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2015 Annual Water Quality Report




Prepared for:

Shingle Creek and West Mississippi
Watershed Management Commissions

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Executive Summary

The Shingle Creek and West Mississippi Watershed Management Commissions annually monitor water quality in the lakes, streams and outfalls of the watersheds. The Commissions' technical staff obtains the stream and some lake water quality data while volunteers collect most lake water quality and stream and wetland macroinvertebrate and vegetation data.

Water quality in a given year is influenced by the amount of precipitation and the type of precipitation events. Overall, 2015 was an above average precipitation year. Rainfall in late summer (July) and fall (November) were above average, while spring (April, May, and June) precipitation was below average. This annual variability is why ongoing, long-term monitoring is necessary to determine potential trends in the data and what may be considered natural variability.

Water quality in Shingle Creek and Bass Creek and in the outfalls of the West Mississippi watershed is typical of an urban stream in the Twin Cities metropolitan area, and is dominated by watershed runoff. Continued monitoring of stream water quality will allow us to evaluate the effectiveness of BMPs, assess progress toward TMDLs, and provide a baseline for reasonable water quality goals.

The lakes in Shingle Creek are typical of urban lakes. Thirteen of the 16 lakes are listed as Impaired Waters due to excess nutrients, and TMDLs and Implementation Plans have been approved for all 13 of the lakes. Three of the lakes are proposed for delisting on the pending 303(d) list of Impaired Waters – Lower Twin Lake, Ryan Lake, and Schmidt Lake.

The lake TMDLs and the Shingle and Bass Creeks chloride, biotic, and dissolved oxygen TMDLs and Upper Mississippi River bacteria TMDL set forth action plans for improving water quality and biotic integrity in the impaired lakes and streams in the Shingle Creek watershed.

1.0 Introduction

1.1 BACKGROUND

Minnesota Administrative Rule 8410.0100 Subp.5 requires watershed management organizations to conduct monitoring programs "capable of producing accurate data to the extent necessary to determine whether the water quality and quantity goals of the organization are being achieved."

The Shingle Creek and West Mississippi Watershed Management Commissions (WMC) began monitoring water quality and streamflow in 1990. In Shingle Creek, 12 sites were monitored from 1992-1995, however monitoring was discontinued from 1992 – 1995. Shingle Creek has since resumed on an annual basis at two long-term monitoring sites (SC-0 and SC-3) (Figure 1.1). In 2013, a third stream monitoring site was added near the outlet of Bass Creek (BCP). The West Mississippi WMC monitored water quality and streamflow from 1990-1992 at two outfall sites in the Oxbow Creek and Mattson Brook watersheds (Figure 1.1). Results indicated very little flow in these tributaries and no water quality or quantity problems or concerns. Thus, the Commission chose to discontinue monitoring after the 1992 monitoring season. In 2010, the Commission elected to once again monitor water quality and flow at 2-3 outfall monitoring sites per year in the West Mississippi watershed.

Thirteen of the sixteen lakes in Shingle Creek are periodically monitored for water quality by volunteers through the Citizen Assisted Monitoring program (CAMP) (Figure 1.1). Two lakes were monitored through the CAMP program in 2015: Bass Lake and Lake Magda. Additionally, Wenck staff conducted intensive monitoring on Cedar Island, Eagle, and Pike Lake in 2015 as part of the 5-year TMDL review for these lakes. High school volunteers coordinated by Hennepin County Environmental Services (HCES) performed macroinvertebrate monitoring at two locations in 2015 on Shingle Creek. Due to lack of volunteers no monitoring was performed on Mattson Brook in the West Mississippi watershed (Figure 1.1). HCES also coordinates wetland monitoring by adult volunteers. In 2015, wetland monitoring was performed at two locations in the Shingle Creek watershed, and three locations in the West Mississippi watershed (Figure 1.1).

1.2 OBJECTIVES

The Shingle Creek and West Mississippi WMCs have established monitoring objectives to guide their monitoring programs. The following objectives have been established for stream, outfall and lake monitoring in both watersheds:

- To quantify the current status of streams/outfalls and lakes (Shingle Creek only) throughout the watershed in comparison to state water quality standards established for nutrients, turbidity, chloride, bacteria, and other parameters currently regulated by the State.
- To quantify changes over time, or trends, in stream and lake water quality in the Shingle Creek and West Mississippi watersheds.
- To quantify the effectiveness of implemented BMPs throughout the watershed for the protection of water quality.

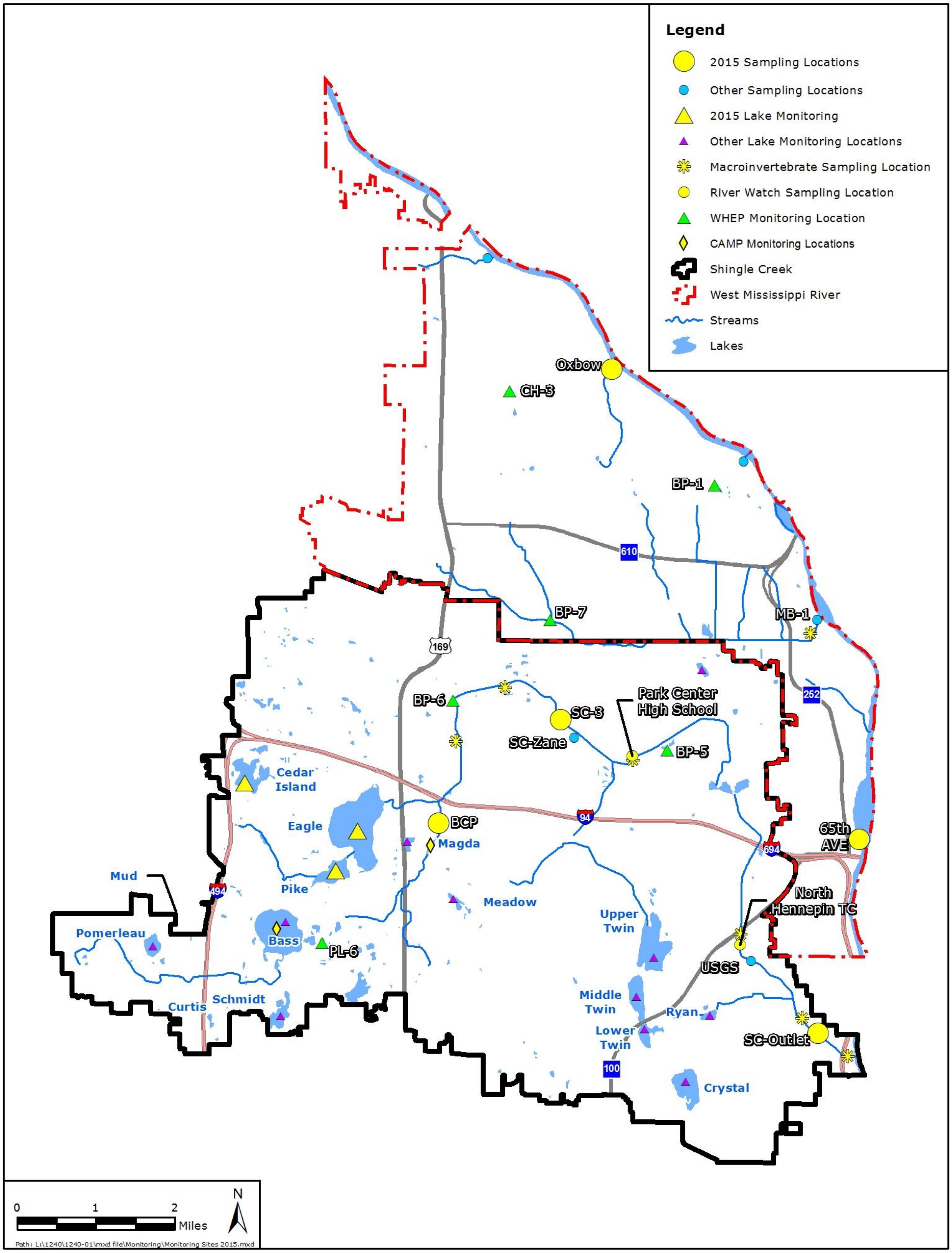


Figure 1.1. Shingle Creek and West Mississippi stream, outfall and lake sites.
Note: Stream and Lake monitoring stations in yellow were sampled in 2015.

1.3 TMDLS AND IMPLEMENTATION PLANS

Most of the lakes in the Shingle Creek watershed do not meet state standards for water quality, and are included on the Minnesota Pollution Control Agency (MPCA) 303(d) List of Impaired Waters. The 303(d) list is named after the section of the federal Clean Water Act that requires states to set water quality standards and to assess conditions in lakes, rivers, and streams to determine if those standards are being met. If the standards are not met, a Total Maximum Daily Load (TMDL) study must be completed to identify the course of action needed to restore the resource to meet state standards. Table 1.1 below shows the Impaired Waters in the Shingle Creek watershed. Regional or statewide impairments that affect the watershed are also noted in Table 1.1 and are being sponsored by the MPCA. The Commission has completed TMDLs for the balance of the impairments.

Each TMDL establishes a water quality goal and a pollutant load reduction to achieve that goal. A separate TMDL Implementation Plan sets forth actions that will be undertaken by various stakeholders. Those actions include the continuation and expansion of lake and stream monitoring to assess progress toward the load reductions and water quality goals.

Table 1.1. Impaired Waters in the Shingle Creek watershed.

Water Resource	Impairment	Date TMDL Approved	5-year Review
Bass Lake	Nutrients	9/25/09	In process
Cedar Island Lake	Nutrients	4/14/10	2016-2017
Crystal Lake	Nutrients	3/25/09	In process
Eagle Lake	Nutrients	4/14/10	2016-2017
Lake Magda	Nutrients	9/30/10	2017
Meadow Lake	Nutrients	3/23/10	2017
Pike Lake	Nutrients	4/14/10	2016-2017
Pomerleau Lake	Nutrients	9/25/09	In process
Ryan Lake	Nutrients	11/9/07	2014
Schmidt Lake	Nutrients	9/25/09	In process
Upper, Middle, and Lower Twin Lake	Nutrients Mercury in fish PFOS in fish PCB in fish	11/9/07 3/27/07 (MPCA) Not yet begun (MPCA) Not yet begun (MPCA)	Completed 2014
Shingle Creek	Chloride	2/14/07	Completed 2014
Shingle Creek	Dissolved oxygen	11/4/11	2017
Shingle Creek	Biota-macroinvertebrates	11/4/11	2017
Shingle Creek	*E. coli*	11/20/14 (MPCA)	2019
Bass Creek	Biota-fish	11/4/11	2017
Bass Creek	Chloride	Metro wide TMDL awaiting final approval (MPCA)	2019

2.0 Precipitation

Table 2.1 summarizes monthly precipitation data for the New Hope National Weather Service located in the Shingle Creek watershed (Figure 2.1). Precipitation was well above average in July and November, and was close to average or below average during all other months. Precipitation was well below average in the spring of 2015, which is unusual since spring months usually receive the greatest amount of precipitation. Overall, precipitation was 3.04 inches above normal in 2015, which was driven by above average rainfall during late summer and fall months.

Table 2.1. 2015 precipitation measured at the New Hope weather station.

Month	2015 Precipitation (inches)	1992-2015 Monthly Average Precipitation (inches)	Departure from Long-Term Average (inches)
January	0.34	0.99	-0.65
February	0.31	0.89	-0.58
March	0.80	1.81	-1.01
April	1.81	3.21	-1.40
May	4.46	4.19	0.27
June	3.37	4.56	-1.19
July	8.30	4.36	3.94
August	2.98	3.79	-0.81
September	3.79	2.97	0.82
October	2.93	2.68	0.25
November	4.56	1.69	2.87
December	1.86	1.34	0.52
TOTAL	35.51	32.47	3.04

3.0 West Mississippi Outfall Monitoring

3.1 OVERVIEW

Water quality and continuous flow were collected at two outfall locations (Oxbow and 65th Avenue) in the West Mississippi watershed in 2015 (Figure 3.1). Located in Champlin, the Oxbow storm sewer outfall site was first sampled during the 1990-1992 West Mississippi monitoring program. When monitoring resumed in 2010, this site was not sampled the first few years because the outfall to the Mississippi River was completely submerged and not accessible to sample. In 2013, an alternative site upstream of where the outfall discharges to the Mississippi River at 112th Avenue North was selected for monitoring (Figure 3.1). Flow at this site is contained below ground in a 48 inch pipe which is accessible through a 2 foot manhole. Most of the Oxbow outfall watershed consists of a series of storm sewer pipes that drain approximately 1,167 acres of land in Champlin.

