN DNR, Lake Minnetonka Conservation District (LMCD) and Three Rivers Park District (TRPD). The MCWD is a cost-sharing partner with the LMCD.

AIS Monitoring:



Aquatic plants - Eurasian watermilfoil and Curly-leaf pondweed have varying distribution and abundance across Lake Minnetonka Bays. Generally, aquatic plants are more diverse and abundant in the clearer eastern bays, and less diverse and abundant in the far western bays, which tend to be more algae dominated. Recent research studies on the lake are starting to assess the distribution of Hybrid watermilfoil in the lake, which is discussed further in the Research section (Figure 15 and 16).





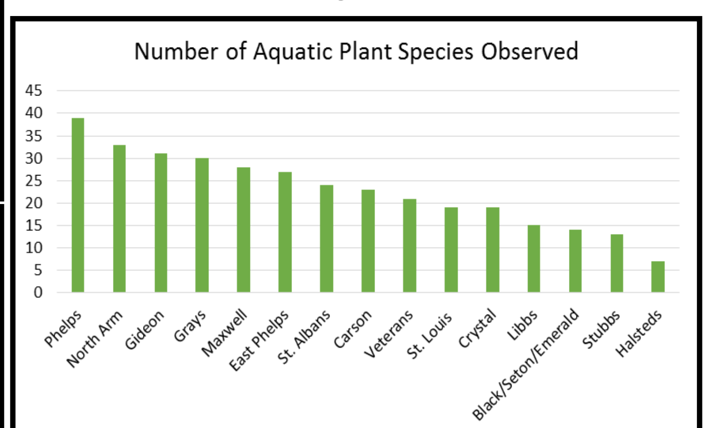
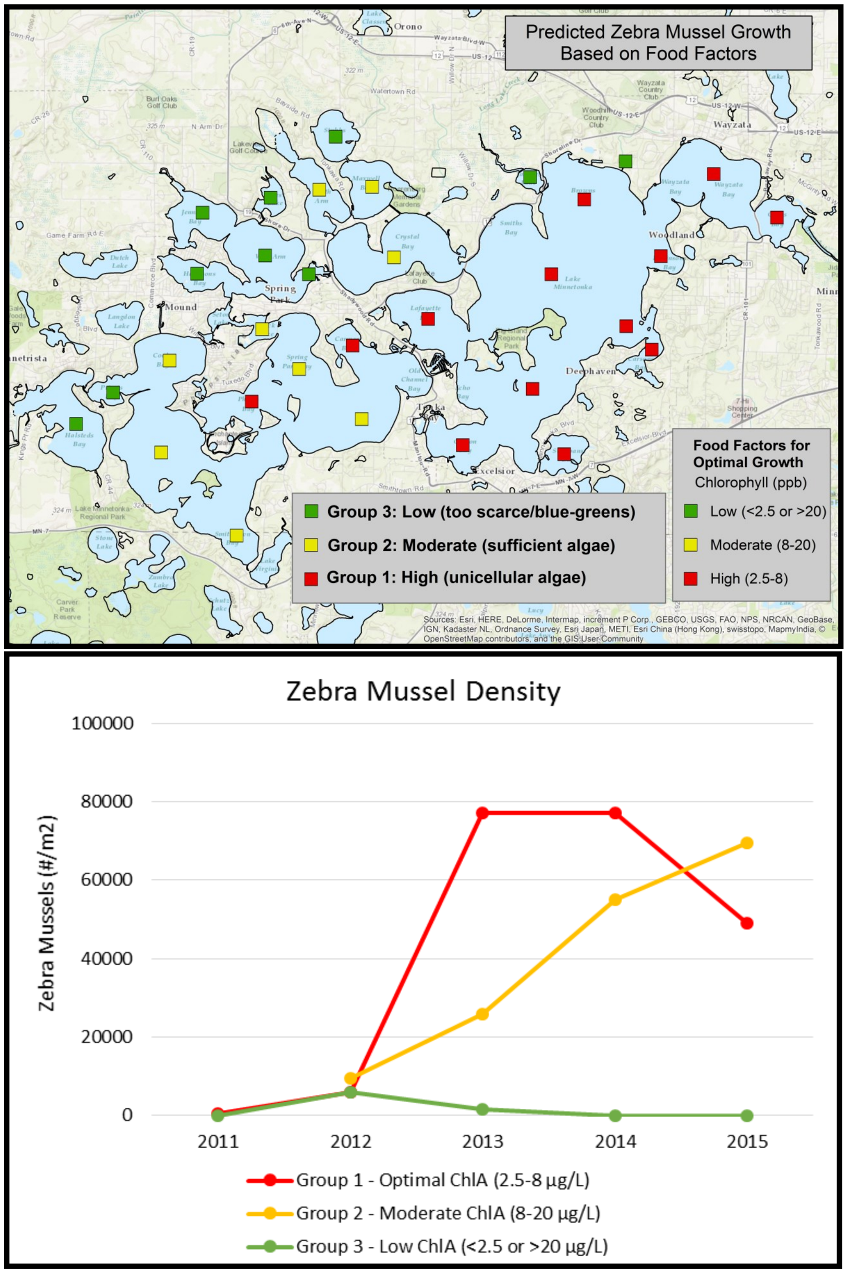


Figure 15. Occurrence of Eurasian Watermilfoil and Curlyleaf Pondweed in Lake Minnetonka (data collected from different years); Figure 16. Number of Aquatic plant species observed in Lake Minnetonka.

Zebra mussels - Zebra mussel abundance has been climbing steadily in most of Lake Minnetonka, with the exception of the far western bays which tend to be more blue-green algae dominated, which is not a preferred food source for zebra mussels. Bays have been divided into three groups based on pre-zebra mussel chlorophyll concentrations (Figure 17a). In 2015, a decline was observed in the annual population of zebra mussels in the Group 1 bays, possibly from these bays becoming food limited from zebra mussel filtering activity (Figure 17b). A population crash in those Group 1 bays could occur in the next couple of years.

Figure 17. (a) Optimal Zebra Mussel Growth in Lake Minnetonka based on pre-infestation chlorophyll-*a* concentrations; (b) Zebra mussel density from 2001-2015 for each group.



Water Level:
The water level of Lake Minnetonka fluctuated 10.56 in. throughout 2015, which is below the 10-year average of 19.29 in. Precipitation, evaporation and runoff are main reasons for water level variation.

Water Quality:
For this report, the water quality of the Lake Minnetonka bays was divided into the three zebra mussel growth groups. Group 1 is the far eastern bays (Figure 17a). There are no known nutrient impairments in these bays, and in 2015, the average water quality continued to meet the eutrophication standards (Table 11). The water quality for Group 1 bays was assessed for long-term change (See Appendix A). There were significant trends indicating improving water quality for Carsons, Grays, Lafayette, Lower Lake South, St. Albans and Wayzata bays (Figure 18).

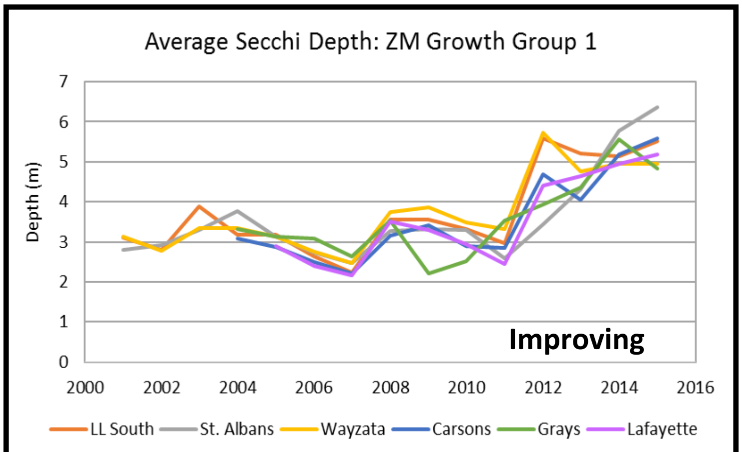
Table 11. 2015 Means and List of Known Impairments for Zebra Mussel Growth Group #1 bays.

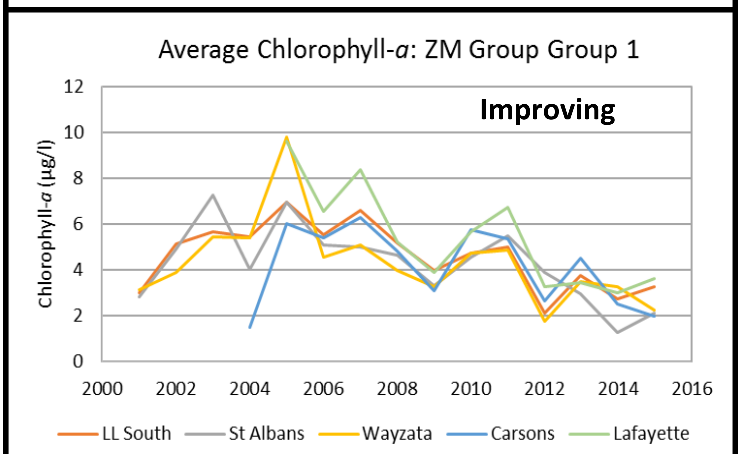
Zebra Mussel Growth Group #1				
Lake/Bay	Mean SECC (m)	Mean CHLA (µg/L)	Mean TP (µg/L)	Impairment
Lake Minnetonka	June-Sept 2015			
Carsons	5.58	2.00	23.13	Mercury
Gideon	5.26	4.00	18.00	None
Grays	4.82	3.00	19.00	Mercury
Lafayette	5.19	3.63	19.25	None
Lower Lake South	5.53	3.25	16.25	Mercury
St. Albans	6.36	2.13	15.50	Mercury
Wayzata	4.94	1.75	18.00	None

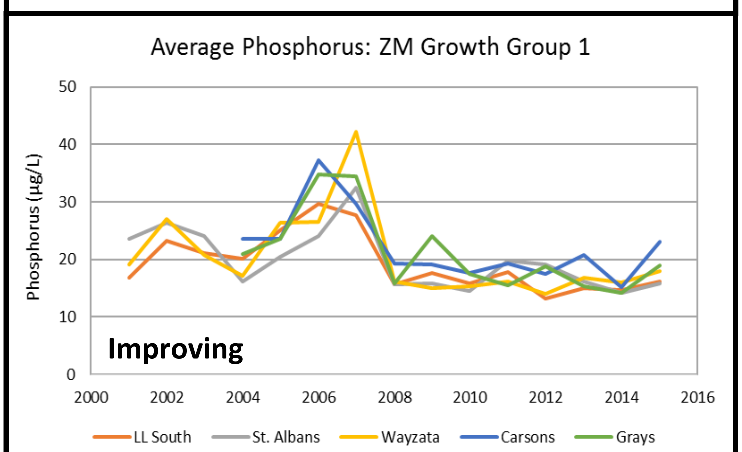
Table 12. Trends of Known Impairments for Zebra Mussel Growth Group #1 bays

Trends: Lake Minnetonka - Group 1				
Parameter	**Years**	**Bay**	**Slope**	**p-value**
SECC	2004-2015	Carsons	0.250	0.016
	2004-2015	Grays	0.182	0.047
	2005-2015	Lafayette	0.265	0.008
	2001-2015	LL South	0.157	0.037
	2001-2015	St Albans	0.101	0.023
	2001-2015	Wayzata	0.145	0.010
CHLA	2004-2015	Carsons	-0.254	0.086
	2005-2015	Lafayette	-0.493	0.013
	2001-2015	LL South	-0.191	0.038
	2001-2015	St Albans	-0.220	0.038
	2001-2015	Wayzata	-0.154	0.075
TP	2004-2015	Carsons	-0.773	0.064
	2004-2015	Grays	-0.814	0.047
	2001-2015	LL South	-0.572	0.038
	2001-2015	St Albans	-0.687	0.018
	2001-2015	Wayzata	-0.419	0.092

Figure 18. (a) Average Secchi depth trend from 2001-2015 for six Lake Minnetonka bays in Group 1 (b) Average chlorophyll-*a* trend from 2001-2015 for five Lake Minnetonka bays in Group 1; (c) Average Phosphorus Trend for five Lake Minnetonka bays in Group 1 from 2001-2015.







There are three factors for better water quality that favor the majority of the eastern bays compared to the western bays of Lake Minnetonka: there are fewer creeks discharging into the eastern bays, the water is not eutrophic, and the zebra mussel population is at a higher density. Zebra mussels were discovered in Lake Minnetonka in 2011. As an extension of the zebra mussel study conducted by the District, water quality from 5 years before and after 2011 was statistically compared. The eastern bays had significant improvements in water clarity, chlorophyll-*a*, and phosphorus after the introduction of zebra mussels than the rest of the lake (Figure 18). For more detail on the Lake Minnetonka zebra mussel study see Section 5 - Lake Minnetonka Zebra Mussel Study summary.

A view of Lake Minnetonka.

Zebra Mussel Growth Group #2				
Lake/Bay	Mean SECC (m)	Mean CHLA (µg/L)	Mean TP (µg/L)	Impairment
Lake Minnetonka	June-Sept 2015			
Black	2.68	17.50	31.75	Mercury
Crystal	3.84	3.50	22.88	Mercury
Cooks	3.83	6.00	24.25	None
Maxwell	3.76	7.50	26.50	Mercury
Spring Park	5.51	3.75	17.75	None
West Upper	4.63	4.00	20.50	Mercury

Table 13. 2015 Means and List of Known Impairments for Zebra Mussel Growth Group #2 bays (Note: red indicates not meeting standard).

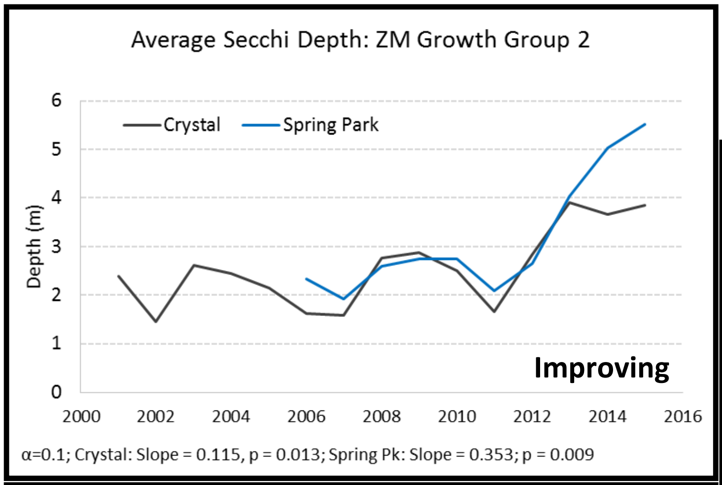
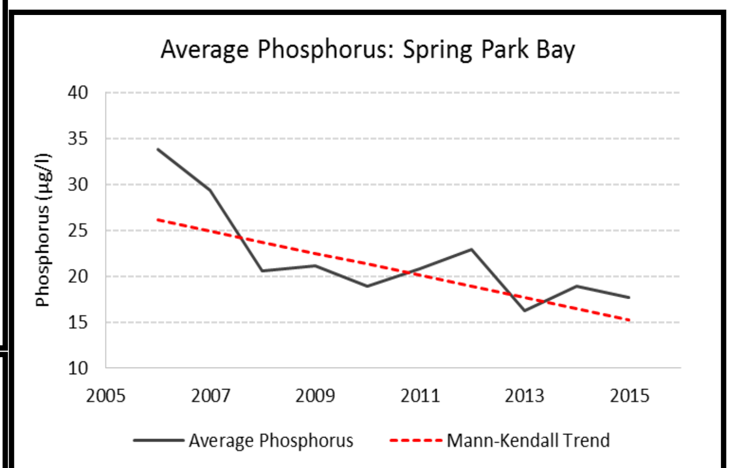
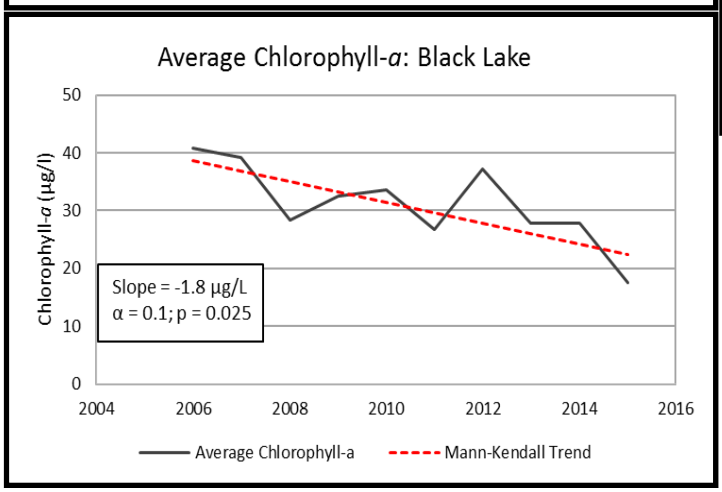


Figure 19. Statistically significant trends for bays in Zebra Mussel Growth Group 2





Group 2 is the northwestern bays including Crystal, North Arm and Maxwell bays in the North (Figure 17a). These bays have no known nutrient impairments. Emerald, North Arm, and Seton bays, which are not monitored, are also known for mercury impairments. In 2015, the majority of these bays had average water quality that continued to meet the eutrophication standards (Table 13). The average chlorophyll-*a* concentrations in Black Lake exceeded the standard by 3.5 µg/L. The water quality for Group 2 bays was assessed for long-term change (See Appendix A). Most bays in Group 2 had data ranging from 2001-2015. Black and Spring Park bays had data ranging from 2006-2015. There were significant trends indicating improving Secchi depth for Crystal Bay and Spring Park Bay, and decreasing chlorophyll-a concentrations for Black Lake and decreasing phosphorus concentrations for Spring Park Bay (Figure 19). For how zebra mussels have affected water quality in Group 2 bays, see Section 5 - Lake Minnetonka Zebra Mussel Study summary.

As mentioned earlier, Lake Minnetonka receives water from nine major sources. Phosphorus loading at seven of the nine sources is monitored. Three of the seven sources are major contributors of phosphorus to

Lake Minnetonka - Painter Creek, Six Mile Creek, and Long Lake Creek. Painter Creek discharges into Jennings Bay, while Six Mile Creek discharges into Halsted Bay. Long Lake Creek discharges into Tanager Lake, which is connected to Browns Bay on the eastern side of Lake Minnetonka (See Long Lake Creek Subwatershed section). In 2015, Painter Creek inlet (CPA01) and Six Mile Creek inlet (CSI02) were below historic average (Figure 20). All of the sources into Lake Minnetonka are driven by precipitation and flow. Both Painter Creek and Six Mile Creek have historic nutrient impacts. The creeks were primary receiving waters from wastewater treatment plants (WWTP), which contained high concentrations of dissolved phosphorus. The plants were in operation from 1927-1986. Decommissioning of the WWTP plants did not begin until the 1970s (MCWD 2007).

Stubbs Bay receives waters from Classen Creek, while Forest Lake receives waters from Forest Lake Creek (Figure 20). The loading from Classen Creek was above historic average, but below the pounds discharged in 2014. The 2013 macroinvertebrate assessment indicates low pollution in Classen Creek; however, the creek scored poorly on MPCA's Index of Biological Integrity (IBI). This is most likely due to Classen Creek drying up during the summer. In 2015, Forest Lake Creek had higher phosphorus loading than the historic average. No macroinvertebrate assessment has been conducted on Forest Lake Creek.

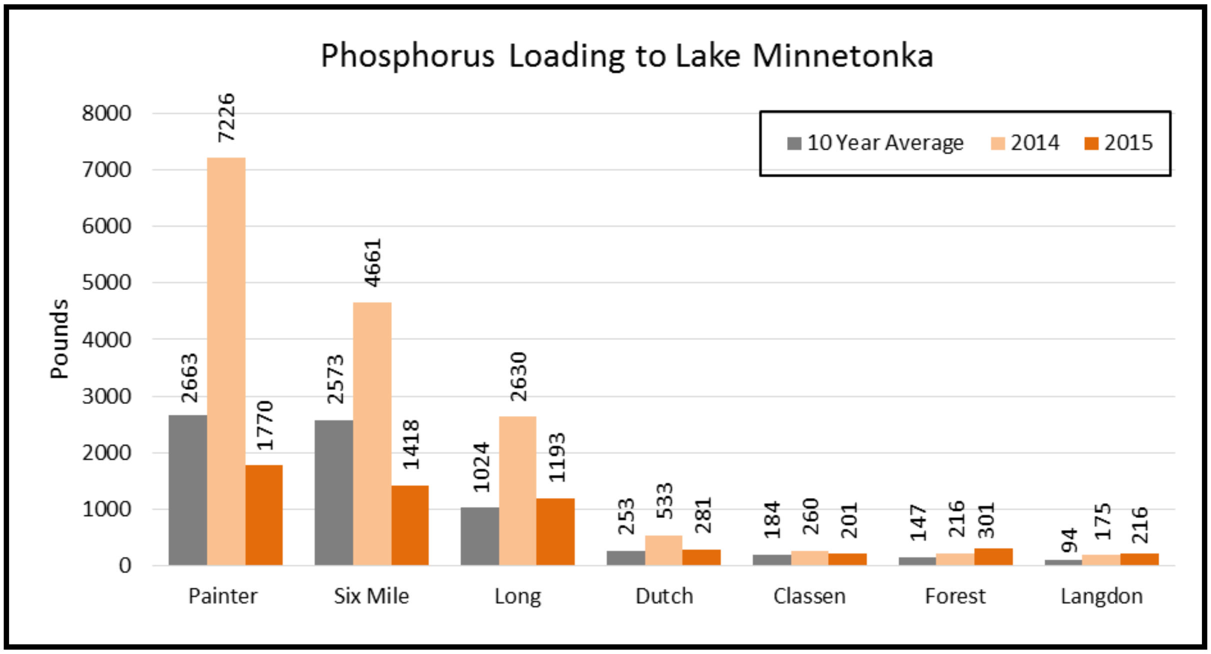


Figure 20. Comparison of phosphorus loading at all inlets into Lake Minnetonka.

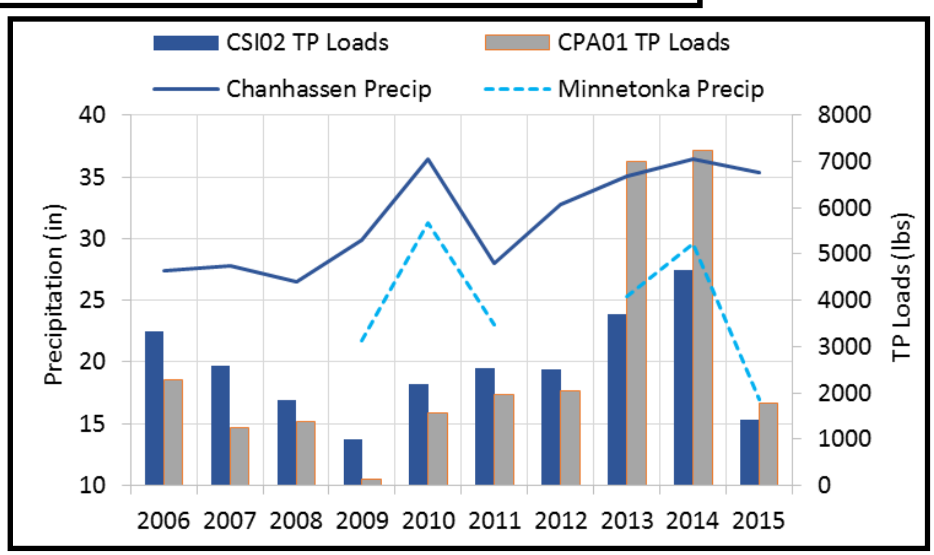


Figure 20b. Comparison of annual precipitation and loading at Six Mile Creek (CSI02) and Painter Creek (CPA01) inlets.

Table 14. 2015 Means and List of Known Impairments for Zebra Mussel Growth Group #3 bays (Note: red indicates not meeting standard).

Zebra Mussel Growth Group #3				
Lake/Bay	Mean SECC (m)	Mean CHLA (µg/L)	Mean TP (µg/L)	Impairment
Lake Minnetonka	June-Sept 2015			
Forest	1.08	45.50	55.75	Nutrients
Halsted	1.03	55.13	125.25	Mercury; Nutrients
Jennings	0.80	54.50	115.63	Mercury; Nutrients
Peavey	N/A			Chloride; Nutrients
Priests	1.93	21.75	48.25	None
Stubbs	0.90	29.13	48.38	Mercury; Nutrients
West Arm	0.80	50.75	74.25	Mercury; Nutrients

Group 3 are the far western bays, including Stubbs Bay in the north, Peavey Lake and Tanager Lake in the east (Figure 17a) (Tanager Lake - See Long Lake Creek Subwatershed). Most of these bays have nutrient impairments (Table 14). Harrisons Bay is not monitored due to water quality being statistically comparable to West Arm. Prior to 2014, the water quality in Harrisons Bay was exceeding the eutrophication standards. After 2014, as West Arm was exceeding the standards, then Harrisons Bay was as well. Harrisons Bay is not on the impaired waters list, but needs to be evaluated for listing. Priests Bay has exceeded two of the eutrophication standards for 2014-2015 seasons, and now needs to be evaluated for listing as well. Due to bridge construction, MCWD was not able to monitor Peavey Lake during September, therefore no mean value was calculated.

Historically, Peavey Lake was the primary receiving water from a now decommissioned WWTP, while Jennings and Halsted bays were the secondary receiving waters (MCWD 2007). The remnant phosphorus deposits coupled with external and internal loading lead to excessive nutrients and algal abundance in Peavey, Jennings and Halsted bays. The inlet to Peavey Lake is not monitored, but the lake has one of the largest watershed to lake area ratio for Group 3 at 80:1, indicating external loading maybe a major source of nutrients. Halsted Bay follows dynamics of a shallow lake mixing during storm events, which brings available nutrients to the epilimnion. Jennings Bay receives loading from Painter Creek and Dutch Lake Creek. Priests Bay has the second largest watershed to lake area ratio at 27:1, but the water quality is also impacted from Halsted Bay. The water quality in West Arm is affected by Jennings Bay.

The 2015 means for the lake are displayed in Table 14. The chlorophyll-*a* and phosphorus concentrations are the highest in Group 3 bays compared to the concentrations observed Group 1 and 2 bays. The water quality for Group 3 bays was assessed for long-term change (See Appendix A). Most data sets were from 2001-2015, but Priests Bay data was from 2006-2015 and Stubbs Bay was from 2007-2015. There were significant trends indicating degrading water clarity for Peavey Lake and increasing phosphorus concentrations for Peavey Lake and Priests Bay (Figure 22,23). For how zebra mussels have affected water quality in Group 3 bays, see Section 5 -Lake Minnetonka Zebra Mussel Study summary.

Lower Lake North, Carman, Phelps, Smithtown, North

View of typical green Lake Minnetonka waters flowing into Crystal Bay from the riprap of Coffee Cove (circa August 2010).

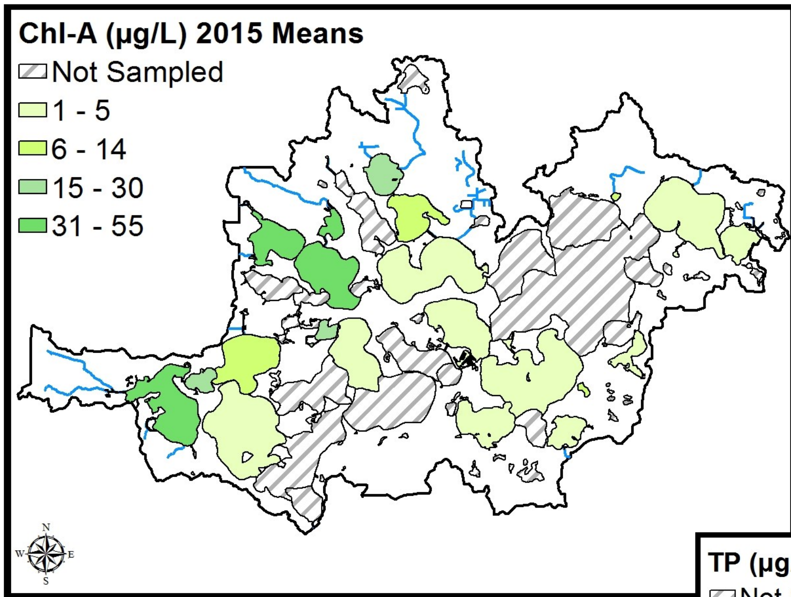
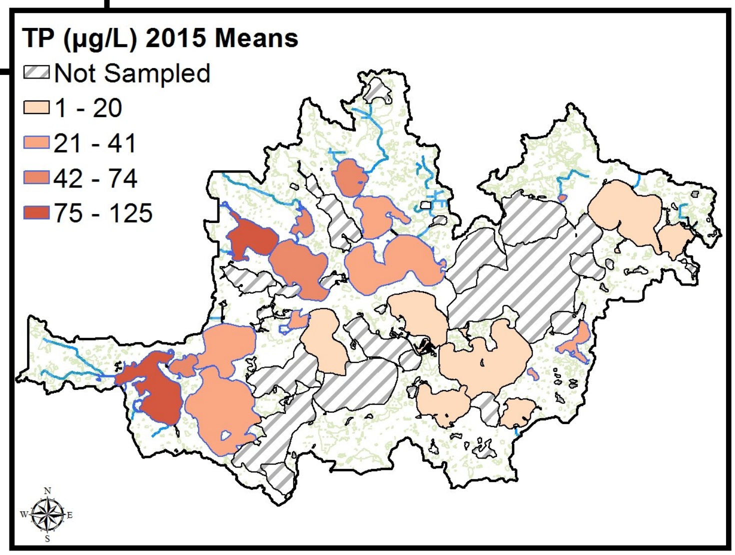


Figure 21. Maps displaying the 2015 chlorophyll means and total phosphorus means for Lake Minnetonka.

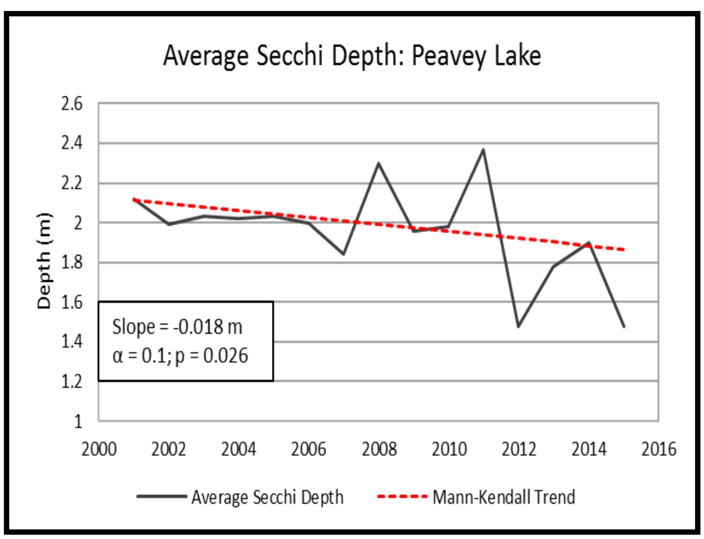


Arm, and Harrisons bays on Lake Minnetonka are not being monitored due to the water quality being statistically similar to adjacent bays. These bays will be monitored on a 10-year cycle, starting in 2021 for the E-Grade program. Table 16 lists which bays have water quality that are statistically similar to each other.

Lake William, which is located east of Lower Lake South, is the only lake monitored within the Lake Minnetonka Subwatershed in 2015 that is not connected to Lake Minnetonka. Lake William has been monitored by an MCWD trained volunteer since 2010. There are no known impairments and the water quality met the eutrophication standards in 2015 (Table 15).

Figure 22. Average Secchi depth trend from 2001-2015 for Peavey Lake.

Figure 23. Average phosphorus trends for 2 Lake Minnetonka bays in Zebra Mussel Growth Group 3.



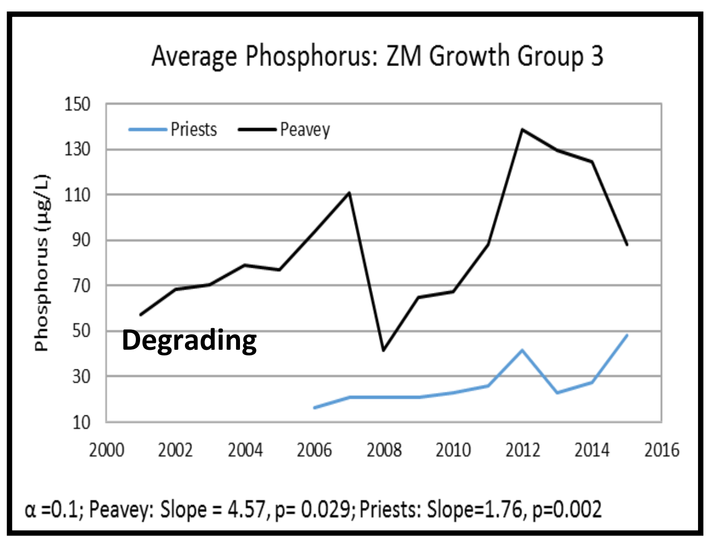


Table 15. 2015 Means and List of Known Impairments for Lake William in the Lake Minnetonka Subwatershed.

Lake	**Mean SECC (m)**	**Mean CHLA (µg/L)**	**Mean TP (µg/L)**	**Impairment**
	June-Sept 2015			
Lake William*		7.25	28.25	None

*Shallow lake

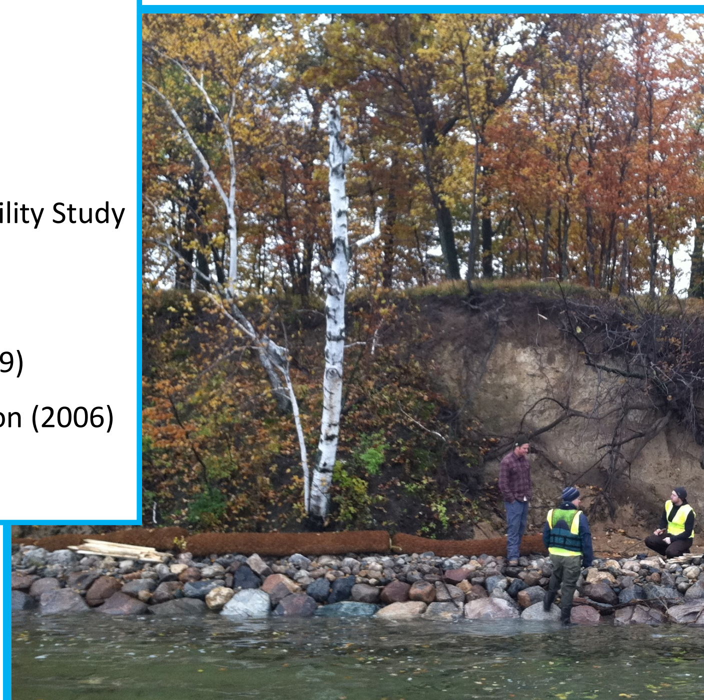
Table 16. Lake Minnetonka Bays with Statistically Similar Water Quality

Statistically Similar Water Quality
Lower Lake North ≈ Lower Lake South and Wayzata Bay
Carman Bay ≈ Spring Park Bay
Phelps Bay ≈ Spring Park Bay and West Upper Lake
Smithtown Bay ≈ West Upper Lake
North Arm ≈ Maxwell Bay
Harrisons Bay ≈ West Arm

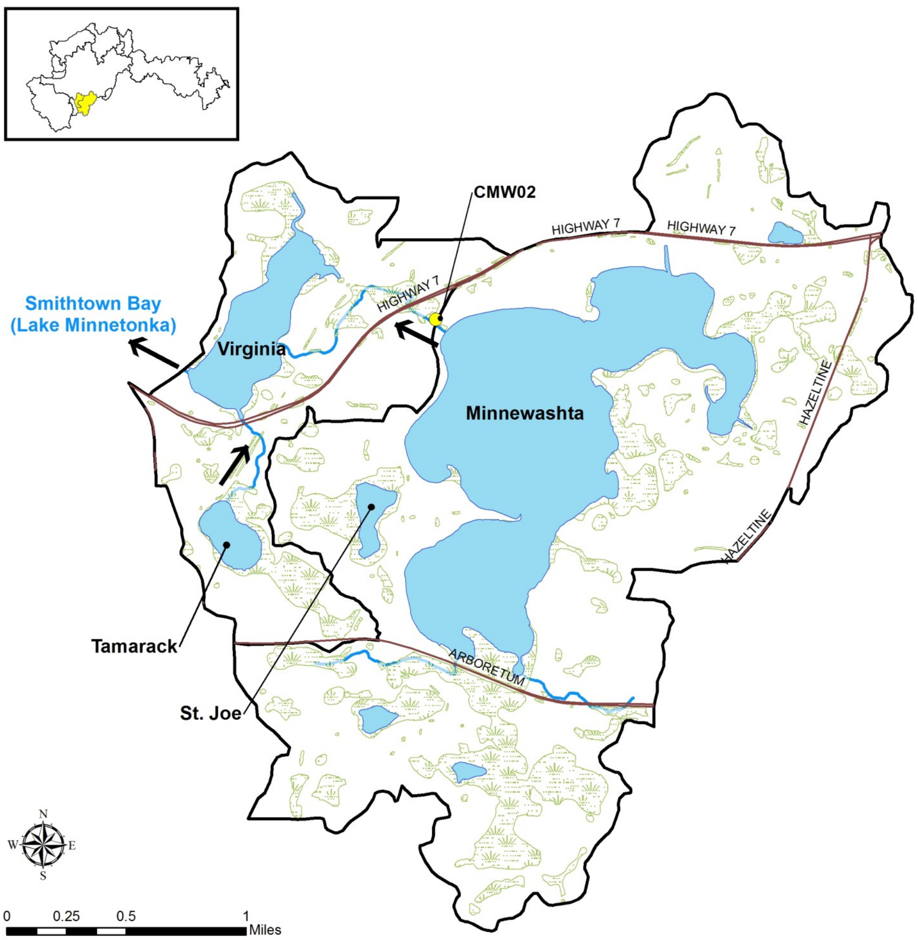
Project/Research Activities (Year Completed):

- Zebra Mussel Study (Active)
- Hybrid Milfoil Study (Active)
- Highway 101 Causeway Reconstruction (Active)
- Promenade at Wayzata (Active)
- Flowering Rush Hand-Removal Pilot (2015)
- USGS Zebra Mussel Zequanox Study (2014)
- Big Island Restoration - North Side (2014)
- Road Reconstruction Assistance (2012)
- Lake Minnetonka's Zebra Mussel Habitat Suitability Study (2010)
- Big Island Restoration (2009)
- Minnetonka Shoreline Stabilization Project (2009)
- Lake Minnetonka: Stubbs Bay Ravine Stabilization (2006)
- Downtown Mound Redevelopment (2005)

During the restoration of Big Island Restoration Project - North Side.