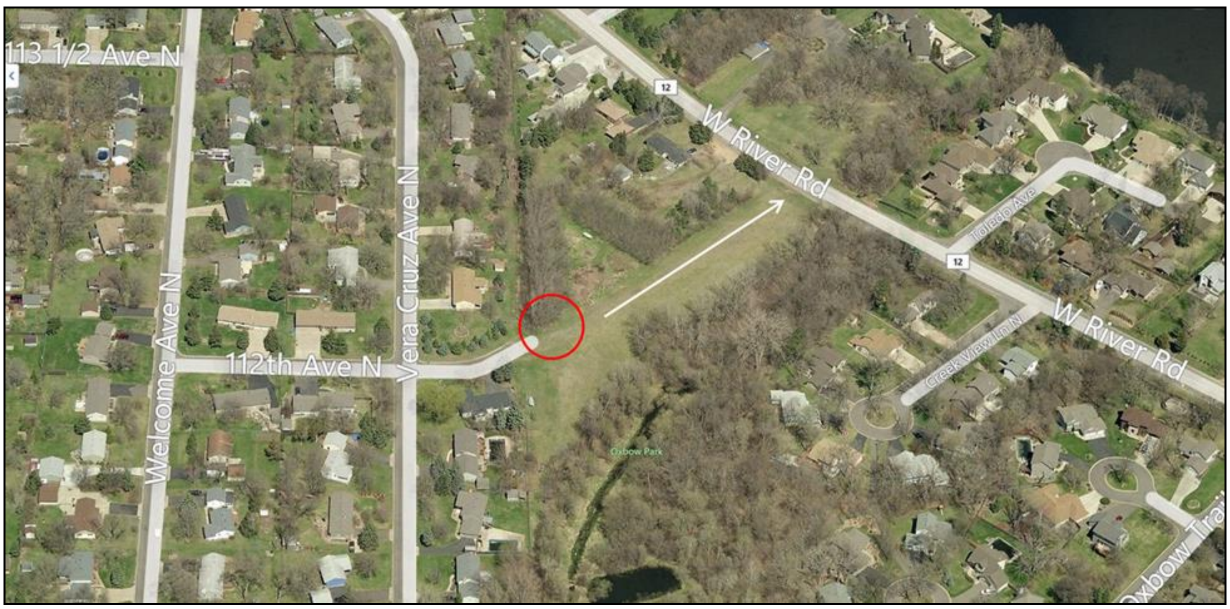


Figure 3.1. Oxbow outfall monitoring location and general flow direction.

The 65th Avenue outfall is located in Brooklyn Center at the northeast corner of the Highway 252 and Interstate 694 interchange (Figure 3.2). This outfall drains approximately 590 acres of land in Brooklyn Center, which includes runoff from the Regal Cinema and other commercial and industrial land west of Highway 252.

Figure 3.2. 65th Avenue outfall monitoring location and general flow direction.

3.2 HYDROLOGY

Water level (stage) was continually recorded from early-April through early-September at the Oxbow and 65th Avenue outfalls. Flow at each station was estimated using measured stage data in the storm sewer pipe and applying Manning's equation for uniform flow. Culvert dimensions and physical parameters were derived from as-built drawings (Appendix B). Figure 3.3 shows the 15-minute flow data (hydrograph) for each site. Both sites typically have consistent base-flow and exhibit extremely flashy hydrographs during storm events. During storm events, the hydrograph rises quickly and typically peaks within 30 minutes of the initial rainfall, then subsides to base-flow conditions within a few hours. This type of flow response is common in smaller urban catchments.

3.3 WATER QUALITY

Routine water quality sampling for each outfall station consisted of monthly base-flow grab samples from May through early October. Six composite storm samples were collected at the Oxbow site and four from the 65th Avenue site using automated sampling equipment. The base-flow and storm samples were analyzed for total phosphorus (TP), ortho phosphorus (ortho-P), and total suspended solids (TSS). Field parameters including dissolved oxygen (DO), temperature, pH, and conductivity were also recorded during each monthly base-flow sample.

The following section provides one page summaries of two major water quality parameters of concern for the West Mississippi outfalls: TSS and TP. Both outfalls outlet to the Mississippi River which is impaired for TSS (TMDL is in draft form), and a potentially TP based on the newly adopted state river eutrophication standards.

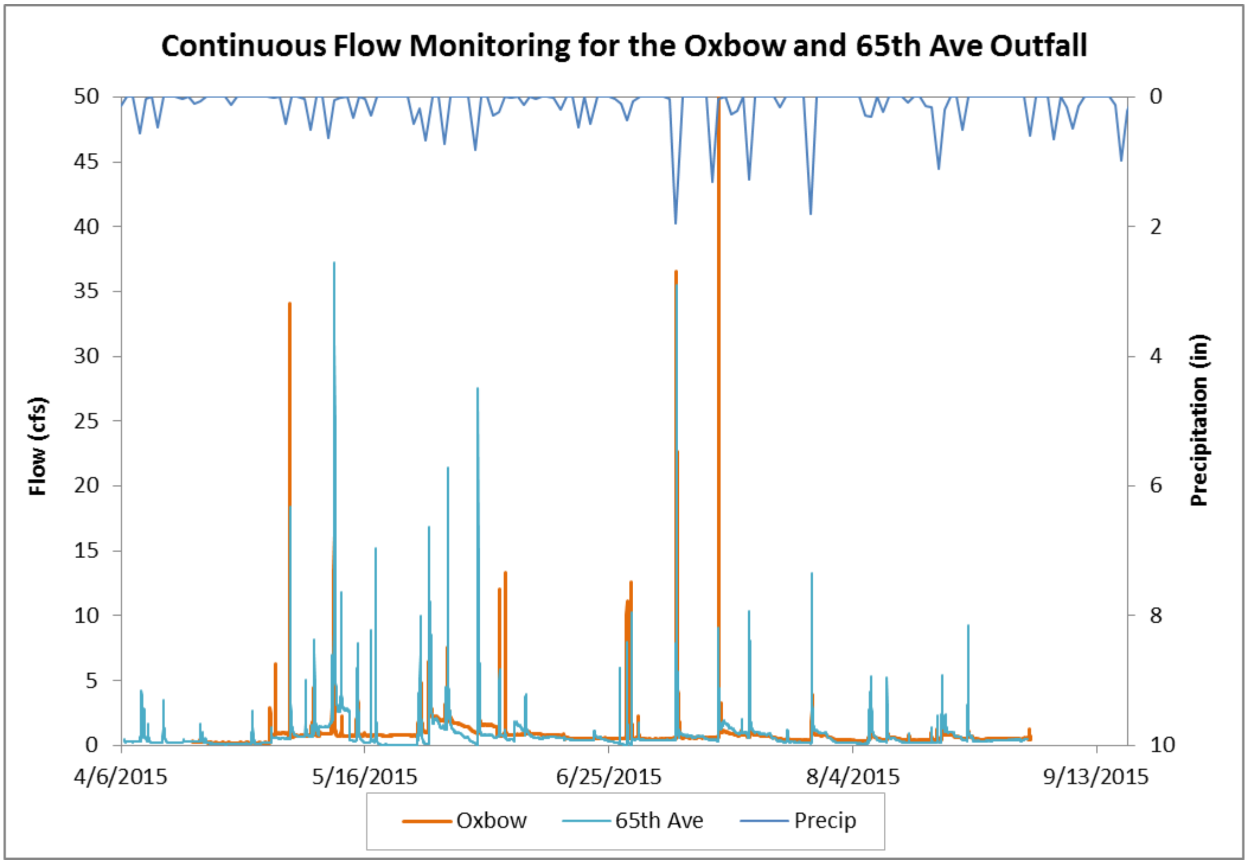


Figure 3.3. 15-minute flow measurements for the West Mississippi outfall monitoring sites.

Neither the Oxbow or 65th Avenue outfalls have been assigned beneficial use classifications by the State of Minnesota. Both features are underground stormwater conveyance systems and for comparison purposes could be considered similar to Class 7 waters set forth in Minnesota Rules Chapter 7050. Class 7 waters are defined as limited resource value waters that are not subject to state water quality standards as they are not protected for aquatic life and recreation due to lack of water, lack of habitat, or extensive physical alterations. However, both outfalls discharge directly to the Mississippi River, which is a class 2B water. Class 2B waters of the state are subject to certain pollutant water quality standards that are intended to protect aquatic life and recreation. For each water quality parameter discussed below, the class 2B standards are plotted to provide a general benchmark and give a sense of current water quality conditions of each site and how they may be impacting water quality in the Mississippi River.

Sediment

Why We Monitor Sediment

Total suspended sediment (TSS) is the amount of mineral (e.g. soil particles) and/or organic (e.g. algae) solids suspended in the water column. High concentrations of TSS cause turbid conditions which can lead to poor water clarity, decreased light penetration, and increased sedimentation and siltation. These conditions can lead to degraded habitat for fish and macroinvertebrates. TSS particles also provide sorption or attachment sites for other pollutants, such as metals and bacteria. Thus, high TSS can be used as "indicators" of other potential pollutants.

State Standards and TMDLs

The Oxbow and 65th Avenue storm sewer outfalls to the Mississippi River are not subject to the state water quality standards that govern class 2 waters (streams and rivers). The draft South Metro Mississippi River TSS TMDL includes general TSS allocations and will require 20 percent reductions in annual loading from the Upper Mississippi watershed. When this TMDL is adopted, the West Mississippi outfall monitoring data will be assessed against the TMDL requirements. Until then, the newly adopted 30 mg/L TSS standard for 2B streams will be used as a general benchmark.

Watershed Actions to Address Sediment

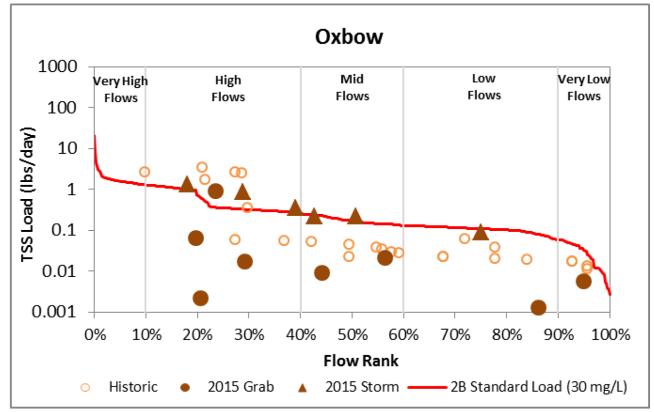
Numerous Best Management Practices such as ponds, infiltration basins, and rain gardens have been constructed in the watershed to capture and filter sediment from runoff. Cities have also increased street sweeping to capture particles and organic material.

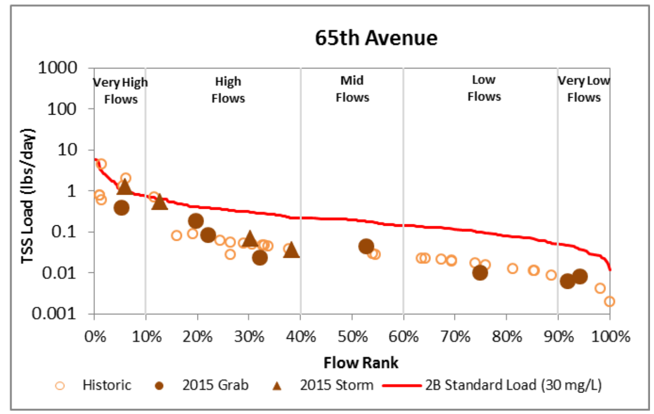
Sampling Results and Data Trends

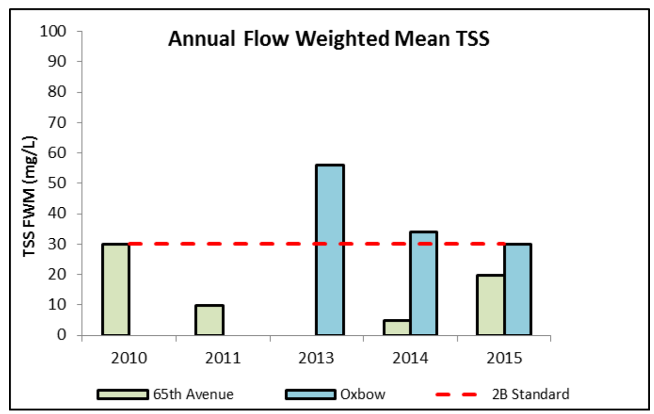
Oxbow outfall TSS concentrations are high during the high and very high flow conditions. All of the elevated samples were collected during, or shortly after rainfall storm events using automated sampling equipment. TSS concentrations for the Oxbow outfall were low and at or near detection limit (<5 mg/L) during the mid, low and very low flow conditions.

TSS at the 65th Avenue outfall is similar to the patterns noted for the Oxbow outfall. Elevated TSS was observed only during large storm events and very high flow conditions. TSS was at or below detection limit (<5 mg/L) during the high, mid, low and very low flow conditions.

These outfalls have only been sampled for a few years, which makes it difficult to determine long-term trends. At the 65th Avenue outfall, there is no clear trend in relation to TSS. Flow weighted mean (FWM) TSS decreased at the Oxbow outfall between 2013, 2014, and 2015. Several more years of TSS monitoring will need to be conducted to determine if these outfalls are exhibiting any real water quality trends.







Phosphorus

Why We Monitor Phosphorus

Phosphorus is an essential nutrient for all life forms and occurs naturally in soils and aquatic systems. High concentrations of phosphorus in streams can lead to algal blooms which decrease water clarity, and also depletes DO needed by aquatic organisms. Phosphorus in streams is typically measured in two ways, ortho-phosphate (ortho-P) and total phosphorus (TP). Ortho-P is the chemically active dissolved form of phosphate that algae and plants can directly consume. TP includes both ortho-P and particulate phosphorus (from plant and animal fragments and phosphorus attached to soil particles and suspended sediment).

In 2005 the State of Minnesota banned the general use of phosphorus in fertilizers used on lawns and turf, allowing it only where soil tests indicate a need.

State Standards and TMDLs

The Oxbow and 65th Avenue storm sewer outfalls to the Mississippi River are not subject to the state water quality standards that govern class 2 waters (streams and rivers). The Mississippi River flows to Lake Pepin, which is impaired for TP. The Lake Pepin Nutrient TMDL is in progress and will develop TP allocations and reduction targets for the Mississippi River watershed. At that time the outfall monitoring data can be assessed against the requirements set forth in the TMDL. Until then, the 100 µg/L TP standard for 2B streams and rivers will be used as a general benchmark.

Watershed Actions to Address Phosphorus

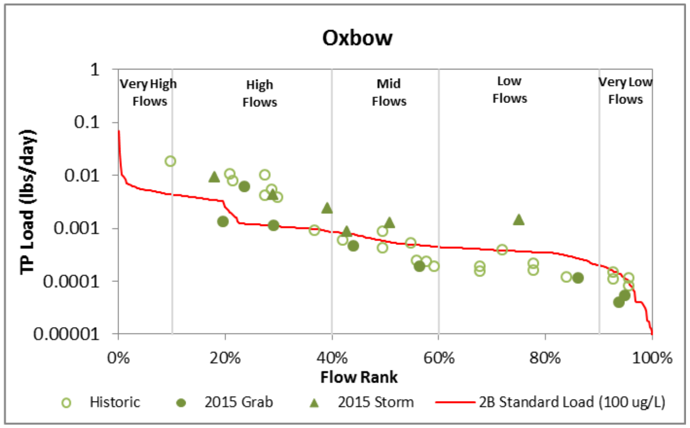
Numerous Best Management Practices such as ponds, infiltration basins, and rain gardens have been constructed in the watershed to capture and filter phosphorus from runoff. Cities have also increased street sweeping to capture particles and organic material.

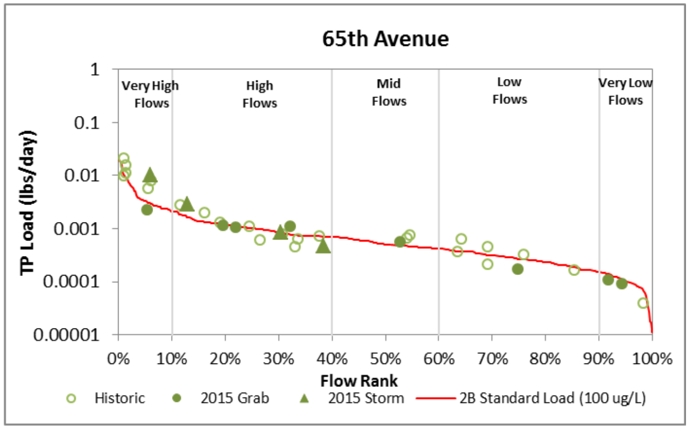
Sampling Results and Data Trends

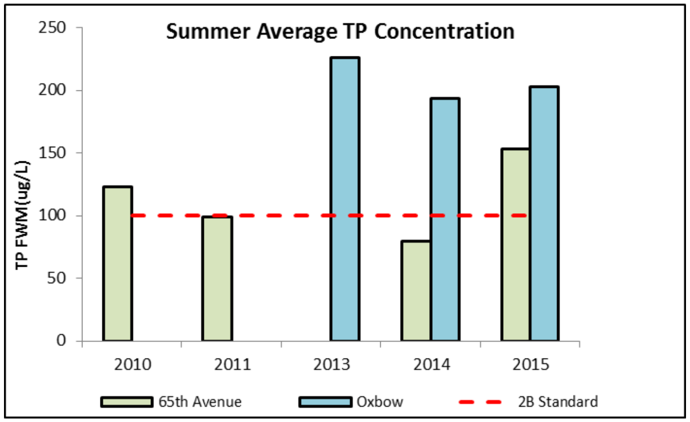
Oxbow outfall TP concentrations are elevated during high and very high flow conditions. All of the elevated samples were collected during or shortly after rainfall storm events, where the phosphorus from sediment and organic material is easily washed off into storm sewers. TP concentrations are lower during mid and low flows, but exceedances still do occur.

TP at the 65th Avenue outfall exceeds 100 µg/L across most flow regimes. Interestingly, elevated TP concentrations were not observed during rainfall events during 2015. Since TP concentrations are consistently high, but do not appear to be influenced by storms the resulting TP FWM is consistently near the 100 µg/L standard.

Oxbow outfall TP FWMs are consistently high on an annual basis. High TP FWM concentrations appear to be driven by storm events with elevated TP concentrations. The 65th Avenue station has lower annual FWM. This suggests that stormwater runoff is the primary cause of annual exceedances since baseflow TP concentrations are typically below the 100 µg/L standard.







3.4 SUMMARY AND RECOMMENDATIONS

Results of the 2015 flow and water monitoring for the Oxbow and 65th Avenue outfalls support the following conclusions and recommendations:

- Overall, 2015 was an above average year for precipitation and runoff in the West Mississippi watershed.
- The above average precipitation and rainfall in 2015 was driven by an unusually wet late-summer and fall. Rainfall was at or below average during the spring and early-summer.
- Flow data collected at the Oxbow and 65th Avenue sites in 2015 indicate these outfalls are extremely flashy and respond quickly to rainfall events.
- Both the Oxbow and 65th Avenue outfalls have continuous, year around baseflow and never go dry or stop flowing.
- Due to the flashiness of these sites, high TSS concentrations at the Oxbow and 65th Avenue outfalls have only been observed during "first flush" events using automated sampling equipment. TSS levels fall quickly to below detection limit (<5 mg/L) within a few hours of storm event. TSS does not seem to be a major concern at these outfalls.
- High TP concentrations at both outfalls sites are typically associated with higher flow events and therefore follow a similar pattern to TSS. Dissolved phosphorus (ortho-P) at both stations is relatively low, suggesting most of the phosphorus is in particulate form and likely attached to TSS particles.

4.0 Shingle Creek Stream Monitoring

4.1 OVERVIEW

Continuous flow monitoring and water quality data was collected at two long-term stations (SC-0 and SC-3) and one newer station in Bass Creek (BCP) in 2015 (Figure 4.1). Station SC-0, also referred to as the outlet site or Webber Park site, is upstream of the 45th Avenue crossing in Minneapolis. The SC-3 monitoring station is on Shingle Creek at Brooklyn Boulevard, west of Zane Avenue in Brooklyn Park. The BCP site is in Bass Creek Park in Brooklyn Park. SC-0 collects drainage from about 41 square miles, or approximately 93% of the watershed. The drainage area for SC-3 covers about 21 square miles which is approximately 47% of the Shingle Creek watershed. The BCP drainage area covers 8 square miles, or about 18% of the Shingle Creek watershed.

Additionally, there is one long-term USGS monitoring station on Shingle Creek at Queen Avenue near the border of Minneapolis and Brooklyn Center. This site is upstream of SC-0 and drains approximately 31 square miles (70% of the watershed). The Shingle Creek WMC and USGS collected continuous flow and storm event samples at this location from 1996 through 1999. The USGS has monitored continuous flow at this site since 2001 and continuous conductivity since 2004. Real-time data is available through the USGS website (http://waterdata.usgs.gov/mn/nwis/uv?05288705).

4.2 HYDROLOGY

Stream stage (water level) was continuously recorded from April 8 through November 13 at the BCP, SC-0, and SC-3 monitoring stations. Stage was converted to flow using site-specific stage-discharge relationships (Appendix B). Flows outside the monitored period at each station were estimated using regression relationships with the USGS station, which operates and records flow measurements year around (Appendix B). Figure 4.1 presents the daily rainfall and average daily flow data for SC-0. Figure 4.2 presents daily rainfall and cumulative flow volume for all four Shingle Creek monitoring stations. The largest cumulative flow occurred in late July and November, which were in response to a series of rainfall events in late-summer and fall. Typically, the largest increases in cumulative flow volume occur in the spring, however, this was not observed in 2015.

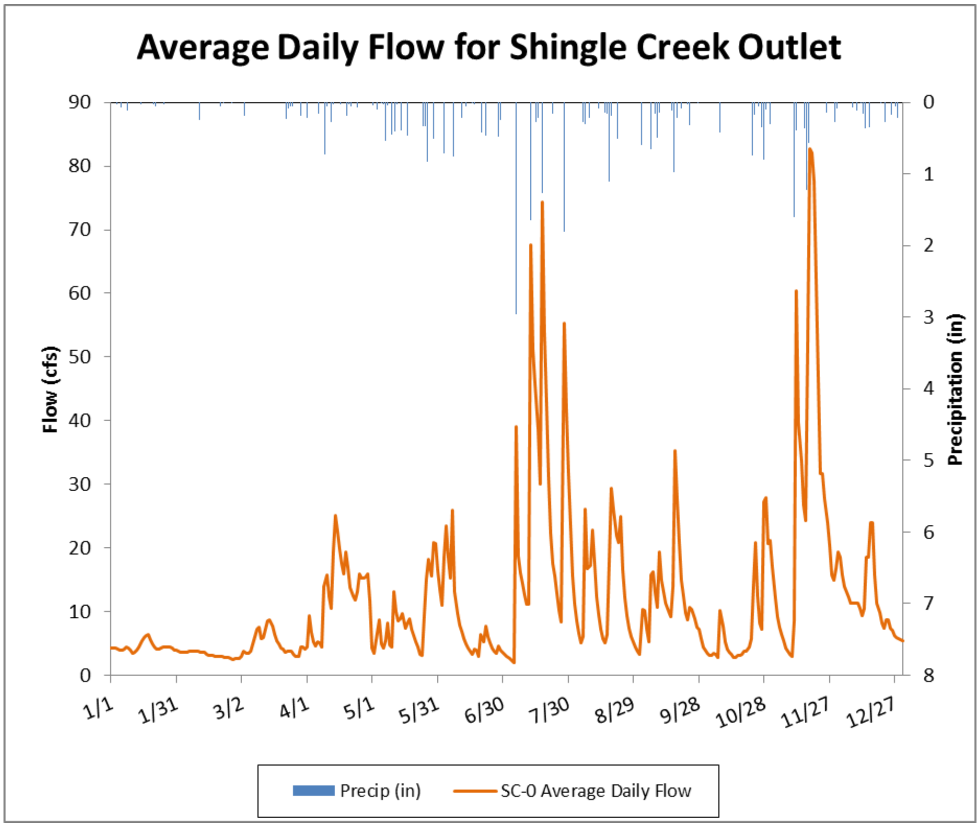


Figure 4.1. 2015 average daily flow for Shingle Creek SC-0 monitoring station.

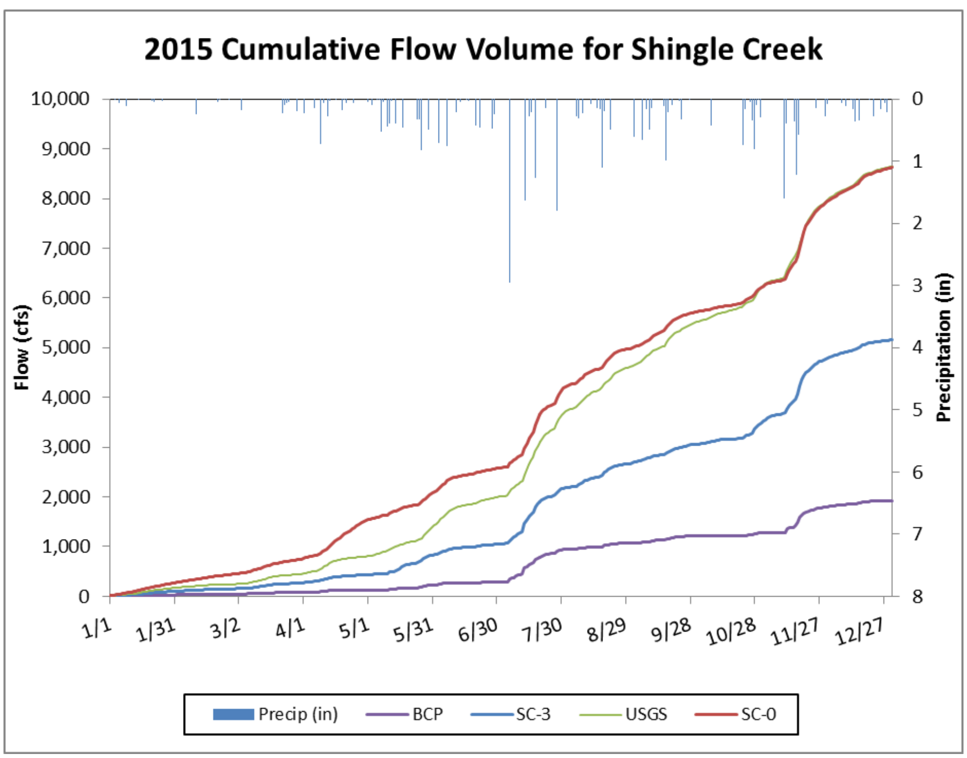


Figure 4.2. 2015 cumulative flow volume for each Shingle Creek monitoring station.

Annual runoff depth and precipitation in inches for 2015 and the previous fifteen years are presented in Figure 4.3. The runoff depths for each flow monitoring station were calculated by dividing annual flow volume by the total area (acres) that drains to each station. Results indicate runoff depths for each monitoring station are quite variable and driven by the annual precipitation for that year, as well as precipitation in the preceding 1-2 years. For example, 2010 experienced above average rainfall (approximately 5.5 inches above normal), however runoff at all three monitoring stations was well below normal. Drought conditions and below average precipitation in both 2008 and 2009 likely resulted in increased storage availability throughout watershed which led to the low runoff observed in 2010.