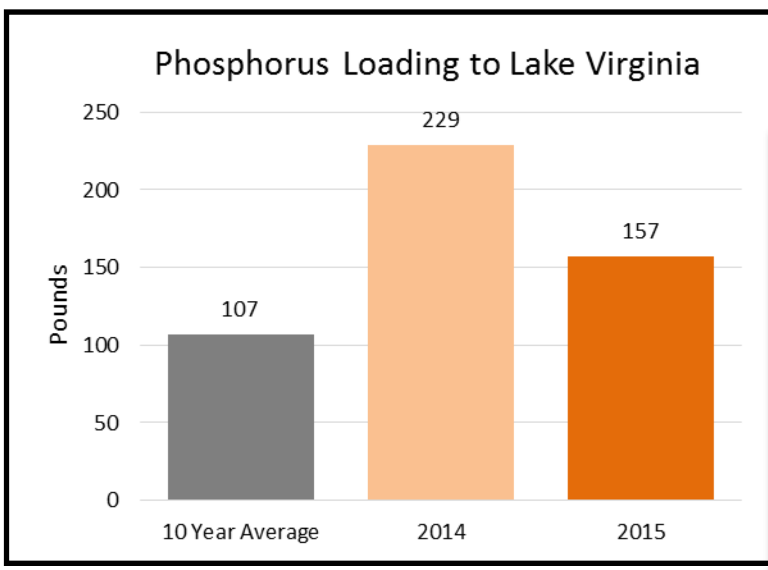
3.6 Lake Virginia Subwatershed



The Lake Virginia Subwatershed is dominated by four lakes and a mix of wetlands, agricultural, and residential land cover. The Lake Minnewashta Regional Park resides within this subwatershed and provides recreational access to Lake Minnewashta from the east. The park is dominated by forest, woodland, grassland and wetlands. The water drains into Lake Virginia from Lake Minnewashta and Tamarack Lake. The outlet of Lake Virginia is ditched, connecting the lake directly to Smithtown Bay, Lake Minnetonka. The nutrient loading into Smithtown Bay is not monitored due to inaccessibility at the station.

Water Quality: Phosphorus loading into Lake Virginia in 2015 was slightly above the 10 year loading average (Figure 24). Precipitation, but more often water level of Lake Minnewashta control the discharge at the outlet station. The nutrient loading into Lake Virginia may be underestimated, and in 2016, MCWD will be monitoring a station closer to the inlet of Lake Virginia.

Figure 24. Comparison of phosphorus loading into Lake Virginia (CMW02).



Lake Minnewashta outlet dried up.

Lake Virginia and Tamarack Lake are impaired for excessive nutrients (Table 17). In 2015, the water quality in Lake Virginia again did not meet the eutrophication standards, where the water quality in Tamarack Lake did. Often algal abundance in Tamarack Lake tends to exceed the standard.

Evaluating water quality (SECC, CHLA and TP) in the lakes of the Lake Virginia Subwatershed reveals only one lake with significant long-term changes. Tamarack Lake had significant improvements in water clarity from 2001-2015 at about 0.07 m/year (Figure 25).

The water quality in Lake Virginia from 2005-2012 showed statistically significant trends of degradation. The addition of data from 2013-2015 indicates the water quality is still degrading in the lake, but there is no longer a significant trend.

Lake	Mean SECC (m)	Mean CHLA (µg/L)	Mean TP (µg/L)	Impair-ment
	June-Sept 2015			
St. Joe (CAMP)	2.28	5.86	19.33	None
Minnewashta	2.14	7.75	22.50	Mercury
Tamarack (MCWD Volunteer)	2.48	8.75	25.00	Nutrients
Virginia	1.24	38.13	54.38	Nutrients

Table 17. Lake Virginia Subwatershed's Lakes 2015 Means and List of Known Impairments (Note: red indicates not meeting standard).

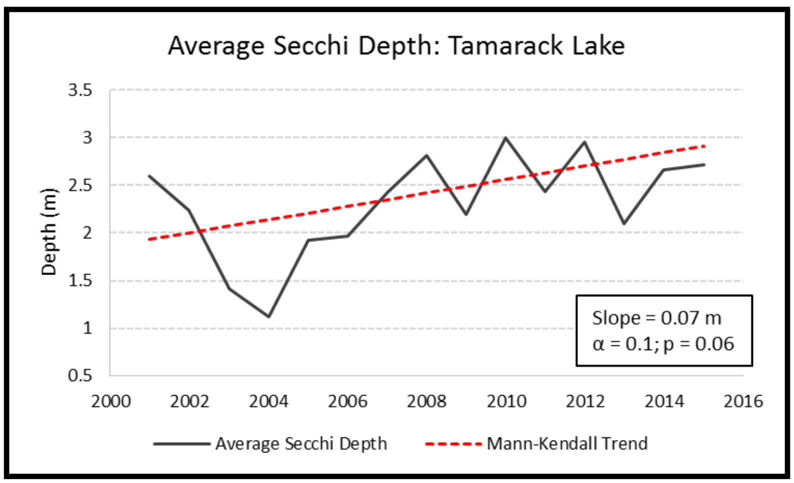


Figure 25. Average Secchi Depth Trend from 2001-2015 for Tamarack Lake

View of Tamarack Lake from the Lake Minnetonka LRT Regional Trail (Photo courtesy of Mike Shouldice)

Project Activities (Year Completed):

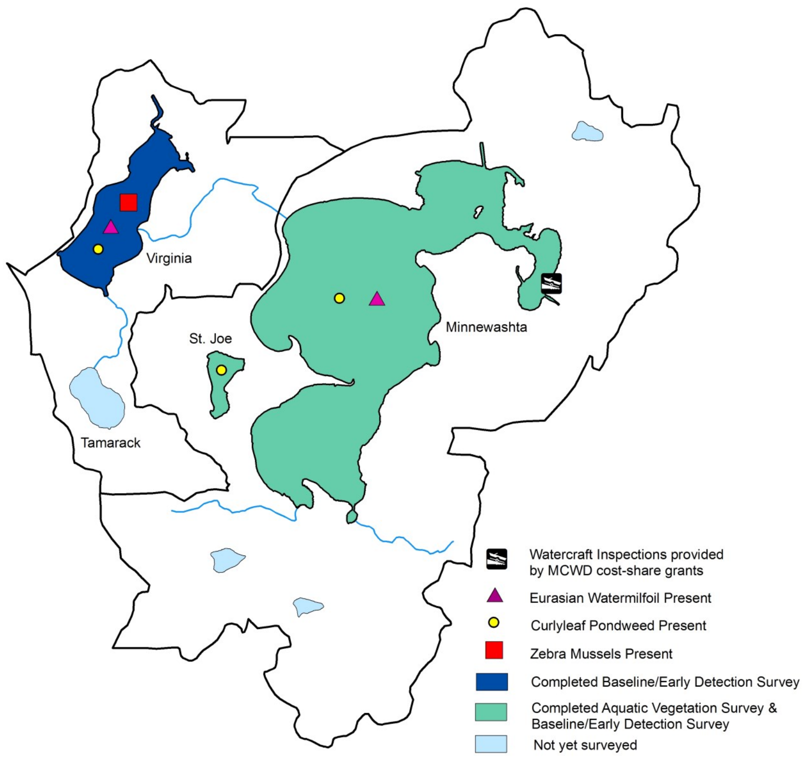
- Arboretum Wetland Restoration (1997)

AIS Prevention: Watercraft Inspections

Inspection Hours	# Inspections (Inbound and Outbound)	Avg. % Compliance with MN drain plug law	Avg. % Watercraft entering with possible AIS	# Inbound Watercraft stopped with zebra mussels attached
2,115	4,481	99.1%	3.7%	2

The MCWD cost-shares the watercraft inspection program at Lake Minnewashta with Carver County, who operates the program. St. Joe Lake and Lake Virginia have small, low-use public launches that do not receive watercraft inspections.

AIS Monitoring:

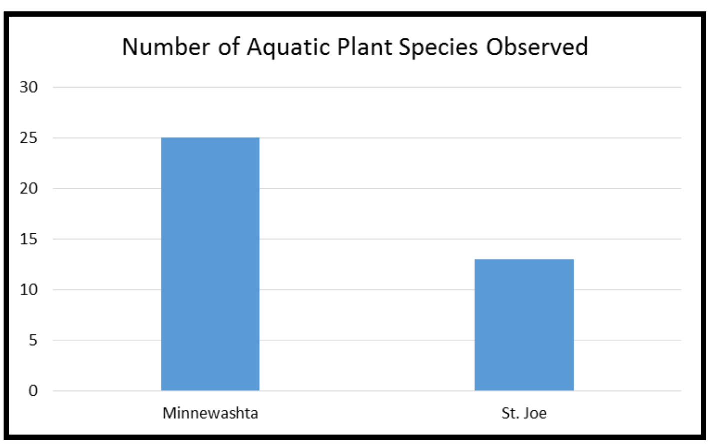


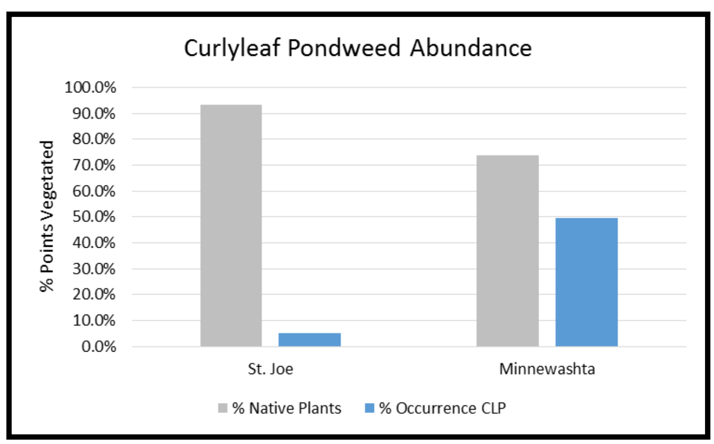
Virginia, linked by a direct channel to Lake Minnetonka, was declared infested with zebra mussels in 2014. Because of its close proximity to Lake Minnetonka it has been treated as an infested waterbody since 2011, but 2014 was the first year adult zebra mussels were discovered in the lake. Zebra mussel abundance has remained low so far.

Aquatic plants are abundant in Minnewashta, with a good diversity of native plants, especially compared to other lakes in the area. The most recent survey shows 85% of the littoral area is vegetated with 25 plant species found. Curlyleaf Pondweed is abundant and forms dense mats in the spring, but dies off in mid summer. Eurasian watermilfoil is also present, and will be surveyed in 2016.

Lake St. Joe has a healthy abundance and diversity of aquatic plant species for a lake of its size (Figure 26 and 27).

Figure 26. Number of aquatic plant species observed in Lake Minnewashta and St. Joe lakes; Figure 27. Curlyleaf pondweed abundance in Lake Minnewashta and St. Joe lakes.





3.7 Langdon Lake Subwatershed

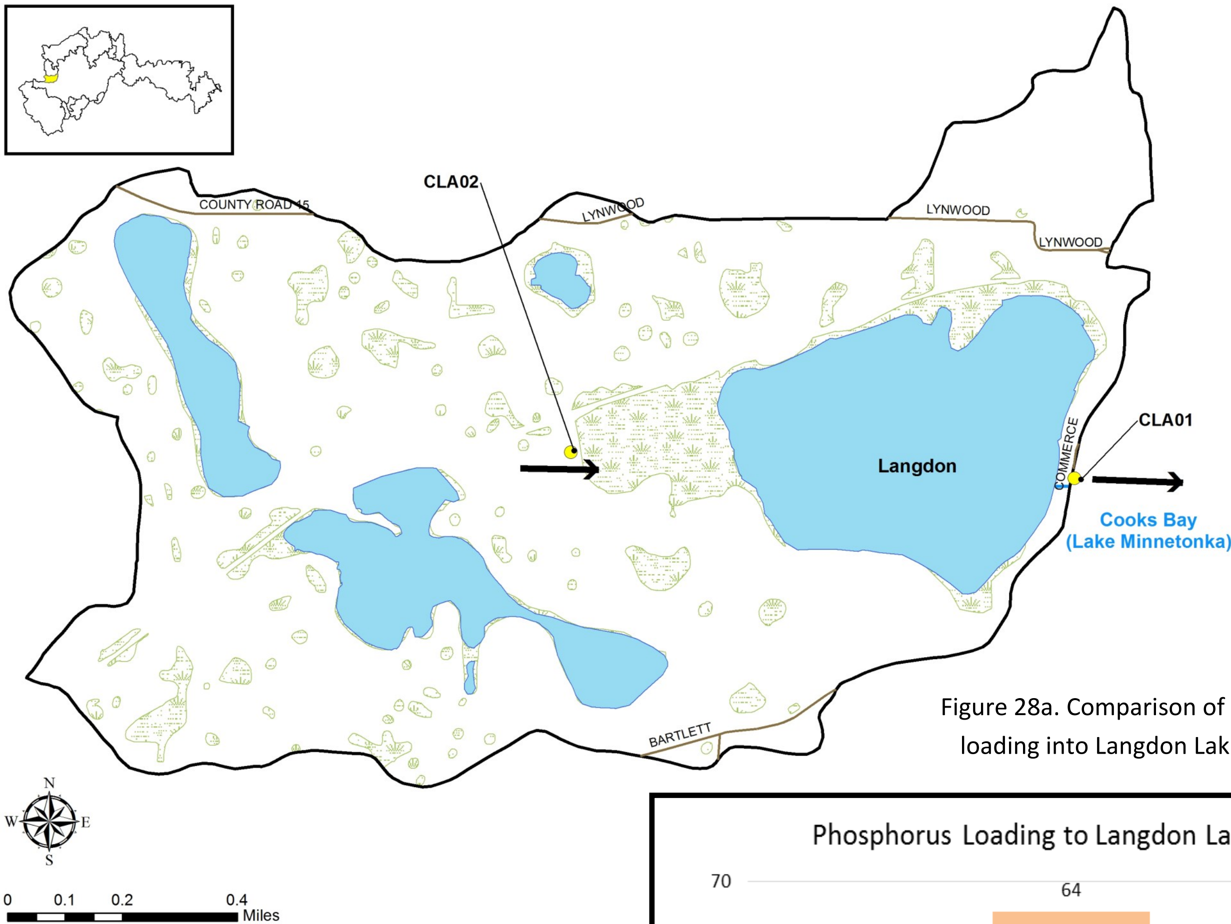
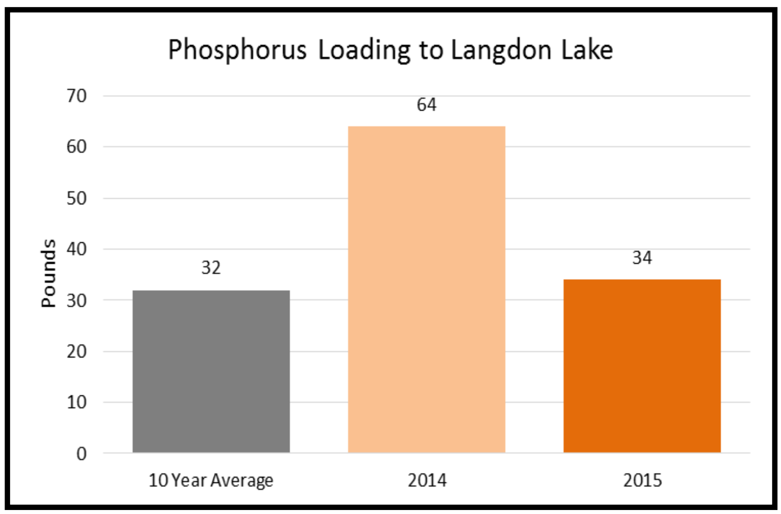


Figure 28a. Comparison of phosphorus loading into Langdon Lake (CLA02).



The land cover in the Langdon Lake Subwatershed is dramatically different between Minnetrista and Mound. In Minnetrista, the western portion of the subwatershed, there is a mix of woodlands, forests, grasslands, wetlands (Black-Flanagan and Saunders), and agricultural land use. In Mound, the eastern portion of the subwatershed, contains wetlands adjacent to Langdon Lake with the remaining land cover dominated by residential and commercial/institutional use. The Dakota Rail line runs north of Saunders and Langdon lakes.

Langdon Lake inlet (CLA02) drains the subdivisions around Saunders Lake and flows through a wetland before reaching Langdon Lake. The lake outlet (CLA01) flows into Lost Lake wetland complex and eventually into Cooks Bay, Lake Minnetonka.

The Langdon lake inlet was comparable to the 10-year loading average (Figure 28a). Both the inlet and out-let of Langdon Lake are intermittent streams with loading influenced by precipitation events (Figure 28b). The loading Langdon Lake receives is the least amount of pounds of phosphorus observed throughout the watershed; however, Langdon Lake is impaired for excessive nutrients. Langdon Lake was also the receiving waters for wastewater treatment plant in the past (MCWD 2007). The remnant concentrations of phosphorus contributing to the internal loading issues has led to the nutrient impairment. In 2015, the water quality in Langdon Lake again exceeded the eutrophication standards set by the MPCA (Table 18). The past 14 years of data in Langdon shows improvements in all three water quality parameters, but the changes have no significant ecological impacts.

Langdon Lake inlet (CLA02)

Figure 28b. Comparison of annual precipitation and loading at Langdon Lake inlet (CLA02).

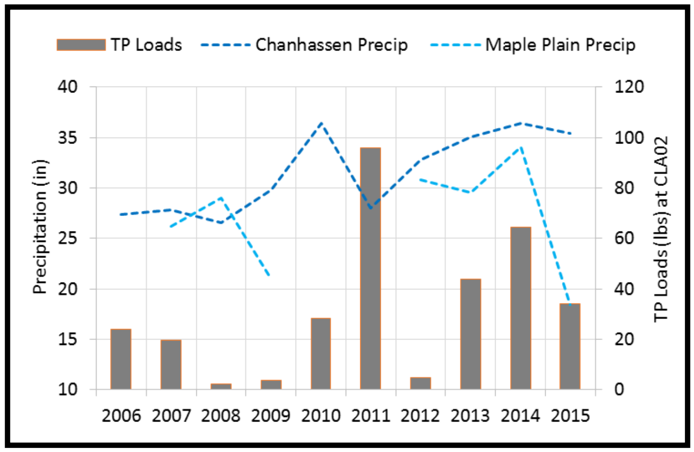


Table 18. Langdon Lake 2015 Means and List of Known Impairments

(Note: red indicates not meeting standard).

Lake	Mean SECC (m)	Mean CHLA (µg/L)	Mean TP (µg/L)	Impairment
	June-Sept 2015			
Langdon	1.06	22.38	51.13	Nutrients

Langdon Lake (above);
Saunders Lake boardwalk (left)

Project Activities (Year Completed):

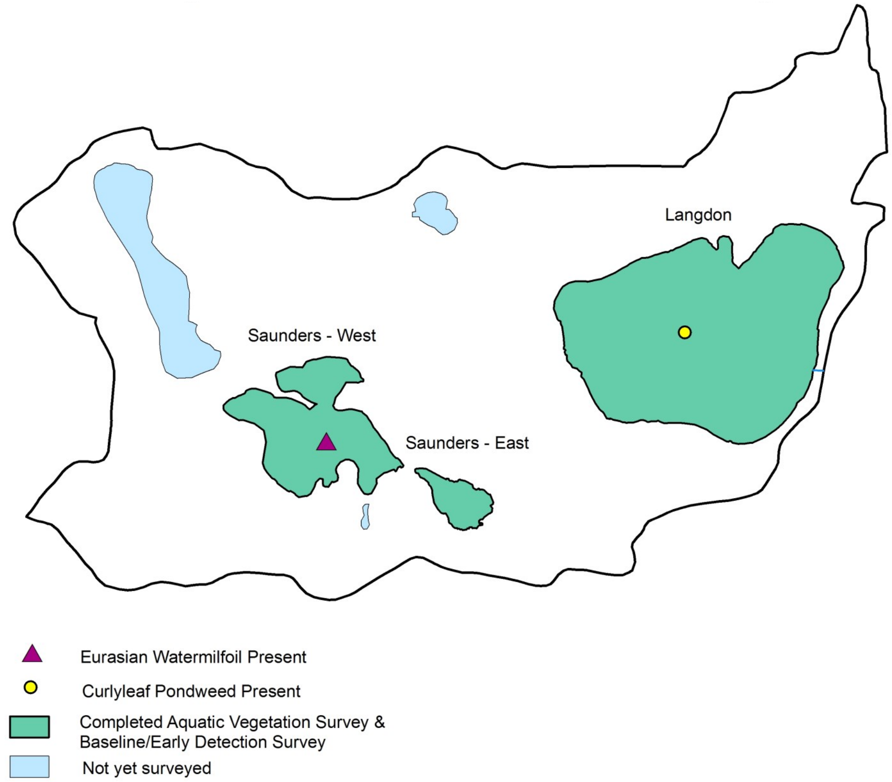
- Alum Treatment - Langdon Lake (1998)
- South Saunders Neighborhood Raingarden Project (2012)

AIS Monitoring:

The east and west basins of Saunders Lake have very different plant communities. The two basins are connected through a channel of Cattails.

West Basin: Diverse plant community and good abundance. 12 different species were found, with the plant community being dominated by Coontail and Flat-Stem Pondweed.

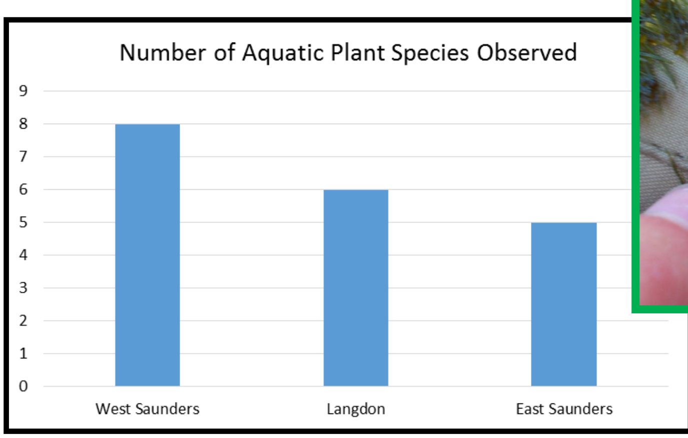
East Basin: Less diverse plant community, with 6 plant species being found, but the whole basin was mostly matted with the native Coontail.



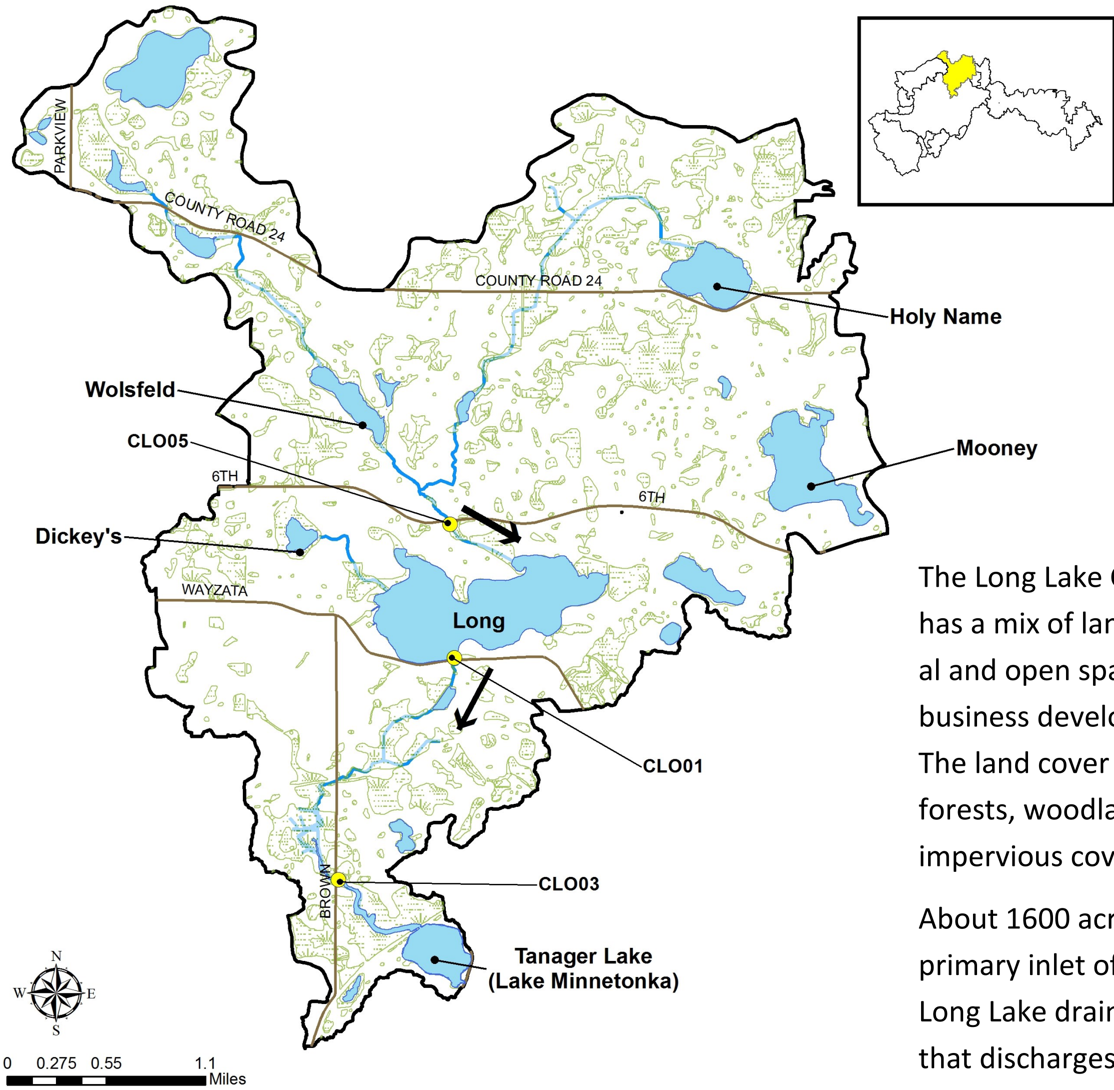
One lone plant of Eurasian Watermilfoil was found during the 2014 survey. A search for more plants was conducted, but none were found. The lone plant was carefully hand-removed by the root shortly after the search. A brief assessment was conducted in 2015 looking for more Eurasian Watermilfoil plants, with more being found along the same shoreline where the plant was located in 2014. A survey in 2016 will further characterize the infestation.

Aquatic plants are abundant in Langdon, but mostly dominated by the native plant Coontail. The most recent survey showed about 80% of the littoral area has vegetation, with 8 different plant species found. Coontail, Curlyleaf Pondweed and Sago Pondweed are the most common plant species found (Figure X).

Figure 29. Number of aquatic plant species observed in the Langdon Lake Sub-watershed.



3.8 Long Lake Creek Subwatershed

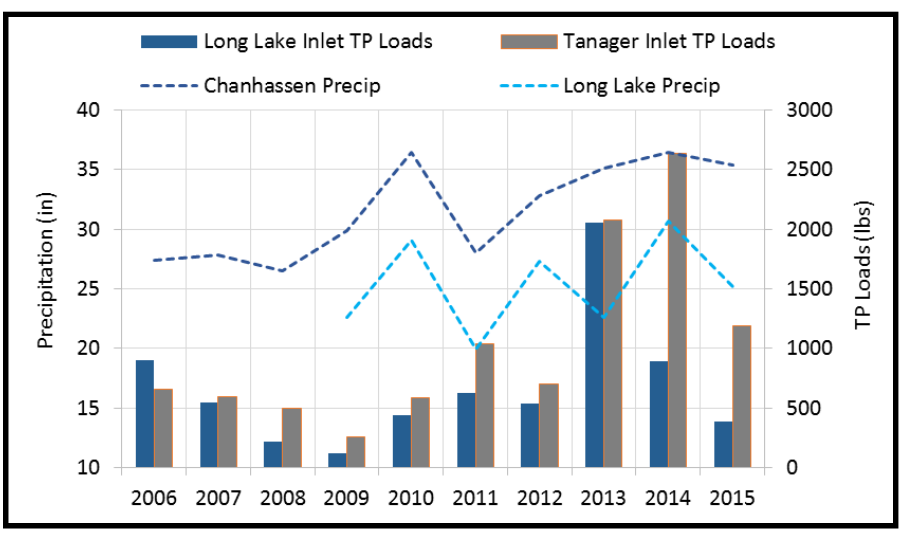


The Long Lake Creek Subwatershed has a mix of land use with agricultural and open space and residential/ business development in the south. The land cover is a mix of wetlands, forests, woodlands, grasslands and impervious cover.

About 1600 acres drain into the primary inlet of Long Lake (CLO05). Long Lake drains south into wetland that discharges into Lake Minnetonka: Tanager Lake (CLO03).

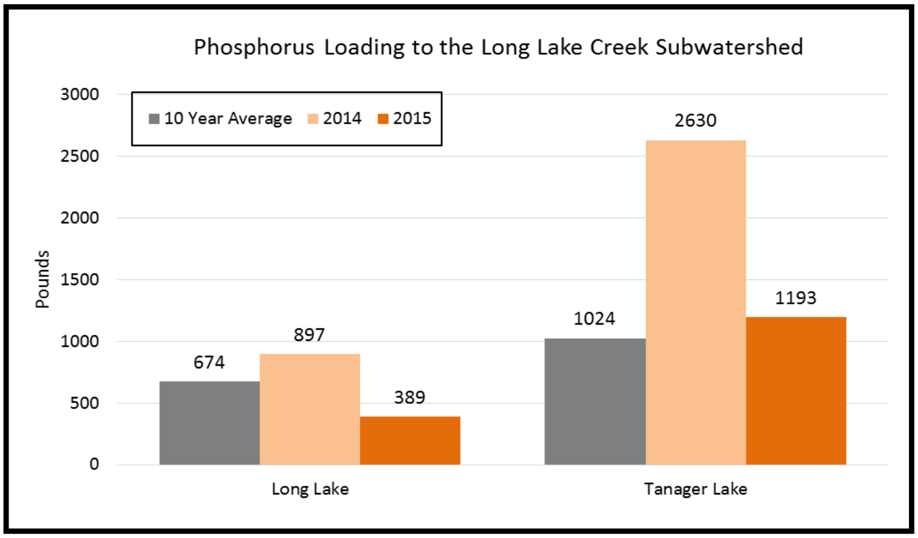
The creeks in the Long Lake Subwatershed are intermittent with loading influenced by precipitation (Figure 30) and flow. Tanager Lake's inlet is also influenced by the water level of Lake Minnetonka, which produces backflow conditions.

Figure 30. Comparison of annual precipitation and phosphorus loading at Long Lake and Tanager inlets.



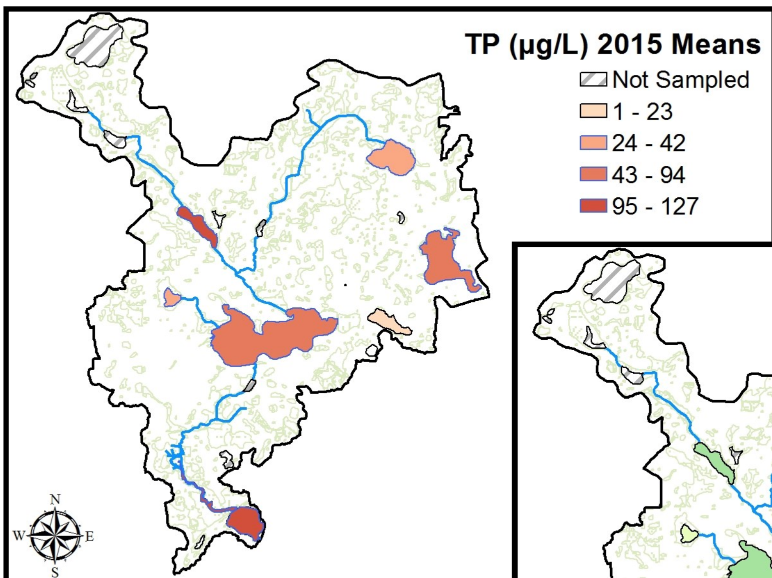
Water Quality: The phosphorus loading into Long Lake in 2015 was about half the pounds observed historically at that station, where the loading into Tanager Lake was slightly higher than the historical average (Figure 2).

Figure 31. Comparison of phosphorus loading into Long Lake (CLO05) and Lake Minnetonka: Tanager Lake (CLO03).



With a watershed to lake area ratio of 151:1, external loading into Tanager Lake is one of the main reasons the lake is impaired for excessive nutrients (Table 19). The other reason is internal loading. Tanager was the receiving waters for high concentrations of phosphorus for a period up to 59 years. The waste-water treatment plant was decommissioned by the late 1980s (MCWD 2007).

The 2013 macroinvertebrate assessment surveyed the creek flowing from Long Lake into Tanager Lake. The macroinvertebrate community indicated the presence of pollution, low DO and low flow conditions downstream towards Tanager Lake.



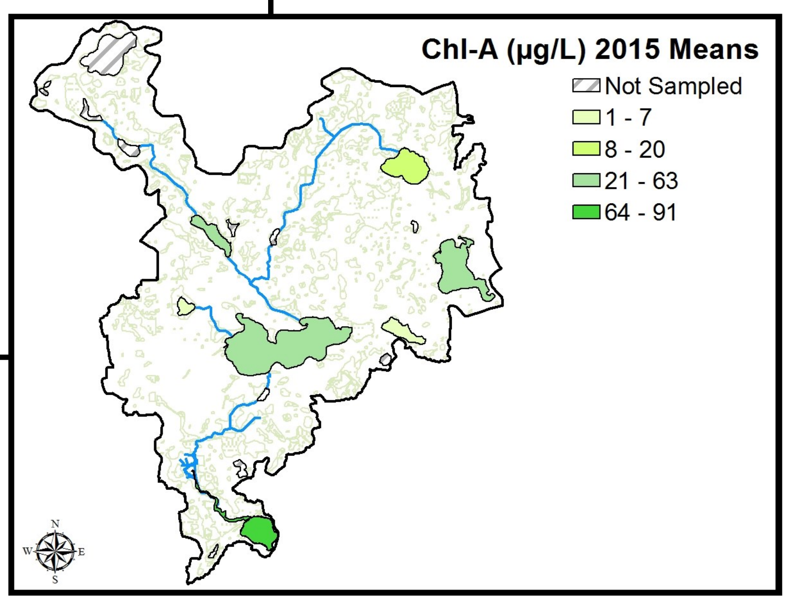


Figure 32. 2015 means of phosphorus and chlorophyll-a for the lakes throughout the Long Lake Creek Subwatershed.

In 2015, Tanager Lake had the highest concentrations of algal abundance and second highest phosphorus concentrations compared to all the monitored lakes in the subwatershed (Table 19).

Dickeys, Holy Name and Wolsfeld lakes discharge into Long Lake. Wolsfeld Lake, which is surrounded by agricultural use and woodlands, has the highest phosphorus concentrations (Figure 3). Wolsfeld's watershed to lake area ratio is the third largest in the subwatershed at 47:1. Dickey's Lake is the only monitored lake in the Long Lake Creek Subwatershed that is not impaired for excessive nutrients (Table 19). Historically, the phosphorus concentrations in Dickey's is the only parameter that often, but not always, exceeds the eutrophication standard. Until another parameter in Dickey's Lake exceeds the standards, the lake will remain off the impaired waters list.

The water quality in Long Lake (2003-2015) and Tanager Lake (2006-2015) was assessed for long-term change. There were no significant changes in Tanager Lake. The water quality in Long Lake had shown significant improvement in algal abundance levels and water clarity prior to adding data from 2013-2015. Now the only significant trend is a slight improvement in water clarity (Figure 33). Chlorophyll-a and phosphorus concentrations have increased since 2014 flood waters, but the trend analysis did not show significance.

Residents around Long Lake have also been taking note of the increased algal levels. The past two years, MCWD has received calls about large algal blooms and/or water like pea-green soup. Unfortunately, its not an isolated event. For the past five years, green and/or blue-green blooms often occur in Long Lake in July or August and may last until the ice-in (Figure 34), most likely a delayed response to external and internal phosphorus loading. By June, in most years, the algal abundance in Long Lake is above the eutrophication standard (Table 19).

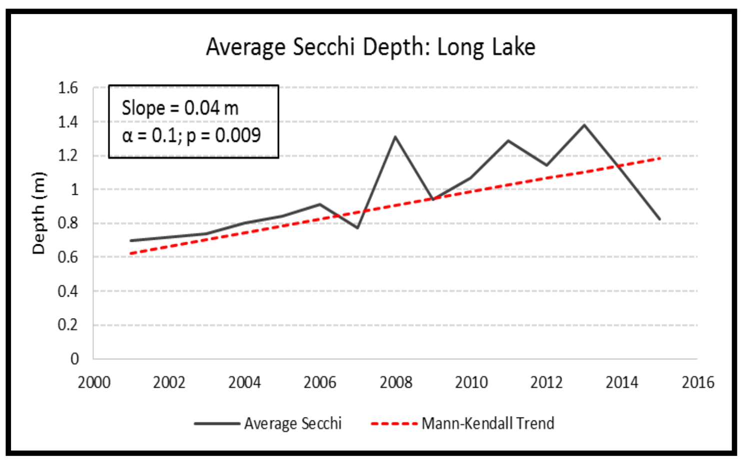
MCWD plans to identify and asses the sources impacting Long and Tanager Lakes further in 2018 through the E-grade assessment.