In general, runoff depth decreases from upstream to downstream (BCP to SC-0) throughout the Shingle Creek watershed. Bass Creek (BCP) exhibited the highest runoff depth of all the Shingle Creek stations in 2013 and 2014. However, Bass Creek runoff depths in 2015 were similar to the other monitoring stations. Bass Creek and the upper portions of the watershed tend to have more areas with tighter soils than the lower watershed. Overall, flow volumes and runoff depths were low in 2015 despite above average rainfall conditions. This is likely due to the timing of storm events in 2015. The below average spring rainfall (April and May) resulted in low runoff volumes during the time of year we expect to see the largest amount of runoff.

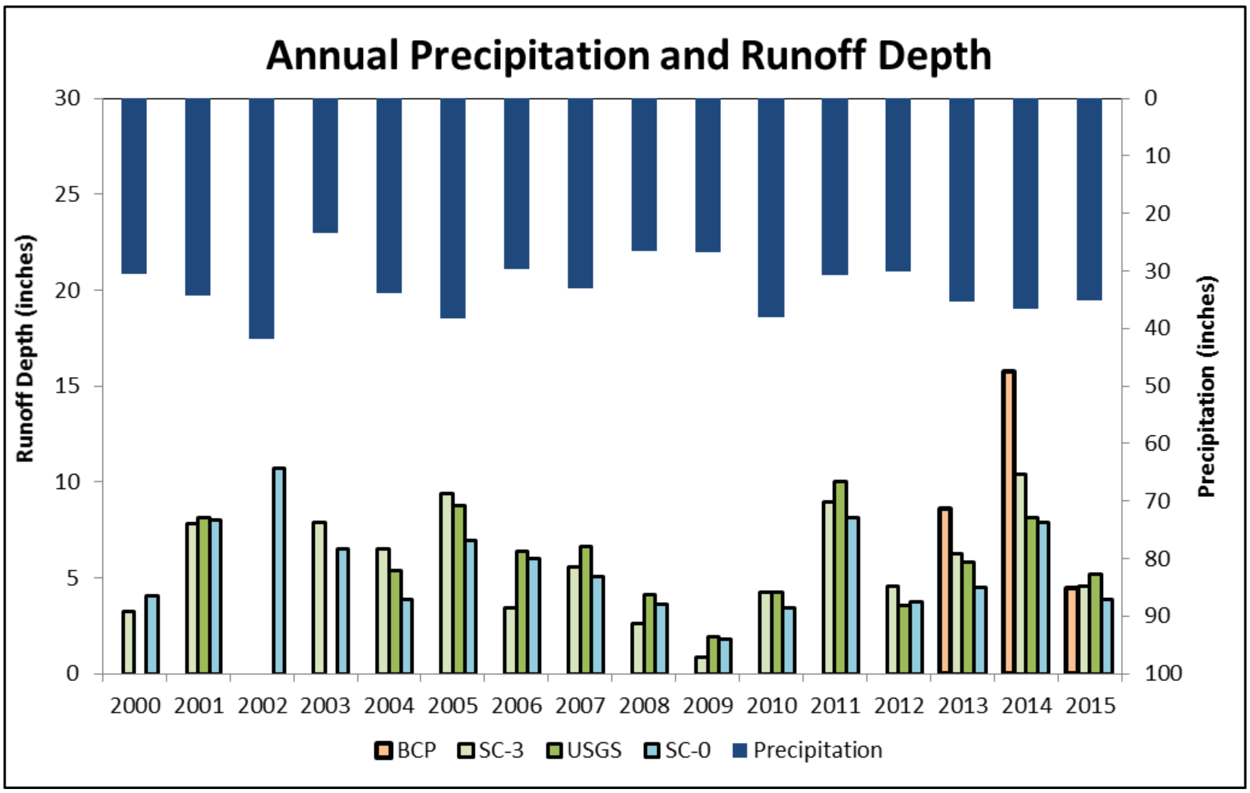


Figure 4.3. Annual precipitation and runoff depth for Shingle Creek monitoring stations.

4.3 WATER QUALITY

Routine water quality sampling in Bass Creek and Shingle Creek consisted of bi-weekly grab samples at BCP, SC-3, and SC-0 from early April through October. In addition to bi-weekly water quality samples, at least four storm composite samples were collected at each monitoring station. Routine and storm samples at each site were analyzed for TSS, TP, ortho-P, total Kjehldal nitrogen (TKN), nitrate, chloride. Field parameters including dissolved oxygen (DO), temperature, pH, and conductivity were also recorded during each routine sample site visit.

This section provides one page summaries of four major water quality parameters of concern for Bass Creek and Shingle Creek: TSS, TP, chloride, and DO. The selected parameters either have completed TMDL studies (chloride and DO), or may be subject to future TMDL studies based on newly adopted or proposed state water quality standards (TSS and TP).

One parameter not covered in this section, *E. coli*, has not been monitored in the Shingle Creek watershed since 2012. Historic *E. coli* monitoring in Shingle Creek indicate bacteria levels are high and consistently exceed state water quality standards. In November 2014 the MPCA completed the Upper Mississippi River Bacteria TMDL Study and Protection Plan which outlines bacteria allocations and reductions for Shingle Creek and other tributaries to the Upper Mississippi River. The Shingle Creek watershed is assigned a 69 percent reduction in *E. coli* loading to the Mississippi River. The MPCA will allocate wasteload reductions to each of the MS4s in the watershed.

Monitoring results for the water quality parameters not covered in this section (ortho-P, TKN and nitrate) are summarized in Appendix C. Appendix C also provides a summary of annual pollutant loads for each parameter calculated using the Flux32 Load Estimate Software (Walker, 1999).

Bass Creek and Shingle Creek are considered class 2B waters and are subject to certain pollutant water quality standards that are intended to protect aquatic life and recreation. Protection of aquatic life is defined as the maintenance of healthy, diverse, and successfully reproducing populations of aquatic organisms, including invertebrates as well as fish. For each water quality parameter discussed below the current or class 2B water quality standards are plotted to give a general sense of water quality conditions in Bass and Shingle Creek.

Sediment

Why We Monitor Sediment

Total suspended sediment (TSS) is the amount of mineral (e.g. soil particles) and/or organic (e.g. algae) solids suspended in the water column. High concentrations of TSS cause turbid conditions which can lead to poor water clarity decreased light penetration, and increased sedimentation and siltation. These conditions can lead to degraded habitat for fish and macroinvertebrates. TSS particles also provide sorption or attachment sites for other pollutants, such as metals and bacteria. Thus, high TSS can be used as an indicator of other potential pollutants.

State Standards and TMDLs

In 2011, the MPCA published a technical support document for state-wide TSS standards for all Minnesota rivers and streams. TSS standards were approved by EPA in January 2015. For Shingle Creek, the newly adopted TSS standards will require a concentration limit of 30 mg/L that must not be exceeded more than 10% of the time from April through September over a multiyear data window.

Watershed Actions to Address Sediment

Numerous Best Management Practices such as ponds, infiltration basins, and rain gardens have been constructed in the watershed to capture and filter sediment from runoff. Cities have also increased street sweeping to capture particles and organic material.

Streambank erosion can also contribute to TSS, and several bank stabilization projects have been completed on Shingle and Bass Creeks.

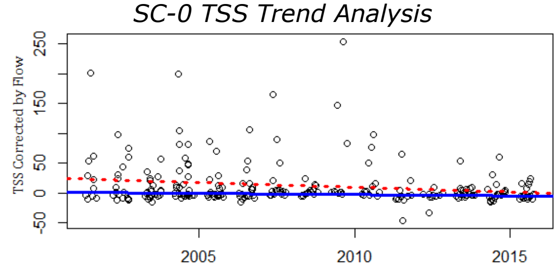
Sampling Results and Data Trends

For Bass Creek, only 7% of the TSS samples collected between April and September in 2013, 2014, and 2015 exceed the 30 mg/L TSS standard. There are several large lakes and flow-through wetlands upstream of the monitoring location, which likely settle out most of the larger sediment particles.

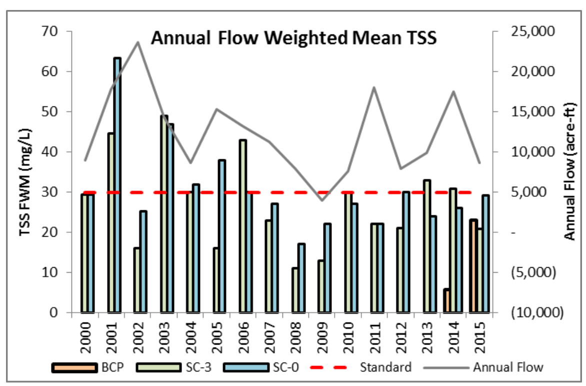
For Shingle Creek, approximately 19% (SC-3) and 23% (SC-0) of the TSS samples collected between April and September in the last 10 years exceed the 30 mg/L TSS standard. TSS exceedances are most common during the "very high" and "high" flow conditions. In general these flow conditions are associated with rain events greater than 0.5 inches.

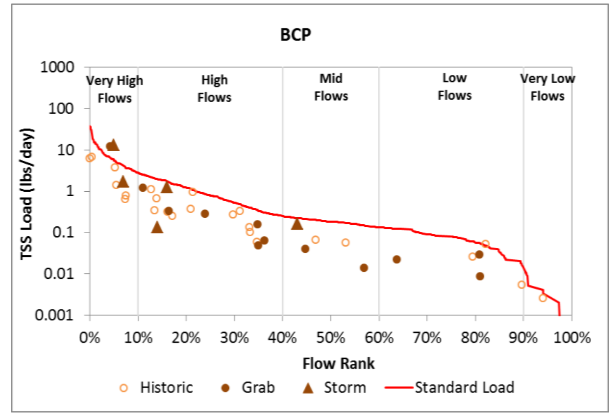
A Mann-Kendall trend analysis on historical SC-0 TSS data shows that there has been a significant decrease in suspended solid concentrations. This analysis compares TSS values over time and adjusts for flow. A clear trend can be seen when looking at the annual flow weighted mean TSS for SC-0 and SC-3.

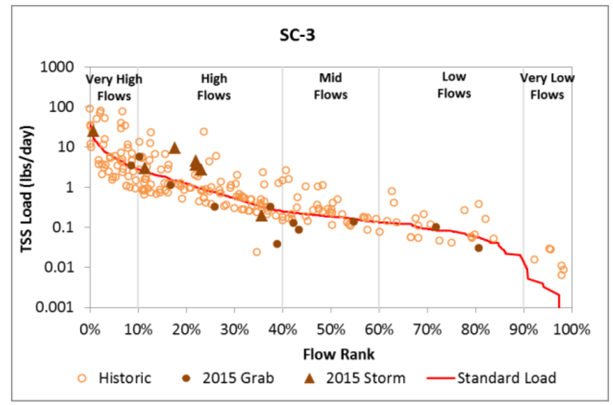
SC-0 TSS Trend Analysis

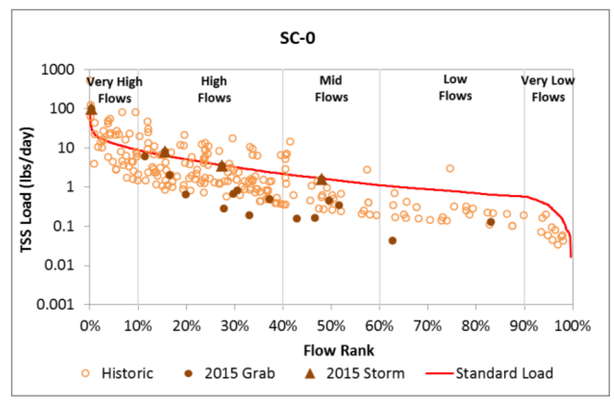


Note: Blue line represents if no trend exists. Red line represents the Thiel-Sen trend line









Phosphorus

Why We Monitor Phosphorus

Phosphorus is an essential nutrient for all life forms and occurs naturally in soils and aquatic systems. High concentrations of phosphorus in streams can lead to algal blooms that decrease water clarity and depletes DO needed by aquatic organisms. Phosphorus in streams is typically measured in two ways: ortho-phosphate (ortho-P) and total phosphorus (TP). Ortho-P is the chemically-active dissolved form of phosphate that algae and plants can directly consume. TP includes both ortho-P and particulate phosphorus (from plant and animal fragments and phosphorus attached to soil particles and suspended sediment).

In 2005 the State of Minnesota banned the general use of phosphorus in fertilizers used on lawns and turf, allowing it only where soil tests indicate a need.

State Standards and TMDLs

In 2013, the MPCA published a technical support document which proposed state-wide standards for TP and other eutrophication criteria for all Minnesota rivers and streams. For Bass and Shingle Creeks, the TP standard requires summer (June-September) average TP concentration limit of 100 µg/L.

The 2013-2015 monitoring data for Bass Creek average summer TP concentration is 125 µg/L. For Shingle Creek, average summer TP concentrations for the past 10 years are 164 µg/L (SC-3) and 151 µg/L (SC-0).

Watershed Actions to Address Phosphorus

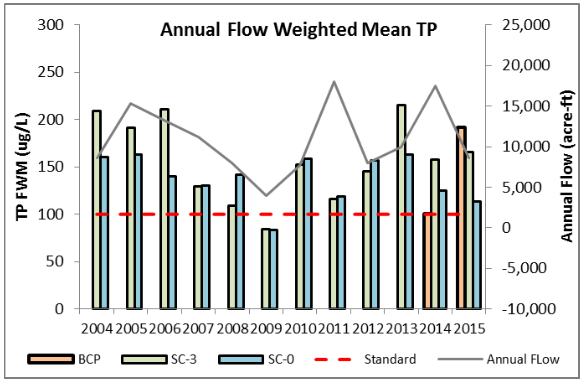
Numerous Best Management Practices such as ponds, infiltration basins, and rain gardens have been constructed in the watershed to capture and filter phosphorus from runoff. Cities have also increased street sweeping to capture particles and organic material.

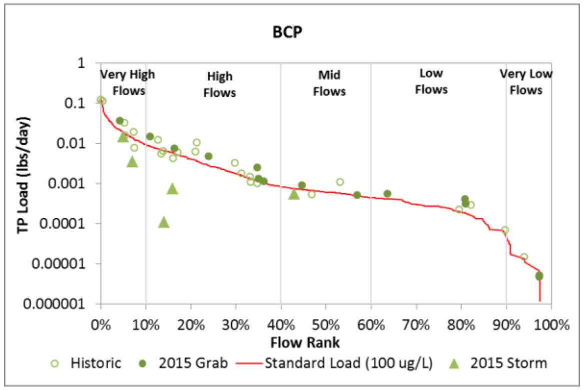
Sampling Results and Data Trends

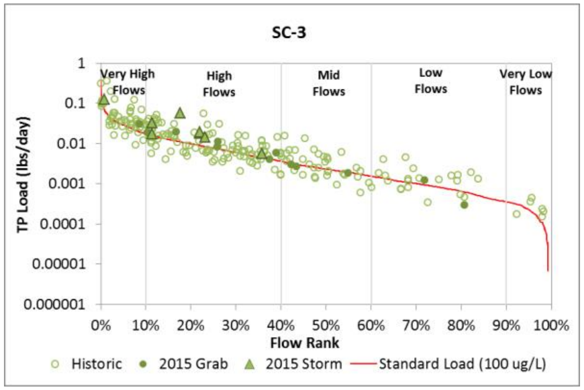
Bass Creek TP concentrations are high and exceed State standards during all flow conditions. In Bass Creek, most of the TP at lower flow conditions is comprised of ortho-phosphate. The Bass Creek monitoring station is downstream of Bass Lake and the Cherokee Wetland, which may be releasing high levels of ortho-phosphate from sediment during summer low-flow conditions.

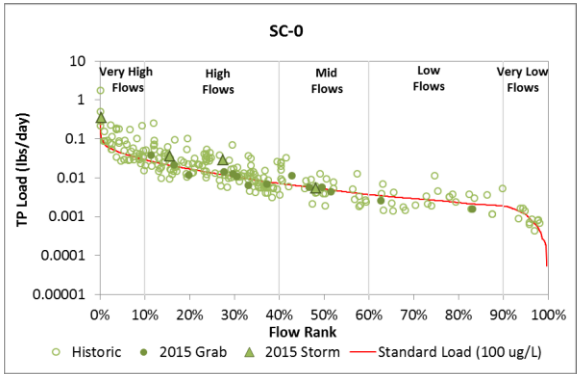
Shingle Creek TP concentrations are consistently high and regularly exceed the 100 µg/L proposed standard. TP is slightly higher at SC-3 compared to SC-0, which may be the result of upstream loading from Bass Creek.

Historic TP trends (figure below) indicate summer average TP concentrations fluctuate year to year depending on site and flow condition. Sampling has only been conducted in Bass Creek for three years; however summer average TP concentrations were above the proposed standard both years. Shingle Creek summer TP is consistently low with no significant data trends since 2000.









Chloride

Why We Monitor Chloride

Chloride is one of the major anions found in saltwater and freshwater systems. Chloride originates from the dissolution of salts in water that are found in soils as well as human/ industrial pollution. Elevated chloride levels in urban streams are an indicator of non-point source loading from salt piles or urban streets where road salt has been applied. High levels of chloride can harm aquatic organisms by interfering with their osmo-regulatory capabilities.

State Standards and TMDLs

Minnesota chloride standards for Class 2B waters state two or more samples exceeding 230 mg/L (chronic standard) over a consecutive three year period indicate impairment. Additionally, one or more samples exceeding 860 mg/L (acute standard) over the most recent 3 year period would also be considered impaired.

In 1998, Shingle Creek was designated as impaired for chloride. Bass Creek was designated as impaired in 2002. A TMDL and Implementation Plan were approved in 2007. The TMDL determined that the likeliest source of chloride to the creek was road salt and that a 71% load reduction across the watershed was necessary to meet the TMDL.

In 2014 the Commission undertook a review of progress toward meeting the TMDL. Road salting operations can vary widely event to event and even city to city depending on temperature and precipitation. This leads to extreme variability in the data year to year and even day to day, complicating efforts to identify trends.

Watershed Actions to Address Chloride

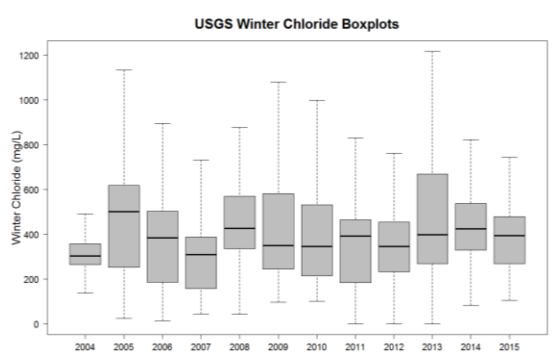
Most of the road authorities in the watershed are now pre-wetting road salt as it is applied, a technology that can reduce application rates by 25% or more. They are also more closely tailoring application rates to pavement temperature and implementing other practices to most efficiently use road salt.

The Commission has sponsored workshops for private applicators to learn about new application practices to reduce the use of salt.

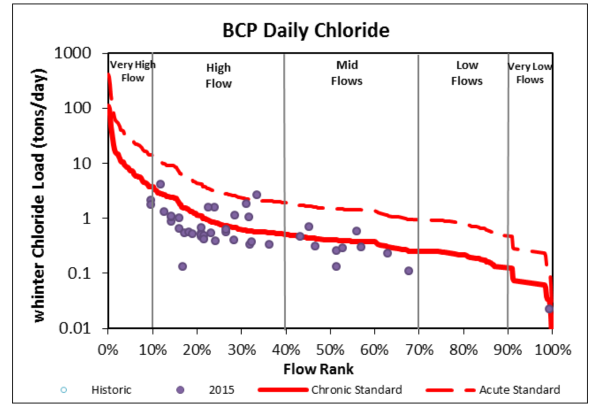
Sampling Results and Data Trends

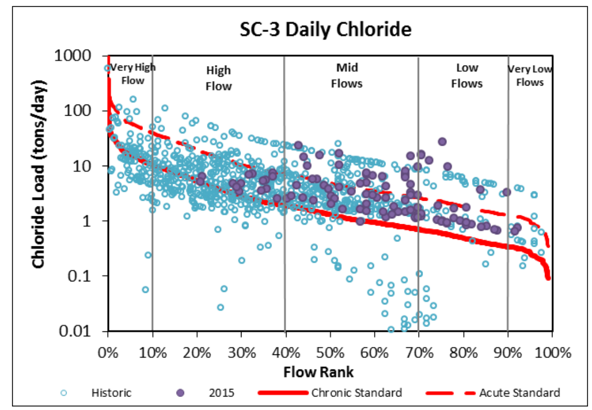
Winter chloride sampling for Shingle Creek shows concentrations are high and consistently exceed the chronic standard at all three monitoring stations.

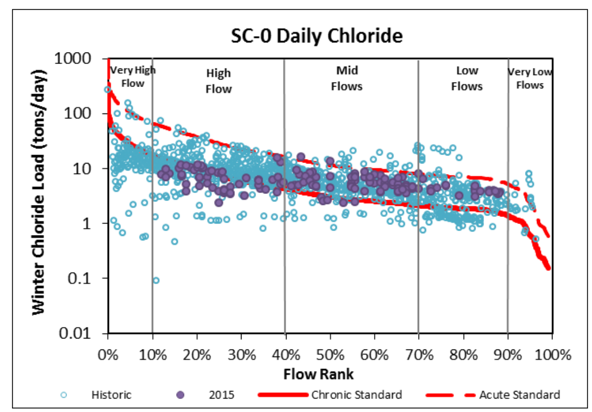
The 5-year TMDL review did note a downward trend in the rate of road salt application for some road authorities. However, historic chloride data recorded at the USGS station (figure below) do not show any significant trends in winter chloride concentrations since the TMDL was completed in 2007. Due to the annual and seasonal nature of chloride, it will likely take several more years of monitoring data before in-stream chloride trends are observed.



Note: Black line denotes the median annual concentration







Dissolved Oxygen

Why We Monitor DO

Dissolved oxygen (DO) is required by aquatic organisms for survival. If DO drops below acceptable levels, fish and other aquatic organisms may be harmed or die. DO concentrations experience daily cycles in most river and stream systems with concentrations reaching daily maximums in late afternoon when photosynthesis by aquatic plants is at its highest. Minimum DO concentrations typically occur early in the morning around sunrise when respiration rates exceed photosynthesis and oxygen is being consumed by aquatic organisms faster than it is replaced. Stream DO is also affected by water column and/or sediment oxygen consumption that occurs through the breakdown of organic compounds or reduced chemical compounds. Critical conditions for stream DO usually occur during late summer when water temperatures are high and stream flows are low.

State Standards and TMDLs

The Minnesota standard for class 2B cool/warm water fisheries requires DO concentrations shall not fall below 5.0 mg/L as a daily minimum in order to support the aquatic life and recreation of the system. Measurements are typically taken in early morning before 9 am when DO is at its lowest.

In 1998, Shingle Creek and Bass Creek were designated as impaired for DO. A TMDL and Implementation Plan were approved in 2007. The TMDL determined that the likeliest source of low DO was headwater DO conditions (Northland Wetland and Palmer Lake), and sediment oxygen demand in the various flow-through wetlands and overwidened sections of the creek. A 70-97% load reduction in sediment oxygen demand was required to meet the TMDL.

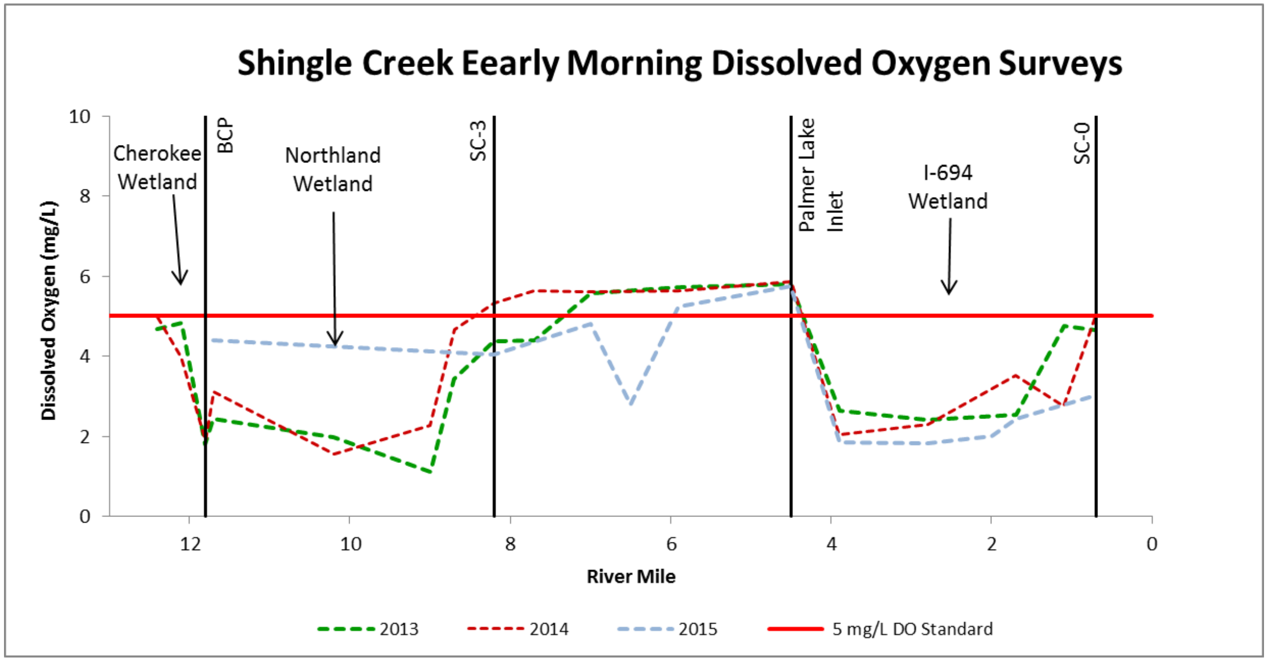
Watershed Actions to Address DO

Cities have stabilized over four miles of stream to incorporate stream aeration features such as riffles and rock vanes, and to narrow overwide channels to reduce sediment oxygen demand. Three aerators will be constructed in Shingle Creek in 2017 in areas with low dissolved oxygen.

Sampling Results and Data Trends

Longitudinal surveys were not performed in 2015 as part of the routine monitoring program; however, combining individual observations (before 9:00 am) and DO observations for other projects produced enough DO data to compare 2015 data to 2013 and 2014 longitudinal surveys. All sites were visited before 9:00 am to ensure that daily minimum DO measurements were being recorded.

2015 DO data showed the reach between the outlet of Palmer Lake to Bass Lake Road (I-694 wetland) had DO concentrations below 2.5 mg/L, likely due to large wetland complexes. Historically, DO in the Northland Wetland between the BCP and SC-3 monitoring sites has been below 2.5 mg/L. In 2015, DO concentrations were slightly higher (~4 mg/L) than previous years. Generally, stream reaches with wetlands decrease stream velocity, which allows for greater contact time with organic rich substrate. This combination of slow moving water and high organic matter results in low DO in these portions of Shingle Creek.