Table 19. Long Lake Creek Subwatershed's Lakes 2015 Means and List of Known Impairments

Lake	Mean SECC (m)	Mean CHLA (µg/L)	Mean TP (µg/L)	Impairment
	June-Sept 2015			
Holy Name* (MCWD Volunteer)	1.15	9.00	42.00	Nutrients
Mooney* (MCWD Volunteer)	0.78	41.00	74.50	Nutrients
Dickey's (MCWD Volunteer)	2.47	6.80	41.60	None
Lake Minnetonka: Tanager	0.82	90.75	108.50	Nutrients
Long	0.83	62.50	93.75	Nutrients, Mercury
Wolsfeld (MCWD Volunteer)	0.37	61.50	126.75	Nutrients

*Shallow lake; red indicates not meeting standard

Figure 33. Average Secchi Depth Trend from 2001-2015 for Long Lake



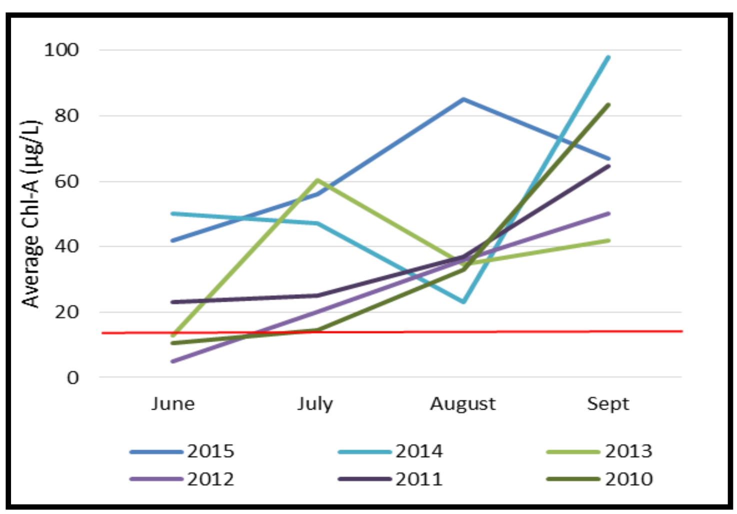


Figure 34. Monthly Chlorophyll-a averages for Long Lake. Red line indicates standard (14 µg/L).

Project Activities (Year Completed):

- Long Lake Creek Corridor Improvements (Active)
- Restoring vegetation to the west shoreline in Long Lake Park (1999)
- Enhancement of existing sediment basins in the city/park (1998)
- Construction of wet detention basins (1996)
- Long Lake alum treatment (1996)

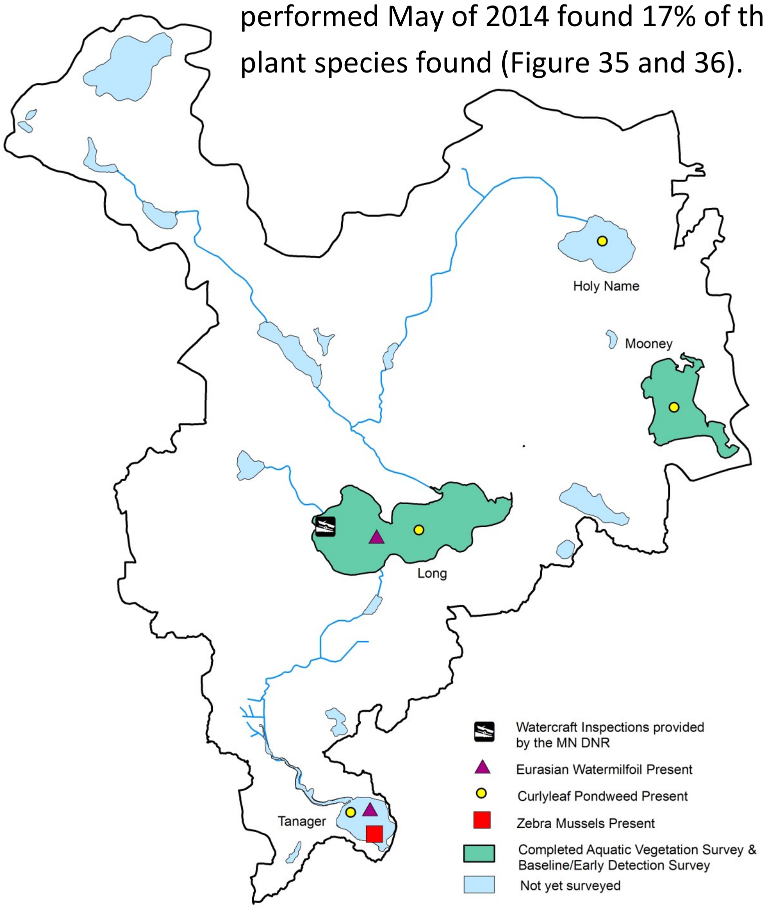
Long Lake Creek outlet (CLO01) in the fall of 2015

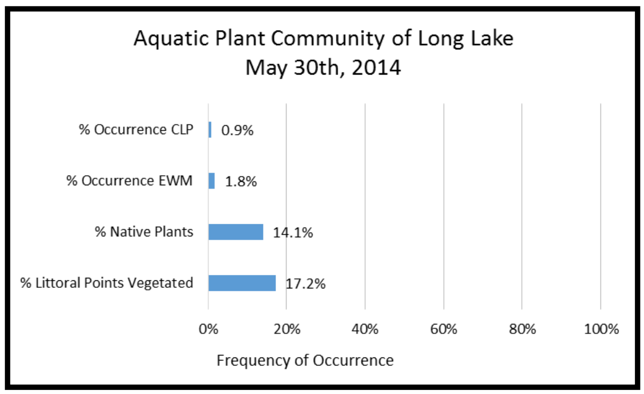
AIS Prevention: Watercraft Inspections

The MN DNR performs a limited amount of watercraft inspection services at Long Lake. The data below is from those inspections. The other lakes in the subwatershed do not have public launches.

Inspection Hours	# Inbound Inspections	# Outbound Inspections	% Compliance with MN Drain Plug Law	% Watercraft Entering with Possible AIS	# Inbound Watercraft stopped with zebra mussels attached
130.25	182	104	92.9%	2.2%	0

AIS Monitoring: There is a low abundance of aquatic plants in Long Lake, likely due to low water clarity and excess nutrients, and possible common carp impacts. The most recent survey performed May of 2014 found 17% of the littoral area is vegetated, with only 6 different plant species found (Figure 35 and 36).





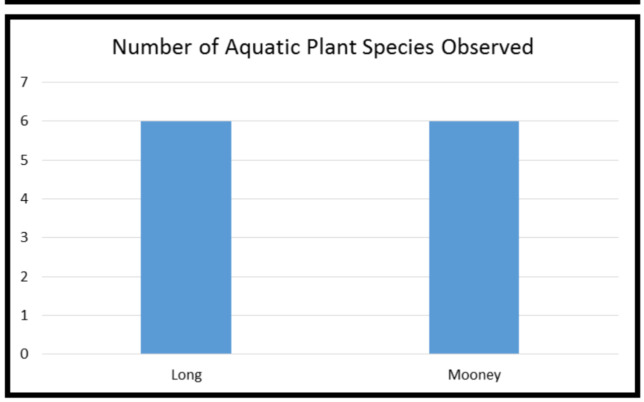
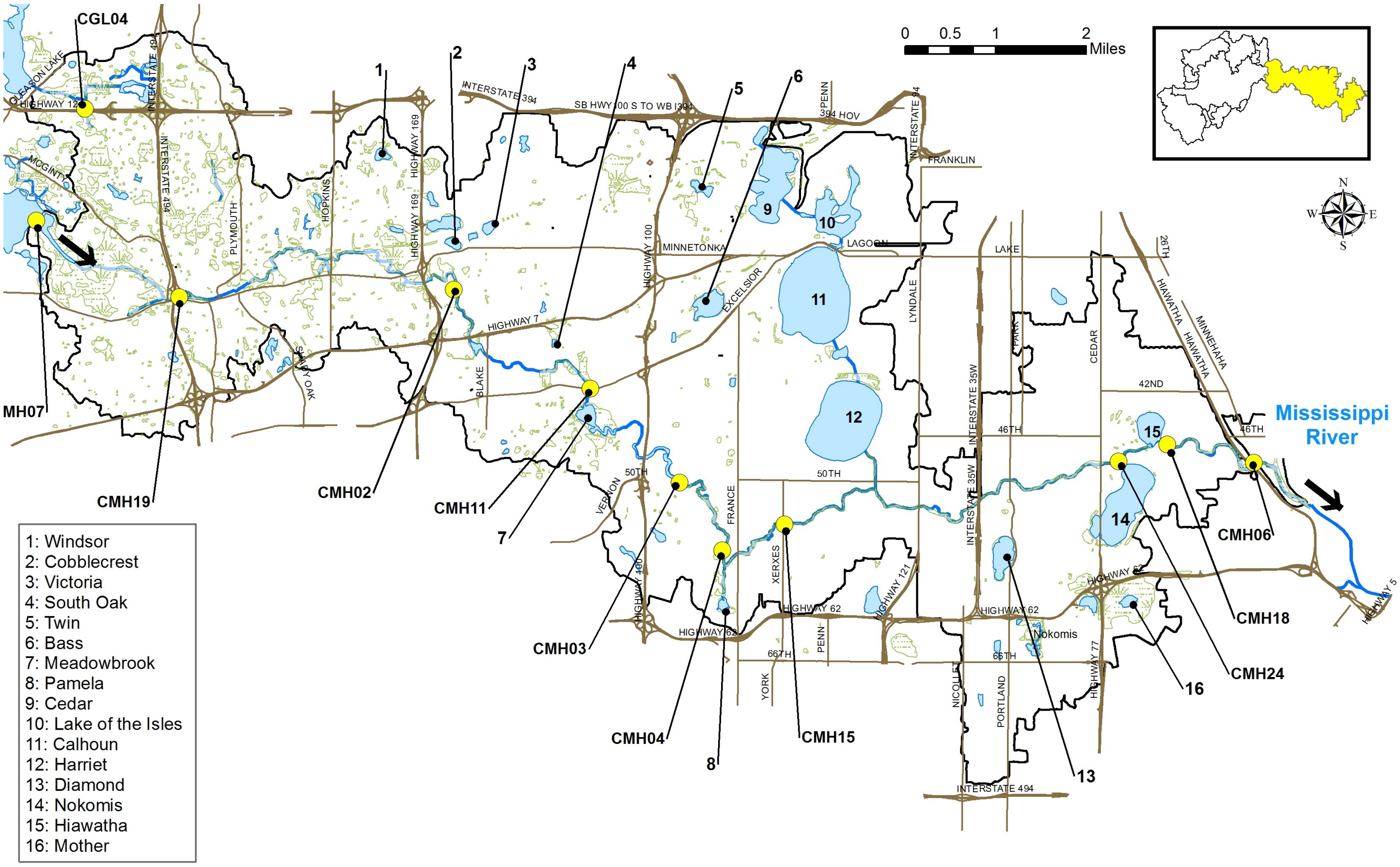


Figure 35. Aquatic plant community of Long Lake; Figure 36. Number of aquatic plant species observed.

3.9 Minnehaha Creek Subwatershed



Minnehaha Creek Subwatershed is the only subwatershed east of the Lake Minnetonka. The land use is dominated by residential, business and industrial entities. The impervious cover on the land is higher in this subwatershed compared to the other ten subwatersheds (EOR 2003). Land designated for parks and recreational areas are scattered throughout the subwatershed; many are adjacent to the lakes and the creek as are the majority of the remaining wetlands and woodlands.

Water Quality: Minnehaha Creek is the only receiving water for the drainage from all ten subwatersheds. The headwaters to the creek is managed by an adjustable control structure to reduce flooding on Lake Minnetonka and Minnehaha Creek. Baseflow conditions, when the dam is closed, are low to stagnant pools that are scattered across the reaches, though can be flashy and maintain flow from runoff even when the dam is closed. Minnehaha Creek is vulnerable to any pollutant the upper watershed discharges, as well as by the pollutants from the surrounding uplands. Currently, Minnehaha Creek is impaired for chloride, dissolved oxygen, fecal coliform (i.e., *E. coli*) and the inability to support macroinvertebrates and fish communities. The 2013 macroinvertebrate assessment indicates that the headwaters, west of

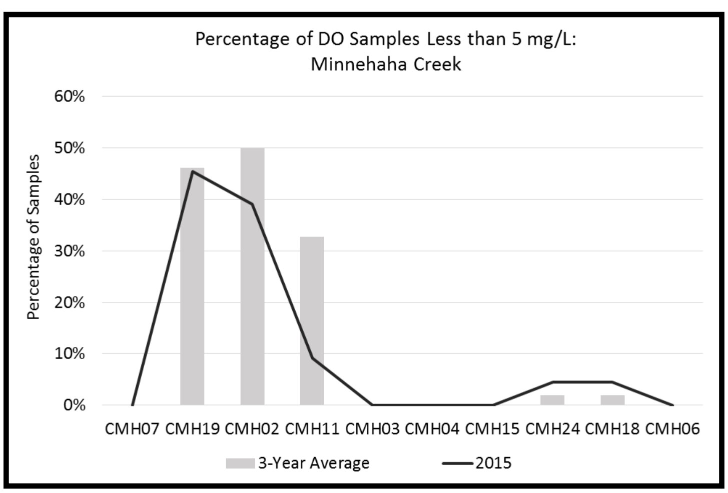
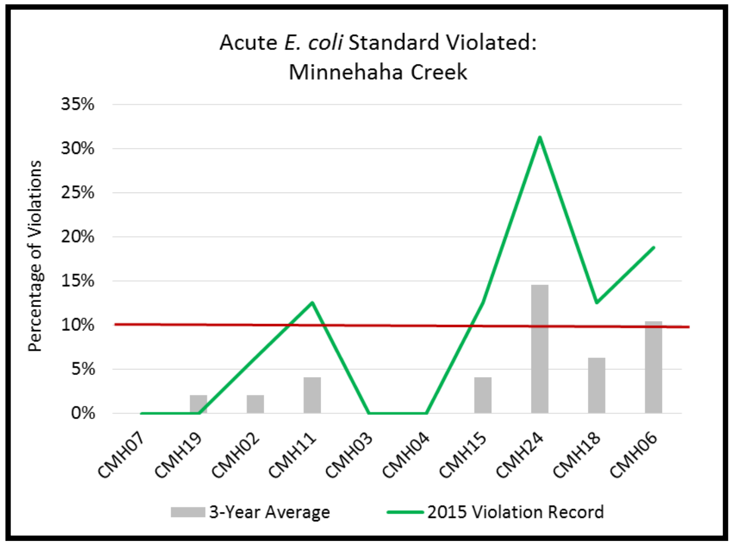


Figure 37. Percentage of DO samples less than 5 mg/L that occurred along Minnehaha Creek.

HWY 169, have a biological community that thrive in low pollution, well-oxygenated waters. East of HWY 169, the biological community reflects the more urban, polluted conditions.



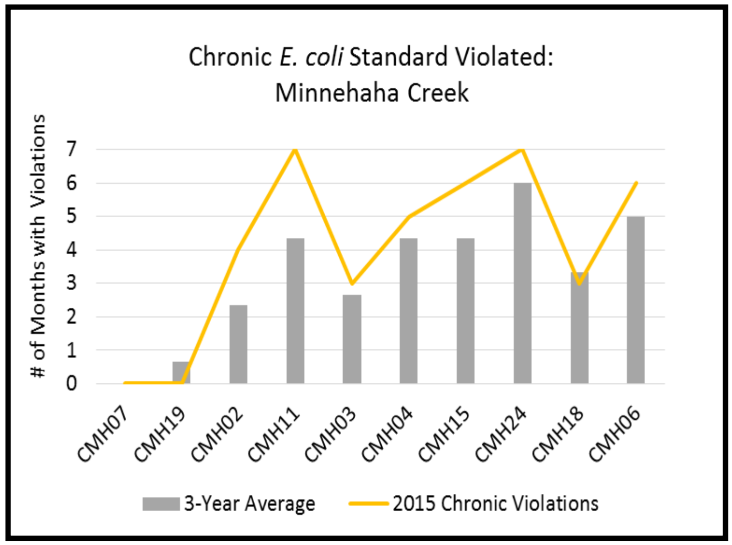
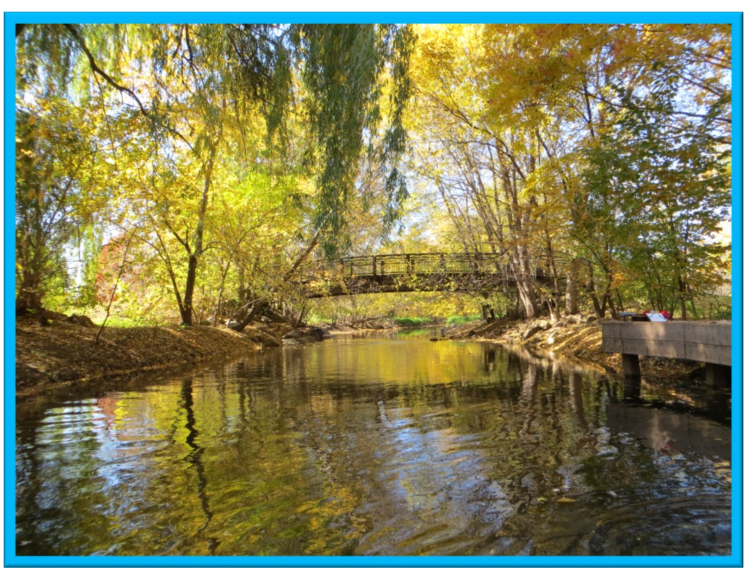


Figure 38. Percentage of violations of acute *E. coli* standard and number of months with violations of the chronic *E. coli* standard along Minnehaha Creek.

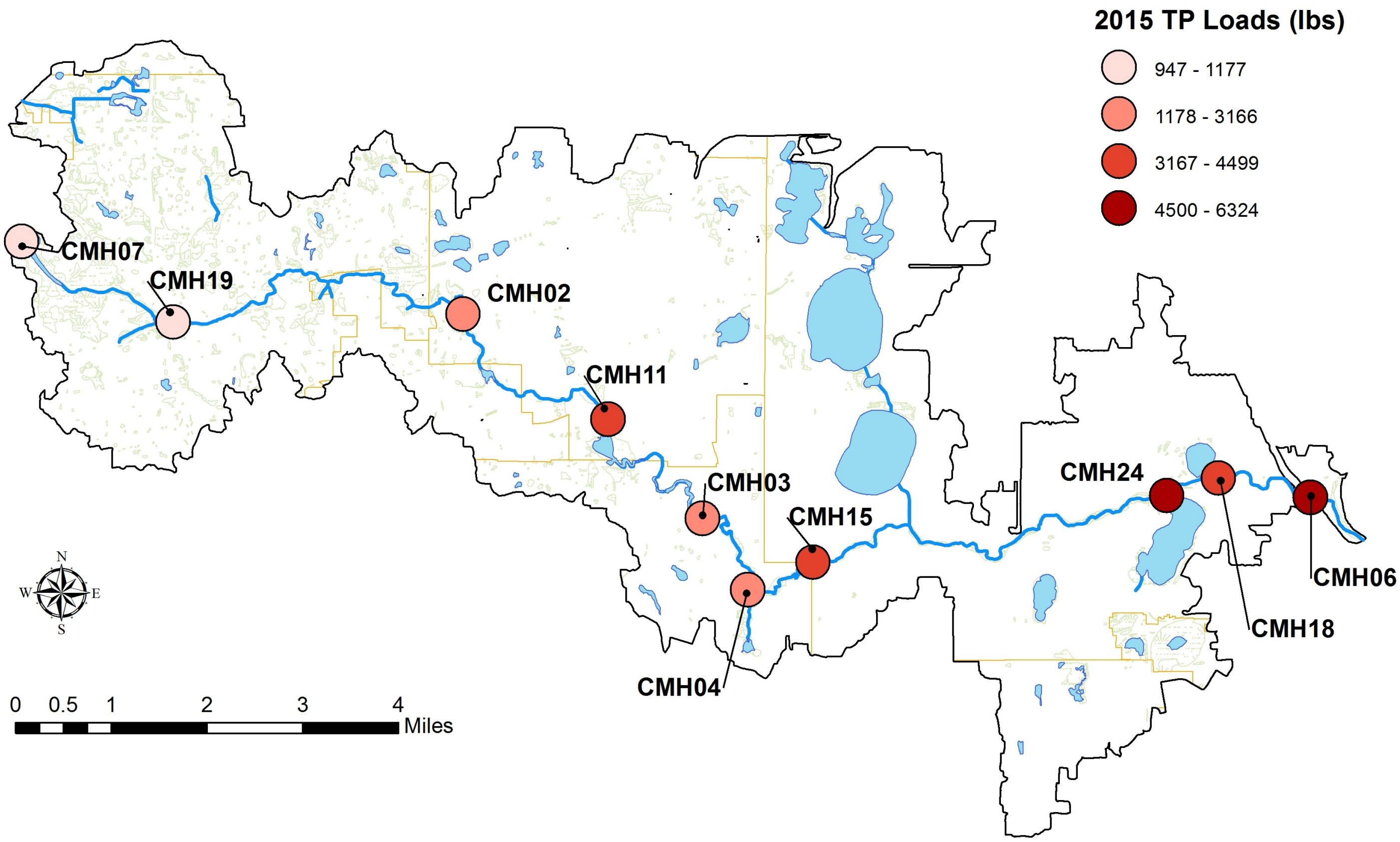
In 2015, five stations along Minnehaha Creek had dissolved oxygen samples less than 5 mg/L (Figure 38). Evaluating the creek on a 3-year average, these same five stations have continuously had DO samples less than 5 mg/L. The samples below 5mg/L often occur during the warmest months, July through September.

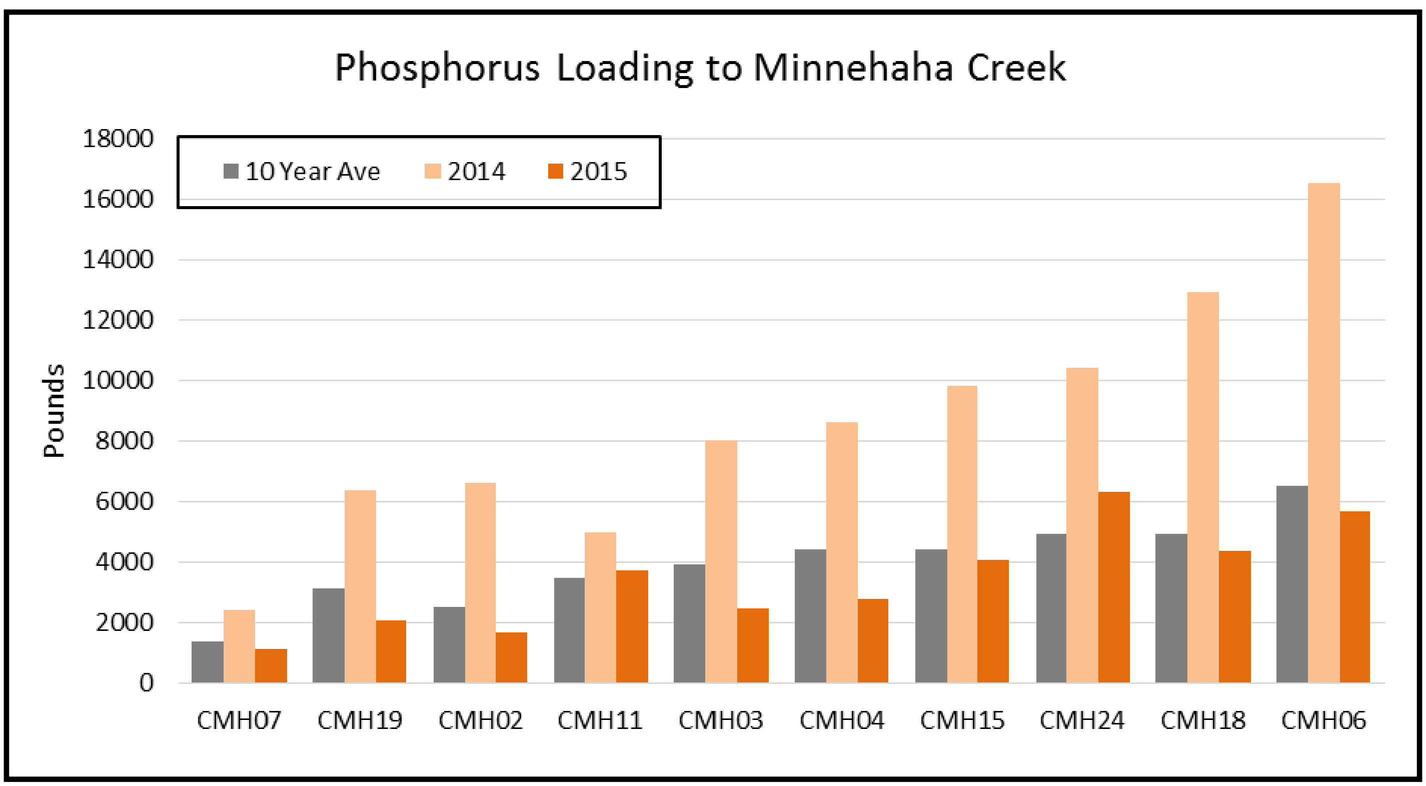
E. coli violations often occur in Minnehaha Creek after a precipitation event. A violation of the acute *Escherichia coli* (*E. coli)* standard for Minnehaha Creek is displayed in Figure 38. Excelsior Blvd. (CMH11) and Xerxes Ave (CMH15) to Hiawatha Ave (CMH06) stations on Minnehaha Creek violate the acute *E. coli* standard in 2015. On average, only 21st Ave. (CMH24) and Hiawatha Ave. (CMH06) violate the acute standard.

A violation of the chronic *E. coli* standard is displayed in Figure 38. MCWD does not collect 5 samples/month unless there are 5 weeks in a month, typically, April, July and October. Five or more samples/month are required to determine chronic *E. coli* impairment; however, Minnehaha Creek violates the chronic *E. coli* units (126 cfu/100 mL) with 5 or less samples/month (Figure 38). In 2015, all stations east of I-494 station (CMH19) violated the chronic *E. coli* standard. On average, all stations except stream side of Grays Bay Dam (CMH07) violates the chronic *E. coli* standard. Excessive nutrient and chloride loading are an issue in Minnehaha Creek. In 2015, the largest phosphorus loads occurred at 21st Ave (CMH24) and Hiawatha Ave (CMH06) (Figure 39. On average, W. 56th St. station (CMH04) down to Hiawatha Ave (CMH06) discharge over 4000 lbs of phosphorus/year to the creek (Figure 40). In 2015, chloride loading increases to over 2500 tons/year at the Browndale Dam (CMH03) down to Hiawatha Ave



Downstream of 21st Ave (CMH24 station)

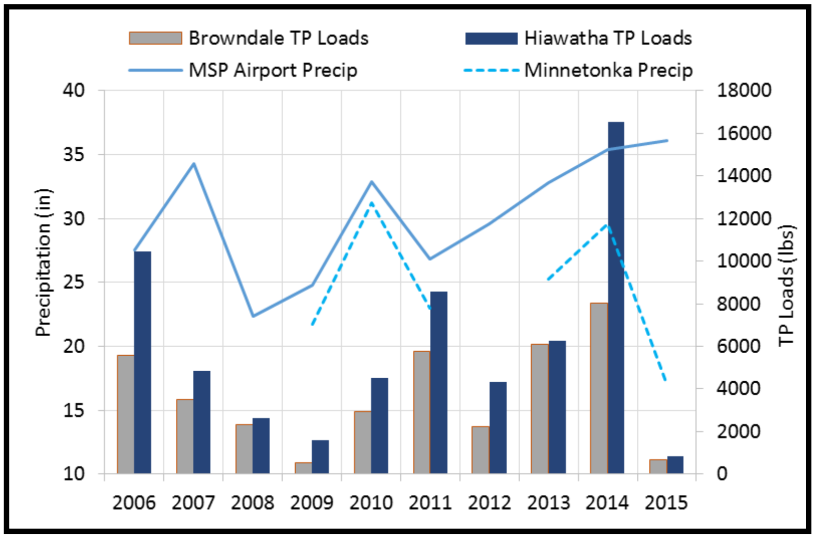




(Top) Figure 39. 2015 phosphorus loads at stations along Minnehaha Creek;

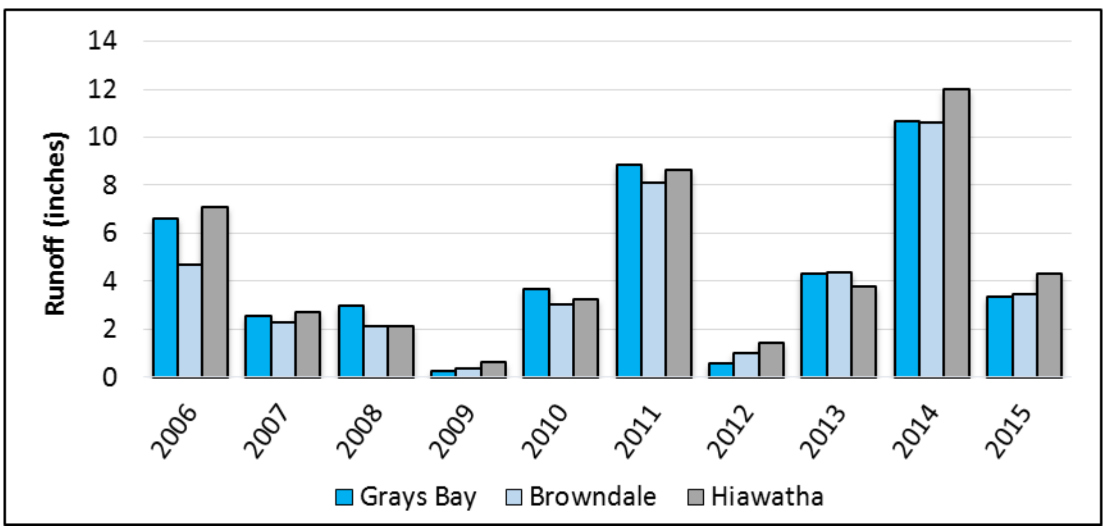
(Bottom) Figure 40. Phosphorus loading to Minnehaha Creek.

Precipitation drives loading in Minnehaha Creek (Figure 41). In wet years, like 2014, loading is above average in Minnehaha Creek, and in dry years, like 2009, the loading is at or below average (Figure 41 and 42). Discharge from Grays Bay Dam also influences loading in the creek. The discharge from the Grays Bay Dam is converted into runoff, which translates into the volume of water drained from the upper watershed. The historic, 10-year average runoff is 4.38 inches. In 2015, the runoff from the upper watershed was below the historic average at 3.36 inches (Figure 42).



(Left) Figure 41. Comparison of annual precipitation and phosphorus loading at Browndale Ave (CMH03) and Hiawatha Ave (CMH06) inlets.

Figure 42. Comparison of annual runoff at Grays Bay (CMH07), Browndale Dam (CMH03), and Hiawatha Ave. stations (CMH06).



(Left) View downstream of Hiawatha Ave (CMH06) during the 2009 drought, (Right) view of the flooded parkway, downstream of Hiawatha Ave station in 2014.

Water Quality (Cont.): Besides Minnehaha Creek and Minnehaha Falls, the Minnehaha Creek Subwatershed also features the Minneapolis Chain of Lakes, Lake Nokomis and Lake Hiawatha. These urban lakes are monitored and managed by the Minneapolis Park and Recreation Board (MPRB). Metropolitan Council Environmental Services' Citizen Assisted Monitoring Program (CAMP) monitored three other lakes in 2015. Minnehaha Creek Watershed District staff and volunteers monitored the remaining waterbodies in 2015 listed in Table 21. Table 21 is broken into three categories: shallow lakes, deep lakes and wetlands. Eutrophication standards differ for shallow and deep lakes, and there are no established eutrophication standards for wetlands.

The majority of the impairments present in the lakes within the Minnehaha Creek Subwatershed are chloride, mercury, PFCs and PCBs. Lake Hiawatha, Lake Nokomis, Cobblecrest, and Windsor Lake are the only waterbodies currently impaired by excessive nutrients. The shallow lakes that exceeded the eutrophication standards need to be evaluated for nutrient impairment. Many of these lakes have more than two years of exceeding the shallow lakes standards. These shallow lakes are often subjected to storm water and urban runoff which most likely is the reason for the excessive nutrients and algae. These lakes only overflow into the Chain of Lakes or Minnehaha Creek during high precipitation years.

In 2015, the water quality in Calhoun and Harriet lakes met the eutrophication standards. The remaining deep lakes, including impaired Lake Nokomis and Lake Hiawatha, had only one water quality parameter that exceeded the eutrophication standard in 2015. A biomanipulation of the fish community in Lake Nokomis and the re-meandering of the Minnehaha Creek in the upper reaches may be contributing to improved water quality in both lakes (See Section 4).

Wetland/Lakes	Mean SECC (m)	Mean CHLA (µg/L)	Mean TP (µg/L)	Impairment
	June-Sept 2015			
Cobblecrest (CAMP)*	0.35	62.25	103.50	Nutrients
Meadowbrook*		8.50	56.25	Chloride
Mother*		9.75	59.50	None
Pamela (MCWD Volunteer)*	0.43	209.25	208.50	None
Powderhorn (MPRB)*	0.43	54.01	97.88	Mercury, Chloride
South Oak (CAMP)*	0.53	63.29	71.71	None
Victoria (MCWD Volunteer)*	0.61	111.25	133.50	None
Windsor*		10.50	109.00	Nutrients
Calhoun (MPRB)	3.57	2.26	15.75	Mercury, PFCs, Chloride
Cedar (MPRB)	1.26	8.55	24.52	Mercury
Harriet (MPRB)	2.34	5.07	22.72	Mercury
Hiawatha (MPRB)	1.61	10.33	62.70	Chloride, Nutrients
Isles (MPRB)	1.64	16.58	36.21	Mercury, PFCs
Nokomis (MPRB)	1.34	11.14	37.68	Mercury, PCBs, Nutrients
Bass (MCWD Volunteer)**	0.79		158.50	None
Diamond (MPRB)**		28.02	122.00	Chloride

* Shallow lake; ** wetland or strong wetland characteristics; red indicates not meeting standard; gray indicates no established standard

Table 21. Minnehaha Creek Subwatershed's Lakes 2015 Water Quality Mean Values and List of Known Impairments

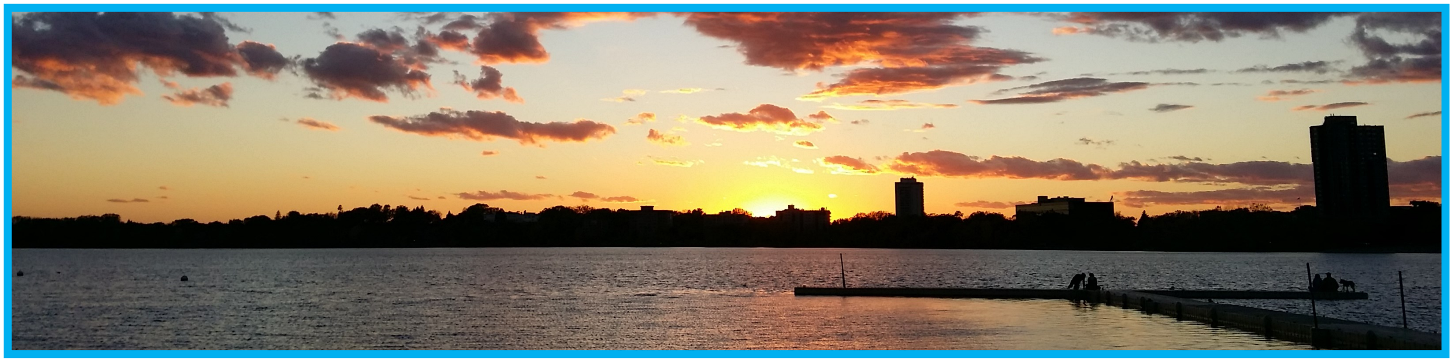
Evaluating water quality (SECC, CHLA and TP) in the lakes of the Minnehaha Creek Subwatershed reveals several significant long-term changes. From 2002-2014, Grass Lake had statistically significant improvements in algal abundance, and Twin Lake had statistically significant improvements in phosphorus concentrations. Grass Lake was not monitored in 2015 and Twin Lake had insufficient data (Figure 43). The change in chlorophyll concentrations from 2003-2004 in Grass Lake is most likely due to change in sampling location (Email correspondence with MPRB, 2016). The location prior to 2004 was adjacent to Highway 62 and influenced by wind. Algal blooms tended to congregate in the sampling location, potentially biasing the results. The sampling location was moved due to the Crosstown Highway project.

Cedar Lake had a significant decline in water clarity from 2002-2015 (Figure 45). From 2001-2015, Lake of the Isles had a significant improvement in chlorophyll-a concentrations. The phosphorus and the chlorophyll-a concentrations in Lake Nokomis showed statistically significant improvements (Figure 44). Lake Harriet, during this same period, had statistically significant increase in phosphorus concentrations; however, the mean concentration in the lake is not yet exceeding the eutrophication standard.

The majority of the deep, urban lakes continue to improve or show no significant change in their water quality. This is likely due to the efforts by MCWD and partners to improve and maintain these recreation meccas.

Project Activities (Year Completed):

- Minnehaha Creek Restoration at 325 Blake Rd (Active)
- Meadowbrook Golf Course Restoration (Active)
- Taft Lake/Legion Lake Volume and Load Reduction (Active)
- Cottageville Park Expansion (2015)
- Minnehaha Creek Preserve and Re-meander (2014)
- Minnehaha Creek Reach 14 Restoration (2013)
- Lake Nokomis Biomanipulation Project (2013)
- Lake Nokomis Weir Renovation (2013)
- El Colegio Charter School Project - LID (2012)
- Cold Storage Acquisition (2011)
- Minnehaha Falls and Glen Restoration (2011)
- St. Mary's Greek Orthodox Church
  Water Quality/Volume Control Project - Cost Share (2011)
- Diamond Lake Community Go Blue Makeover - Cost Share (2011)
- 60th St and 1st Avenue Pond (2000)
- Minnehaha Creek Methodist Hospital Re-meander (2009)
- West End Redevelopment - LID (2008)
- Twin Lakes Subwatershed Improvement (2004)
- Pamela Park Wetland Restoration (2001)
- Lake Nokomis Wetland Settling Ponds (2001)
- Southwest Lake Calhoun Wetland Ponds (1999)
- Twin Lake/Cedar Lake Projects (1996)



Evening on Lake Calhoun (Photo courtesy of Minneapolis Parks and Recreation Board

Figure 43. Average Water Quality Trends from 2002-2014 for Grass Lake and Twin Lake.