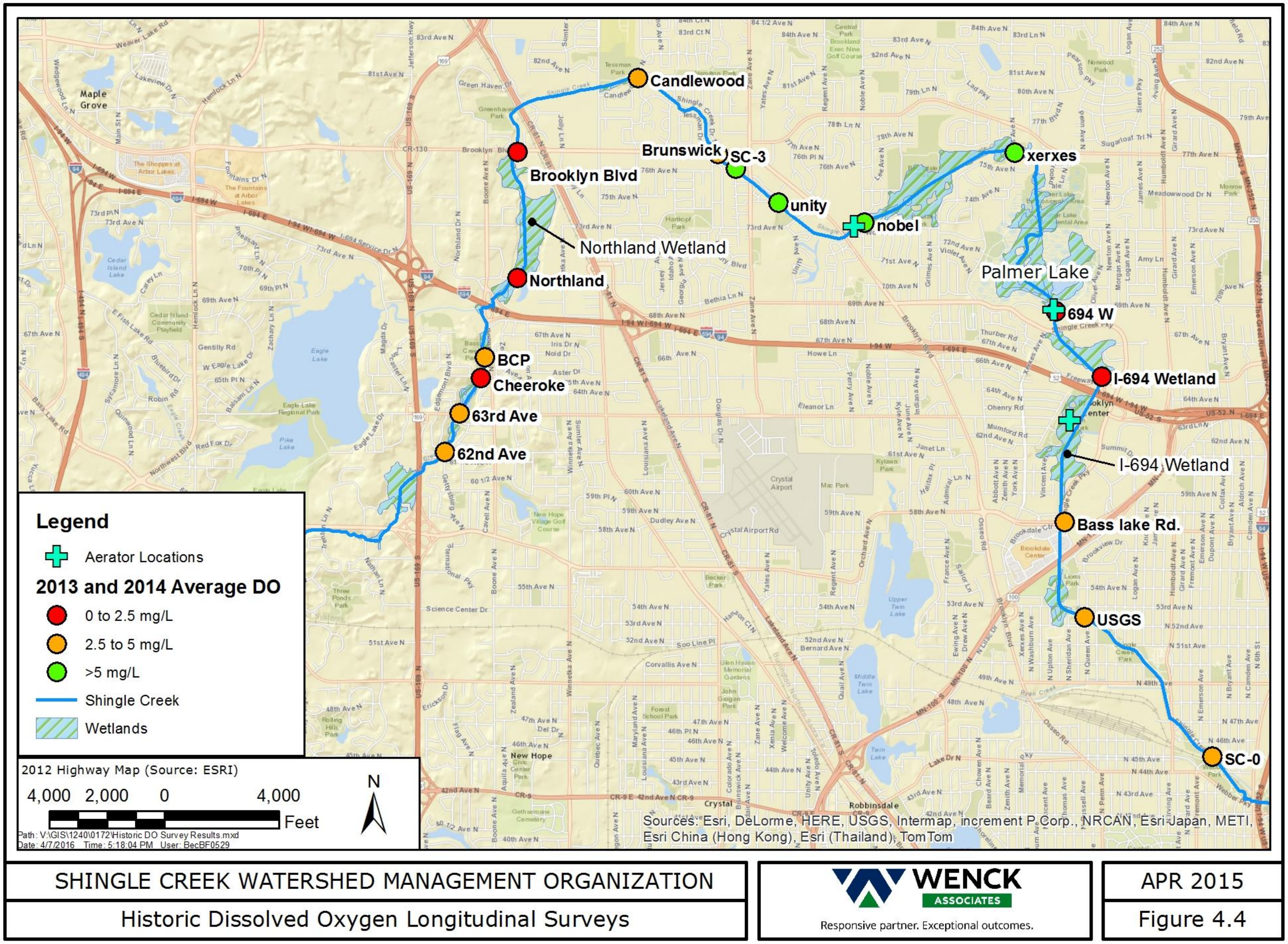


Figure 4.4. Historical dissolved oxygen longitudinal survey results for Shingle Creek.

4.4 SUMMARY AND RECOMMENDATIONS

Results of the 2015 flow and water quality monitoring for Shingle and Bass Creek support the following conclusions and recommendations:

- Overall, 2015 was an above average year in terms of precipitation, but a below average year for runoff in the Shingle Creek watershed.
- The above average precipitation and rainfall in 2015 was driven by a several large rain events in July and November. Rainfall was at or below average for all other months in 2015.
- Sediment (TSS) is consistently low in Bass Creek during all flow conditions, likely due to settling in wetlands and lakes upstream of the Bass Creek monitoring station. For Shingle Creek, TSS is low and not a concern at SC-3 and SC-0 during base-flow conditions and non-storm events. Elevated levels of TSS at SC-3 and SC-0 are common following rainfall events greater than 0.5 inches. Continuing to increase infiltration and treatment in the watershed will help reduce inflow of sediment during storm events.
- Overall, average annual TSS appears to have decreased in Shingle Creek since 2001, however concentrations still occasionally exceed state standards. It is recommended that TSS monitoring in Shingle Creek continue in order to verify these trends.
- Phosphorus (TP) is high in Bass Creek and consistently above the 100 µg/L proposed standard. Phosphorus is relatively low at SC-3 and SC-0 as summer average concentrations are well below State standards. The high phosphorus levels in Bass Creek are likely the result of phosphorus release from sediments in the Cherokee wetland upstream of the Bass Creek monitoring site. Paired sampling (upstream and downstream) of the Cherokee Wetland should be considered in 2017 to determine if it is a source of phosphorus to Bass Creek. If it is, BMPs such as aerators and/or iron enhanced sand filters may could be considered.
- A recent review of the Shingle Creek chloride TMDL found that most of the road authorities in the watershed are now pre-wetting road salt as it is applied, which can reduce application rates by 25% or more. However, historic chloride data recorded at all three Shingle Creek monitoring stations do not show any significant trends in stream chloride concentrations. Due to the annual and seasonal nature of chloride, it will likely take several years of monitoring before in-stream trends are observed.
- Early morning sampling in 2015 confirmed DO to be a concern throughout much of the creek, particularly downstream of flow-through wetland systems. DO sags (decreases) were observed downstream of the Cherokee Wetland, Northland Wetland, Palmer Lake, and the large wetland system downstream of Palmer Lake. The Section 319 grant to install artistic reaeration structures will address two of these locations. Additionally, channel alteration through these wetland systems and/or bypass could be considered to improve DO.

5.0 Citizen Assisted Lake Monitoring Program

5.1 OVERVIEW

There are 16 lakes in the Shingle Creek watershed, and none in West Mississippi. The Shingle Creek Watershed Management Commission has participated in the Metropolitan Council's Citizen Assisted Lake Monitoring Program (CAMP) since 1996. This program is also an NPDES Education and Public Outreach BMP.

CAMP was initiated by the Met Council to supplement the water quality monitoring performed by Met Council staff and to increase knowledge of water quality of Metro area lakes. Volunteers in the program monitor the lakes every other week from mid-April to mid-October, approximately 14 sampling events. They measure surface water temperature, Secchi depth, and collect surface water samples that are analyzed by the Met Council for TP, TKN, and chlorophyll-a. The volunteers also judged the appearance of the lake, its odor, and its suitability for recreation. Two lakes were monitored in 2015: Bass Lake and Lake Magda.

CAMP data supplement the monitoring conducted by the Commission every five years. The larger lakes are monitored every other year, and Magda, Success, Pomerleau, Meadow, and Cedar Island are monitored every three years.

5.2 WATER QUALITY STANDARDS

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

The State of Minnesota has established water quality standards for lakes (Tables 5.1 and 4.2). Thirteen of the 16 lakes in Shingle Creek do not meet those standards, and have been listed by the State and the EPA as Impaired Waters.

Table 5.1. State of Minnesota water quality standards.
(North Central Hardwood Forest Ecoregion)

	Total Phosphorus (µ/L)	Chlorophyll-a (µ/L)	Secchi Depth (meters)
Deep	≤40	≤14	≥1.4
Shallow	≤60	≤20	≥1.0

Table 5.2. Shingle Creek lakes by depth.

Deep		Shallow	
Eagle	Ryan	Bass	Pike
Crystal	Twin Middle	Cedar Island	Success
Pomerleau		Twin Upper	Schmidt
		Twin Lower	Magda
		Meadow	

Note: Palmer and Curtis are considered by the MnDNR to be wetlands.

5.3 2015 CAMP MONITORING RESULTS

Table 5.3 shows the provisional data from the Metropolitan Council for the two lakes monitored by volunteers in 2015. Both are shallow lakes that are impaired by excess nutrients.

Table 5.3. 2015 CAMP summer average monitoring results.
(Provisional data from Met Council; subject to change)

Lake	Summer Average		
	Total Phosphorus (µ/L)	**Chlorophyll-a (µ/L)**	**Secchi Depth (m)**
Bass Lake	76	50	0.9
Lake Magda	117	38	0.7
Shallow Lake Standard	*60*	*20*	*1.0*

Figures 5.1 and 5.2 shows the water quality data for the lakes monitored in 2015 compared to the associated water quality standard. Shallow lakes tend to experience wide fluctuations in water quality over the summer season (June to September) compared to the deep lakes. Based on the data, Bass Lake appears to start the season with relatively acceptable water quality, but then degrades as the weather becomes hotter and aquatic vegetation begins to grow. In 2015 an apparent late August algae bloom extended into early September, which saw spikes of increased TP and chlorophyll-a.

Magda's water quality was poor throughout the June-September growing season, although it did not see the high concentrations of chlorophyll-a as did Bass Lake. Lake Magda has a small watershed but a short residence time.

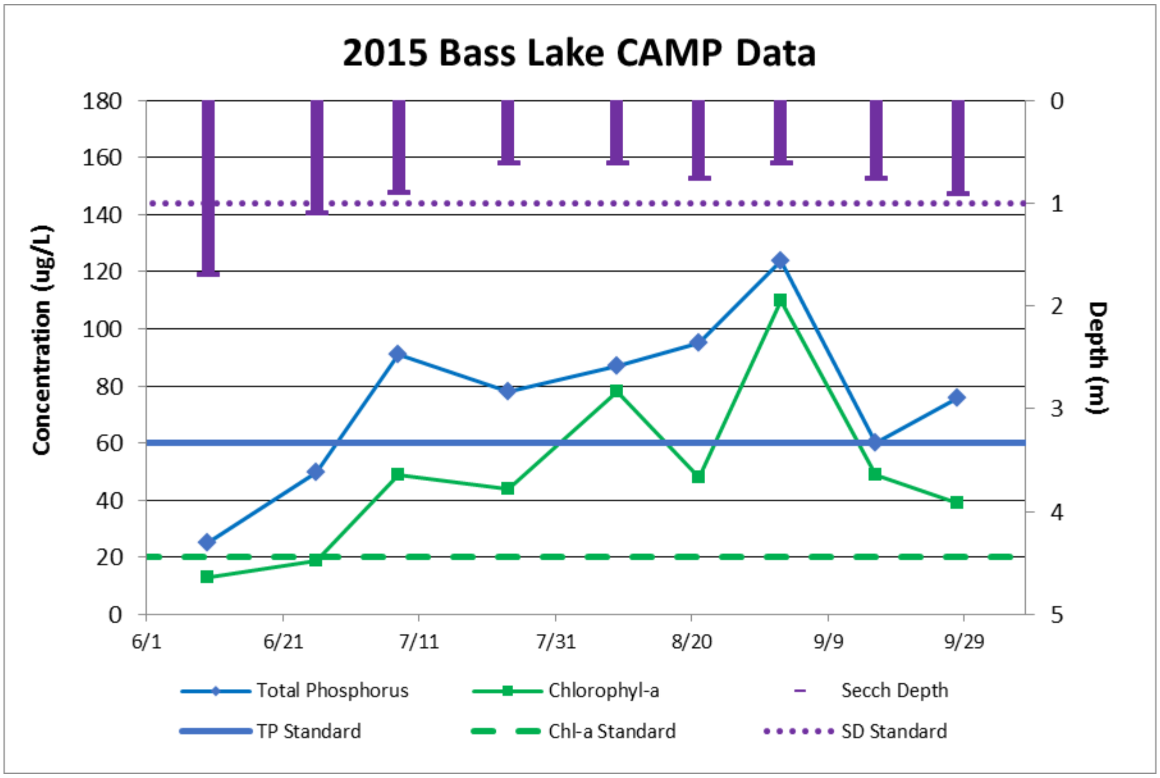


Figure 5.1. 2015 Bass Lake CAMP water quality data.

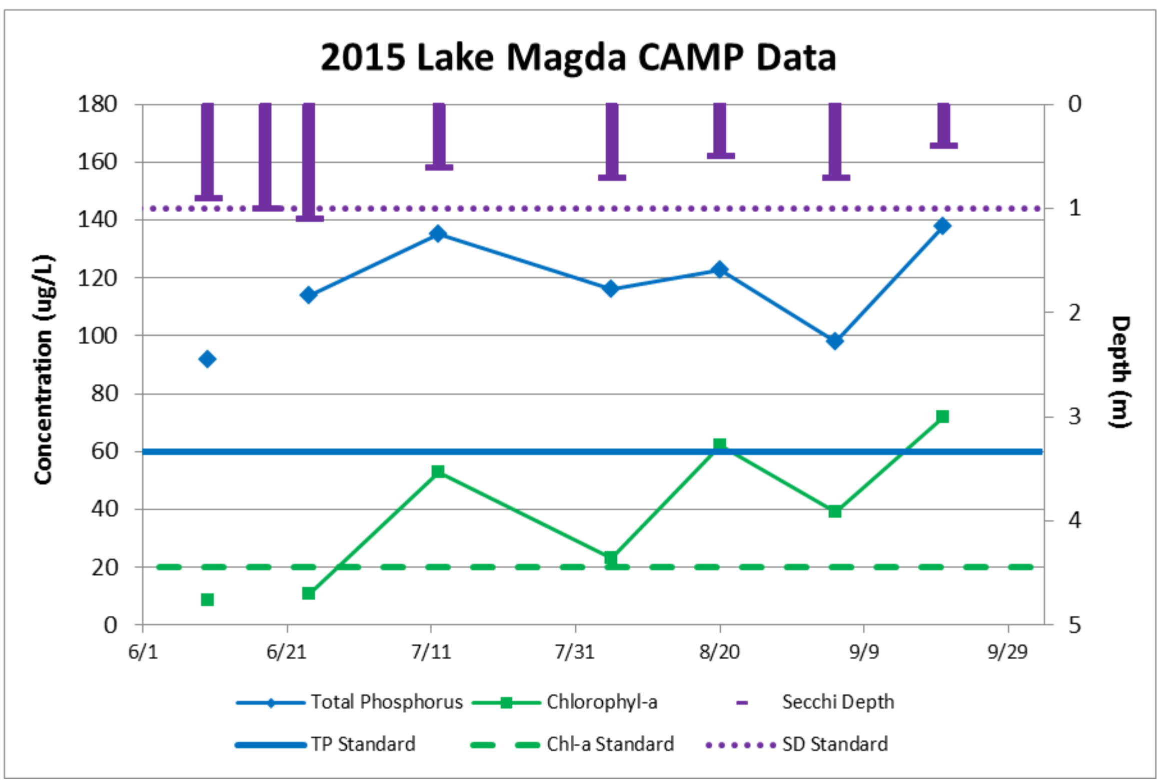


Figure 5.2. 2015 Lake Magda CAMP water quality data.

6.0 5-Year TMDL Review Lake Monitoring

6.1 OVERVIEW

Pike Lakes was placed on Minnesota's 303(d) list of impaired waters for nutrients (total phosphorus) in 2002. Cedar Island Lake was listed in 2004 and Eagle Lake was listed in 2008. A Total Maximum Daily Load (TMDL) study and Implementation Plan for those lakes and Pomerleau Lake were completed and approved in 2010. The Implementation Plans for these lakes recommended future monitoring activities to assess progress toward achieving the TMDL and state water quality standards. Those activities were incorporated into the Shingle Creek Watershed Management Commission's Third Generation Watershed Management Plan, including periodic intensive water quality monitoring, aquatic vegetation surveys, and fish sampling coordinated with the Department of Natural Resources (DNR).

This section details the results of intensive water quality sampling and vegetation surveys conducted in 2015 on Eagle and Pike Lakes in anticipation of the five year review of TMDL progress (including Cedar Island Lake) which will be started in 2016 and completed in 2017.

6.2 LAKE DESCRIPTION

Eagle Lake is approximately 287 acres in size with an average depth of 12.5 feet. About 68% of the surface area is littoral and, therefore, aquatic vegetation has an impact on the water quality in this deep lake. The residence time indicates that runoff from the watershed displaces the lake volume approximately once every 4 years. There are about 15 storm sewer outfalls discharging into the lake or its extensive wetland fringe

Pike Lake is approximately 60 acres in size with an average depth of 7 feet. About 95% of the surface area is littoral and, therefore, aquatic vegetation has a significant impact on the water quality in this shallow lake. The residence time indicates that runoff from the watershed in an average year displaces the lake volume twice per year. There are about 5 storm sewer outfalls discharging into the lake or its extensive wetland fringe.

Cedar Island Lake is approximately 79 acres in size with an average depth of 4.6 feet. The lake is entirely littoral (i.e., less than 15 feet in depth) and, therefore, aquatic vegetation has a significant impact on the water quality in this shallow lake. The residence time indicates that runoff from the watershed in an average year displaces lake volume in just over half a year, providing a significant supply of nutrients to the lake regularly. There are about 10 storm sewer outfalls discharging into the lake.

6.3 WATER QUALITY MONITORING

Water quality sampling was conducted by Wenck staff at the long-term Eagle, Pike, and Cedar Island monitoring sites in 2015. Water depth at the Eagle Lake monitoring site is approximately 30 feet deep and near the basin's deep hole. Water depth at the Pike Lake monitoring site is approximately 25 feet near the lake's deep hole. Water depth at the Cedar Island Lake monitoring site is approximately 6 feet near the lake's deep hole. For each lake, surface samples were collected bi-weekly from late May to late September and analyzed for TP, Secchi depth, and chlorophyll-a.

6.3.1 Eagle Lake Water Quality

Surface TP concentrations in 2015 initially met the 40 μg/L standard until late July when concentrations increased above the State standard from mid-August to mid-September (Figure 6.1). Chlorophyll-a concentrations initially met the shallow lake standard (14 μg/L) through late July. Chlorophyll-a concentrations peaked in late August, and remained above the standard until late-September and didn't meet State standards. Secchi depths began the season meeting deep lake standards, but decreased throughout most of the summer growing season. Historic data suggest growing season average TP, chlorophyll-a, and Secchi depths are close to meeting water quality standards (Figure 6.2).

6.3.2 Pike Lake Water Quality

Surface TP concentrations exceeded the 60 μg/L standard for shallow lakes in six of the nine site visits in 2015 (Figure 6.3). Chlorophyll-a concentrations were high in early June then decreased until a second smaller peak occurred in late-August. Secchi depth initially met water quality standards from early June until early July. Secchi depth in Pike Lake did not meet State standards from early July through late September.

Historic data suggests Pike Lake has high TP concentrations that regularly exceed the shallow lake water quality standard (Figure 6.4) and there is no clear increasing or decreasing trend. Similar to TP, average annual chlorophyll-a and Secchi depth measurements have not met shallow lake standards, however, chlorophyll-a concentrations appear to have decreased (Figure 6.4).

6.3.3 Cedar Island Water Quality

In 2015, surface TP, chlorophyll-a, and Secchi depth did not meet water quality standards for shallow lakes at any time (Figure 6.5). Historic data indicates Cedar Island Lake has not met State water quality standards for TP, chlorophyll-a, or Secchi depth in the past 16 years (Figure 6.6). Furthermore, there is no trend to indicate that water quality has improved in recent history.

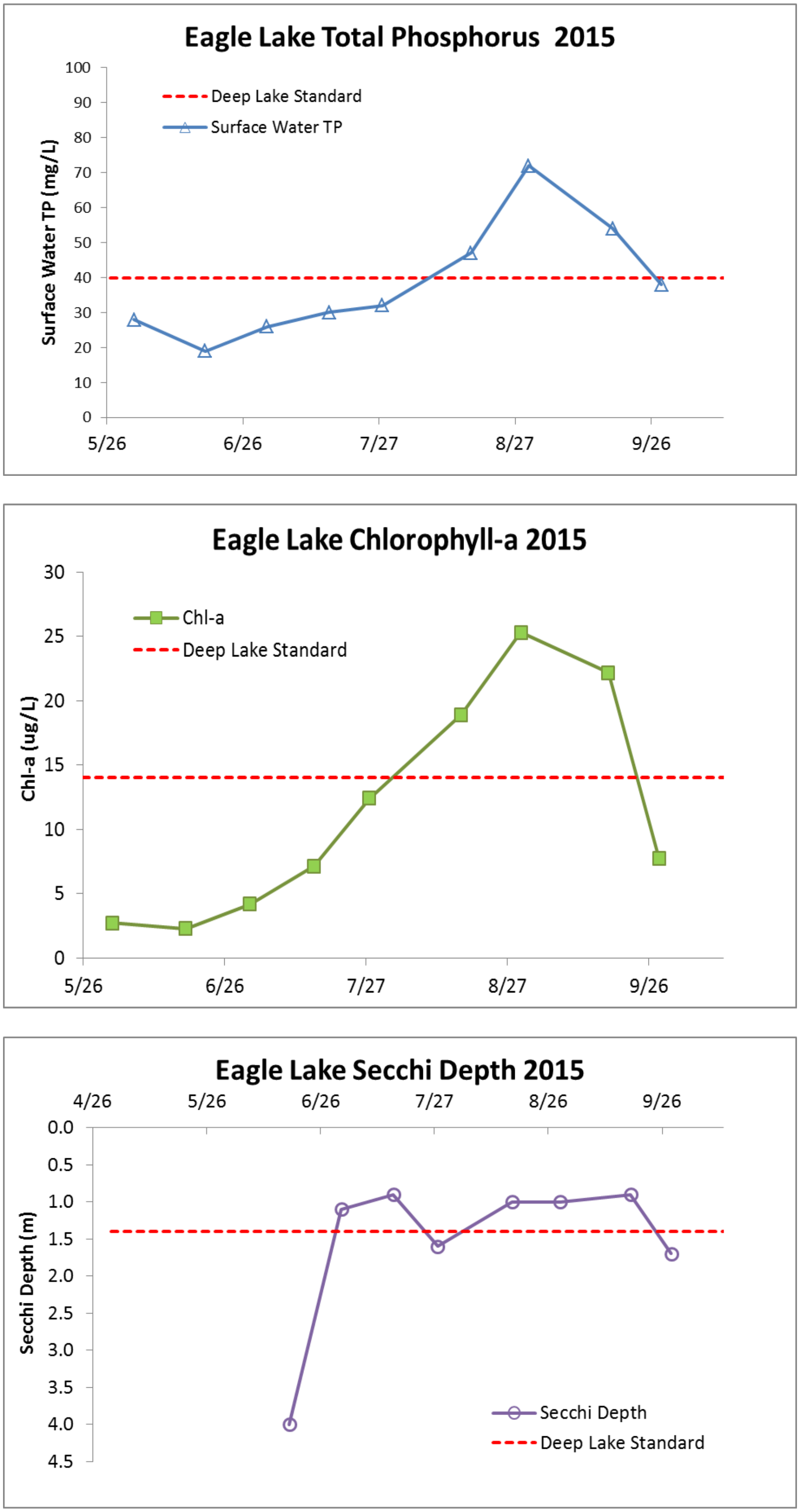


Figure 6.1. Eagle Lake 2015 TP, chlorophyll-a and Secchi depth data.

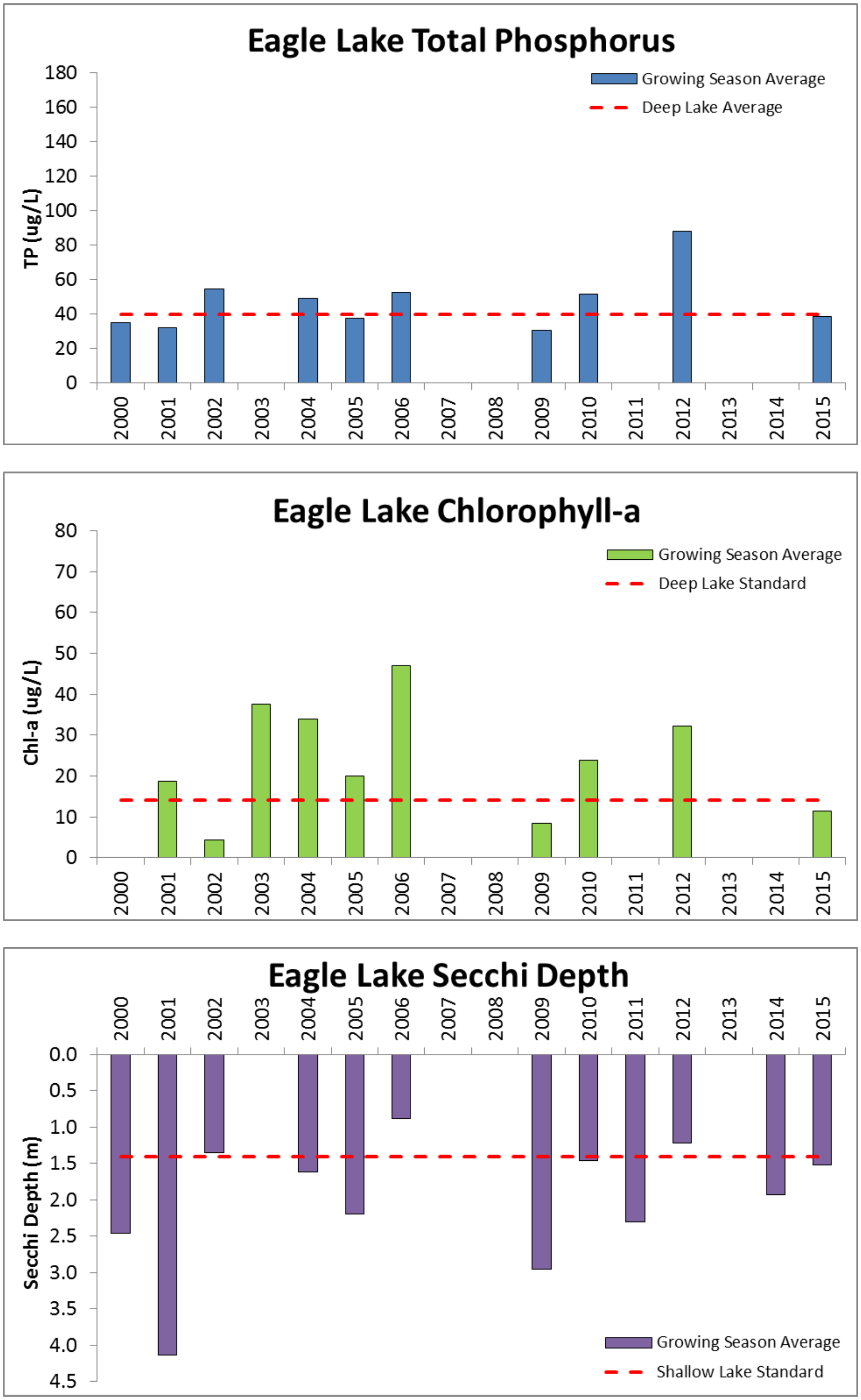


Figure 6.2. Eagle Lake historic TP, chlorophyll-a and Secchi depth data.