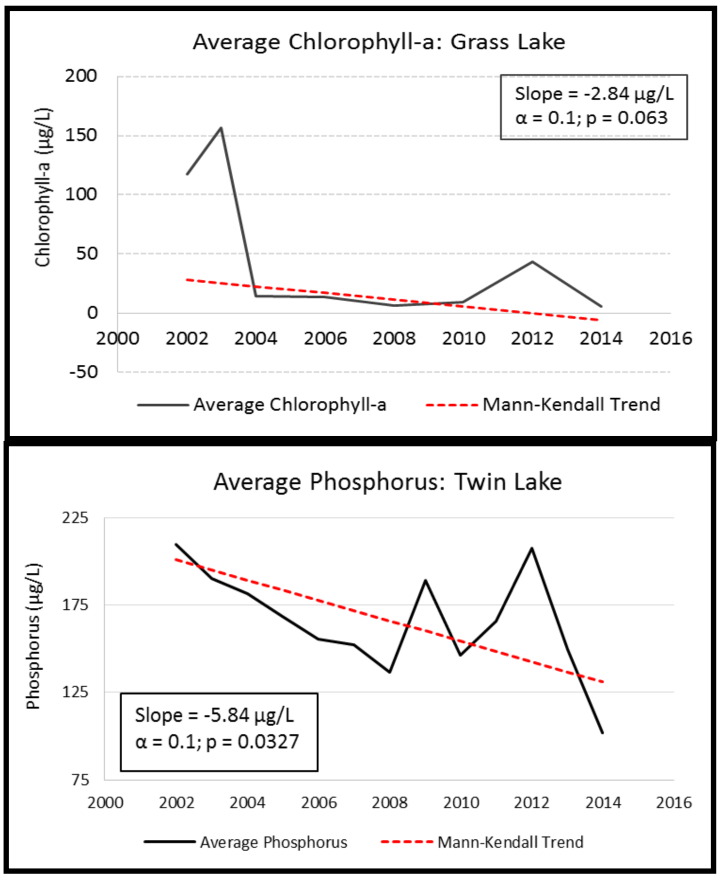


Figure 44. Average Water Quality Trends from 2001-2015 for Lake of the Isles, Lake Nokomis, and Lake Harriet.

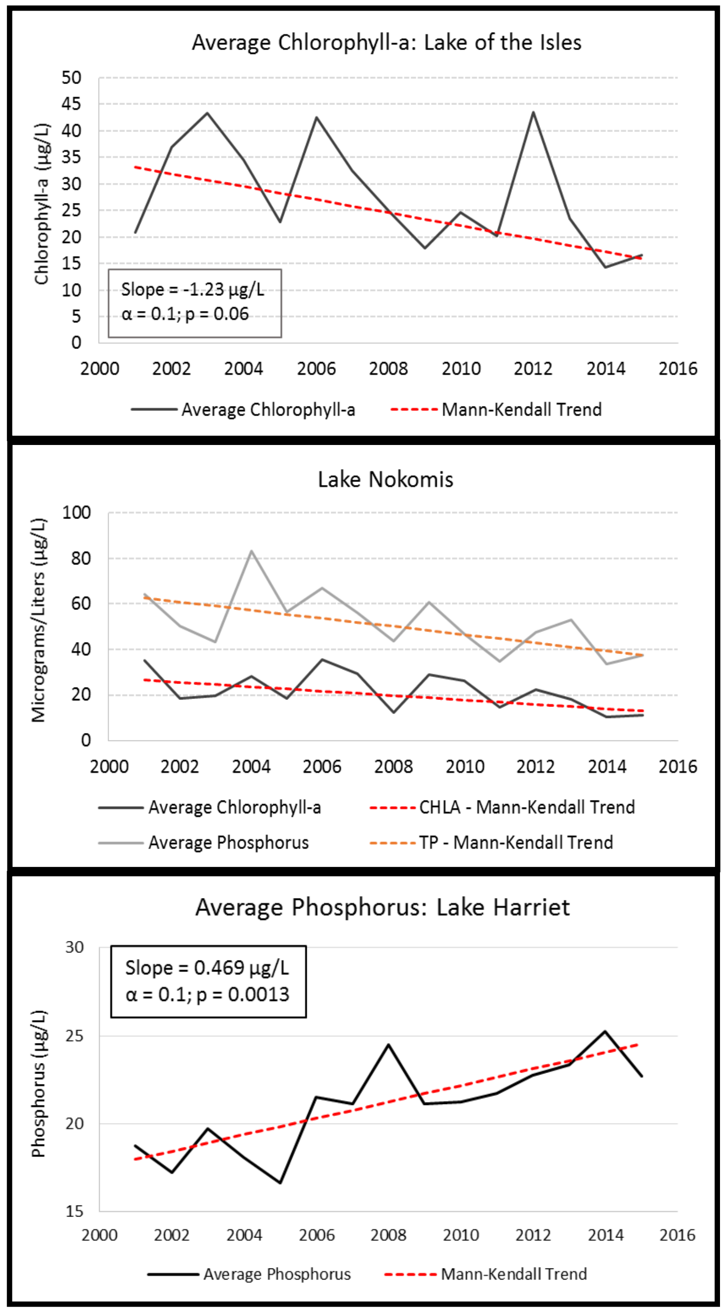
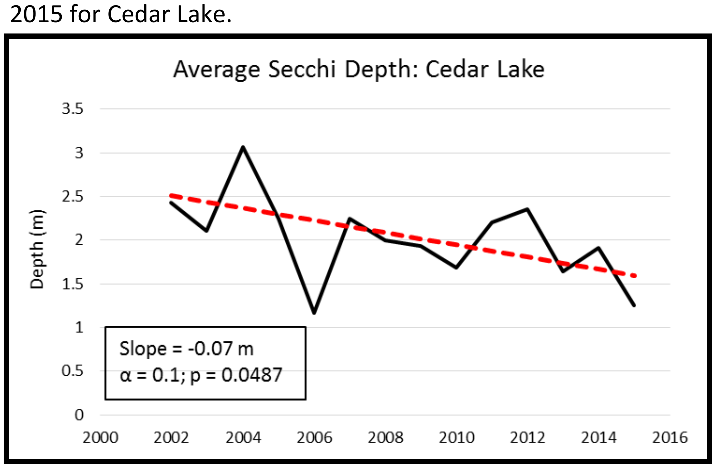


Figure 45. Average Secchi Depth Trend from 2002-2015 for Cedar Lake.

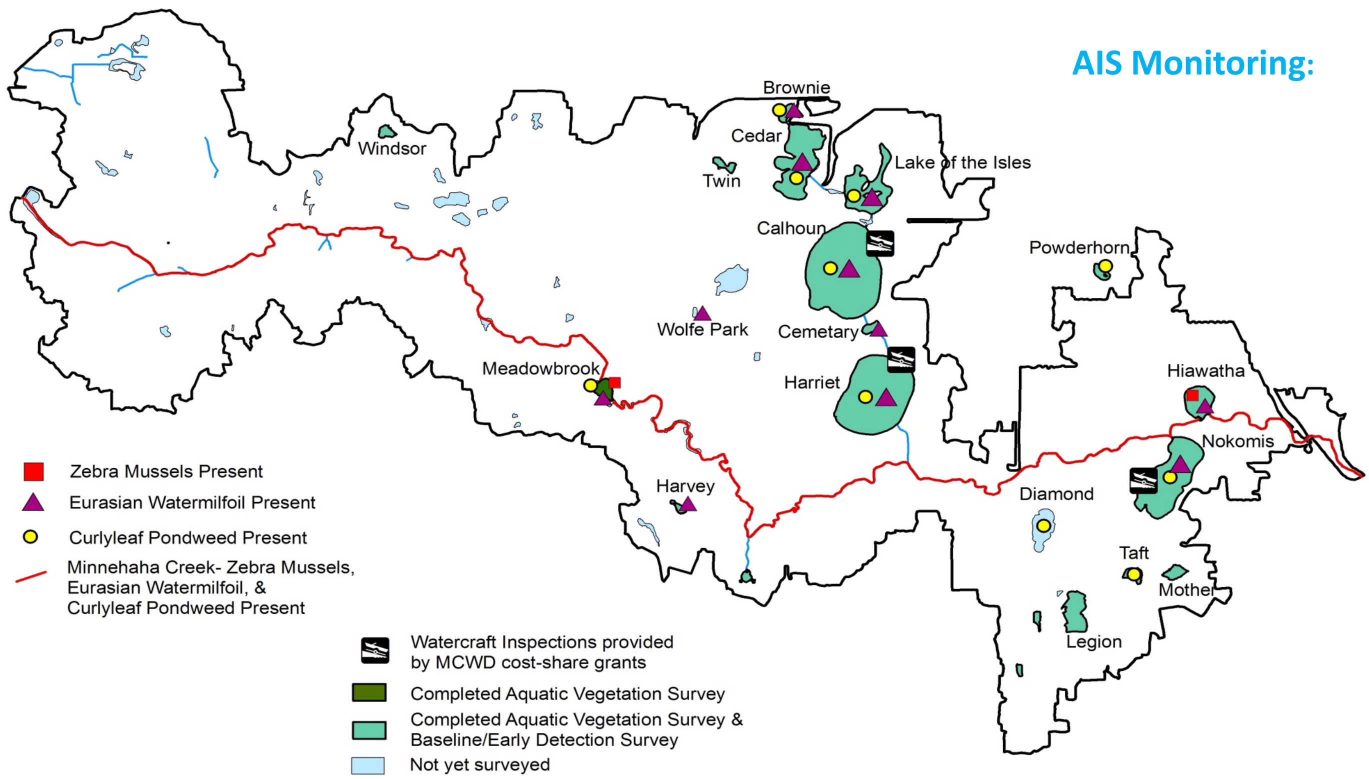


AIS Prevention: Watercraft Inspections (Harriet, Calhoun & Nokomis)

Inspection Hours	# Inspections (Inbound and Outbound)	Avg. % Compliance with MN drain plug law	Avg. % Watercraft entering with possible AIS	# Inbound Watercraft stopped with zebra mussels attached
10,020	8,489	96.38%	6.24%	12

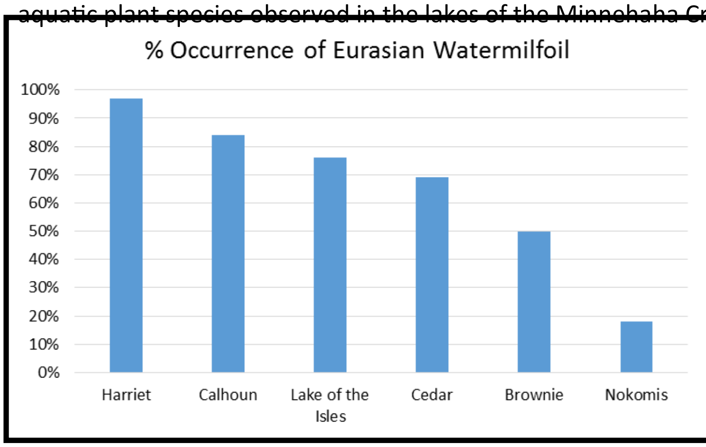
The MCWD cost-shares the watercraft inspection program on the Minneapolis Chain of Lakes (Harriet, Calhoun & Nokomis) with the Minneapolis Park and Recreation Board, who operate the program.

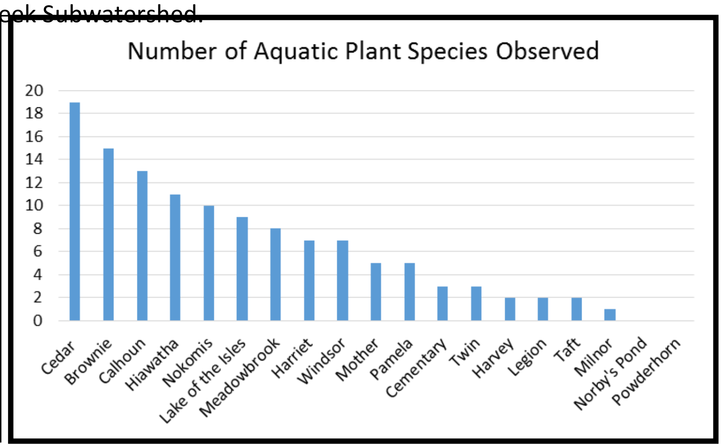
AIS Monitoring:



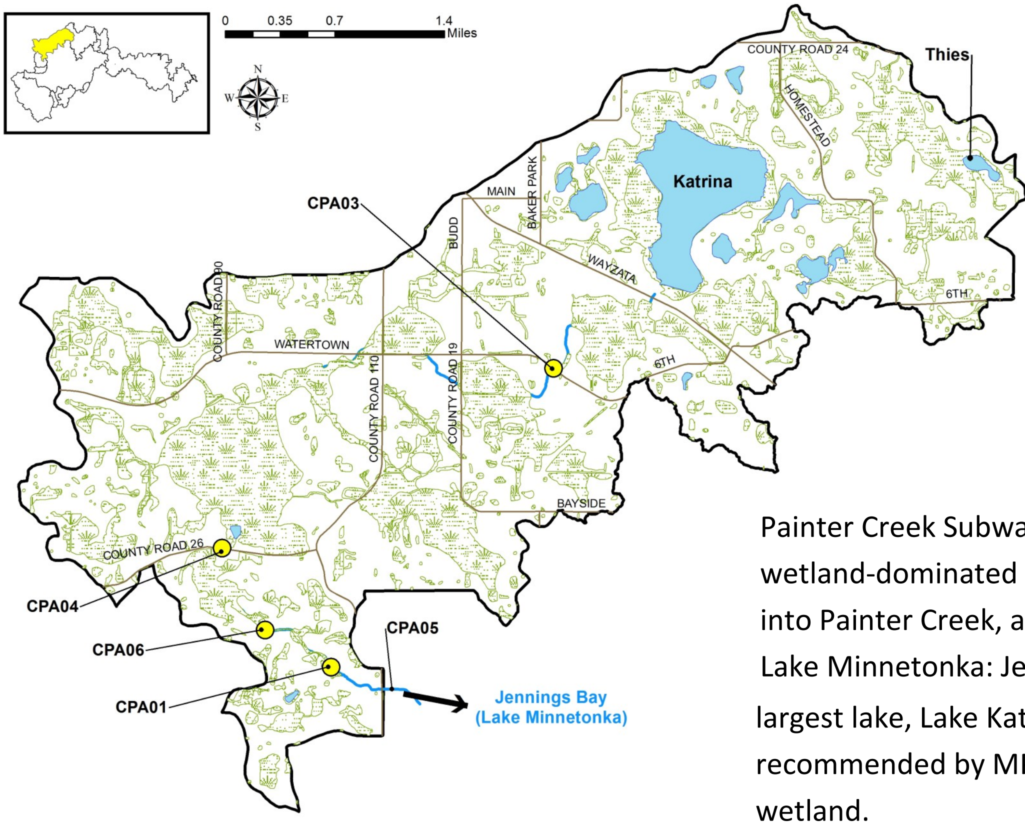
Zebra mussels are found throughout most of the Minnehaha Creek at various locations. The creek flows directly through Lake Hiawatha, which is also infested with zebra mussels, but at a low abundance. Lake Nokomis was listed as infested with zebra mussels due to the interconnectedness with Minnehaha Creek flowing out of Lake Minnetonka, but the Nokomis weir has acted as a barrier and no zebra mussels have been found to date in Lake Nokomis.

Figure 46. Percent occurrence of Eurasian watermilfoil in the lakes of the Minnehaha Creek Subwatershed; Figure Y. Number of aquatic plant species observed in the lakes of the Minnehaha Creek Subwatershed.





3.10 Painter Creek Subwatershed



Painter Creek Subwatershed is classified as a wetland-dominated subwatershed that drains into Painter Creek, and eventually drains into Lake Minnetonka: Jennings Bay. Even the largest lake, Lake Katrina, was recently recommended by MPCA to be classified as a wetland.

Although wetlands make up over 25% of the land cover in the subwatershed, the remaining 75% is a mix of agriculture, forests and woodlands, grasslands, and impervious cover.

View of Jennings Bay inlet station (CPA01) - in May 2016

Painter Creek flows in and out of Katrina and flows through woodlands and through Painter Marsh before curving towards Lake Minnetonka. Most of Painter Creek is classified as ditched due to efforts to drain the landscape.

Water Quality: MCWD staff monitor Painter Creek at 5 stations. Jennings Bay inlet (CPA05) receives backwater from Jennings Bay, and due to this issue, 2015 is the last year it will be monitored. Nutrient loading is more accurate at West Branch Rd upstream station (CPA01) (Figure 47).

In 2015, the loading to Jennings Bay was below average, but still the highest contributor of phosphorus to Lake Minnetonka in the entire Watershed District (See Section 3.5).

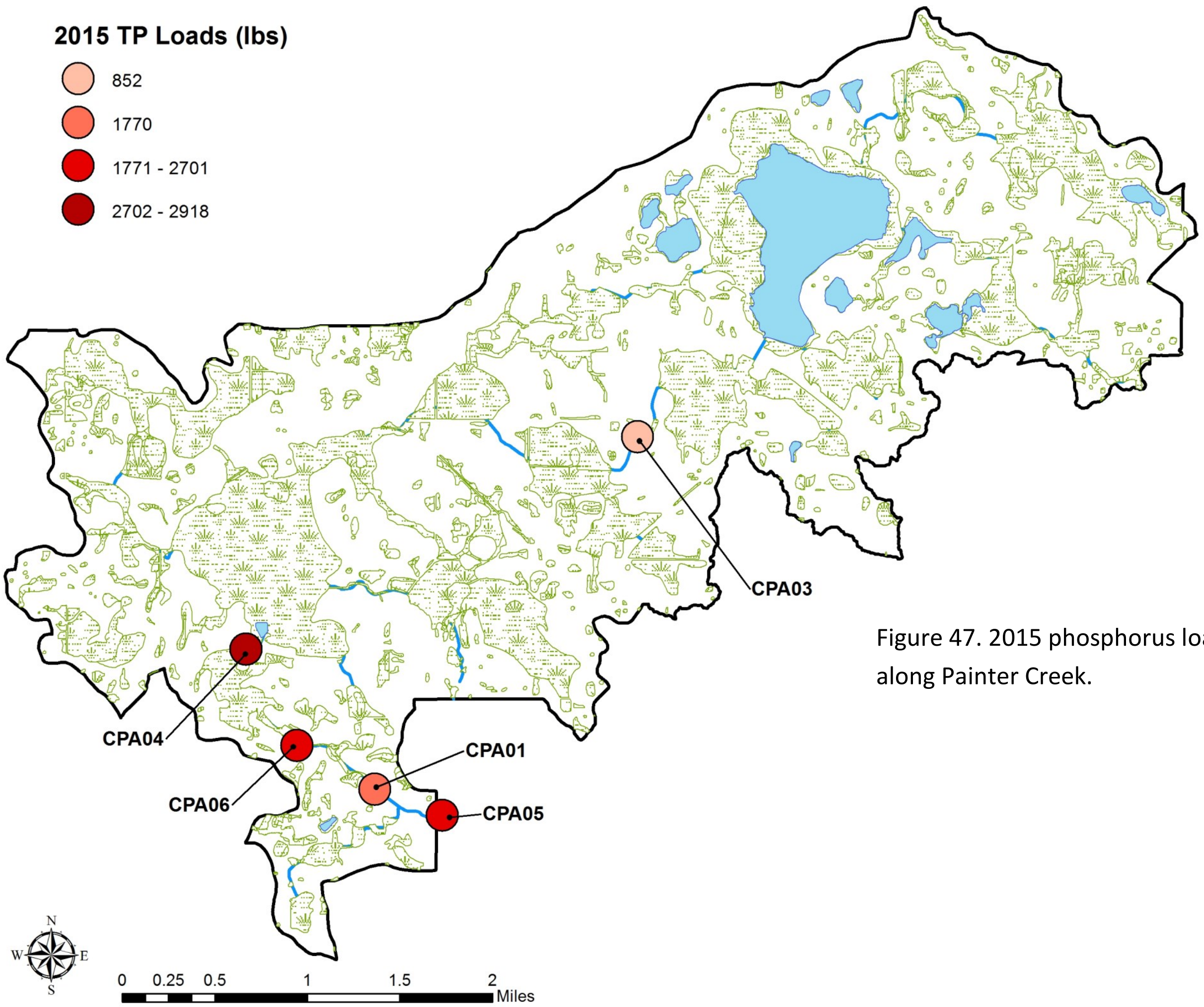


Figure 47. 2015 phosphorus loads at stations along Painter Creek.

CPA01 station did not have the highest phosphorus loads within the Painter Creek Subwatershed in 2015; actually, the Painter Marsh outlet station (CPA04) did at 2,918 lbs (Figure 47). The Painter Marsh outlet has a largest contributing watershed area of all the monitored stations in this subwatershed, and on average has the largest phosphorus loads too. Conditions have not changed much since 2013, when a macroinvertebrate assessment found Painter Creek had the most impacted biological community out of all the streams assessed throughout MCWD due to polluted conditions, low dissolved oxygen (DO) and low habitat quality.

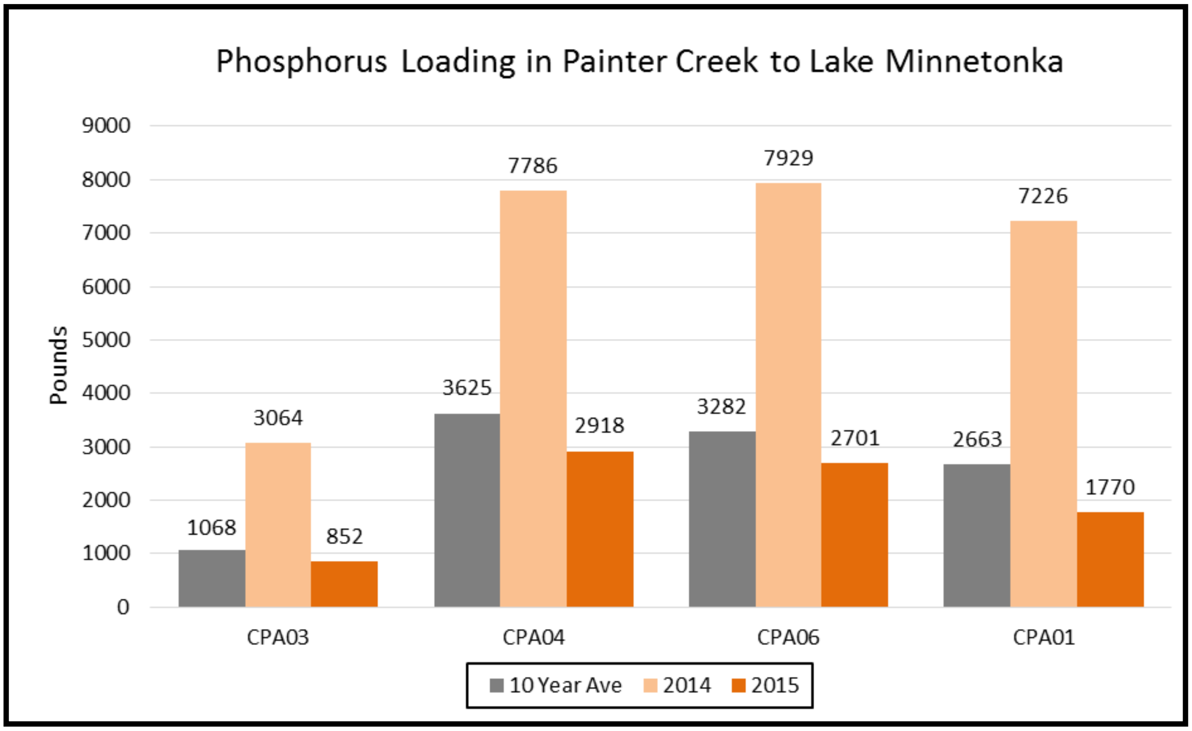
As with most of the creeks throughout the Minnehaha Creek watershed, Painter Creek is an intermittent stream that is dependent on precipitation. In wetter years, phosphorus loading is above average, and in dry years, loading is practically non-existent (Figure 49).

In addition to phosphorus loading issues in Painter Creek, the water quality in the creek has DO and *E. coli* issues. In 2015, the five stations along Painter Creek violated the DO standard. Similar percentage of violations occurred on a 3-year average (Figure 50). Since Painter Creek is ditched, the creek can not be listed impaired for DO, yet the creek is listed impaired *E. coli*.

Project Activities (Year Completed):

- Painter Creek/Painter Marsh Project (Active)
- Culvert Replacement west of South Katrina Marsh to reduce future flooding (Active)
- Cattle Crossing Replacement in Painter Marsh to repair flood damage/reduce flooding (Active)
- Painter Marsh Bird Inventory (2012)
- Painter Creek Restoration (2009)
- Lake Minnetonka: Jennings Bay/Painter Creek Project (1985; 1997)

Figure 48. Comparison of phosphorus loading in Painter Creek to Lake Minnetonka.



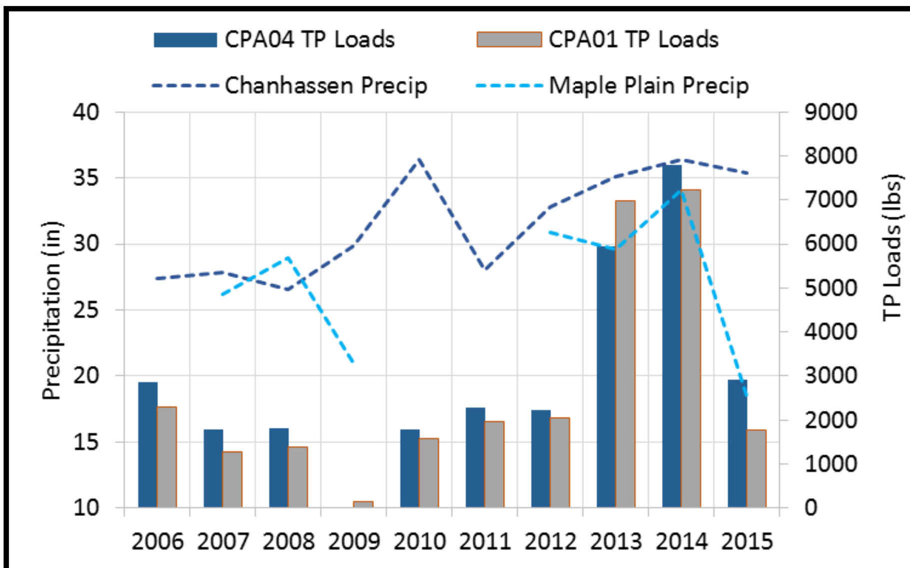
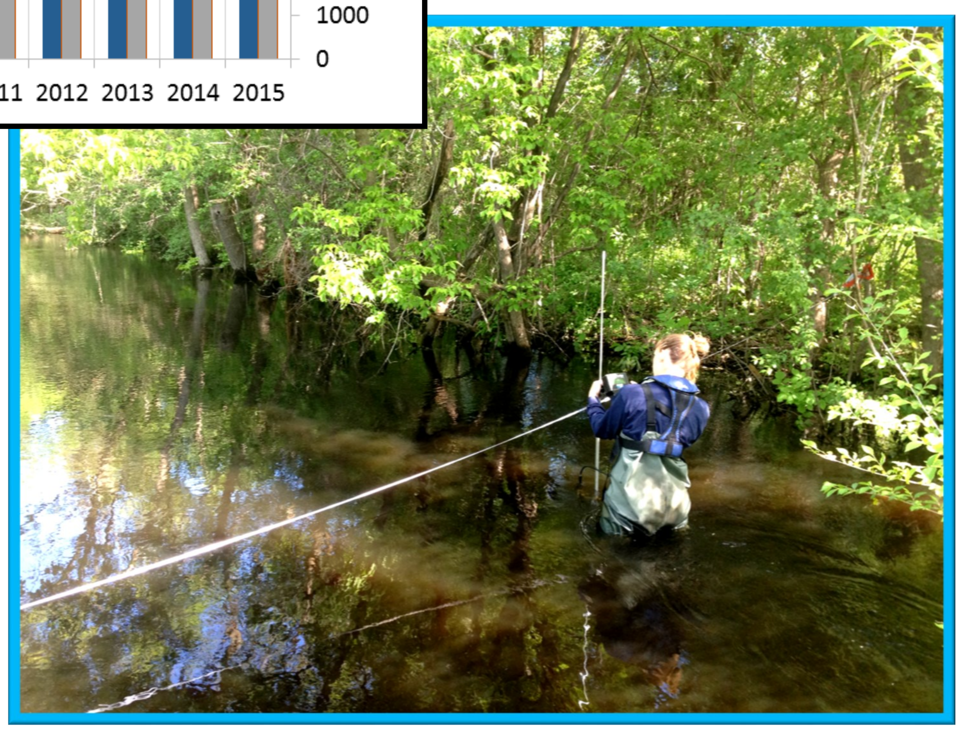


Figure 49. Comparison of annual precipitation and phosphorus loading at Painter Creek Marsh outlet (CPA04) and West Branch Rd (CPA01).



MCWD staff in process of monitoring velocity and discharge at upstream at Painter Creek Dr (CPA06).

In 2015, Painter Creek violated the chronic *E. coli* standard (Figure 51). Jennings Bay inlet (CPA05) station had six of the seven months of the open water season with waters containing *E. coli* concentrations greater than 126 cfu/ 100 mL. On a 3-year average, at most there is three months of the open water season where violations of chronic E. *coli* standard occur in Painter Creek (Figure 51). In terms of the Acute *E. coli* standard, Painter Creek does not often violate. The violation can occur with heavy precipitation, but not always. The violation will be from one sample during either May or October, and occurs at one station or sometimes at all stations, but not always on an annual basis.

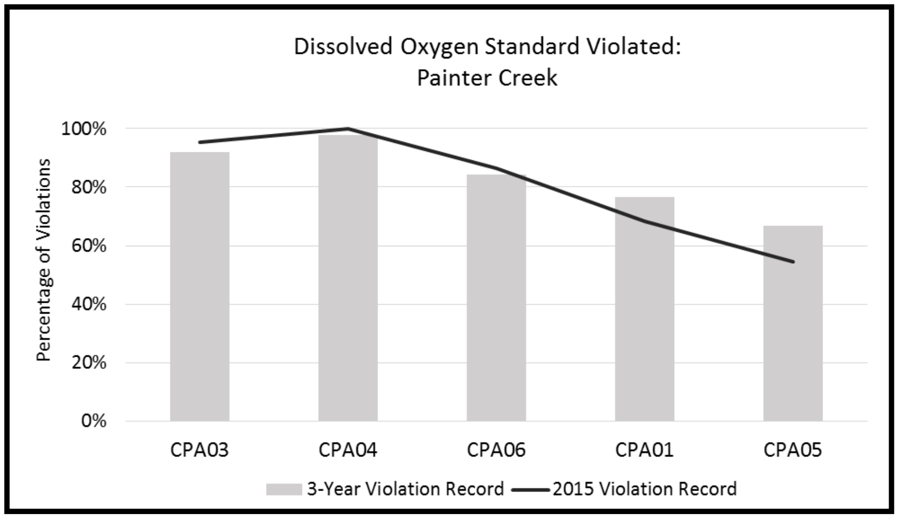


Figure 50. Percentage of dissolved oxygen violations that occurred along Minnehaha Creek.

Figure 51. Number of months with violations of the chronic *E. coli* standard along Painter Creek.

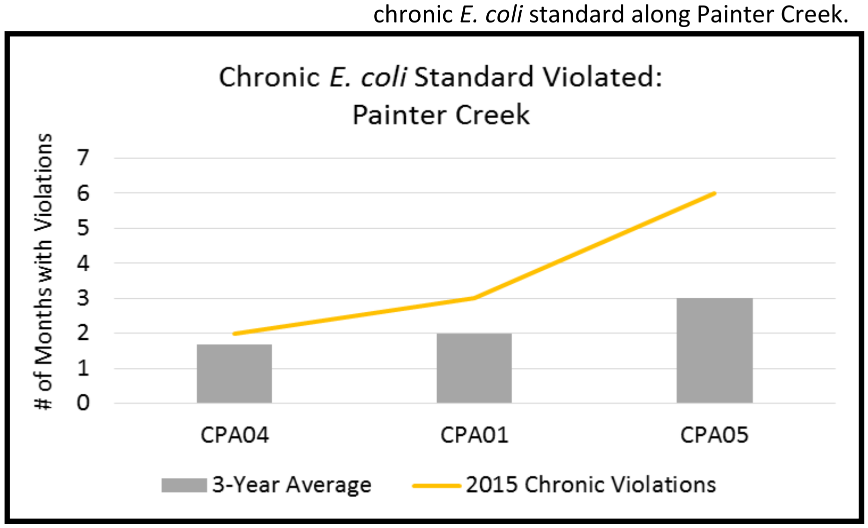


Table 52. Thies Lake 2015 Means and List of Known Impairments

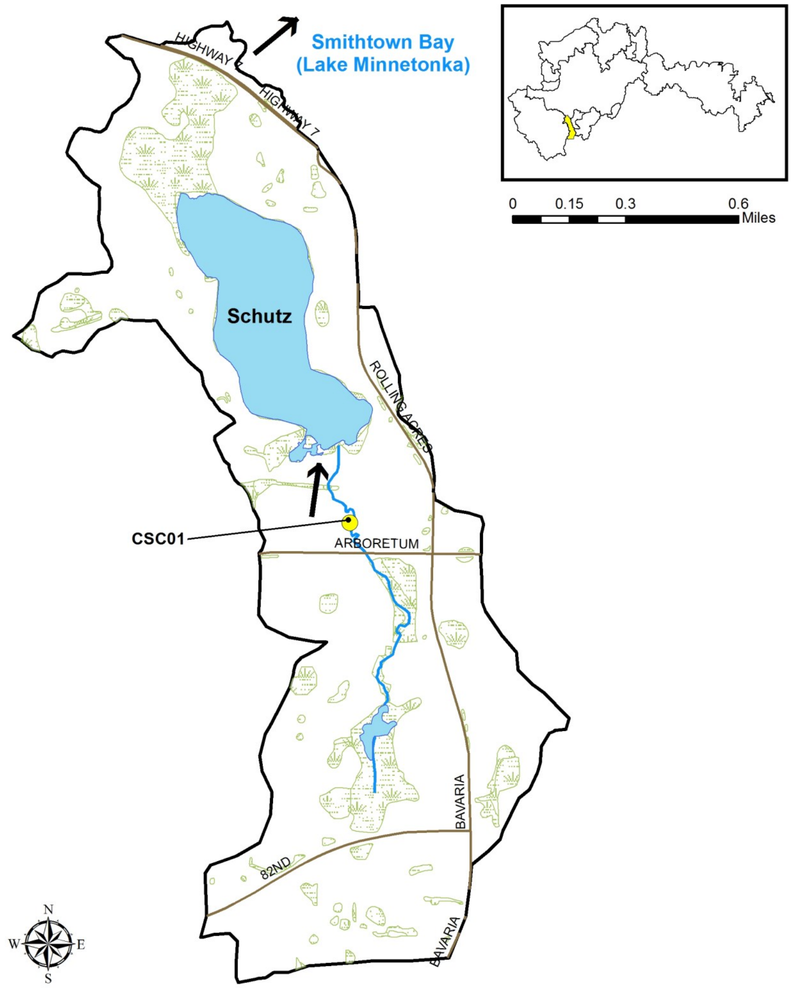
Water-body	Mean SECC	Mean CHLA	Mean TP (µg/L)	Impairment
	June-Sept 2015			
Thies	0.54	32.50	74.50	None

Red indicates not meeting the standard

In 2015, the only open-waterbody in Painter Creek Subwatershed that was monitored was Thies Lake. Thies Lake is monitored by MCWD volunteer. Thies Lake is deep, but has a fringe wetland. Its is very possible, like the other waterbodies in Painter Creek Subwatershed, that Thies Lake is actually a deep wetland. More information is needed for determination, such as percentage of the littoral area. MCWD plans to gather this data in 2018 for E-Grade Evaluation. Assuming lake conditions, Thies Lake did not meet any of the eutrophication standards in 2015. The water quality in has not met the standards for two years in a row. Prior to 2014, the lake was monitored from 2009-2010. 2010 was the first year, where MCWD noticed the lake was not meeting eutrophication standards. Very likely landscape activities or internal loading are impacting the water quality of the lake. Further investigation is needed.

AIS Prevention and Monitoring: At this time, there are no AIS prevention and monitoring efforts in the Painter Creek Subwatershed. AIS monitoring will begin in 2018 to part of the E-Grade Report. See Section 5 for more details on E-Grade.

3.11 Schutz Lake Subwatershed

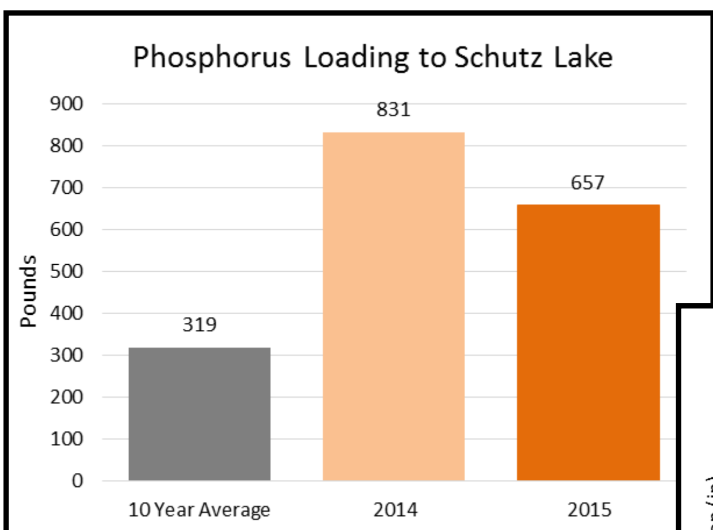


Schutz Lake Subwatershed is one of the smaller subwatersheds throughout MCWD. It has a mixed land use - open space in Carver Park Reserve in the north, residential use in the east and agricultural use in the south. Wetlands, forests and woodlands are patchy throughout the subwatershed, but mostly concentrated around Schutz Lake.

The subwatershed drains into Schutz Lake and then the lake drains into Lake Minnetonka: Smithtown Bay. The nutrient contribution to Lake Minnetonka from the Schutz Lake Subwatershed is not known for the outlet of Schutz Lake has never been monitored. MCWD staff has begun to resolve this issue in 2016.

Water Quality: The Schutz Lake creek inlet had above average phosphorus loads in 2015 (Figure 53), which is odd, since most other creeks throughout the watershed returned to almost average loading levels. From 2006-2013, the discharge in the Schutz Lake Creek inlet has been on average 0.64 cfs; since 2014, the discharge in the Schutz Lake Creek inlet increased above 1.3 cfs. Heavy precipitation and flow was a major driver of discharge and nutrient loading in 2014; but some other activity, such as

Figure 53. 2015 phosphorus loads in Schutz Lake.



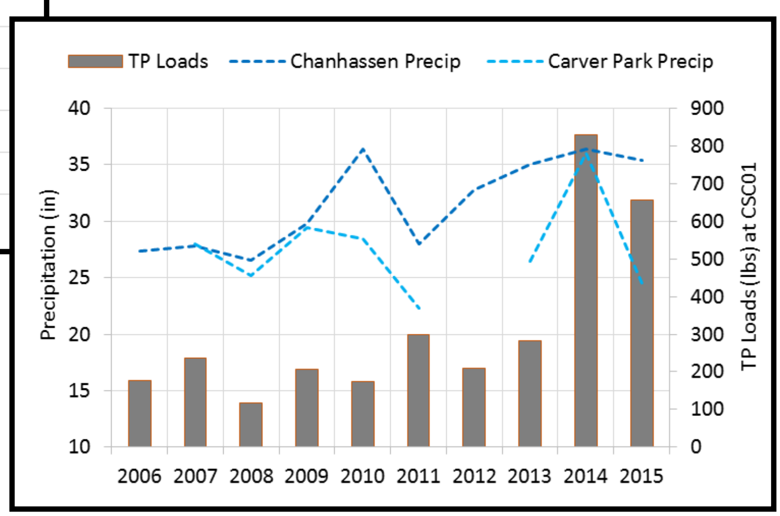


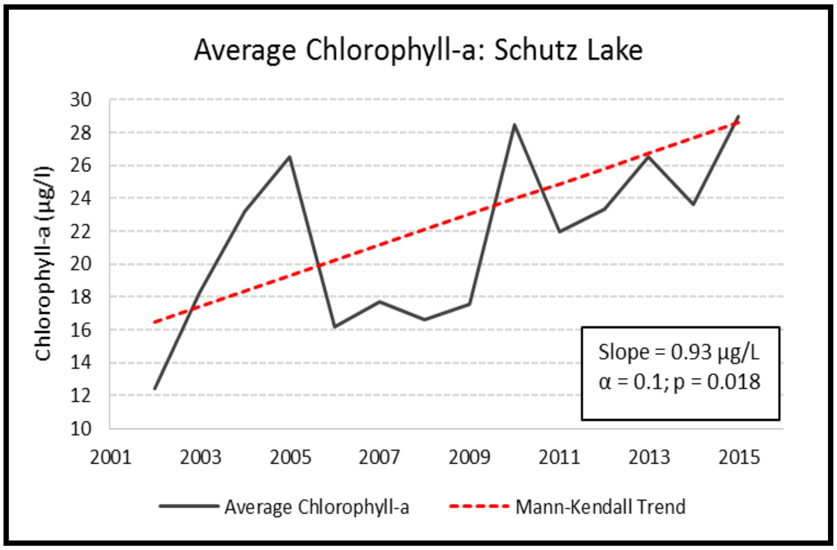
Figure 54. Comparison of annual precipitation and phosphorus loading at Schutz Lake Inlet (CSC01).

Table 22. Schutz Lake 2015 Means and List of Known Impairments

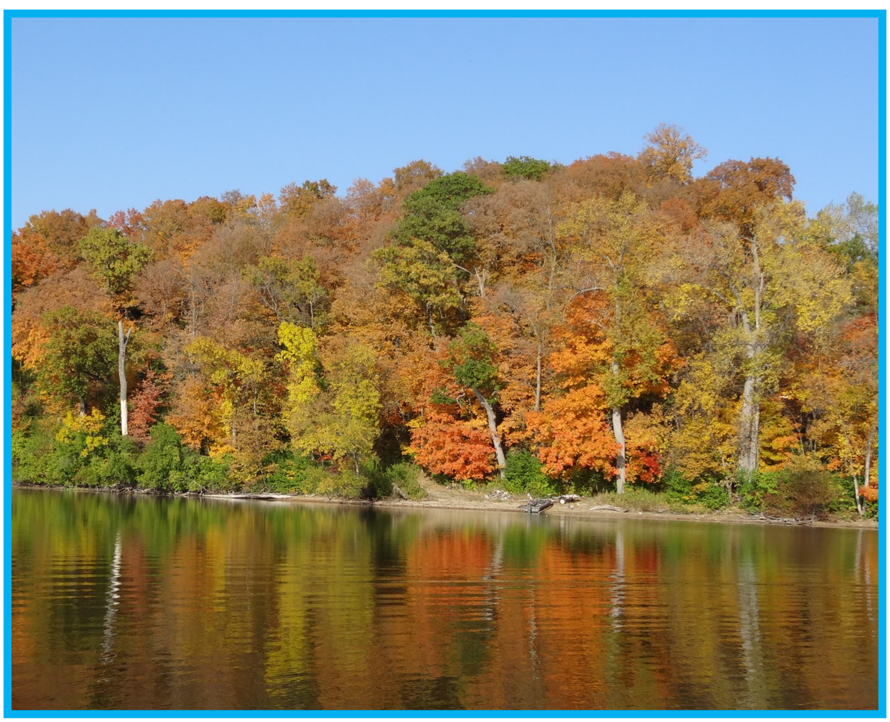
Lake	Mean SECC (m)	Mean CHLA (µg/L)	Mean TP (µg/L)	Impairment
	June-Sept 2015			
Schutz	0.90	29.00	46.75	None

Red indicates not meeting the standard

Figure 55. Average Chlorophyll-a Trend from 2001-2015 for Schutz Lake.



View on Schutz Lake (Photo courtesy of Mike Shouldice)



land use change timed with precipitation events, may explain the elevated discharge and nutrient loading in 2015.

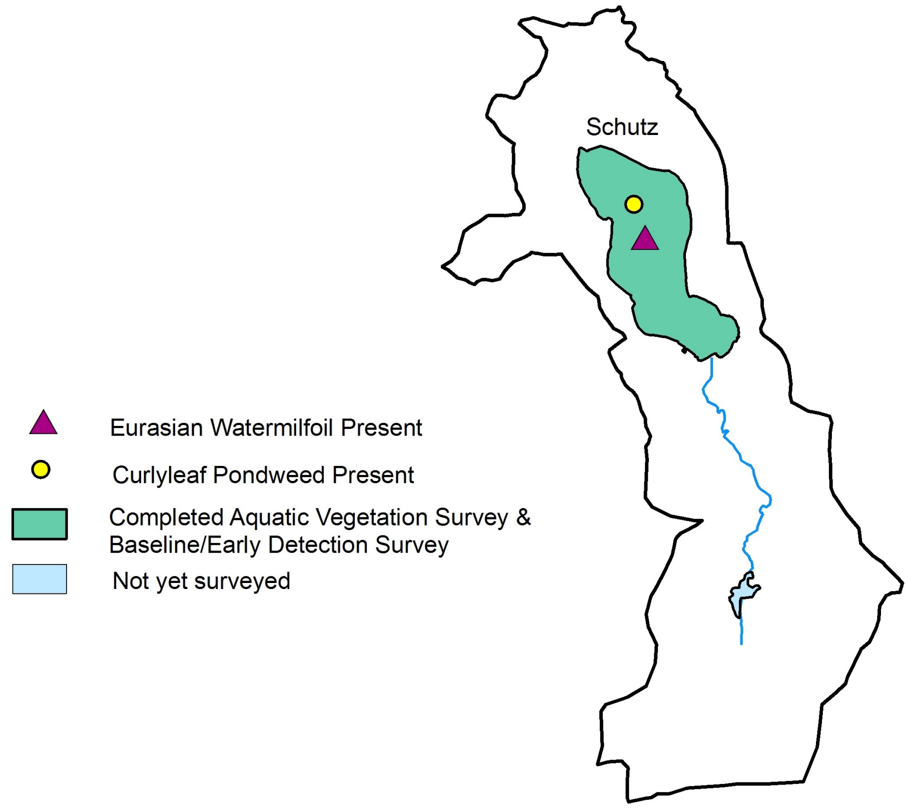
The 2013 macroinvertebrate assessment found the habitat diversity was high in Schutz Lake Creek, but the creek may be shifting from an intolerant pollutant to a pollutant tolerant macroinvertebrate community. Since only a year of data was collected on Schutz Lake Creek, the assessment recommended additional monitoring to confirm the shift.

The recent years of increased nutrient loading to Schutz Lake, in addition to internal loading in the lake itself, has finally impacted the water quality of the lake. The 2015 water quality in Schutz Lake did not meet all three eutrophication standards for the first time since 2002 (Table 22).

The water quality in Schutz Lake from 2002-2015 was assessed for long-term trends. Degrading water quality conditions are evident with all three water quality parameters, but the only statistically significant change was with chlorophyll-*a* (Figure 55). Chlorophyll-a concentrations have significantly increased over time. Algal blooms have been noticed as early as June. Schutz Lake is currently not listed as impaired, but that may change. MCWD will investigate to determine the source(s) impacting the water quality and biological communities of the waterbodies in Schutz Lake Subwatershed.

AIS Monitoring:

Schutz Lake has three volunteers that monitor zebra mussel early detection plates at the private boat launch and two other locations.



Aquatic plants are moderately abundant in Schutz Lake, with the most recent summer survey showing about 58% of the littoral area with vegetation. Six different plant species are known to be present, but the plant community is dominated by the native Coontail. Two invasives, Eurasian Watermilfoil and Curlyleaf Pondweed, are both present but in low abundance (Figure 56).

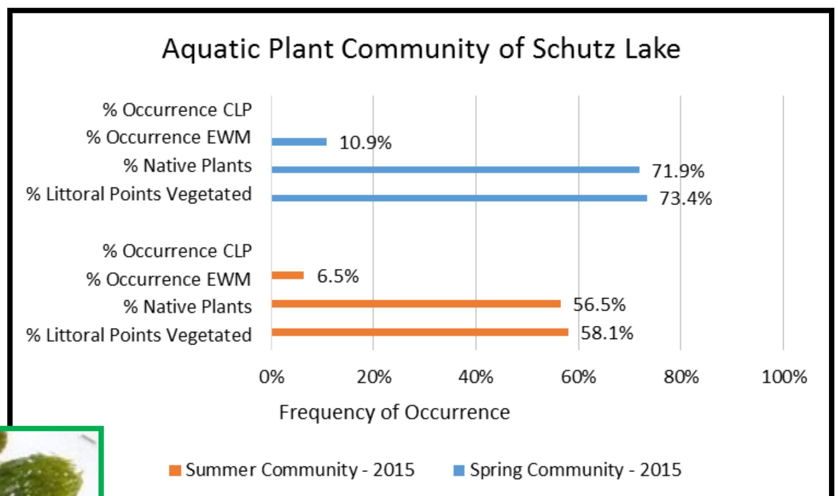
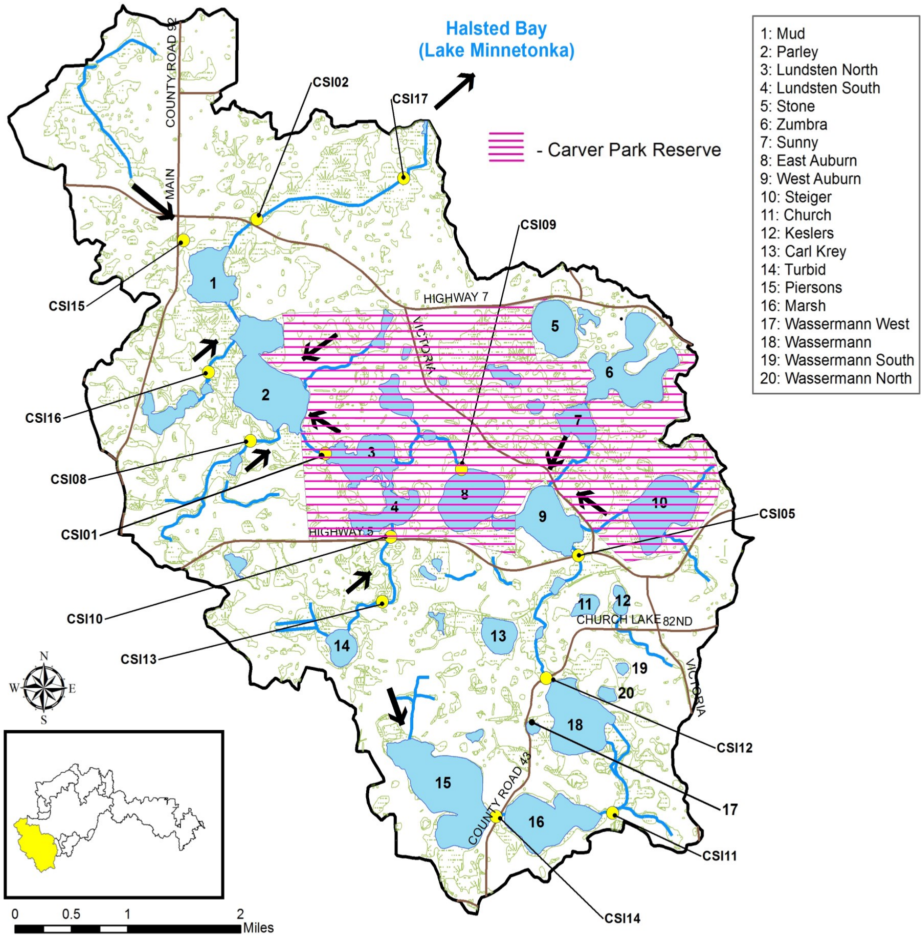


Figure 56. Aquatic plant community of Schutz Lake.

Image of Coontail.

3.12 Six Mile Marsh Subwatershed



Six Mile Marsh Subwatershed is the third largest subwatershed within Minnehaha Creek Watershed. The land use is primarily agricultural, but residential and commercial development is on the rise as cities and townships within the subwatershed grow.

Natural, open areas reside within the Carver Park Reserve, which is managed by Three Rivers Park District. The land cover within Carver Park Reserve is grassland, woodlands, forest and wetlands, that surrounds the following lakes: Steiger, Lundsten, Auburn and portions of Zumbra. These lakes are part of a larger series of lakes within the subwatershed nicknamed the 'western chain of lakes.'

Six Mile Creek, which is actually 11 miles long, flows through the 'western chain of lakes,' beginning with Piersons Lake and passes through Mud Lake wetland before discharging into Lake Minnetonka: Halsted Bay.

Water Quality: Six Mile Creek, like other creeks in the watershed, is partially ditched, and has intermittent flow. Precipitation is a driver of the amount of discharge and loading that occurs in Six Mile Creek. Phosphorus loading at North Lundsten Lake outlet (CSI01) is representative of many stations along Six Mile Creek (Figure 57). During wet years, phosphorus loading is extremely high, while during dry years, like 2009, the nutrient loading is minimal.

The land use, lakes and wetlands also have an influence on the water quality in Six Mile Creek. A 2013 Six Mile Creek Diagnostic Study identified land use stressors and several lakes and wetlands throughout the Six Mile Marsh

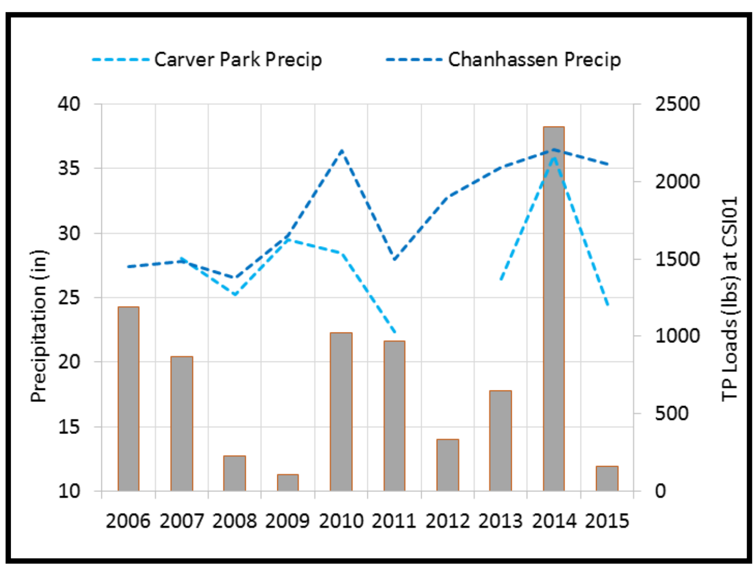


Figure 57. Comparison of annual precipitation and phosphorus loading at North Lundsten Lake outlet (CSI01).

Subwatershed that were sources of phosphorus. Additional questions arose from the Diagnostic Study, and the 2015 dataset will be analyzed through modeling to address those questions.

For this report, the water quality of the waterbodies throughout Six Mile Marsh Subwatershed have been divided into 6 watershed management units: (1) Piersons-Marsh-Wassermann, (2) Auburn Corridor, (3) Auburn-North Lundsten, (4) Carver Park Reserve, (5) Turbid-South Lundsten, and (6) Parley-Mud (Figure 61).

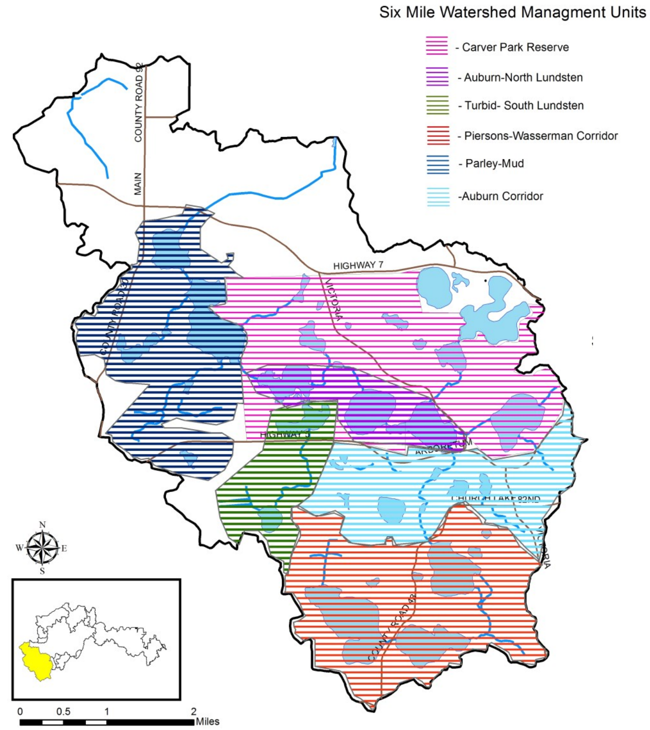


Figure 58. Map of the Management Units in Six Mile Marsh Subwatershed.

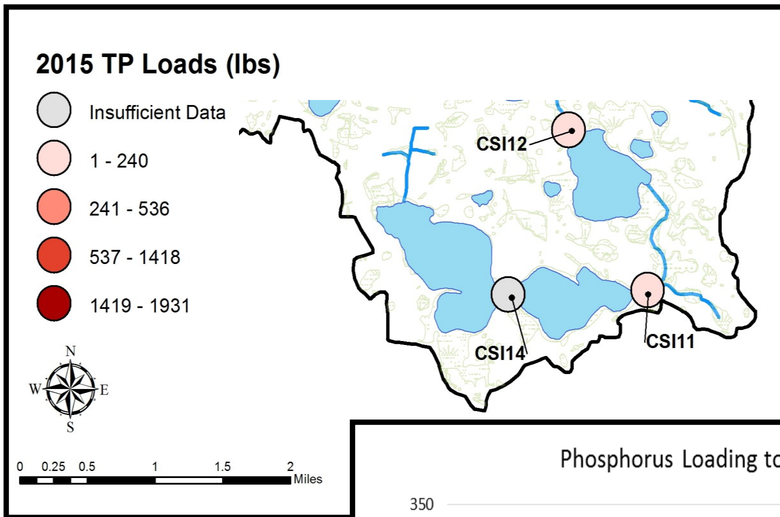
Piersons-Marsh-Wasserman Management Unit: The Piersons-Marsh-Wassermann Management Unit (MU) has water quality that progressively gets worse as the creek flows north from Piersons Lake. Marsh Lake, Piersons Lake and Wasserman South Pond have water quality that met the eutrophication standards in 2015. Wassermann Lake is on the northern end of the MU and did not meet any of the eutrophication standards in 2015 (Table 23). Although internal loading is occurring in Wassermann Lake, external loading is a larger contributor of phosphorus. This is the first year for the Wasserman North Pond to not meet two of the three eutrophication standards. The poorer water quality conditions in 2015 is most likely the result of the 2014 flood waters.

Table 23. 2015 Means and List of Known Impairments of Six Mile Marsh Subwatershed's Lakes within the Piersons-Marsh-Wassermann Management Unit.

Wetlands/Lakes by Watershed Management Units	Mean SECC (m)	Mean CHLA (µg/L)	Mean TP (µg/L)	Impairment
	June-Sept 2015			
Piersons-Marsh-Wassermann				
Marsh*		4.50	26.25	None
North Pond (adjacent of Wassermann)	2.08	20.00	65.25	None
Piersons	2.08	5.75	21.00	None
South Pond (adjacent of Wassermann)	2.58	2.75	20.00	None
Wassermann	0.76	47.81	69.13	Mercury, Nutrients
Wassermann (West Bay)	1.78	12.00	349.00	None

* Shallow lake; red indicates not meeting standard

Wassermann Lake - West Bay has extremely elevated surface phosphorus (Table 20). This bay of Wassermann Lake is located east of CO RD 43 just south of Tellers Rd. Agricultural land use is prominent in this area and most likely is the source of nutrients. MCWD plans to further investigate the issue in 2016.



The water quality in Piersons and Wassermann lakes from 2001-2015 were assessed for long-term trends. Both lakes had minor improvements in water clarity, phosphorus and chlorophyll-a concentrations, but the change in both lakes was neither statistically or ecologically significant (Appendix A).

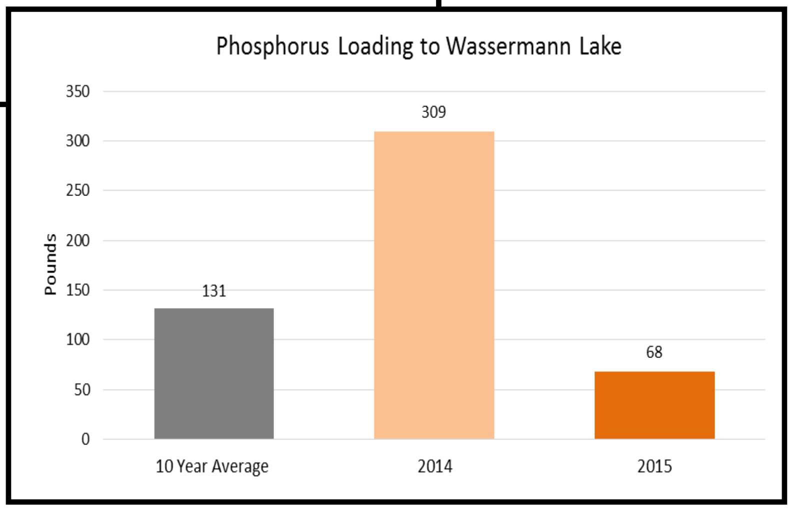


Figure 59. 2015 phosphorus loading in the Piersons-Marsh-Wassermann MU; Comparison of phosphorus loading to Wassermann Lake (CSI11).

The water quality in Six Mile Creek in the Piersons-Marsh-Wassermann MU has low phosphorus loading compared to the loading in other MUs in the Six Mile Marsh Subwatershed. The loading into Wassermann Lake from the Marsh Lake outlet (CSI11) was below average in 2015, but twice the average in 2014 (Figure 59). The discharge and nutrient loading in the creek is often dependent on precipitation.

View of Wassermann Lake outlet (CSI12).

The dissolved oxygen (DO) concentration in the creek in this MU is often below 5 mg/L. In 2015, the outlets of both Piersons Lake (CSI14) and Wassermann Lake (CSI12) had high percentage of samples less than 5 mg/L. Typically Marsh (CSI11) and Wassermann lakes outlets are the stations with low DO (Figure 60). The low DO in this section of the Six Mile Creek provides poor conditions to support aquatic life. Although Six Mile Creek had the best biological community of all the upper watershed streams, the macroinvertebrate community sampled in this MU in the 2013 assessment indicates that the polluted and low DO conditions are persistent issues.

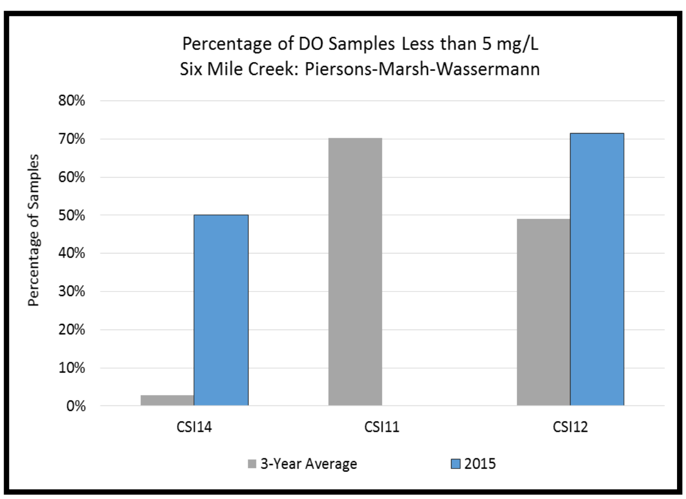
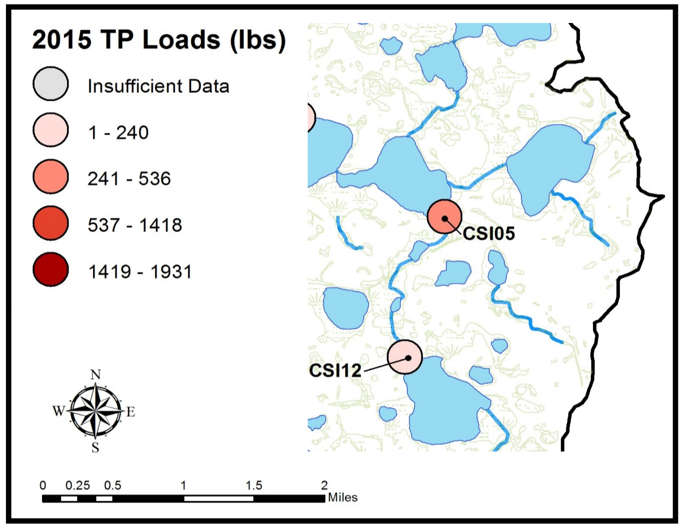


Figure 60. Percentage of DO samples that were less than 5 mg/L that occurred along Piersons-Marsh-Wassermann MU.

Auburn Corridor Management Unit: Six Mile Creek in the Auburn Corridor MU receives more nutrients as it drains into Auburn Lake (Figure 64). In 2015, Auburn Lake inlet (CSI05) had above average phosphorus loading, but was still less than loading observed in 2014 (Figure 65).

Both Carl Krey and Church lakes drain into Six Mile Creek between Wassermann Lake and Auburn Lake (East Bay). Kelser's Pond only overflows into Six Mile Creek during precipitation events that significantly exceed a 100 year flood.

The water quality of Carl Krey is meeting the eutrophication standards and is not major contributing source (Table 24).



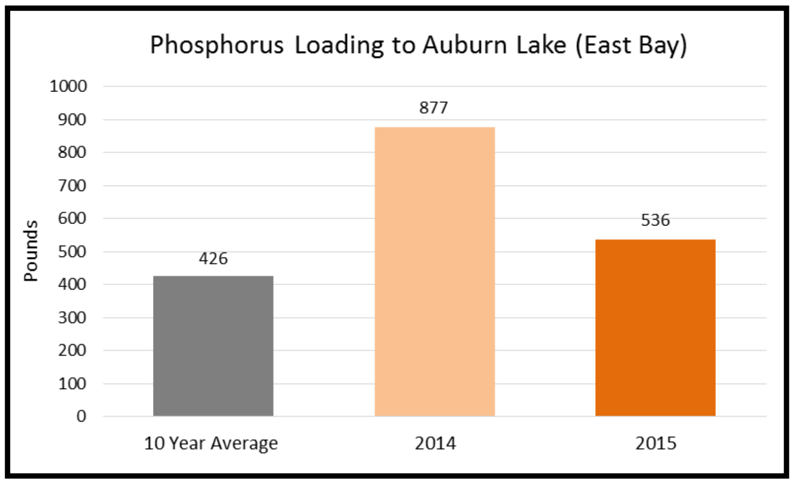


Figure 61. 2015 phosphorus loading in the Auburn Corridor MU; Figure 62. Comparison of phosphorus loading to Auburn Lake (CSI05).

In 2015, the water quality in Church Lake and Kelser's Pond did not meet one or more of the eutrophication standards (Table 24). The external nutrient loading that occurred from the 2014 flood waters is most likely the reason for degraded water quality in Kelser's Pond. For Church Lake, external loading from the surrounding landscape is a larger contributor of phosphorus to the lake than internal loading itself.

According to the Diagnostic study, a greater contributor of phosphorus to Auburn Lake (East Bay), than Church Lake, is a wetland complex between Carl Krey Lake and section of Six Mile Creek in this MU. This wetland complex and Church Lake are the areas of focus for MCWD in the Auburn Corridor to improve water resources.

Table 24. 2015 Means and List of Known Impairments of Six Mile Marsh Sub-watershed's Lakes within the Auburn Corridor MU.

Wetlands/Lakes by Watershed Management Units	Mean SECC (m)	Mean CHLA (µg/L)	Mean TP (µg/L)	Impairment
	June-Sept 2015			
Auburn Corridor				
Carl Krey*	1.78	8.50	32.75	None
Church	0.54	77.75	129.25	None
Kelser's	1.86	18.00	29.38	None

* Shallow lake; red indicates not meeting standard

Another indicator of degraded water quality in the Auburn Corridor MU is the DO levels in the Six Mile Creek. Wassermann Lake outlet (CSI12) has on average 50% of the samples violating the DO standard, where just downstream at the Auburn Lake (East Bay) inlet (CSI05) there is 85% violations. In 2015, both stations had above average violations. The 2013 macroinvertebrate assessment indicates the poor biological conditions in this MU have been persistent.

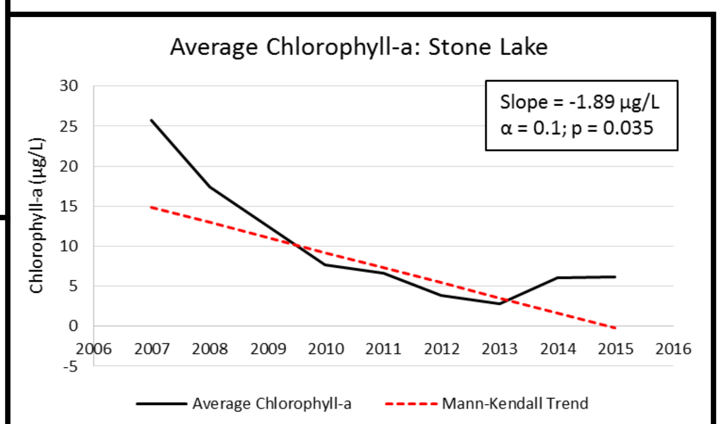
__Carver Park Reserve Management Unit:__ The lakes within the Carver Park Reserve MU have the best water quality of all the management units in the Six Mile Marsh Subwatershed. In 2015, all the lakes in this MU met the eutrophication standard (Table 25). Although Stone Lake is listed as impaired for nutrients, the lake has not exceeded the eutrophication standards since 2007. MCWD does not monitor any of the creeks draining into Auburn Lake from this MU. MCWD plans to collect grab samples to determine if there are phosphorus loading issues.

Table 25. 2015 Means and List of Known Impairments of Six Mile Marsh Subwatershed's Lakes within the Carver Park Reserve MU.

Wetlands/Lakes by Watershed Management Units	Mean SECC (m)	Mean CHLA (µg/L)	Mean TP (µg/L)	Impairment
	June-Sept 2015			
Carver Park Reserve				
Steiger (TRPD)	2.69	12.11	33.57	Mercury
Stone (TRPD)	2.67	6.13	33.99	Nutrients
Sunny (Zumbra-Sunny)	1.96	14.50	36.00	Mercury
Zumbra (Zumbra-Sunny) (TRPD)	3.78	5.34	19.66	Mercury

The water quality of Steiger Lake, Stone Lake and Zumbra Bay of Zumbra-Sunny Lake was evaluated for long-term trends. Statistically significant improvements were found in all three lakes. Stone had statistically significant decline in chlorophyll-a concentrations (Figure 63). Steiger Lake had statistically significant increase in Secchi disk depth (i.e., water clarity) and statistically significant decline in chlorophyll-a concentrations (Figure 64). Zumbra Bay of Zumbra-Sunny Lake had statistically significant improvements in water clarity, chlorophyll-a and phosphorus concentrations (Figure 65). In order to maintain these water quality trends, the Carver Park Reserve MU needs to be an area that is protected from degradation.

Figure 63. Statistically significant average chlorophyll-a trend from 2007-2015 for Stone Lake.



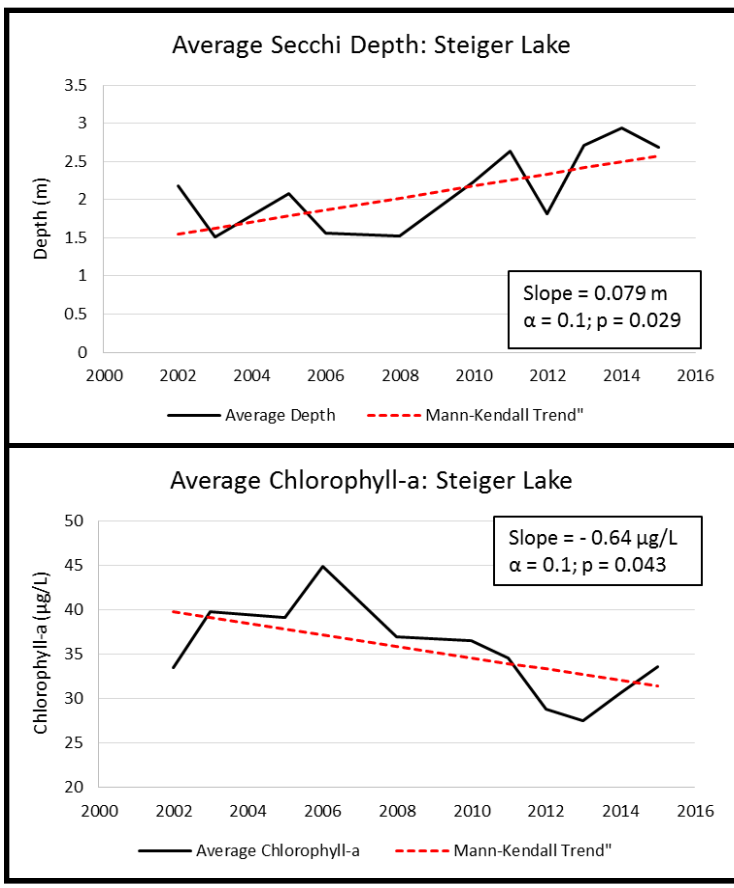


Figure 64. Statistically significant average Secchi depth trend and average chlorophyll-a trend from 2002-2015 for Steiger Lake.

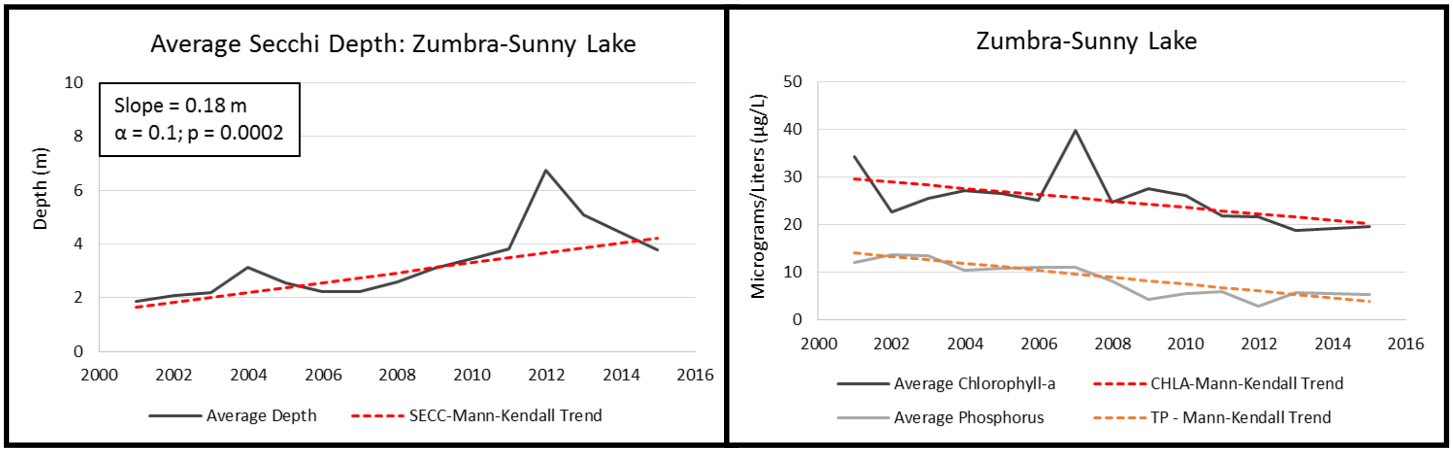


Figure 65. Statistically significant average Secchi depth trend, average chlorophyll-a and phosphorus trends from 2002-2015 for Zumbra Bay of Zumbra-Sunny Lake.

Auburn-North Lundsten Management Unit: Auburn Lake flows east to west draining into Lundsten Lake – North Bay via Six Mile Creek. The elevated phosphorus loading into Auburn Lake (East Bay) (CSI05) from up-stream sources has impacted the Auburn Lake's water quality. Although only chlorophyll-a concentrations in the eastern bay exceeded the eutrophication standard in 2015, for the past three years both chlorophyll-a and total phosphorus concentrations exceeded the standards (Table 26, See Appx A). The western bay of Auburn Lake met the eutrophication standards in 2015.

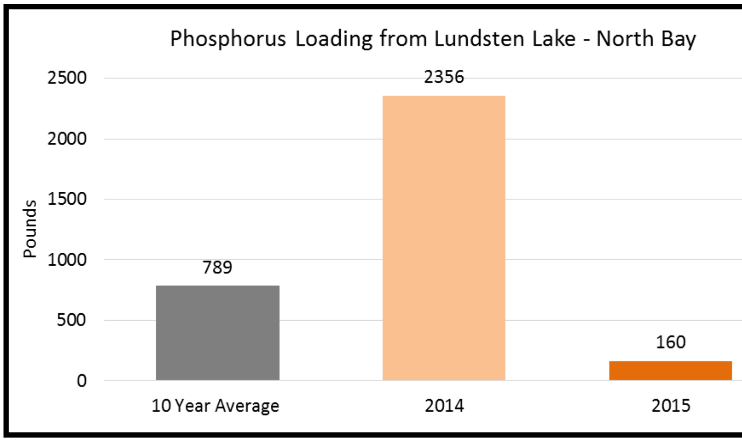
In Lundsten Lake (North Bay), the chlorophyll-a and total phosphorus concentrations did not meet the shallow lake eutrophication standards for the past two years (Table 26, See Appx A). Historically, Lundsten Lake (North Bay) has often met the shallow lake eutrophication standards. The phosphorus loading out of Lundsten Lake—North Bay (CSI01) in 2014 was twice the average pounds of phosphorus observed at this station (Figure 69). The excessive nutrient loading deposited into the lake during the 2014 flood is most likely why Lundsten Lake - North Bay is recently experiencing degraded conditions.

In 2015, the phosphorus loading out of Lundsten Lake - North Bay (CSI01) was extremely below the average pounds observed at this station (Figure 66). Precipitation is a driver of nutrient loading at the Lundsten Lake outlet. The last time the annual loading was about 100 lbs of phosphorus at this station was in 2009, when there was a drought.

Table 26. 2015 Means and List of Known Impairments of Six Mile Marsh Subwatershed's Lakes within the Auburn-North Lundsten MU.

Wetlands/Lakes by Watershed Management Units	Mean SECC (m)	Mean CHLA (µg/L)	Mean TP (µg/L)	Impairment
	June-Sept 2015			
Auburn-North Lundsten				
Auburn (East Bay)	1.59	19.13	34.75	Nutrients
Auburn (West Bay) (TRPD)	2.53	11.61	26.52	None
Lundsten (North Bay)*		41.63	85.25	None

* Shallow lake; red indicates not meeting standard



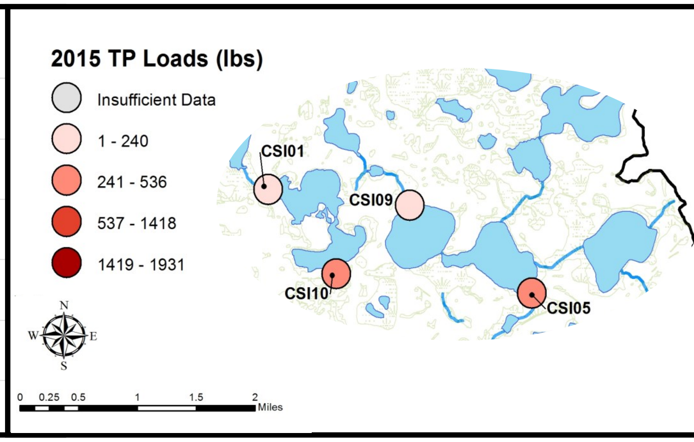


Figure 66. 2015 phosphorus loading in the Auburn-North Lundsten MU (CSI09 - CSI01) and comparison of phosphorus loading from Lundsten Lake (CSI01).

View of Lundsten Lake - North Bay from a trail in the Carver Park Reserve.

__Turbid - South Lundsten Management Unit:__

Turbid Lake drains into a tributary of Six Mile Creek that flows into Lundsten Lake - South Bay. Turbid Lake is a turbid, deep lake, where Lundsten Lake - South is a turbid, shallow lake.

Turbid Lake and Lundsten Lake - South Bay did not meet the eutrophication standards in 2015, as well as for the three years prior (Table 27). The Diagnostic Study found that internal loading rather than external loading is the major contributor of phosphorus to Turbid and Lundsten - South lakes. Carp, which reside in both lakes, have been documented at disturbing the sediment layer at the bottom of lakes contributing to the internal loading process.

The Diagnostic Study also identified, based on the stream data MCWD collects, that the wetlands between Turbid and Lundsten South are a source of phosphorus that is negatively impacting Lundsten South. The phosphorus loading in the tributary increases as it travels from north through the wetland to the Lundsten South inlet (CSI10) (Figure 71-72). MCWD has only monitored the Lundsten South inlet (CSI10) for two years, but the phosphorus loading is twice the loads observed at the Turbid Lake outlet (CSI13) upstream (Figure 72). DO samples are below 5mg/L more often at the Lundsten South inlet station than the Turbid Lake outlet, another indicator of degraded water quality (Figure 73).

Wetlands/Lakes by Watershed Management Units	Mean SECC (m)	Mean CHLA (µg/L)	Mean TP (µg/L)	Impairment
	June-Sept 2015			
Turbid-South Lundsten				
Lundsten (South Bay)*	0.88	115.38	291.75	None
Turbid	0.93	37.75	80.50	Nutrients

* Shallow lake; red indicates not meeting standard

Table 27. 2015 Means and List of Known Impairments of Lakes within the Turbid–South Lundsten MU.

Figure 67. 2015 phosphorus loading in the Turbid-South Lundsten MU

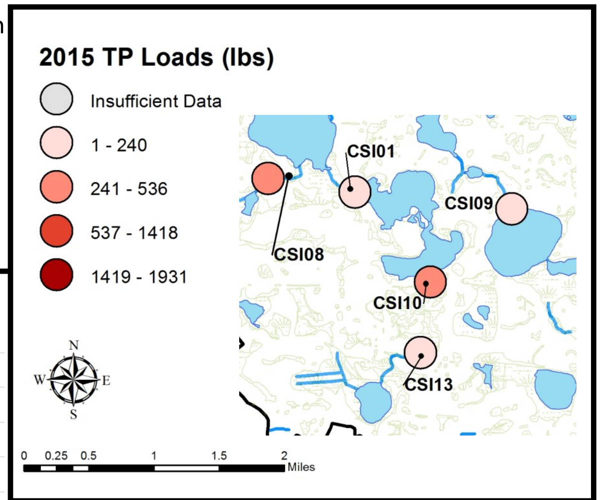


Figure 68. Comparison of phosphorus loading to Lundsten Lake—South Bay.

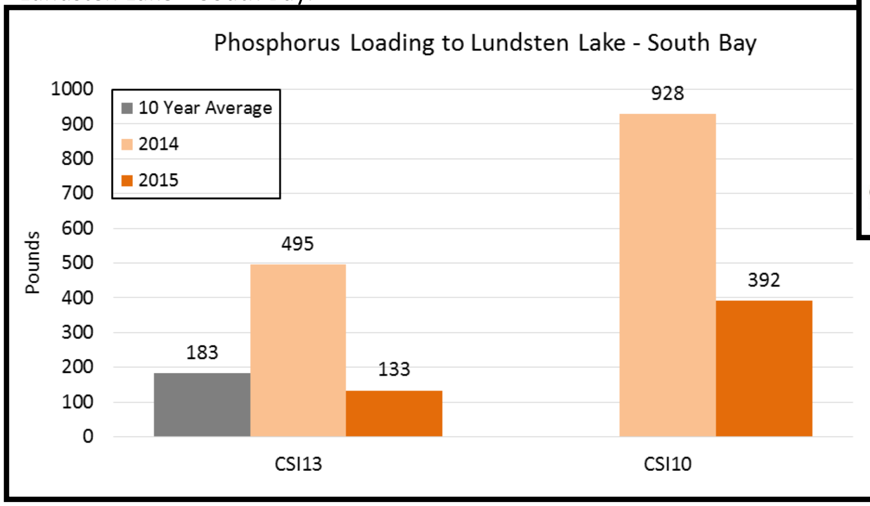
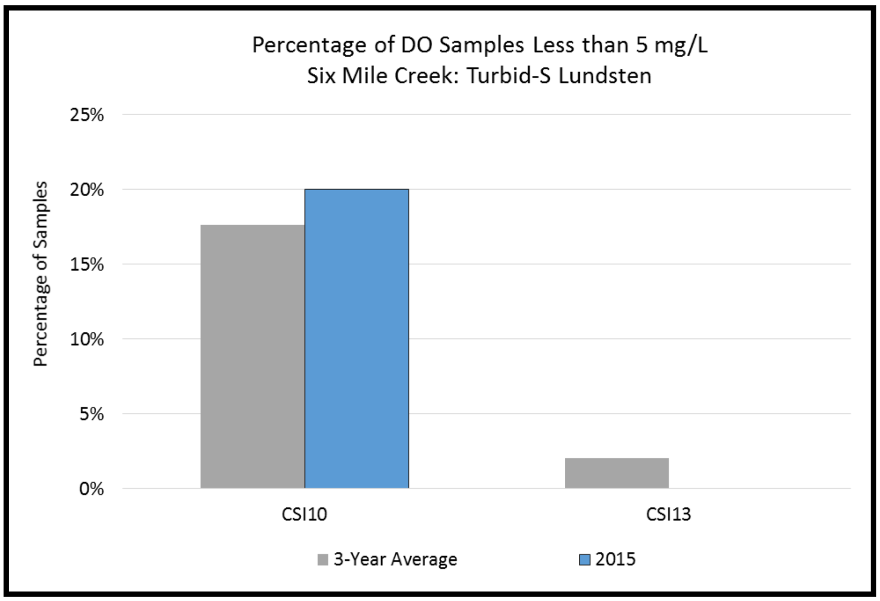


Figure 69. Percentage of DO samples less than 5 mg/L that occurred along Turbid-South Lundsten MU.



Parley-Mud Management Unit: Six Mile Creek flows from Lundsten Lake North into wetland, then into Parley Lake, then into a wetland, then into Mud Lake, which could be argued is a wetland, and then through a series of wetlands before discharging into Lake Minnetonka: Halsted Bay. Lundsten Lake North outlet creates a biological barrier (e.g., fish) separating this MU from the other MUs in the Six Mile Marsh Subwatershed. Fish move between Parley, Mud and Halsted Bay. The Diagnostic Study found that both Parley and Mud have a dense carp population which has most likely led to depleted submerged aquatic vegetation communities. Similar to Lundsten Lake North, both Parley and Mud lakes are shallow waterbodies with large littoral areas, yet Parley and Mud lakes have degraded water quality, similar to Lundsten Lake South.

Parley and Mud lakes are impaired with excessive nutrients. In 2015, the water quality in Parley Lake again did not meet the eutrophication standard for shallow lakes. By a recent MPCA statement on the proposed 2014 Impaired Waters List, Mud Lake has been reclassified as a wetland or a shallow lake with strong wetland characteristics. There are currently no wetland eutrophication standards if Mud Lake were to be managed as a wetland. If Mud Lake were to continue to be managed as a shallow lake, then the lake did exceed the eutrophication standards for shallow lakes in 2015 (Table 28). Carp and internal loading are issues, but external loading is the main contributor of phosphorus to both Parley and Mud lakes. The water quality in Parley Lake from 2005-2015 was assessed for long-term trends. The water quality is improving, but the trends are not ecologically or statistically significant. (See Appendix A).

Wetlands/Lakes by Watershed Management Units	Mean SECC (m)	Mean CHLA (µg/L)	Mean TP (µg/L)	Impairment
	June-Sept 2015			
Parley-Mud				
Mud**	0.40	86.50	206.88	Nutrients
Parley*	0.64	82.00	116.94	Nutrients

* Shallow lake; ** wetland or strong wetland characteristics ; red indicates not meeting standard; grey indicates no established standard

Table 28. 2015 Means and List of Known Impairments within the Lakes of the Parley-Mud MU.

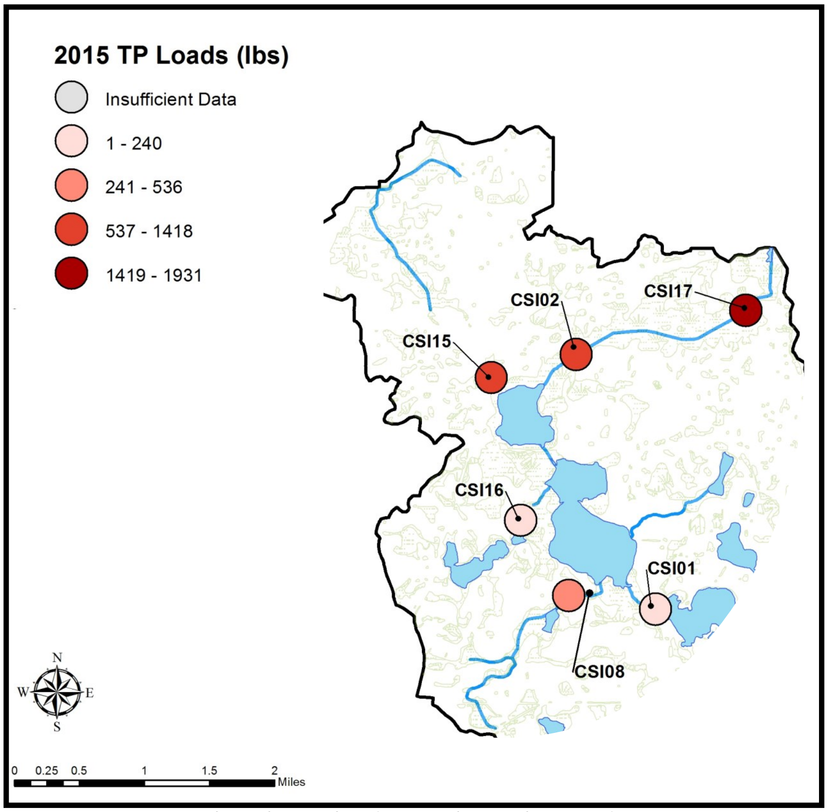


Figure 70. 2015 phosphorus loading in the Parley-Mud MU

The external loading to Parley and Mud lakes is monitored by MCWD. The 2015 phosphorus loads in the inlets of both Parley and Mud is displayed in Figure 70. Three of the four major inlets into Parley Lake are monitored. The fouth inlet is difficult to access. Comparing the loads between the inlets, the Lundsten Lake North outlet (CSI01) on average contributes more phosphorus to Parley Lake that the other two inlets (Figure 70). Precipitation is a major driver of loading at Lundsten Lake North outlet. In 2015, the Big SOB Lake outlet (CSI08) contributed more phosphorus to Parley than Lundsten Lake North outlet (CSI01) (Figure 71).

In 2015, Mud Lake inlet (CSI15) received higher phosphorus loads than the combined total of all three inlets into Parley Lake (Figure 70). The northwest region of Six Mile Marsh Subwatershed drains into Mud Lake. In 2016, MCWD will be conducting investigational monitoring to determine nutrient sources in this region.

The Mud Lake outlet (CSI02) and last section of Six Mile Creek through the wetlands (CSI17) prior to discharging into Halsted Bay: Lake Minnetonka had the highest loading throughout the entire subwatershed in 2015. On average these two stations also have the highest loading throughout the entire subwatershed (Figure 72). A portion of the eutrophication issues in Halsted Bay: Lake Minnetonka definitely contributed to the phosphorus loading from the last section of Six Mile Creek. In 2016, modeling of the data for these two stream stations will be conducted to determine if the wetlands between the two stations are a source or a sink for phosphorus.

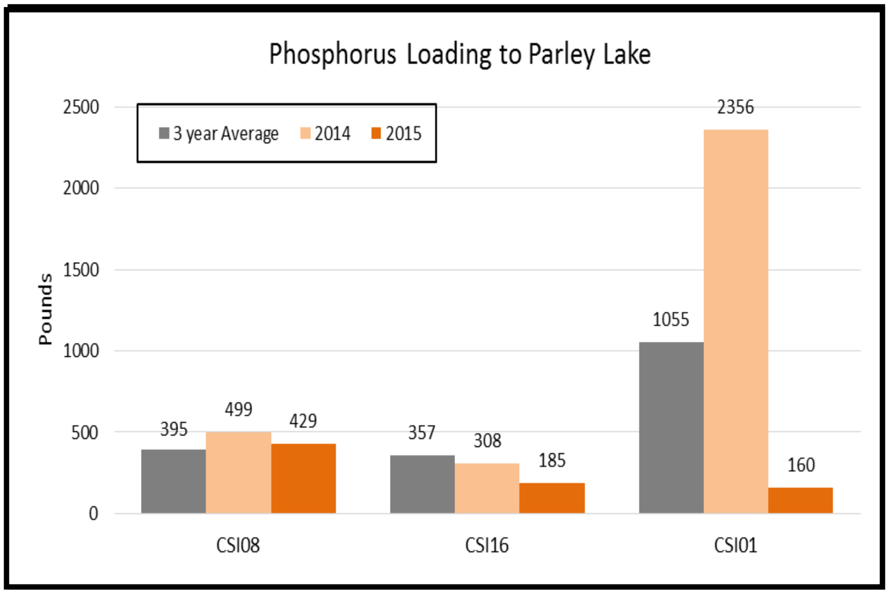
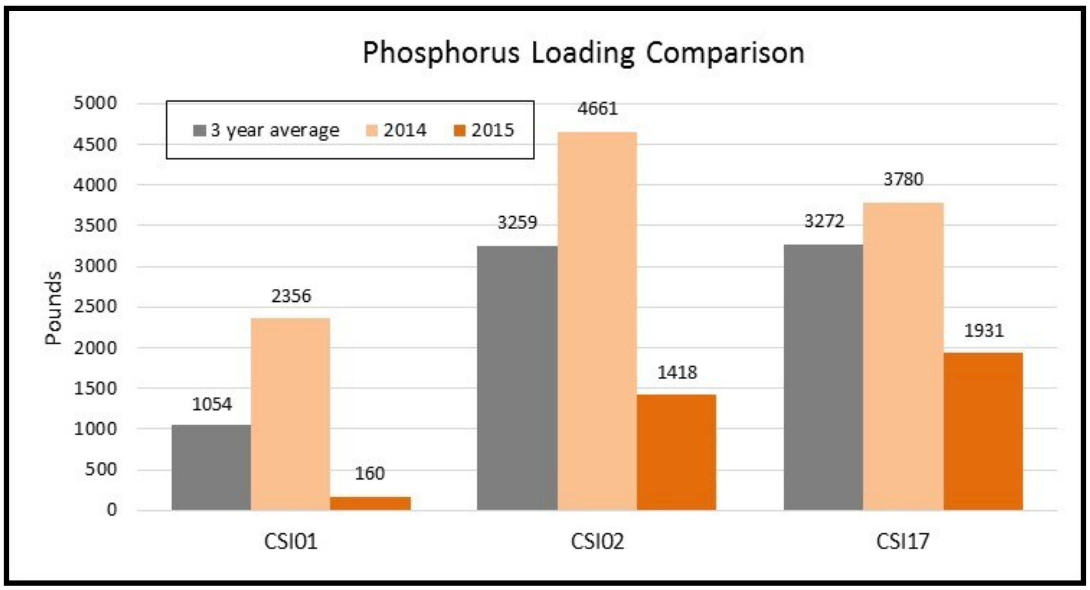


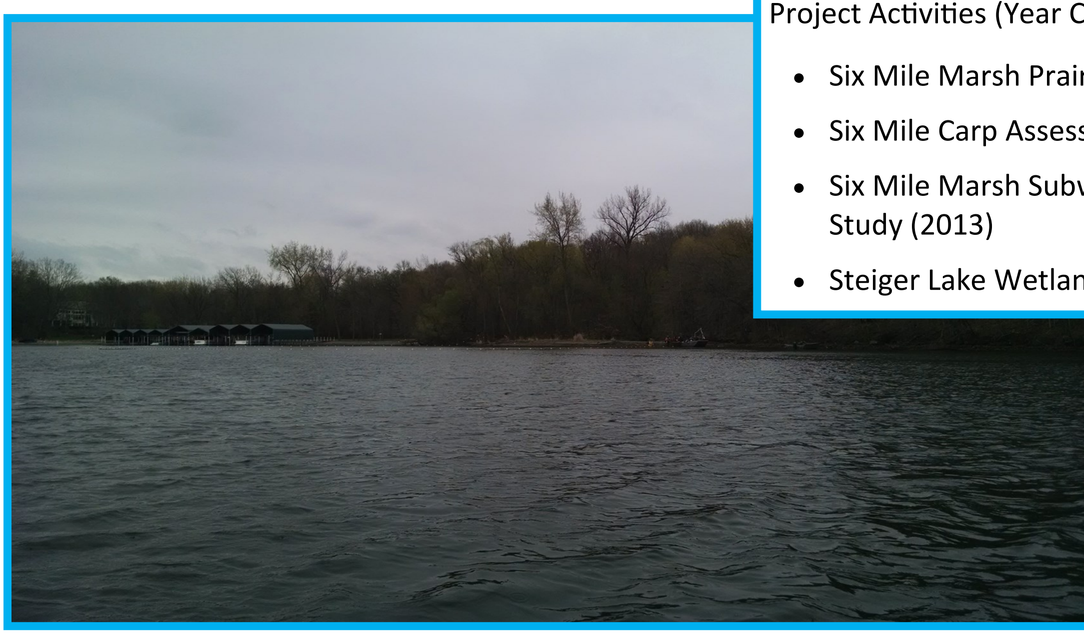
Figure 71. Comparison of phosphorus loading of the inlets into Parley Lake.

Below - Figure 72. Comparison of phosphorus loading at high pollutant loading stations in Six Mile Marsh Subwatershed.



Project Activities (Year Completed):

- Six Mile Marsh Prairie Restoration (Active)
- Six Mile Carp Assessment (Active)
- Six Mile Marsh Subwatershed Diagnostic Study (2013)
- Steiger Lake Wetland Restoration (2013)

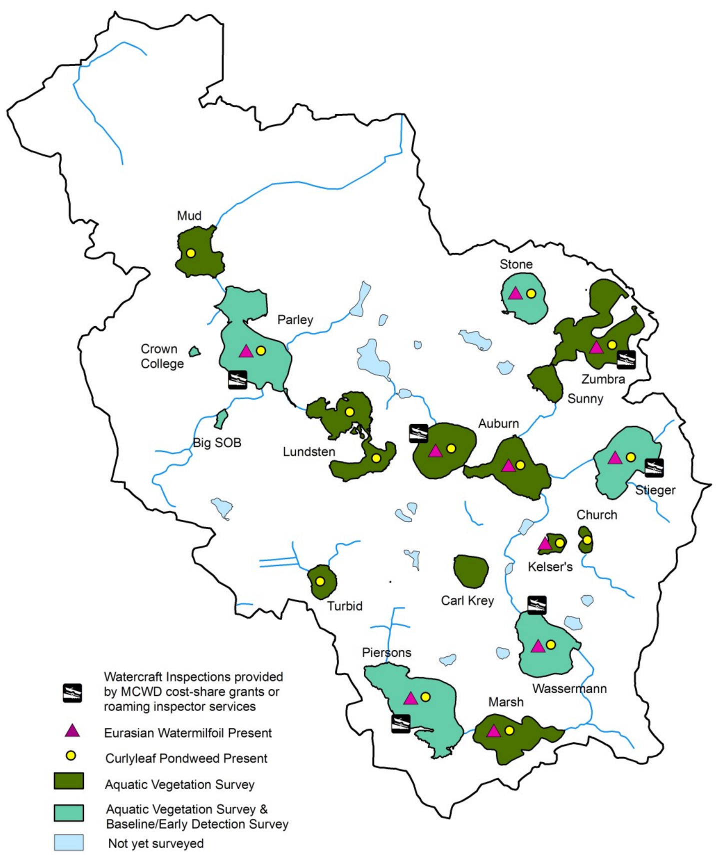


View of Halsted Bay: Lake Minnetonka

AIS Prevention - Watercraft Inspections: Public accesses within the Six Mile Marsh Subwatershed are part of the MCWD's Roaming Watercraft Inspector Program, which provides watercraft inspections at District lakes that would not otherwise receive coverage from another agency. MCWD contracts with Three Rivers Park District and Carver County to provide the service.

Inspection Hours	# Inspections (Inbound and Outbound)	Avg. % Compliance with MN drain plug law	Avg. % Watercraft entering with possible AIS	# Inbound Watercraft stopped with zebra mussels attached
2,452	2,856	98.26%	1.54%	0

AIS Monitoring:



Eurasian watermilfoil and Curlyleaf pondweed are well established in most lakes within the subwatershed, but their impact and abundance vary by waterbody. Common carp appear to be having an impact on the aquatic plant community in many lakes, especially Parley and Wassermann where carp abundance is very high.

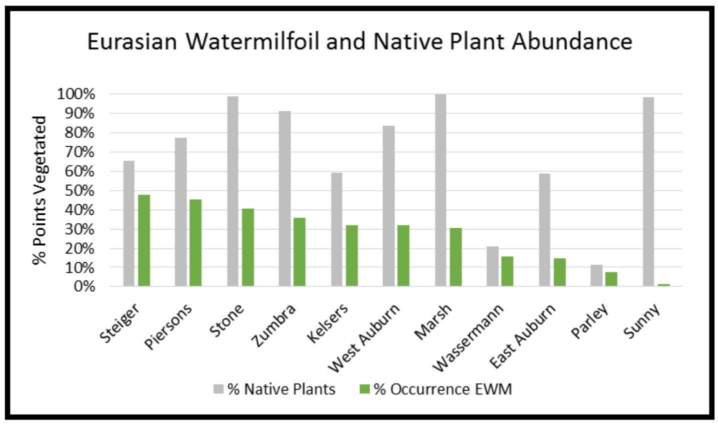
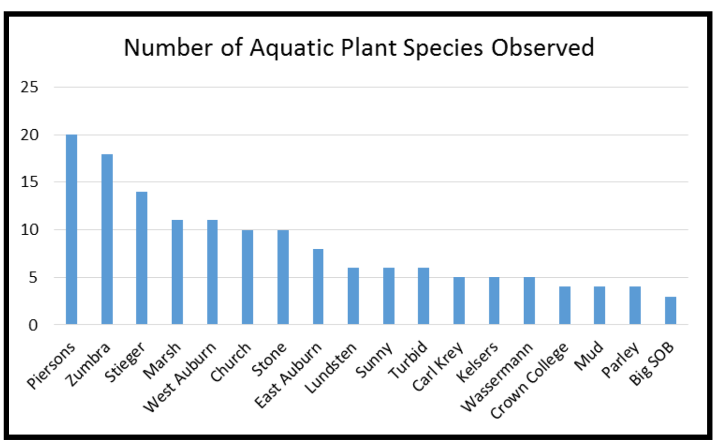
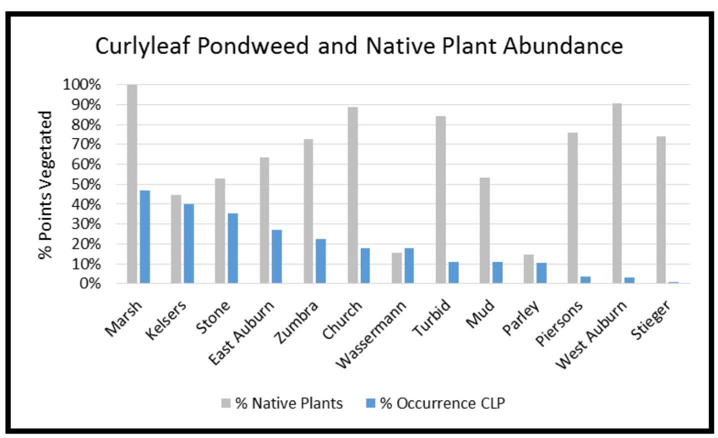


Figure 73. Eurasian watermilfoil, curlyleaf pondweed and native plant abundance in the lakes of Six Mile Marsh Subwatershed; Figure 74. Number of aquatic plant species observed in the lakes of Six Mile Marsh Subwatershed.

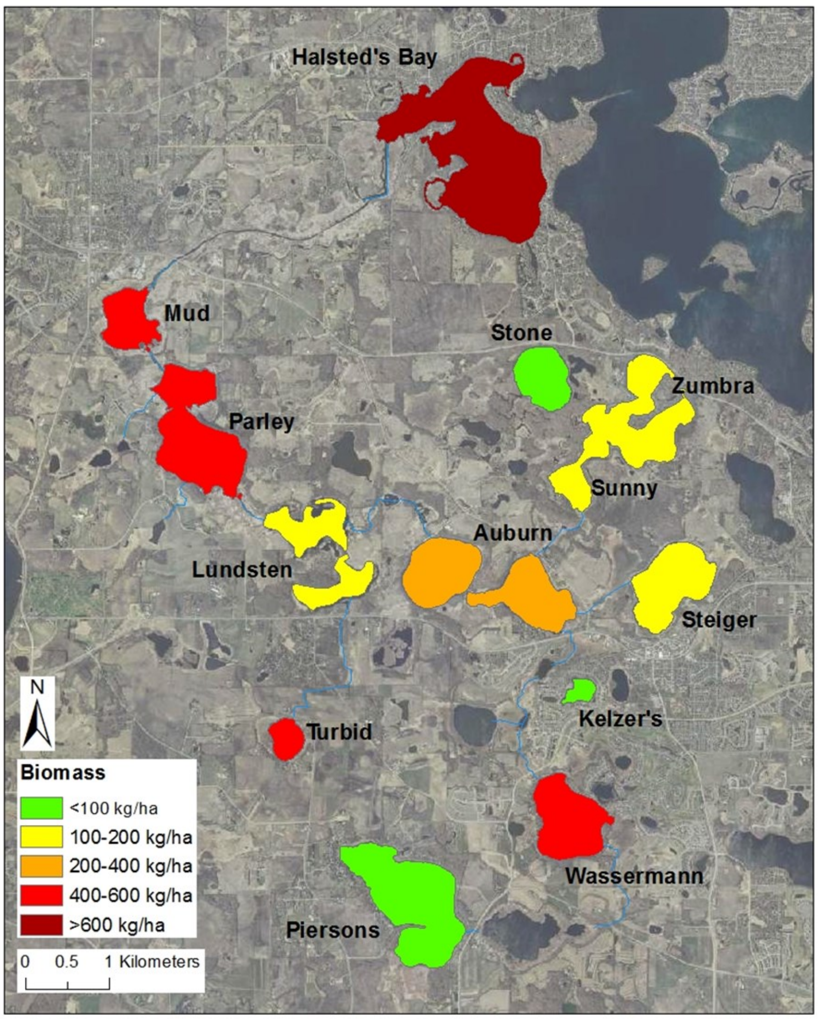




4. RESEARCH PROJECTS SUMMARY

Six Mile Creek Carp Assessment: Many lakes in the Six Mile Creek subwatershed have been ravaged by the effects of common carp, which disrupt ecosystems, destroy aquatic plant communities and stir up the lake bottom. Because carp reproduce so quickly, simply trying to remove them is not an effective option. In 2014, the District began a three-year study with the University of Minnesota to better understand these invasive fish in this system.

Now in its third year, the study has found a significant carp infestation—12 of the 15 lakes surveyed had populations above the threshold at which carp become ecologically damaging. Some lakes have populations nearly ten times this threshold. We have also discovered how carp move through the system and where they reproduce, which will determine the most effective ways to manage carp in the future. Annual reports can be found on the Districts website.



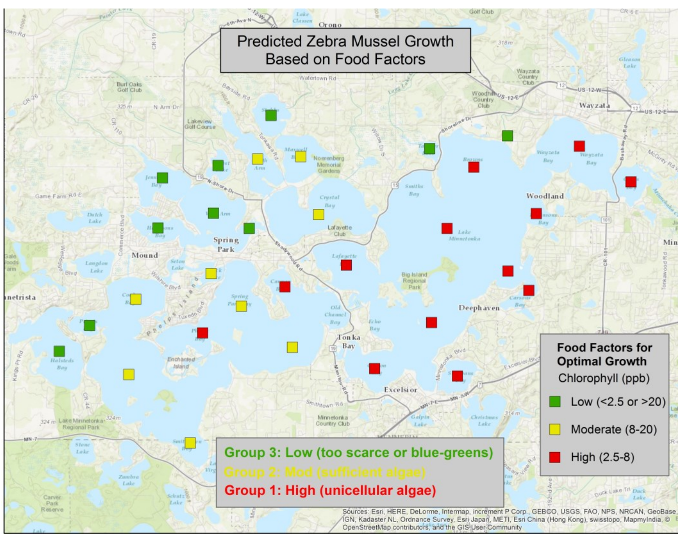
Negative impacts of carp observed at ~100 kg/ha in shallow Midwestern systems (Bajer et al. 2009)

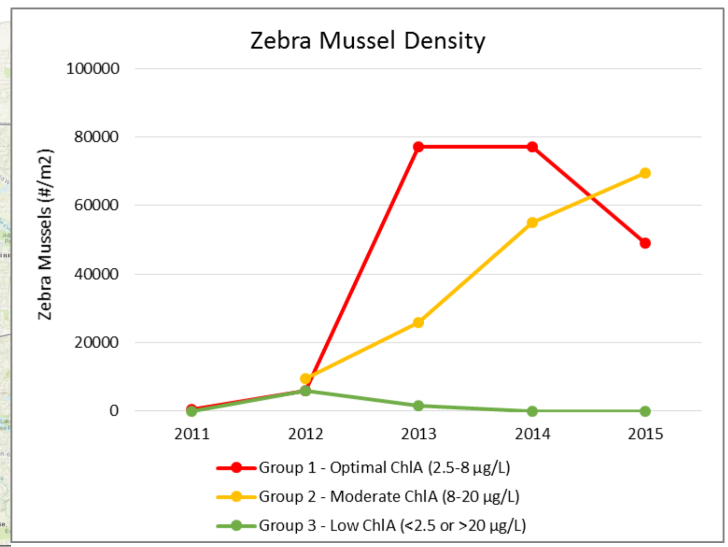
12 of 15 lakes exceed this threshold

Lake Minnetonka Zebra Mussel Study

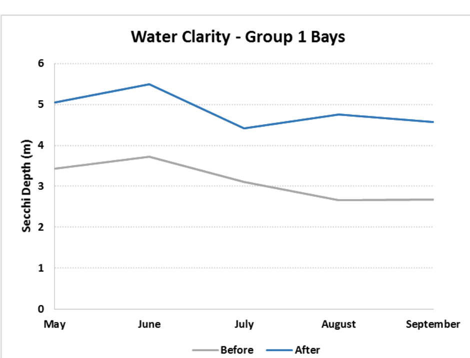
Zebra mussels were first discovered in Lake Minnetonka in 2010. In 2011, the District developed a way to track the population, and assess its impact on water quality in the lake. The study is ongoing, but some initial findings are below.

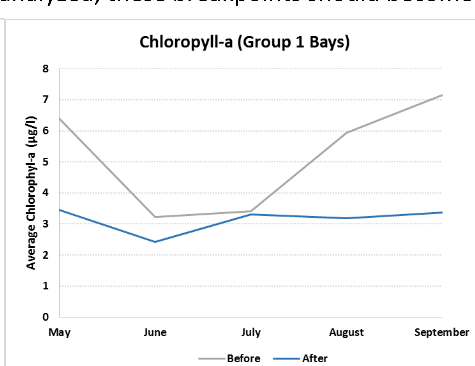
Zebra mussels can act as both a low impact and high impact species but are influenced by water quality conditions of 26 semi-isolated bays in Lake Minnetonka. A paired t-test was performed on water quality data from 18 of these bays 5 years before and 5 years after the infestation. Bays were divided into 3 groups based on pre-infestation chlorophyll levels; Group 1 (2.5-8 mg/L), Group 2 (8-20 mg/L) and Group 3 (<2.5 or >20 mg/L). Water clarity showed significant increases and chlorophyll showed significant decreases in Group 1, but no significant changes in the other two groups. The bays in Group 1 have the highest zebra mussel densities in the lake, with Group 2 bays increasing quickly. However, all three groups showed significant changes in phosphorus. Groups 1 and 2 had a significant decline in phosphorus after infestation, where group 3 had an increase, but likely due to other factors. At the bay scale (50 – 200 ha) other trophic changes have occurred with pelagic production changing to benthic production. Zebra mussel densities have been increasing in most bays at different rates, but in some they appear to be becoming food limited. Zebra mussel densities ranged from 28/m2 in Halsteds Bay to over 200,000/m2 in Wayzata Bay. The abundance and the type of algal species probably influenced zebra mussel densities within Lake Minnetonka and cyanobacteria are likely limiting the zebra mussel population in Halsteds Bay.

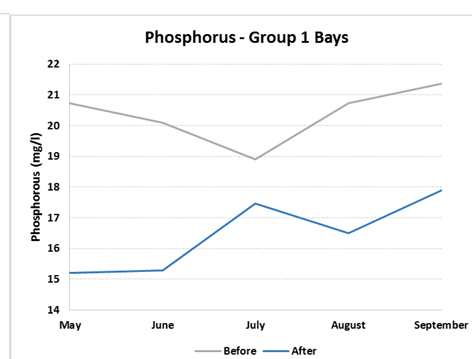




The pre-infestation levels of algae (measured by Chlorophyll-a), seem to dictate growing conditions for zebra mussels. Estimated ranges for optimum levels is indicated on the map, as more data is gathered and further analyzed, these breakpoints should become clearer.

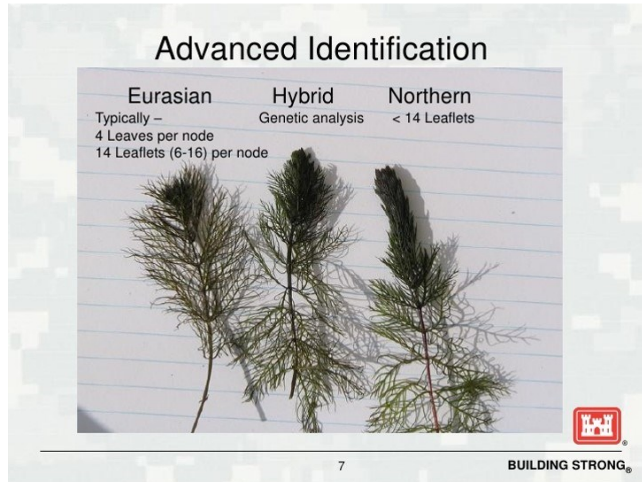




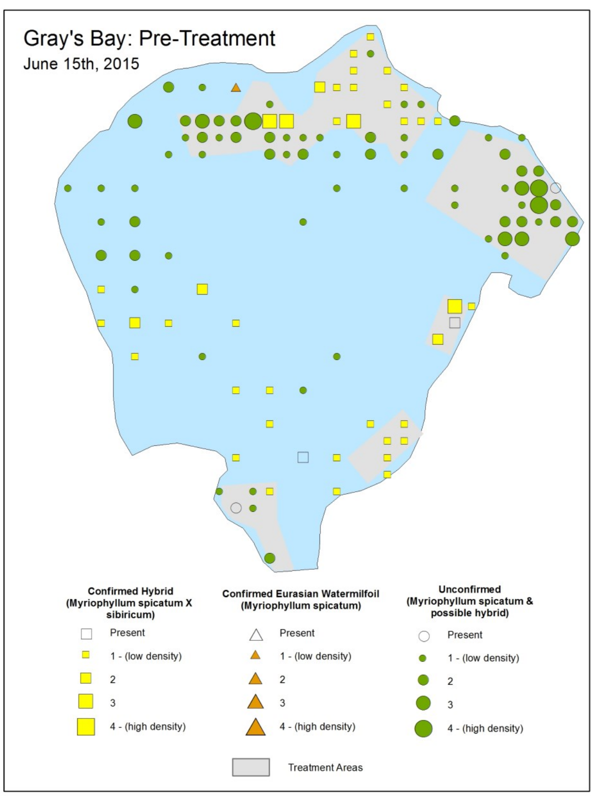


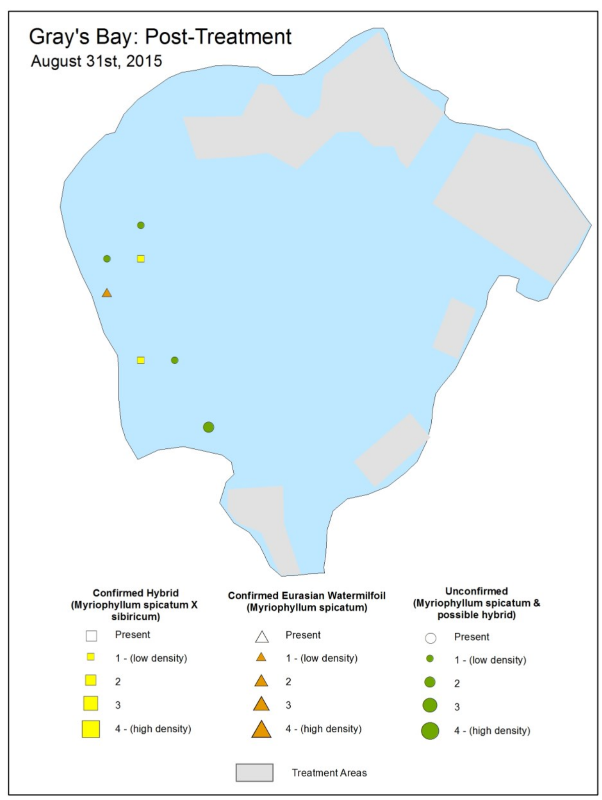
Hybrid Milfoil Study

Eurasian watermilfoil (*Myriophyllum spicatum*) can hybridize with the native northern watermilfoil (*M. sibiricum*) and all three taxa, Eurasian, northern and hybrid watermilfoil are present in Minnesota, but their occurrence and distribution is not well documented. We examined the genetic composition of watermilfoils in three bays of Lake Minnetonka that are being managed with herbicides to control Eurasian watermilfoil and two bays and one lake that have not been extensively managed with herbicides but were known to have populations of the milfoil weevil. The plant community was characterized in each lake from point intercept surveys conducted in June (before herbicide treatment with triclopyr) and in August (after treatments) and samples of watermilfoil were collected for genetic analysis.



Eurasian, northern and hybrid watermilfoil geno-types were found, but northern watermilfoil was only found in the untreated bays; hybrid water milfoil was much more common in the treated bays whereas pure Eurasian and northern were more common in the untreated bays. Genetic analysis found 3 potentially different genotypes of Hybrid throughout the study stations. Overall, this analysis shows that all three watermilfoil taxa are present in Lake Minnetonka and Christmas Lake, hybrid watermilfoil appears more common and northern less common in bays that have had extensive herbicide treatments and there is a potential for intensive management to shift the frequency of the taxa. Further analysis is being completed in 2016, and a final report will then be available.





Example Pre– and Post-Treatment Survey in Grays Bay, Lake Minnetonka

Lake Nokomis Biomanipulation Study—2nd Year of Post-Project Monitoring

Background

Lake Nokomis is a 201-acre lake located in Minneapolis, Minnesota. Water quality in Lake Nokomis is impaired for nutrients, algal abundance and water transparency. Lake analyses and lake modeling scenarios suggest phosphorus from internal sources may be keeping Lake Nokomis reaching acceptable nutrient goals. One of the many internal sources that may be contributing to the nutrient impairment is the omnivorous, bottom feeding fish populations – black bullheads and bluegill sunfish. An estimated reduction of 126 kg of phosphorus in Lake Nokomis via fish community manipulation would bring the water quality of the lake closer to Minnesota Pollution Control Agency's (MPCA) nutrient criteria.

Summary of Biomanipulation Project

Project Objectives

From 2010-2013, the biomanipulation project attempted to re-balance the fish community over the 4-year period. By re-balancing the fish community in Lake Nokomis, the following was expected to occur: increase walleye population, reduced black bullhead and blue gill populations, observe an increase in native aquatic plants, reduce an estimated 126 kg of phosphorus, and water quality parameters meet the MPCA's nutrient criteria

Project Summary

At the end of 2013, the biomanipulation project resulted in achieving the first three objectives: an increase in the walleye population and in number of native aquatic plants species, and a reduction in the black bullhead and bluegill populations. Positive changes in the water quality of natural systems, such as Lake Nokomis, often are observed after the timeframe of the project.

Summary of Post-Project Monitoring:

Post project monitoring in Lake Nokomis began in 2014 and will occur through the fall of 2016. The monitoring of the water quality and the fish, aquatic plants, and plankton communities in Lake Nokomis are shared among Minnehaha Creek Watershed District, Minneapolis Parks and Recreation Board (MPRB) and the consultant, Blue Water Science.

2015 Summary

- Water quality of Lake Nokomis was monitored from June-September 2015 (MPRB)
  - ⇒ Two of the three parameters met the standards in 2015
  - ⇒ Second year in a row that chlorophyll and total phosphorus concentrations met the standards (See Section 3.9)

- Aquatic plant survey conducted on August 3, 2015 (Blue Water Science)
  - ⇒ 8 species of aquatic plants were identified; 6 of the 8 were native plants
  - ⇒ Estimated aquatic plant coverage was up to 29 acres, about double the coverage compared to the coverage in 2010
  - ⇒ Aquatic plants grew out to depths of 11 feet, one foot deeper than in 2014

- Fish survey conducted on October 20-22, 2015 (Blue Water Science)
  - ⇒ 12 fish species were sampled
  - ⇒ Black crappies dominated the catch, and were above the range recommended by the DNR
  - ⇒ Bluegill sunfish were slightly higher in 2015 compared to 2014, but not significantly higher; in fact, the population has been declining in the last few years
  - ⇒ Declining blue gill population has created a niche for the black crappies
  - ⇒ Continued predation by the walleye and yellow perch is needed to keep the blue gills and black crappie populations in check
  - ⇒ Stocking walleye in Lake Nokomis is recommended

<u>Additional Activities: 2015</u>

- Three settling ponds adjacent to Lake Nokomis were monitored from May-September 2015: (MCWD). The range of total phosphorus concentrations for the three ponds was 120 µg/L to 800 µg/L.

- Possible pathways that carp travel to and from Lake Nokomis were scouted this summer by Blue Water Science (Attachment 3). Five possible pathways were discovered. Two of the five pathways were rated a high probability of being used as carp transport. Solomon wetland south of Lake Nokomis and Taft Lake are the two pathways. Since 2015 was not a high water year, the results are not conclusive.

- MPRB submitted a grant proposal to Legislative-Citizen Commission on Minnesota Resources (LCCMR) in May 2015 to request funds to conduct invasive carp applied research in Lake Nokomis Subwatershed.

- MPRB and MCWD staff presented the grant proposal at the LCCMR grant committee in October 2015. The LCCMR grant committee will recommend the legislature to fund the invasive carp applied research in Lake Nokomis Subwatershed.

- August 2015: Justine Koch, Research Fellow for the Six Mile Creek Subwatershed Carp Assessment, conducted a snap-shot carp survey on Lake Nokomis (Table 1)
  - ⇒ Results are preliminary, since a snap-shot survey was conducted
  - ⇒ Results of 2015 were comparable to the 2014 results
  - ⇒ A one-year-old carp was captured in 2015, so some level of recruitment is occurring in Lake Nokomis or in connected waters

Table 1. Results from the snap-shot carp survey on Lake Nokomis

Year	Estimated # of Carp	Estimated Biomass (kg/ha)
Ecological Limit		100
2014	8,421	298
2015	10,908	373

Note: Carp biomass above ~100 kg/ha has been found to cause ecological damage in shallow lakes (Bajer et al. 2009)

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MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

Appendix A: Additional Analyses

Appendix B - 2015 Concentrations and Loading Summary

				TP		SRP		TN		TSS		Cl	
Station	Station Type	Water-shed Area (acre)	Mean-Flow (cfs)	Load (lbs)	Flow Wt Mean (µg/L)	Load (lbs)	Flow Wt Mean (µg/L)	Load (lbs)	Flow Wt Mean (mg/L)	Load (lbs)	Flow Wt Mean (mg/L)	Load (lbs)	Flow Wt Mean (mg/L)
Christmas Lake Creek													
CCH02	Inlet	176.73	0.34	234	350	84	125	313	0.47	15,167	23	16,706	25
Dutch Lake Creek													
CDU02	Inlet	608.67	0.60	394	334	230	195	1,037	0.88	6,795 - 6,815	6	23,564	20
CDU01	Outlet	987.56	0.90	281	158	128	72	1,595	0.90	11,343	6	60,372	34
Gleason Lake Creek													
CGL03	Inlet	1642.10	1.09	353	160	146	70	1,665	0.78	26,653	12	253,156	118
CGL01	Outlet	962.97	0.43	99	120	0.95 - 3	1 - 3	515	0.61	8,232	10	32,227	38
Classen Lake Creek													
CCL04	Upstream	773.77	0.96	343	180	231	122	3,096	2	7,066 - 7,090	4	156,006	83
CCL01	Stubbs Lk Inlet	219.57	0.49	202	209	153	158	1,555	2	12,935 - 12,952	13	89,498	92
Classen Wetland Creek													
CST01	Stubbs Lk Inlet	506.55	0.49	429	449	270	282	727	0.76	3,534	4	22,609	24
Forest Lake Creek													
CFO01	Inlet	294.96	0.54	301	282	219	205	1,015	0.95	8,143 - 8175	8	74,857	70
Lake Minnewashta Creek													
CMW02	Outlet	2985.30	1.44	157	55	1.00 - 9.44	0.35 - 3.34	2,544	0.90	16,364	6	130,244	46
Langdon Lake Creek													
CLA02	Inlet	508.10	0.24	34	72	17	36	115	0.24	931	2	8,203	17
CLA01	Outlet	547.35	1.78	216	62	0 - 10	0 - 3	3,223	0.92	37,994	11	122,576	35
Long Lake Creek													
CLO05	Long Lake: Inlet	1632.79	1.02	390	194	92	46	2,563	1	26,069	13	79,491	40
CLO01	Long Lake: Outlet	3563.15	2.49	594	121	68 - 74	15	7,146	1	48,114	10	226,060	46
CLO03	Tanager Lake: Inlet	892.88	3.65	1,193	166	437	61	11,491	1	98,180	14	425,052	59

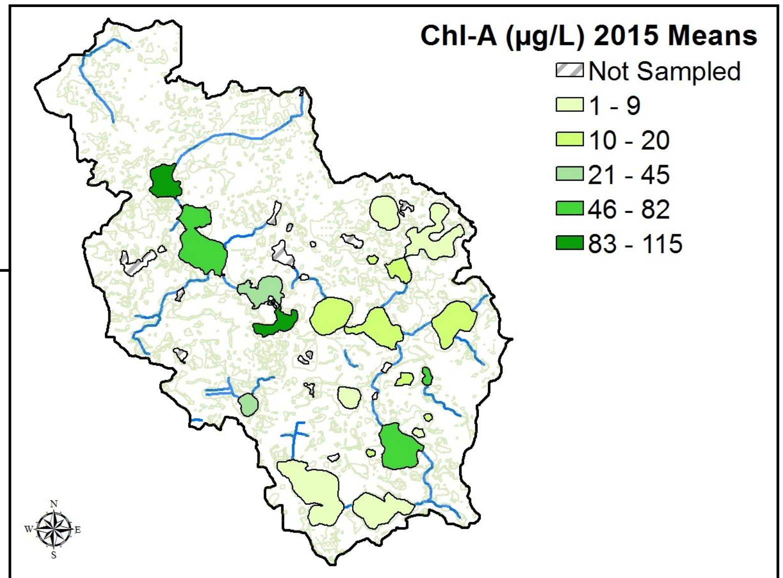
				TP		SRP		TN		TSS		Cl	
Station	Station Name	Water-shed Area (acre)	Mean-Flow (cfs)	Load (lbs)	Flow Wt Mean (µg/L)	Load (lbs)	Flow Wt Mean (µg/L)	Load (lbs)	Flow Wt Mean (mg/L)	Load (lbs)	Flow Wt Mean (mg/L)	Load (lbs)	Flow Wt Mean (mg/L)
Gleason Wetland Creek													
CGL04	Wetland Outlet	714.14	0.72	247	178	88	62	774	0.54	9,611	7	382,836	269
Minnehaha Creek													
CMH07	Grays Bay Dam	79276.81	30.68	1,117	18	162 - 247	3 - 4	24,908	0.41	14,791 - 63,843	0.24 - 1.1	3,057,300	51
CMH19	I-494	81843.24	24.92	1,694	55	381 - 418	8 - 9	31,519	0.64	203,380	4	2,840,184	58
CMH02	W 34 St	85182.50	29.27	3,082	53	795	14	37,981	0.66	258,383	4.48	4,365,468	76
CMH11	Excelsior Blvd	86238.45	28.66	3,712	66	657-662	11.6 - 12	58,220	1.03	1,118,392	28.88	4,070,048	105
CMH03	Brown-dale Dam	87050.69	34.55	2,483	37	664-684	9.8 - 10	41,619	0.61	200,775	2.95	5,644,384	83
CMH04	W 56th St	87352.64	28.49	2,766	49	652-654	11.6 - 11.7	41,480	0.74	634,668	22	4,614,397	82
CMH15	Xerxes Ave	87794.45	34.26	4,092	61	982-991	14 - 15	55,612	0.88	1,187,975	19	5,026,240	75
CMH24	21st Ave	93218.04	39.74	6,324	81	1092	14	97,754	1.25	3,213,822	41	5,548,294	71
CMH18	28th Ave	94286.50	39.18	4,366	57	601-636	7.8 - 8.3	55,836	0.72	458,841	5.95	6,635,216	86
CMH06	Hiawatha Ave	94568.90	46.82	5,669	61	838-873	9.1 - 9.5	72,075	0.78	685,831	7.44	7,893,012	86
Painter Creek													
CPA03	Katrina Wetland Outlet	3502.58	1.74	852	248	619	180	5,631	2	19,747	6	205,577	60
CPA04	Painter Marsh Outlet	3907.78	3.92	2,918	378	1,611	209	9,052	1	25,826 - 26,799	3	419,817	54
CPA06	Upstream (Painter Ck Dr)	225.94	3.37	2,701	407	1,414	213	10,390	2	23,246 - 40,035	6	373,921	56
CPA01	Upstream (W Branch Rd)	174.78	2.54	1,770	353	1,022	204	5,943	1	61,495	12	234,796	47
CPA05	Jennings Bay: Inlet	314.48	3.58	2,623	372	1,347	191	7,302	1	112,824	16	298,545	42

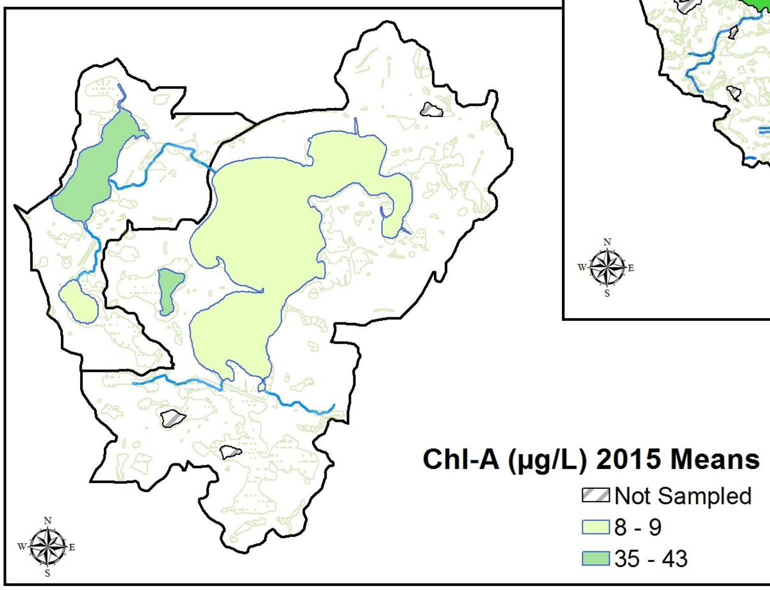
Station	Six Mile Creek	Water-shed Area (acre)	Mean-Flow (cfs)	TP Load (lbs)	TP Flow Wt Mean (µg/L)	SRP Load (lbs)	SRP Flow Wt Mean (µg/L)	TN Load (lbs)	TN Flow Wt Mean (mg/L)	TSS Load (lbs)	TSS Flow Wt Mean (mg/L)	Cl Load (lbs)	Cl Flow Wt Mean (mg/L)
Schutz Lake Creek													
CSC01	Inlet	457.58	1.38	657	242	307	113	2,648	0.97	152,290	56	146,179	54
Six Mile Creek: Piersons-Marsh-Wassermann													
CSI14	Piersons Lk Outlet	1297.23	0.09	Insufficient Data Due to No Flow									
CSI11	Wassermann Lk Inlet	392.95	0.37	68	94	26	36	Insufficient Data Due to No Flow					
CSI12	Wassermann Lk Outlet	1199.68	1.59	240	77	45-48	15	3,257	1.04	15,917	5.08	50,0172	16.01
Six Mile Creek: Auburn-North Lundsten - Carver Park Reserve													
CSI05	East Auburn Lk Inlet	775.46	2.02	536	135	280	70	2,322	0.58	6,573	1.65	93,332	23.46
CSI09	West Auburn Lk Outlet	1086.99	2.53	225	45	34 - 41	7 - 10	3,531	0.71	19,337	3.88	171,266	34.44
CSI01	Lundsten Lk North Outlet	924.48	2.00	160	41	14 - 17	3 - 4	2,154	0.55	10,932	2.78	54,866	13.93
Six Mile Creek: Turbid-South Lundsten													
CSI13	Turbid Lk Outlet	622.04	0.34	133	201	72	108	831	1.26	2,849	4.31	11,442	17.29
CSI10	Lundsten Lk South Inlet	164.42	0.53	392	379	280	270	1,433	1.38	3,526	3.41	19,380	18.72
Six Mile Creek: Parley-Mud													
CSI08	Parley Lk Inlet	1880.04	0.87	429	251	62	36	1,011	0.59	26,232	15.40	13,632	8.00
CSI16	Parley Lk Inlet	1454.81	0.537	185	175	75	71	1,306	1.24	11,521	10.90	17,691	16.70
CSI15	Mud Wetland Inlet	656.09	1.34	1,014	385	726	275	1,735	0.66	9,195	3.49	84,626	32.01
CSI02	Mud Wetland Outlet	1021.69	5.09	1,418	141	386	39	13,517	1.35	79,607	7.94	303,169	30.25
CSI17	Halsted Bay: Inlet	1700.22	6.39	1,931	154	992	79	12,655	1.01	49,485	3.94	255,428	20.3

Appendix A - 2015 Water Quality Means for Lakes

Six Mile Marsh Subwatershed (right);

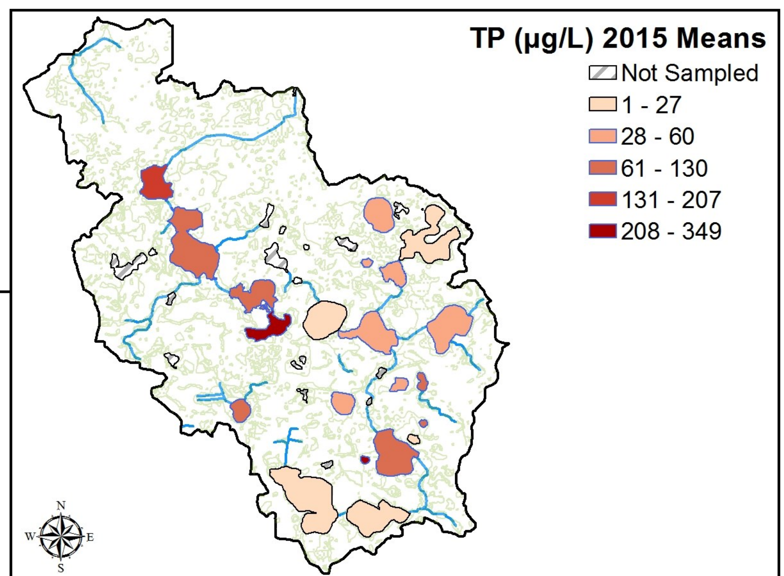
Lake Virginia Subwatershed (below)

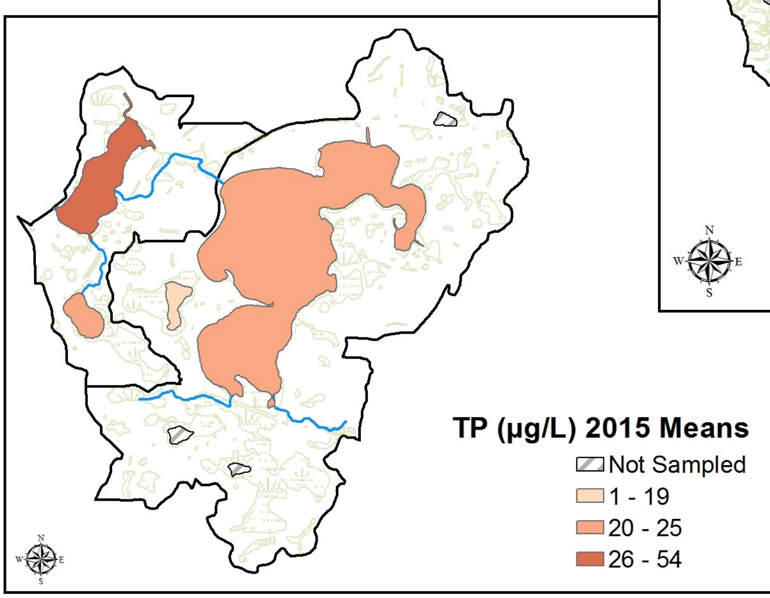




Six Mile Marsh Subwatershed (right);

Lake Virginia Subwatershed (below)





Appendix A - Water Quality Trend Statistics

Trend: 2001-2015					
Lake Minnetonka:	**Parameter**	**Slope**	**Tau**	**p-value**	**Improving or Degrading**
Cooks	SECC	0.034	0.200	0.322	
	CHLA	0.290	0.114	0.586	
	TP	-0.560	-0.276	0.166	
Crystal	SECC	0.115	0.486	**0.013**	Improving
	CHLA	-0.230	-0.143	0.488	
	TP	-0.427	-0.276	0.166	
Forest	SECC	0.012	0.171	0.400	
	CHLA	0.329	0.067	0.767	
	TP	-0.850	-0.219	0.276	
Halsted	SECC	-0.015	-0.200	0.322	
	CHLA	1.873	0.257	0.198	
	TP	-0.220	-0.048	0.843	
Jennings	SECC	0.000	0.019	0.960	
	CHLA	1.170	0.181	0.373	
	TP	-0.949	-0.086	0.692	
Lower Lake South	SECC	0.157	0.410	**0.037**	Improving
	CHLA	-0.191	-0.410	**0.038**	Improving
	TP	-0.572	-0.410	**0.038**	Improving
Maxwell	SECC	0.037	0.200	0.322	
	CHLA	-0.350	-0.257	0.198	
	TP	-0.428	-0.181	0.373	
Peavey	SECC	-0.018	-0.438	**0.026**	Degrading
	CHLA	-0.434	-0.200	0.322	
	TP	4.569	0.429	**0.029**	Degrading

Trend: 2001-2015					
Lake Minnetonka:	**Parameter**	**Slope**	**Tau**	**p-value**	**Improving or Degrading**
St Albans	SECC	0.101	0.448	**0.023**	Improving
	CHLA	-0.220	-0.410	**0.038**	Improving
	TP	-0.687	-0.467	**0.018**	Improving
Wayzata	SECC	0.145	0.505	**0.010**	Improving
	CHLA	-0.154	-0.352	**0.075**	Improving
	TP	-0.419	-0.333	**0.092**	Improving
West Arm	SECC	-0.007	-0.105	0.620	
	CHLA	1.045	0.314	0.113	
	TP	0.536	0.067	0.767	
West Upper	SECC	0.025	0.181	0.373	
	CHLA	-0.071	-0.057	0.804	
	TP	-0.458	-0.295	0.138	

Trend:					
Lake Minnetonka:	**Parameter**	**Slope**	**Tau**	**p-value**	**Improving or Degrading**
Trend: 2004-2015					
Carsons	SECC	0.250	0.545	**0.016**	Improving
	CHLA	-0.254	-0.394	**0.086**	Improving
	TP	-0.773	-0.424	**0.064**	Improving
Grays	SECC	0.182	0.455	**0.047**	Improving
	CHLA	-0.138	-0.121	0.631	
	TP	-0.814	-0.455	**0.047**	Improving
Trend: 2005-2015					
Lafayette	SECC	0.265	0.636	**0.008**	Improving
	CHLA	-0.493	-0.600	**0.013**	Improving
	TP	-1.078	-0.400	0.101	
Trend: 2006-2015					
Black	SECC	0.103	0.378	0.152	
	CHLA	-1.800	-0.578	**0.025**	Improving
	TP	-0.675	-0.156	0.592	
Priests	SECC	0.031	0.156	0.592	
	CHLA	-0.681	-0.222	0.419	
	TP	1.762	0.778	**0.002**	Degrading
Spring Park	SECC	0.353	0.667	**0.009**	Improving
	CHLA	-0.625	-0.422	0.107	
	TP	-1.215	-0.600	**0.020**	Improving
Trend: 2007-2015					
Stubbs	SECC	0.013	0.067	0.858	
	CHLA	-1.267	-0.111	0.721	
	TP	0.394	0.067	0.858	

Trend: 2001-2015					
Lake	**Parameter**	**Slope**	**Tau**	**p-value**	**Improving or Degrading**
Calhoun	SECC	-0.029	-0.105	0.621	
	CHLA	-0.051	-0.210	0.298	
	TP	0.125	0.133	0.519	
Christmas	SECC	0.118	0.319	0.125	
	CHLA	0.000	0.010	1.000	
	TP	-0.135	-0.248	0.214	
Dutch	SECC	0.005	0.048	0.843	
	CHLA	-0.423	-0.124	0.553	
	TP	0.212	0.019	0.960	
Gleason	SECC	0.032	0.295	0.137	
	CHLA	-0.986	-0.124	0.553	
	TP	-2.577	-0.219	0.276	
Harriet	SECC	-0.077	-0.200	0.322	
	CHLA	0.034	0.086	0.692	
	TP	0.469	0.629	**0.001**	Degrading
Isles	SECC	0.025	0.219	0.276	
	CHLA	-1.226	-0.371	**0.060**	Improving
	TP	-0.750	-0.314	0.113	
Langdon	SECC	0.035	0.286	0.151	
	CHLA	-2.099	-0.257	0.198	
	TP	-1.445	-0.086	0.692	
Long	SECC	0.040	0.538	**0.009**	Improving
	CHLA	-0.125	-0.055	0.827	
	TP	1.565	0.275	0.189	
Minnewashta	SECC	-0.041	-0.308	0.139	
	CHLA	0.337	0.276	0.166	
	TP	0.170	0.095	0.656	
Nokomis	SECC	-0.008	-0.048	0.843	
	CHLA	-0.964	-0.429	**0.029**	Improving
	TP	-1.789	-0.410	**0.038**	Improving
Tamarack	SECC	0.070	0.371	**0.060**	Improving
	CHLA	-0.506	-0.257	0.198	
	TP	-0.279	-0.181	0.373	
Wassermann	SECC	0.010	0.099	0.661	
	CHLA	-0.229	-0.010	1.000	
	TP	-0.212	-0.086	0.692	

Trend:					
Lake	CHLA	Slope	Tau	p-value	Improving or Degrading
Trend: 2005-2015					
Parley	SECC	0.028	0.382	0.119	
	CHLA	-2.154	-0.091	0.755	
	TP	-0.165	-0.018	1.000	
Piersons	SECC	0.061	0.291	0.241	
	CHLA	-0.350	-0.345	0.161	
	TP	-1.198	-0.400	0.101	
Virginia	SECC	0.008	0.055	0.876	
	CHLA	1.529	0.345	0.161	
	TP	0.042	0.018	1.000	
Trend: 2006-2015					
Tanager	SECC	0.022	0.222	0.466	
	CHLA	0.526	0.111	0.754	
	TP	-2.528	-0.278	0.348	

Trends: 2002-2015					
Lake	**Parameter**	**Slope**	**Tau**	**p-value**	**Improving or Degrading**
Cedar	SECC	-0.070	-0.407	**0.049**	Degrading
	CHLA	0.047	0.077	0.743	
	TP	0.219	0.308	0.139	
Powderhorn	SECC	-0.059	-0.333	0.127	
	CHLA	0.438	0.128	0.583	
	TP	1.105	0.077	0.760	
Schutz	SECC	-0.029	-0.176	0.411	
	CHLA	0.933	0.484	**0.018**	Degrading
	TP	0.465	0.103	0.669	
South Oak	SECC	0.009	0.111	0.754	
	CHLA	-0.793	-0.127	0.640	
	TP	-2.646	-0.121	0.631	
Steiger	SECC	0.079	0.527	**0.029**	Improving
	CHLA	-0.646	-0.491	**0.043**	Improving
	TP	-0.384	-0.236	0.350	
West Auburn	SECC	0.032	0.253	0.228	
	CHLA	-0.566	-0.319	0.125	
	TP	-0.065	-0.055	0.827	
Zumbra-Sunny (Zumbra Bay)	SECC	0.184	0.758	**0.0002**	Improving
	CHLA	-0.678	-0.473	**0.020**	Improving
	TP	-0.728	-0.648	**0.001**	Improving

Trends: 2002-2014					
Lake	**Parameter**	**Slope**	**Tau**	**p-value**	**Improving or Degrading**
Grass	SECC	n/a			
	CHLA	-2.840	-0.571	**0.063**	Improving
	TP	-6.198	-0.429	0.174	
Twin	SECC	-0.001	-0.076	0.783	
	CHLA	3.744	0.364	0.115	
	TP	-5.841	-0.462	**0.033**	Improving
Trends: 2004-2015					
Lake	**Parameter**	**Slope**	**Tau**	**p-value**	**Improving or Degrading**
Cobblecrest	SECC	-0.0005	-0.056	0.916	
	CHLA	-5.602	-0.222	0.466	
	TP	-6.381	-0.111	0.754	
Hiawatha	SECC	0.028	0.242	0.304	
	CHLA	-0.574	-0.152	0.537	
	TP	-0.788	-0.273	0.244	
St. Joe	SECC	-0.022	-0.267	0.323	
	CHLA	-0.270	-0.333	0.210	
	TP	-0.194	-0.156	0.592	
Trends: 2007-2015					
Lake	**Parameter**	**Slope**	**Tau**	**p-value**	**Improving or Degrading**
Stone	SECC	0.220	0.500	0.108	
	CHLA	-1.888	-0.643	**0.035**	Improving
	TP	-1.162	-0.286	0.386	

MINNEHAHA CREEK WATERSHED DISTRICT
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Appendix B: Programs’ Methods

TABLES

1. THE WATER QUALITY MONITORING PROGRAM: LAKE MONITORING

1.1 Lakes Monitored By MCWD

Lakes within the MCWD are classified by the MPCA as Class 2B lakes, meaning they are protected for aquatic life and recreation. MCWD water quality staff monitored 20 bays on Lake Minnetonka, 12 upper watershed lakes, and 16 canoe accessible lakes in 2015. MCWD's Volunteer Monitoring Program recruited and trained volunteers to monitor an additional 13 lakes throughout the watershed. Monitoring schedules were determined prior to the open-water season (Tables A-1 and A-2).

Table A-1. Lake Minnetonka and Upper Watershed Monitoring Schedule

Parameter	**Units**	**April-October**
Chloride (Cl) (Bottom Samples)	mg/L	April, July, October
Chlorophyll-*a* (CHLA)	µg/L	Monthly
Conductivity	µS/cm	Monthly
Dissolved Oxygen	mg/L	Monthly
pH	--	Monthly
Secchi Depth (SECC)	m	Monthly
Temperature	°C	Monthly
Total Nitrogen (TN), Total Kjeldahl Nitrogen (TKN), Nitrate (NO_3)	mg/L	Monthly
Total Phosphorus (TP), Soluble Reactive Phosphorus (SRP) (Surface and Bottom samples)	µg/L	Monthly
TSS (only on shallow lakes)	mg/L	Monthly

Note: May-Sept Sampling occurs twice a month on Halsted and Jennings Bays, Parley, and Wasser-

Table A-2. MCWD Monitoring Schedule for the Canoe Lakes and Volunteer Monitored Lakes

Parameter	Units	May-Sept
Cl	mg/L	Once a Month
CHLA	µg/L	Once a Month
Conductivity	µS/cm	Once a Month
Dissolved Oxygen	mg/L	Once a Month
pH	--	Once a Month
Secchi Depth	m	Once a Month
Temperature	°C	Once a Month
TN	mg/L	Once a Month
TP, SRP	µg/L	Once a Month
TSS*	mg/L	Once a Month

* Only on Shallow Lakes; Note: shallow canoe lakes are sampled twice a month

There are additional lakes within MCWD that are monitored by the Minneapolis Park and Recreation Board, Three Rivers Park District, and the Metropolitan Council Environmental Services' the Citizen-Assisted lake Monitoring Program. Further information about the lake monitoring conducted by these organizations can be found on their websites (Table A-3).

Table A-3. Links to Other Organizations Water Quality Monitoring Websites

Organization	Link to Monitoring Report Webpage
Minneapolis Park and Recreation Board	https://www.minneapolisparks.org/park_care__improvements/water_resources/lake_water_resources/
Three Rivers Park District	http://www.threeriversparks.org/natural-resources/water-resources-management.aspx
Metropolitan Council Environmental Services	http://www.metrocouncil.org/Wastewater-Water/Services/Water-Quality-Management/Lake-Monitoring-Analysis.aspx?source=child

Lake Monitoring: Sampling consists of three major procedures: measuring a lake's profile with YSI sonde, Secchi disk depth measurements, and water sample collection. MCWD staff use a GPS unit to locate the monitoring station at the deepest point in each lake. Volunteers locate the deepest point on their lakes by using three reference points. MCWD staff monitor the temperature, dissolved oxygen, pH, and specific conductivity at each lake station with a 6820-V2 YSI multi-parameter sonde. Readings are collected from the water surface to the bottom of the lake at one meter increments. Volunteers only measure temperature at the surface of each lake station with a Taylor digital hand-held thermometer.

Water samples were collected within the first two meters of the surface with a 2-meter composite sampling tube. A Van Dorn water sampler collected water samples one meter from the bottom of each lake station. Due to the long record of water quality data collected from the bottom of the lakes, staff decided to place the future hypolimnion (lake bottom) data collection on a 2-year rotation. Hypolimnion water quality samples for phosphorus will be collected again in 2017. Grab water samples were collected within the first meter of the surface at all the canoe and volunteer monitored lake stations (Table A-2). Data collected for each lake is presented in their respective subwatershed report.

Lake Elevation Monitoring: Lake elevation was monitored on Lake Minnetonka in Grays Bay, just west of the Grays Bay Dam and at 19 lakes throughout MCWD (Table A-4). The lake elevations at the 19 lakes are read on a weekly basis via staff gauges from ice-out to ice-in. MCWD submits to the data to the MnDNR. The Grays Bay Dam is operated by MCWD staff in accordance with the Headwaters Control Structure Management Policy and Operating Procedures and Minnesota Department of Natural Resources (DNR) Permit #76-6240. The operating plan was developed by MCWD and approved by local municipalities and the DNR.

The operating range for the control of discharges at the Grays Bay Dam is when the lake level is between 928.6 and 930.0. Elevation 928.6 marks the legal natural runout elevation for Lake Minnetonka, and elevation 930.0 is the crest of the 202-foot long fixed-elevation emergency spillway located north of the dam structure itself. The Dam discharge is reported on the MCWD's website (http://minnehahacreek.org/data-center/faq-water-levels-lake-minnetonka-and-minnehaha-creek).

Table A-4. 2015 MCWD Monitored Lake Elevation Sites

Subwatershed	Lake	OHW (ft, NVGD)	Latitude	Longitude
Christmas Lake	Christmas	932.77	44.9012	-93.5488
Dutch Lake	Dutch	939.20	44.9432	-93.6713
Gleason Lake	Gleason	944.10	44.9856	-93.4912
	Kreatz (East)	972.30	45.0003	-93.5008
Lake Minnetonka	Galpin	943.14	44.8970	-93.5691
	Shaver	929.30	44.9446	-93.5123
Lake Virginia	Minnewashta	944.50	44.8859	-93.6164
	St. Joe	945.20	44.8755	-93.6209
	Tamarack	965.50	44.8749	-93.6371
Langdon Lake	Langdon	932.10	44.9329	-93.6697
	Saunders	944.30	44.9286	-93.6886
Long Lake Creek	Holy Name	993.70	45.0144	-93.5332
	Long	944.30	44.9870	-93.5506
	Lydiard	970.90	44.9920	-93.5367
Six Mile Marsh	Church	N/A	44.8561	-93.6656
	Parley	930.60	44.8789	-93.7360
	Kelser's	956.50	44.8565	-93.6741
	Lundsten N.*	N/A	44.8737	-93.7200
	Stone	947.10	44.8920	-93.6799
	Wassermann	944.30	44.8462	-93.6771
	Zumbra*	943.30	44.8801	-93.6629

OHW data available on MnDNR Lake Finder: http://www.dnr.state.mn.us/lakefind/index.html)

Note: GPS coordinates found using Google Maps

2. THE WATER QUALITY MONITORING PROGRAM: STREAM MONITORING

2.1 Streams Monitored By MCWD

Stream flow was measured and water quality samples were collected at 10 stations along Minnehaha Creek and at 36 stations on 12 tributaries to major streams in the upper watershed, draining to Lake Minnetonka. Sampling schedules were determined prior to the monitoring season (Table A-X5).

Table A-5. MCWD Sampling Schedule for Stream Stations

Parameter	Units	Winter	March - Nov
Cl	mg/L	2-3 Times	Once a Month
CHLA	µg/L	Not Sampled	Weekly (only CSI02 & CSI17)
Conductivity	µS/cm	2-3 Times	Weekly
Dissolved Oxygen	mg/L	Not Sampled	Weekly
Escherichia Coli (E. coli)	CFU/100 mL	Not Sampled	Weekly (April - Oct)
pH	--	Not Sampled	Weekly
Temperature	°C	2-3 Times	Weekly
TN	mg/L	Not Sampled	Once a Month
TP, SRP	µg/L	Not Sampled	Weekly
TSS	mg/L	Not Sampled	Twice a Month
NO2	mg/L	Not Sampled	Weekly (only CMH06)
TDP	µg/L	Not Sampled	Weekly (only CMH06)
TSVS	mg/L	Not Sampled	Weekly (only CMH06)
NH3	mg/L	Not Sampled	Weekly (only CMH06)

3. THE WATER QUALITY MONITORING PROGRAM: HYDROLOGIC MONITORING

3.1 Continuous Water Level Monitoring: Continuous water level monitoring, measured at 15-minute intervals by pressure transducers, was conducted at four stations on Minnehaha Creek (CMH07, CMH19, CMH03, and CMH06), one station on Long Lake Creek (CLO01), three stations on Six Mile Creek (CSI08, CSI01, and CSI17), two stations on Painter Creek (CPA01 and CPA03), and an additional station at the Halsted's boat landing (RLHL01). One station on Six Mile Creek (CSI02) was monitored using a SonTek IQ (velocity beams profiler) to measure flow and volume data.

Located under the Browndale Avenue Bridge in Edina, the Browndale Dam (CMH03) is roughly at the creek's midpoint between Lake Minnetonka and the Mississippi River. The small impoundment created by the dam is referred to as Mill Pond. The dam is an ogee-crested weir, which offers a simple and reliable means for calculating stream discharge based on measured water surface elevations upstream of the dam. Two manual elevation readings were recorded weekly during the open water season.

Telemetry (remote data access uploaded to the MCWD office computer) instruments were used to access continuous water level data from one location on Minnehaha Creek. The collection began in April and brought in house October 2014. Continuous water level data for the streams is available upon request.

3.2 Stormwater Monitoring: Stormwater monitoring equipment was operational at the I-494 (CMH19) station on Minnehaha Creek (Table A-8). The data will be used for defining loads, tracking trends, and modeling for TMDLs for Minnehaha Creek and Mississippi River.

3.3 United States Geological Survey (USGS) Continuous Flow Gauging Station: In 2005, MCWD in partnership with the USGS initiated the gaging station project at the Hiawatha Ave stream monitoring station (CMH06). In response to the creek's chloride impairment, a conductivity and temperature probe were installed in 2010 to collect continuous fifteen minute data (real-time) year-round. In 2012, a stormwater sampler was installed to collect data that will be used for defining loads, tracking trends, and modeling for TMDLs for Minnehaha Creek and Mississippi River (Table A-8). In 2015 a second gage station was set up at Grays Bay dam to manage, operate, and publish water level on Lake Minnetonka. The continuous water level data is available upon request.

Table A-6. Continuous Water Level Monitoring and Stormwater Monitoring Stations

Name	Station	Latitude	Longitude
Minnehaha Creek: Grays Bay Outflow	CMH07	44.9529	-93.4871
Minnehaha Creek: McGinty Road/Minnetonka Blvd	CMH01	44.9409	-93.4582
Minnehaha Creek: I-494 Ramp/Minnetonka Blvd	CMH19	44.9412	-93.4551
Minnehaha Creek: Browndale Dam	CMH03	44.9119	-93.3423
Minnehaha Creek: Hiawatha Ave (USGS Station)	CMH06	44.9147	-93.2134
Six Mile Creek: Lundsten Lake Outlet	CSI01	44.8733	-93.7207
Six Mile Creek: Highland Rd	CSI02	44.9010	-93.7343
Six Mile Creek: Parley Inlet	CSI08	44.8747	-93.7339
Six Mile Creek: Kings Pt Rd	CSI17	44.9075	-93.7051
Halsted Bay: Boat Landing	N/A	44.9165	-93.7029
Painter Creek: W. Branch Rd	CPA01	44.9640	-93.6724
Painter Creek: Deborah Dr	CPA03	44.9918	-93.6436
Long Lake Creek: Outlet	CLO01	44.9850	-93.5606

3.4 Precipitation Monitoring: MCWD maintained and operated tipping bucket precipitation gaging stations at six locations in and near the District (Table A-9). Water quality staff downloads the precipitation data on a weekly basis and performs the required maintenance of precipitation gages to ensure accurate data collection. There are currently three Citizen Precipitation Recorders partnering with the MCWD (Figure A-3). The Precipitation Recorders monitor daily and the data is submitted to MCWD on a monthly basis. This data is also submitted to the Minnesota Climatology Working Group.

Table A-7. Precipitation Monitoring Locations in MCWD

Name	Description	Site	Latitude	Longitude
Carver Park (MCWD)	TRPD Maintenance Garage	PCA01	44.8721	-93.6928
Chanhassen (NOAA)	NOAA	PCN02	44.8541	-93.5741
Long Lake (MCWD)	Long Lk City Public Works Bldg	PLO01	44.9869	-93.5755
Maple Plain (MCWD)	Wenck Office	PME02	45.0113	-93.6690
MSP Airport	MSP Airport	PMP03	44.0740	-93.2218
Minneapolis (MCWD)	Burrough Elementary School	PMP06	44.9116	-93.3004
Minnetonka (MCWD)	City of Minnetonka Public Works	PMA01	44.9471	-93.4273
Shorewood (MCWD)	Former MCWD member's Home	PSW01	44.9014	-93.6020
Shorewood (CPR)	Shorewood	PSW02	44.9176	-93.5514
Minneapolis (CPR)	Minneapolis	PMP04	44.9226	-93.2469

3.5 Groundwater Monitoring:

The Prairie du Chien-Jordan formations serve as major sources of municipal water in the western suburbs and as a major industrial water source in Minneapolis. The MnDNR has monitored groundwater elevations at seven deep wells within the watershed (Table A-10). The Golden Valley well was discontinued in May 2009. The data from wells can be accessed at http://www.dnr.state.mn.us/waters/cgm/index.html.

Table A-8. Long-term Groundwater Monitoring MnDNR Wells in MCWD

MnDNR Well Number	Subwatershed	Location	Ground Elevation (AMSL)	Years Monitored*
27043	Lake Minnetonka	Mound	957 ft	1985-2014
27010	Lake Minnetonka	Orono	931 ft	1945-1952, 2000-2014
27046	Lake Minnetonka	Minnetonka	938 ft	1991-2015
27012	Minnehaha Creek	Golden Valley	890 ft	1971-2009
27041	Minnehaha Creek	St. Louis Park	917 ft	1980-2014
27036	Minnehaha Creek	Minneapolis	830 ft	1979-2014
27044	Six Mile Marsh	St. Bonifacius	950 ft	1991-2014

*Not always continuous

4. QUALITY CONTROL AND ANALYSIS PROCEDURES

4.1 Quality Assurance and Quality Control Summary

Sample Type	Description	Function	Frequency
		Quality Assurance	
Equipment Blank	Reagent-grade deionized water subject to sample collection, processing, and analysis	Used in estimating background due to sampling collection, processing, and analysis	10% of sampling trips*
Bottle Blank	Reagent-grade deionized water subject to sample	Used in estimating background due to sample processing and	Every sampling trip
Field Duplicate	Duplicate of samples	Used in estimating overall within-batch precision	Every sampling trip or 1 per 10 samples)
Laboratory Audit	Synthetic sample of natural lake or stream	Used in estimating overall within-batch precision	Alternate sampling trips
Blind Standard	Standard solution with fictitious site I.D.	Estimates batch precision	Every sampling trip
		Quality Control	
Calibration Blank	Reagent-grade deionized water	Used in identifying signal drift and contamination of samples	One/lab batch
Reagent Blank	Reagent-grade deionized water plus reagents	Used in identifying contamination of reagents	One/lab batch (10% of samples)
Quality Control	Standard solution from source other than calibra-	Used in determining accuracy and consistency of instrument	One/lab batch
Split Samples	Split of lake sample	Used in determining comparability	2 times per year
Laboratory Duplicate	Split of sample aliquot	Used in determining analytical within-batch precision of analytical lab measurements	One/lab batch (10% of samples)
Matrix Spike/Matrix Spike Duplicate	Known spike of sample	Used in determining percent recovery of parameter analyzed	One/lab batch (10% of samples)

*Sampling trip is defined as a sampling cycle, or one cycle of stream samples or lake samples, and not just one day's sampling

4.2 Parameter Methods and Reporting Limits

Parameter	Method	Reporting Limit
Chloride	SM 4500-CL E-1997	1.0 mg/L
Chlorophyll-a	SM 10200 H-2001	1 µg/L
Conductivity	YSI Multiparameter Sonde (Streams: 556, Lakes: 6820V2)	1 µS/cm
Dissolved Oxygen	YSI Multiparameter Sonde (Streams: 556, Lakes: 6820V2)	0.01 mg/L
Escherichia Coli	EPA 9223B	
Nitrate + Nitrite by Flow Injection	EPA 353.2 Rev 2.0 1993	0.03 mg/L
pH	YSI Multiparameter Sonde (Streams: 556, Lakes: 6820V2)	0.01 units
Soluble Reactive Phosphorus	EPA 365.3 (Issued 1978)	0.003 mg/L
Temperature	YSI Multiparameter Sonde (Streams: 556, Lakes: 6820V2)	0.01 °C
Total Coliform	EPA 9223B	
Total Dissolved Phosphorus	EPA 365.3 (Issued 1978)	0.003 mg/L
Total Kjeldahl Nitrogen	EPA 351.2 Rev 2.0 1993	0.04 mg/L
Total Nitrogen	Calculation of TKN + NO3	0.32-0.52 mg/L
Total Phosphorus	EPA 365.3 (Issued 1978)	0.003 mg/L
Total Suspended Solids	SM 2540 D - 1997	1 mg/L
Transparency	Secchi disk depth measurement	0.1 m

Table A-9. Methods and Reporting Limits

Note: MCWD staff followed the sampling procedures, sample preservation, and the holding time procedures described in Standard Operation Procedures (MPCA, 2010), Standard Methods (2005), and the US Environmental Protection Agency (US EPA, 1979 (revised 1983)). All lake and stream water samples were placed on ice in a cooler and stored at approximately 4°C after collection. Samples are then shipped to the contract laboratory for analysis within 48 hours of collection. The contract laboratory that analyzed the water samples for chemical analysis in 2015 was RMB Environmental Laboratories, Inc.

4.3 Relative Percent Difference (RPD)

In accordance with quality assurance guidelines, a duplicate sample is taken for every 10 regular samples. Duplicate samples measure the precision of sampling procedures and lab equipment. To measure the precision between two samples we calculate the Relative Percent Difference (RPD). It is calculated by taking the difference of the sample and the duplicate divided by the average of the two samples.

$$RPD = \frac{|a - b|}{(a + b)/2} * 100$$

The data point is flagged if the RPD is greater than a certain percentage depending on the reporting limit of the parameter and the average of the samples. If the sample average is greater than 20 times the reporting limit for a parameter, the max RPD is 10%. If the average is less than 20 times the reporting limit, the max RPD is 25%. This reduces the number of flagged samples for smaller values that would be unreasonably

4.4 Lake Water Quality Analyses

Data Clean-up: The data is thoroughly reviewed for any errors before the analysis begins. All duplicate samples are run through the RPD analysis to determine precision. Duplicate samples are flagged to note if they were out of range. Then all duplicate samples are averaged. Any sample that is less than the reporting limit is assumed to be zero for the analysis.

Ecoregion Eutrophication Standards: Ecoregion eutrophication standards are used for assessing the recreational use of lakes in Minnesota. The data used for determining impairment must be collected from eight or more monitoring events over two consecutive years. If a lake fails to meet two or more of the water quality standards over the two consecutive years, then the MPCA evaluates listing the lake as impaired for nutrient/eutrophication biological indicators. Wetlands and storm water ponds are not considered for listing of impairments.

Different eutrophication standards have been established for shallow and deep lakes. Shallow lakes are defined as a having a maximum depth less than 15 feet and a littoral zone less than 80 percent of the lake surface area. The NCHF ecoregion eutrophication standards are based on total phosphorus (TP), chlorophyll-*a* (CHLA), and Secchi disc depth (SECC) means collected from June through September (MPCA, 2014). Site-specific water quality standards have been approved for Lake Hiawatha and Lake Nokomis (Table A-10).

Table A-10. Ecoregion and Site-Specific Eutrophication Standards for Lakes

North Central Hardwood Forest Ecoregion	Water Quality State Standards (June-Sept Mean)				
	Units	Shallow Lakes	Deep Lakes	Lake Hiawatha	Lake Nokomis
Secchi Depth (SECC)	m	> 1.0	> 1.4	> 1.4	> 1.4
Chlorophyll-*a* (CHLA)	µg/L	< 20	< 14	< 14	< 20
Total Phosphorus (TP)	µg/L	< 60	< 40	< 50	< 50

Chloride Standard: For lakes to be evaluated for chloride impairment, concentrations of chloride at the surface or bottom of the lake must exceed the chronic or the acute standard by the criteria listed in Table A-11.

Table A-11. Ecoregion Chloride Standard for Lakes

North Central Hardwood Forest Ecoregion	Chloride Standard	
	Chronic	Acute
	Impaired: 2 or more exceedances in 3 years	Impaired: 1 or more exceedances of the max standard
Chloride (Cl)	230 mg/L	860 mg/L

Lake Water Quality Grades: MCWD reports lake water quality grades using the Metropolitan Council's grading system (Osgood, 1989). For each lake, seasonal means are computed for each of the three parameters (surface TP concentration, surface CHLA concentrations, and SECC measurements from data collected from five or more monitoring events between May through September. MCWD then compares these averages to the ranges created from the Metropolitan Council's grading curves. Each water quality parameter for a lake is assigned a letter grade (Table A-12). MCWD then averages these three grades by converting each to a numerical equivalent of the following: A to 5, B to 4, C to 3, D to 2, and F to 1. The numeric values are averaged together to determine an overall letter grade for a lake. In 2015, MCWD is discontinuing the +/- system of the lake grades that the District implemented in 2007 as a mean to transition into the E-Grade system. The lake water quality grades are an indicator of the perceived condition of the open water and are considered average for lakes in a seven-county metro area (Osgood, 1989). An interpretation of the water quality for each letter grade is in Table A-13.

Table A-12. Water Quality Parameters Lake Grade Determination Ranges

Grade	Total Phosphorus (µg/L)	Chlorophyll-*a* (µg/L)	Secchi Depth (m)
A	< 23	< 10	> 3
B	23 - 32	10-20	3.0 - 2.2
C	32 - 68	20 - 48	2.2 - 1.2
D	68 - 152	48 - 77	1.2 - 0.7
F	> 152	> 77	< 0.7

Table A-13. Lake Water Quality Grade Description

Grade	Relative Ranking	Description
A	90% and up	Crystal clear, beautiful. These lakes are exceptional and are enjoyed recreationally without question or hesitation.
B	70 - 90%	These lakes generally have good water quality but algae may limit swimming, particularly toward the end of summer.
C	30 -70%	Average quality. Swimming, boating and fishing may be undesirable relatively early in the season. Algae blooms occasionally.
D	10 - 30%	These lakes have severe algae problems. People are generally not interested in recreation on these lakes.
F	Lowest 10%	Not enjoyable. Such a lake would have several limitations to recreational use.
N/A		Insufficient data to calculate a lake grade (Either < 5 monitoring events and/or the Secchi disk was visible at the bottom of the lake and/or obstructed by vegetation during more than one monitoring event).

Trophic State Index: Trophic State Index (TSI), which measures the productivity level of a lake or trophic state, is calculated from seasonal means of the same three parameters as used by the Metropolitan Council's grading system. The TSI means are calculated from at least four monitoring events between June through September (Carlson, R.E., 1977). Index numbers for TP, CHLA and SECC range from 0 to 100, and are then averaged to determine an overall TSI score (Table 14) (Carlson, R.E., 1977).

If there is an insufficient number of monitoring events for any of the individual component index numbers, than no average is calculated. If this occurs, MCWD still calculates a TSI score with two of the three individual component index numbers. Lakes, to be classified as swimmable in the seven-county metro area, need to have a TSI score less than or equal to 59. An explanation of the productivity level for a range of TSI scores is in Table 15(Moore and Thornton, 1998).

Table A-14. TSI Determination Table

Component	Parameter	Equation
TSIP	Total Phosphorus (µg/L)	(14.42*(LN(TP)))+4.15)
TSIC	Chlorophyll-*a* (µg/L)	(9.81*(LN(Chl-a)))+30.6)
TSIS	Secchi Disc Depth (m)	60-(14.41*(LN(Secchi)))
Overall TSI	Mean average of three individual parameters	

Table A-15. Description of the Carlson's Trophic State Index

Trophic State	TSI	Description
Oligotrophic	< 30	Clear water, oxygen throughout the year in the hypolimnion. Salmonid fisheries in deep lakes.
	30 - 40	Deeper lakes still exhibit oligotrophic characteristics, but some shallower lakes will become anoxic in the hypolimnion during the summer
Mesotrophic	40 - 50	Water moderately clear, but increasing probability of anoxia in hypolimnion
Eutrophic	50 - 60	Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evidence, warm-water fisheries only
	60 - 70	Dominance of blue-green algae, algal scum probable, extensive macrophyte problems
Hypereutrophic	70 - 80	Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration.
	> 80	Algal scum, summer fish kills, few macrophytes, dominance of rough fish

Long-term Trend Analysis: MCWD is interested in the long-term trends of SECC (water clarity), CHLA (estimation of algal abundance) and TP (nutrient that affects algal growth). To calculate long-term trend-lines on the water quality data in any lake, eight to ten consecutive years of data is needed due to climate pattern impacts on the water quality in a lake.

The long-term trendline needs to be statistically analyzed to determine if the trend is significant. Trendlines without statistical support maybe misleading. Statistical analysis of long-term trends for the lakes can be found here - http://minnehahacreek.org/project/lake-data-statistical-analysis.

Monitoring Efficiencies Analysis: MCWD is interested in maximizing the efficiencies in monitoring frequencies, locations, and events in our routinely monitored streams. Statistical analysis is needed to identify anchor stations that best represent the health of the stream for Minnehaha Creek, Painter Creek, Long Lake Creek, and Classen Creek. The report for these streams can be found here - http://minnehahacreek.org/project/stream-data-statistical-analaysis

4.5 Stream Water Quality Analyses

Data Clean-up: The stream data is thoroughly reviewed for any errors before the analysis begins. All duplicate samples are run through the RPD analysis to determine precision. Duplicate samples are flagged to note if they were out of range. Then all duplicate samples are averaged. Any sample that is less than the reporting limit will be calculated as a range between zero and the reporting limit value for further analysis.

Ecoregion Water Quality Guidelines: The MPCA collected and summarized water quality data from minimally impacted streams within Minnesota's seven ecoregions (McCollor and Heiskary, 1993). These data may be used to establish water quality guidelines on ecoregion basis. NCHF ecoregion median data are compared to data collected in MCWD streams (Table A-16).

Table A-16. North Central Hardwood Forest Ecoregion Guidelines for Streams

North Central Hardwood Forest Ecoregion	Water Quality Stream Guidelines (25^{th} -75^{th} percentile)
Temperature (Temp)	2 – 21°C
NOx	0.04 – 0.26 mg/L
Total Suspended Solids (TSS)	4.8 – 16 mg/L
Total Phosphorus (TP)	60 – 150 µg/L
pH	7.9 - 8.3

Dissolved Oxygen Standard: To determine if a stream is able to support aquatic life, at least 20 dissolved oxygen (DO) readings from at least two years in a row is needed. Then from that data set, the standard has to be violated under the following criteria: (1a) more than 10% of the readings collected before 9:00 am May through September or (1b) more than 10% of the total readings from May through September or (1c) more than 10 % of the readings from October through April; and 2) there are at least three violations (Table A-17). MCWD uses the criteria (1b) and (2) to evaluate the DO readings in the streams.

Two factors effect DO levels in the watershed district's streams: intermittent flow and stream stretches classified as ditched. Intermittent streams tend to cease flow occasionally or seasonally. Low flow and/or no water negatively effects DO levels. The MPCA considers ditched streams as streams altered from their natural state, and will evaluate listing these stream stations for DO impairment on a case-by-case basis.

Table A-17. Dissolved Oxygen Standard for Streams

Dissolved Oxygen Standards	
Dissolved Oxygen (DO)	> 5 mg/L

Chloride Standard: In streams, chronic exceedances of chloride occurs over a four-day average while acute exceedances of chloride occur over a one-hour duration. The criteria for streams to be evaluated for impairment is found in Table A-18.

Table A-18. North Central Hardwood Forest Ecoregion Chloride Standard for Streams

North Central Hardwood Forest Ecoregion	Chloride Standard	
	Chronic	Acute
	Impaired: over a 4-day average	Impaired: over a 1-hour duration
Chloride (Cl)	230 mg/L	860 mg/L

***E. coli* Standard:** At least five values for each month is ideal; however, a minimum of five values per month for at least three months, preferably between June and September, is necessary to determine violation of the *E. coli* standard. Sites with less than these minimums will be assessed on a case-by-case basis. The criteria for the *E. coli* standard are shown in Table 19. Due to the intermittent streams, staff cannot always meet the sampling requirement; therefore, MCWD uses the acute criteria for determining violation of the *E. coli* standard (MPCA, 2014).

Table A-19. North Central Hardwood Forest Ecoregion *E. coli* Standard for Streams

North Central Hardwood Forest Ecoregion	Chronic	Acute
	Impaired: Geometric mean of not less than 5 samples within any calendar month	Impaired: Not more than 10% of all samples taken during any calendar month individually exceed
E. coli	126 cfu/100 mL	1,260 cfu/100 mL

Minnehaha Creek Discharge Calculations: Discharge for Grays Bay Dam is calculated by taking into account the month, the lake level, and the stream capacity and applying this information to a discharge formula created by the United States Army Corp of Engineers (USACE). Discharge at Browndale Dam was calculated using automated water surface elevation data collected during the monitoring period and manual readings. Linear interpolation was used to calculate flow between ice out and the first recorded water level of the current year.

Upper Watershed Streams Discharge Calculations: Discharge over the subwatersheds tributary to Lake Minnetonka is calculated in two ways: flow records are developed from continuous stage recorders and stage-discharge relationships, and flow records are developed from weekly manual measurements and stage-discharge relationships. At stations along Painter Creek, Long Lake Creek, and Six Mile Creek, both continuous and weekly measurements are collected; generally, the continuous readings offer a more complete picture of the runoff from a subwatershed.

5. References

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MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

Appendix C: Basin Site Information

Appendix C - Basin Site Information

Basins	MnDNR ID	County	Public Access	Area (ac)	Littoral Area (ac)	% Littoral Area	Volume (ac-ft)	Mean Depth (ft)	Max Depth (ft)	Water-shed Area	Watershed to Lake	Latitude	Longitude
Academy Marsh*	27113600	Hennepin	Limited	7					7	880.18	126:01:00	44.96637	-93.378
Auburn - East	10-0044-02	Carver	No	136			1800	15	34	7628.95	56:01:00	44.8639	-93.6796
Auburn - West	10-0044-01	Carver	Yes	142			3294	23	84	7792.34	55:01:00	44.8683	-93.6947
Bass	27-0015-00	Hennepin	No	48					3.3	1285.61	27:01:00	44.88315	-93.6357
Brownie	27-0038-00	Hennepin	Limited	18		67	404	22	50	391.26	22:01	44.9667	-93.3239
Calhoun	27-0031-00	Hennepin	Yes	415		31	14593	35	90	5529.93	13:01	44.94306	-93.3114
Carl Krey	10-0050-00	Carver	No	48	50	100		5.7	15	370.51	8:01	44.85102	-93.6881
Cedar	27-0039-00	Hennepin	Yes	168		37	3454	20	51	2683.01	16:01	44.95972	-93.3211
Cedar Manor*	27-0713-00	Hennepin	No	6.1						435.88	71:01:00	45.068	-93.6372
Christmas	27-0137-00	Hennepin	Yes	268	77	28.76	9252	36	88	742.24	3:01	44.8992	-93.5378
Church	10-0046-00	Carver	No	12	7.3	59			54	330.73	28:01:00	44.85553	-93.6666
Classen*	27-0162-00	Hennepin	No	92					3.3	321.55	4:01	44.99314	-93.6076
Cobblecrest	27-0053-00	Hennepin	No	10					6	1029.54	103:01:00	44.9502	-93.3932
College*	27-0896-00	Hennepin	No	4.34					9	505.33	115:01:00	44.89878	-93.5713
Como*	27-0145-00	Hennepin	No	8.74						29.57	3:01		
Diamond	27-0022-00	Hennepin	Yes	51		100	57	3	6.9	743.42	15:01	44.90056	-93.2691
Dickey's	27-0161-00	Hennepin	No	12	7	59			26	158.86	13:01	44.9944	-93.5773
Dutch	27-0181-00	Hennepin	Yes	173.8	83	55.42	2560	16	46	1742	10:01	44.94314	-93.6854
Flanagan*	27-0183-00	Hennepin	No	31					28	119.54	4:01	44.0033	-93.7333
French Marsh*	27-0140-00	Hennepin	No	36					6	891.87	25:01:00	44.95896	-93.5804
Galpin*	27-0144-00	Hennepin	No	46						505.33	11:01		
Gleason	27-0095-00	Hennepin	Limited	164	141	83	1201	7.7	17	2605	16:01	44.9783	-93.4926
Grass	27-0681-00	Hennepin	No	27					4.9	414.86	15:01	44.8931	-93.2986
Hadley*	27-0109-00	Hennepin	No	22						537	24:01:00	44.98591	-93.5146
Hannan	27-0052-00	Hennepin	No	27					6	192.98	7:01	44.95338	-93.3945

Basins	MnDNR ID	County	Public Access	Area (ac)	Littoral Area (ac)	% Littoral Area	Volume (ac-ft)	Mean Depth (ft)	Max Depth (ft)	Water-shed Area (ac)	Watershed to Lake Area Ratio	Latitude	Longitude
Harriet	27-0016-00	Hennepin	Yes	339		25	10134	29	82	8681.28	26:01:00	44.92222	-93.3044
Hiawatha	27-0018-00	Hennepin	Limited	54		26	726	15	23	29506	546:01:00	44.92083	-93.2363
Holy Name	27-0158-00	Hennepin	Yes	68	65		376	6	7	463.66	7:01	45.01582	-93.5329
Hooper*	27-0876-00	Hennepin	No	5.14					21	302.09	59:01:00	44.91455	-93.5319
Isles	27-0040-00	Hennepin	Yes	113		89	900	9	31	3628.36	32:01:00	44.95556	-93.3072
Katrina	27015400	Hennepin	Yes	290						3210.4	11:01	45.01095	-93.6242
Kelser’s	10-0047-00	Carver	No	20	13	65			34	58.1	3:01	44.85538	-93.6721
Lamplighter*	27-0710-00	Hennepin	No	7.5					5.5	520.5	69:01:00	44.2228	-93.555
Langdon	27-0182-00	Hennepin	Limited	140	82.7	57.83	1195	8.3	39	1055.4	8:01	44.9326	-93.6727
Legion^	27-0024-00	Hennepin	No	9.16						1196.06	131:01:00		
Long	27-0160-00	Hennepin	Yes	298	131	44	3680	14	33	6850.97	23:01	44.98705	-93.5611
Louise*	27-0870-00	Hennepin	No	7					18	131.05	19:01	44.94103	-93.5207
Lundsten - South	10-0043-00	Carver	No	182	77	100	341	3.5	10	1220.1	7:01	44.87307	-93.7114
Lundsten - North	10-0043-00	Carver	No	182	114	100		4.4	10	9721.71	53:01:00	44.87154	-93.7141
Lydiard	27-0159-00	Hennepin	No	33	23.5	72			52	846.65	26:01:00	44.99126	-93.5332
Marion*	27-0087-00	Hennepin	No	14					45	339.61	24:01:00	44.94678	-93.5178
Marsh	10-0054-00	Carver	No	161	143	100	341	2.8	4.5	1592.63	10:01	44.8296	-93.6801
Mary*	27-0899-00	Hennepin	No	11					6	95.48	9:01	44.89755	-93.584
Meadow-brook	27-0054-00	Hennepin	No	33					7	11383	345:01:00	44.9228	-93.3633
Melody*	27-0669-00	Hennepin	No	7.8					5.1	152.83	20:01	44.915	-93.4349
M-Black	27-0133-06	Hennepin	Yes	86.64					25	464.13	5:01	44.9305	-93.6354
M-Carman*	27-0133-05	Hennepin	Yes	331.29					52	10126.01	31:01:00	44.9226	-93.6018
M-Carsons	27-0133-03	Hennepin	Yes	116.84					24	719.52	6:01	44.9259	-93.5319
M-Cooks	27-0133-05	Hennepin	Yes	466.16					43	3468.4	7:01	44.918	-93.6631
M-Crystal	27-0133-10	Hennepin	Yes	810.2					113	8553.66	11:01	44.9488	-93.5934
M-Forest	27-0139-00	Hennepin	Yes	88.83					42	943.82	11:01	44.95637	-93.634
M-Gideon	27-0133-02	Hennepin	Yes	359.45					66	977.72	3:01	44.91172	-93.5746

Basins	MnDNR ID	County	Public Access	Area (ac)	Littoral Area (ac)	% Littoral Area	Volume (ac-ft)	Mean Depth (ft)	Max Depth (ft)	Water-shed Area (ac)	Watershed to Lake Area Ratio	Latitude	Longitude
M-Grays	27-0133-01	Hennepin	Yes	187.43					28	32420.9	173:01:00	44.9532	-93.4935
M-Halsted	27-0133-09	Hennepin	Yes	578.67			7063	13.1	36	2364.5	4:01	44.9149	-93.6884
M-Harrisons*	27-0133-14	Hennepin	Yes	272.08					46	458.74	2:01	44.9409	-93.6503
M-Jennings	27-0133-15	Hennepin	Yes	311.6			3345	11.3	26	868.7	3:01	44.9543	-93.6523
M-Lafayette	27-0133-02	Hennepin	Yes	487.52					62	11246.17	23:01	44.9314	-93.5823
M-Libbs*	27-0085-00	Hennepin	Yes	23					7	120.41	5:01	44.94728	-93.4885
M-Lower Lake North*	27-0133-03	Hennepin	Yes	2002.72					90	30079.52	15:01	44.94635	-93.5404
M-Lower Lake South	27-0133-02	Hennepin	Yes	938.47					77	3612.35	4:01	44.9149	-93.5667
M-Maxwell	27-0133-11	Hennepin	Yes	305.46			4242	14	44	2524.53	8:01	44.9624	-93.6033
M-North Arm*	27-0133-13	Hennepin	Yes	325.56			4628	13	64	774.1	1:01	44.95313	-93.6201
M-Peavey	27-0138-00	Hennepin	Yes	9.7					63	776	80:01:00	44.9646	-93.5359
M-Phelps*	27-0133-05	Hennepin	Yes	433.92					30	1153.84	3:01	44.9166	-93.642
M-Priests	27-0133-05	Hennepin	Yes	97.9					46	2624	27:01:00	44.91861	-93.6807
M-Smithtown*	27-0133-05	Hennepin/ Carver	Yes	154.39					80	5951.27	39:01:00	44.8892	-93.6403
M-Spring Park	27-0133-05	Hennepin	Yes	440.15					36	1617.97	4:01	44.9325	-93.6268
M-St. Albans	27-0133-04	Hennepin	Yes	167.01					44	379.1	2:01	44.90861	-93.5489
M-Stubbs	27-0133-12	Hennepin	Yes	198.81			3008	16	37	1944.64	10:01	44.9699	-93.6156
M-Wayzata	27-0133-02	Hennepin	Yes	725.92					63	31547.32	43:01:00	44.9664	-93.5167
M-West Arm	27-0133-14	Hennepin	Yes	499.96					44	3230.38	6:01	44.9435	-93.6342
M-West Upper	27-0133-05	Hennepin	Yes	905.73					84	5951.27	7:01	44.9046	-93.6665
Minnewashta	10-0009-00	Carver	Yes	686	371	54	12614	17	70	3081	4:01	44.8783	-93.6101
Mooney	27-0134-00	Hennepin	No	117	116.9	100			10	598.71	5:01	45.00192	-93.5211
Mother	27-0023-00	Hennepin	No	11					3	484.18	44:01:00	44.89317	-93.2423
Mud	27-0186-00	Hennepin	No	102	144	100		3.5	5.5	15097.85	148:01:00	44.89392	-93.7414
Nokomis	27-0019-00	Hennepin	Yes	201		51	2886	14	33	2485.06	12:01	44.90833	-93.2419
Pamela	27-0675-00	Hennepin	No	7					6	153.89	22:01	44.8923	-93.3323

Basins	MnDNR ID	County	Public Access	Area (ac)	Littoral Area (ac)	% Littoral Area	Volume (ac-ft)	Mean Depth (ft)	Max Depth (ft)	Water-shed Area (ac)	Watershed to Lake Area Ratio	Latitude	Longitude
Parley	10-0042-00	Carver	Yes	256	231	90		7	18	12428.61	49:01:00	44.8801	-93.7271
Piersons	10-0053-00	Carver	Yes	292	119	41	1701	16	40	1199.68	4:01	44.8323	-93.6977
Powderhorn	27-0014-00	Hennepin	Yes	12		99	73	4	20	331.67	28:01:00	44.94167	-93.2572
Saunders*	27-0185-00	Hennepin	Limited	26						508.01	20:01	44.92942	-93.6921
School*	27-0151-00	Hennepin	No	11					21	561.98	51:01:00	44.1236	-93.8572
Schutz	10-0018-00	Carver	No	107	40	38.1	2100	20	50	861.52	8:01	44.87585	-93.6464
Shaver**	27-0086-00	Hennepin	No	19					7	229.11	12:01	44.94547	-93.5059
South Oak	27-0661-00	Hennepin	No	3.1						460	148:01:00	44.9342	-93.3705
St. Joe	10-0011-00	Carver	Yes	19	6.5	34			52	214.51	11:01	44.8758	-93.6231
Steiger	10-0045-00	Carver	Yes	153	103	65	3760	13	37	829.3	5:01	44.8677	-93.6593
Stone	10-0056-00	Carver	No	94	71	74	2054	10	29	880.47	9:01	44.888	-93.6779
Sunny	10-0041-00	Carver	No	51.6			2268		18	1968.21	38:01:00	44.87826	-93.6745
Taft^	27-0683-00	Hennepin	No	14					45	1839.08	131:01:00	44.8932	-93.2494
Tamarack	10-0010-00	Carver	No	29	9.9	35			82	215.14	7:01	44.87274	-93.6346
Tanager	27-0141-00	Hennepin	Yes	54	38	75	250	5	23	8127.61	151:01:00	44.96126	-93.5613
Thies	27015600	Hennepin	No	11					29	462.22	42:01:00	44.185	-93.6761
Turbid	10-0051-00	Carver	No	40	26	65	1063		27	532.87	13:01	44.84919	-93.7171
Twin	27-0656-00	Hennepin	No	13					7	1715.39	132:01:00	44.0028	-93.3384
Unnamed East*	27-0108-00	Hennepin	No	9.2				7.7	12	385	42:01:00	45.0019	-93.5065
Unnamed West	27-0468-00	Hennepin	No	16				4.5	7	283	18:01	45.00096	-93.5013
Victoria	27-0051-00	Hennepin	No	10					4.3	174.67	17:01	44.0028	-93.4008
Virginia	10-0015-00	Carver	Yes	113	30	26	1210	11	34	3995.42	35:01:00	44.8833	-93.6357
Wassermann	10-0048-00	Carver	Yes	166	112	67		10	41	2889.86	17:01	44.841	-93.6737
Wassermann West Bay	10-0048-02	Carver	No	6.4					20	2889.86	452:01:00	44.84061	-93.6825
Wassermann Pond North	10-0200-01	Carver	No	5.4			1530		60	2889.86	535:01:00	44.84761	-93.6662
Wassermann Pond South	10-0200-02	Carver	No	10					36	2889.86	289:01:00	44.8446	-93.6689
Westling*	27-0714-00	Hennepin	No	3.6					3	23.55	7:01	44.95115	-93.3891

Basins	**MnDNR ID**	**County**	**Public Access**	**Area (ac)**	**Littoral Area (ac)**	**% Littoral Area**	**Volume (ac-ft)**	**Mean Depth (ft)**	**Max Depth (ft)**	**Water-shed Area (ac)**	**Watershed to Lake Area Ratio**	**Latitude**	**Longitude**
William	27-0142-00	Hennepin	Yes	16					12	131.33	8:01	44.91803	-93.5472
Windsor	27-0082-00	Hennepin	Yes	10					5	197.56	20:01	44.96435	-93.41
Wolsfeld	27-0157-00	Hennepin	No	34	25		380	11	26	1592.28	47:01:00	45.00707	-93.5751
Zumbra*	10-0041-00	Carver	Yes	221	89	55		14	58	523.56	2:01	44.8891	-93.6632