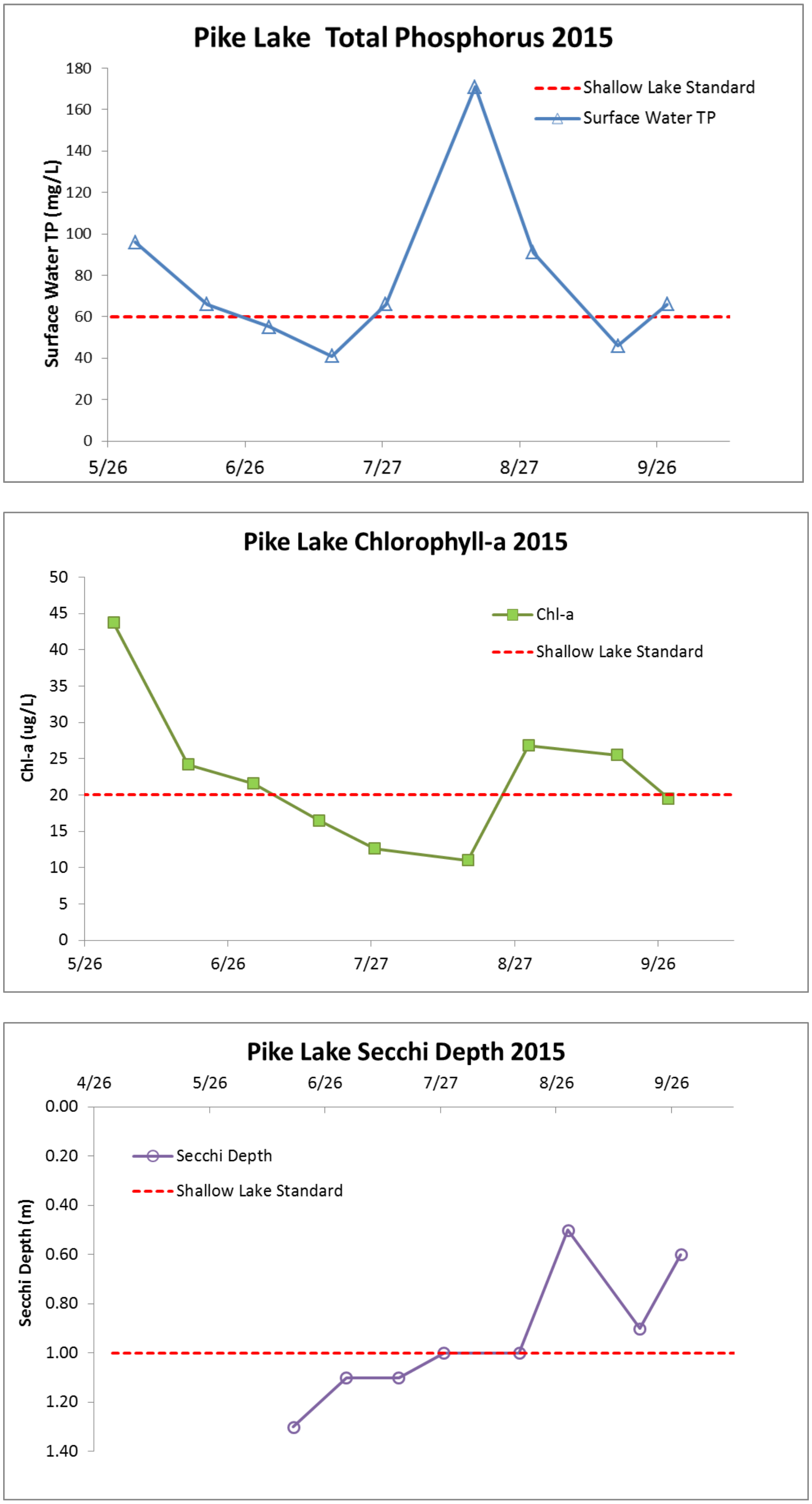


Figure 6.3 Pike Lake 2015 TP, chlorophyll-a and Secchi depth data.

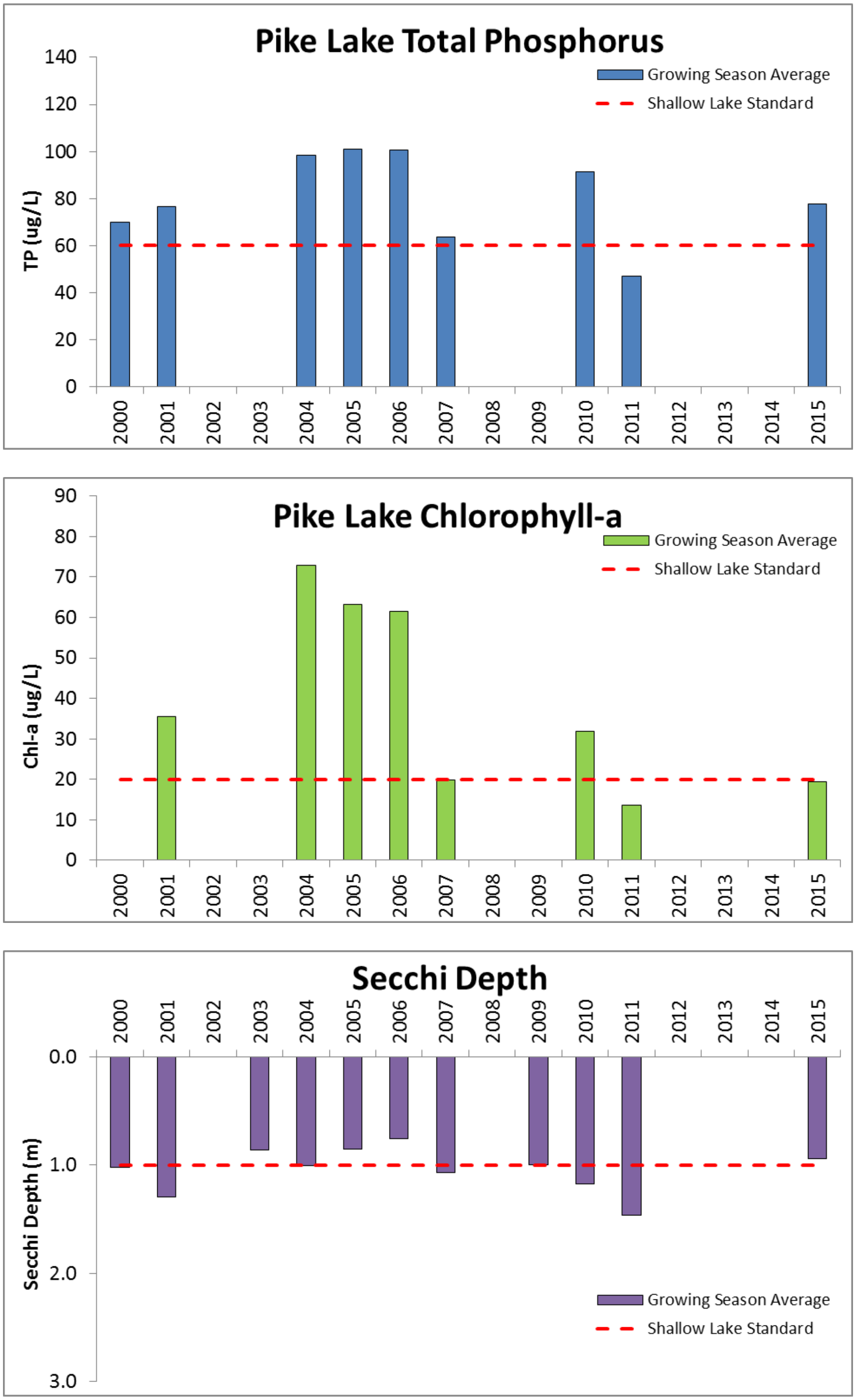
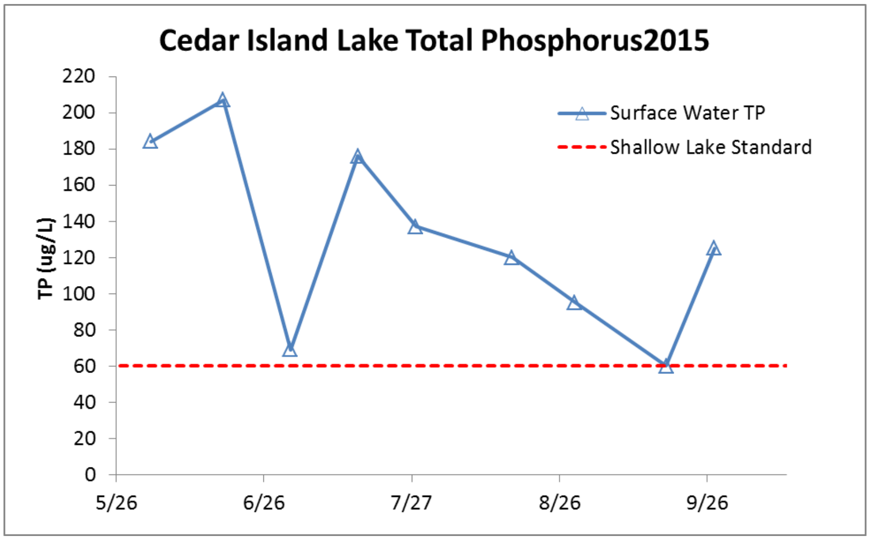
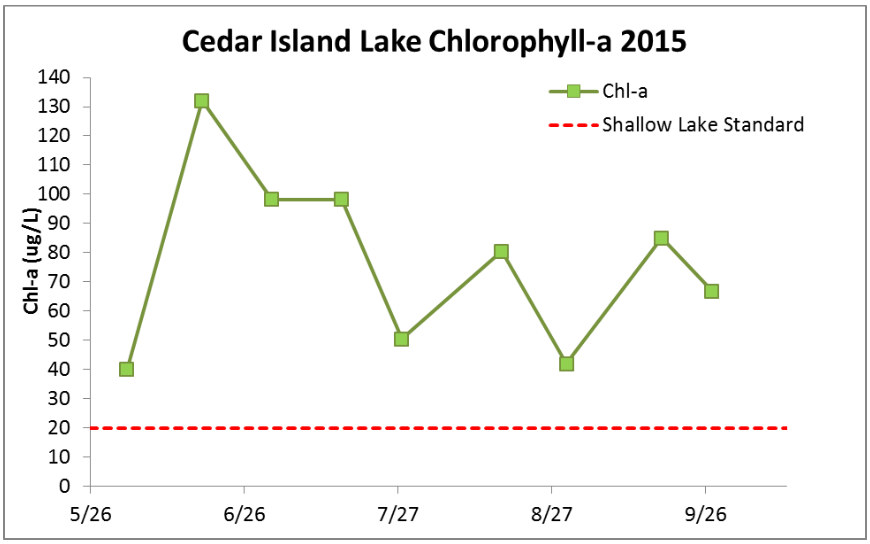


Figure 6.4. Pike Lake historic TP, chlorophyll-a and Secchi depth data.





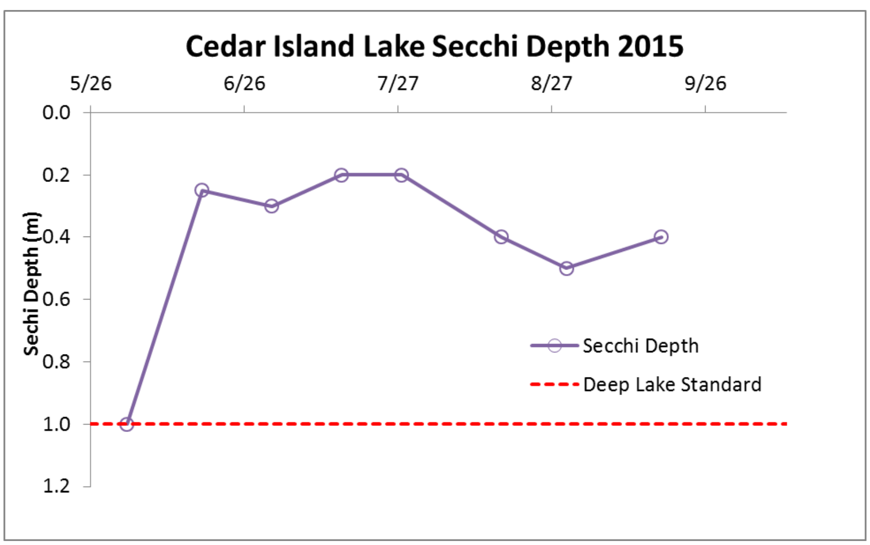


Figure 6.5. Cedar Island Lake 2015 TP, chlorophyll-a and Secchi depth data.

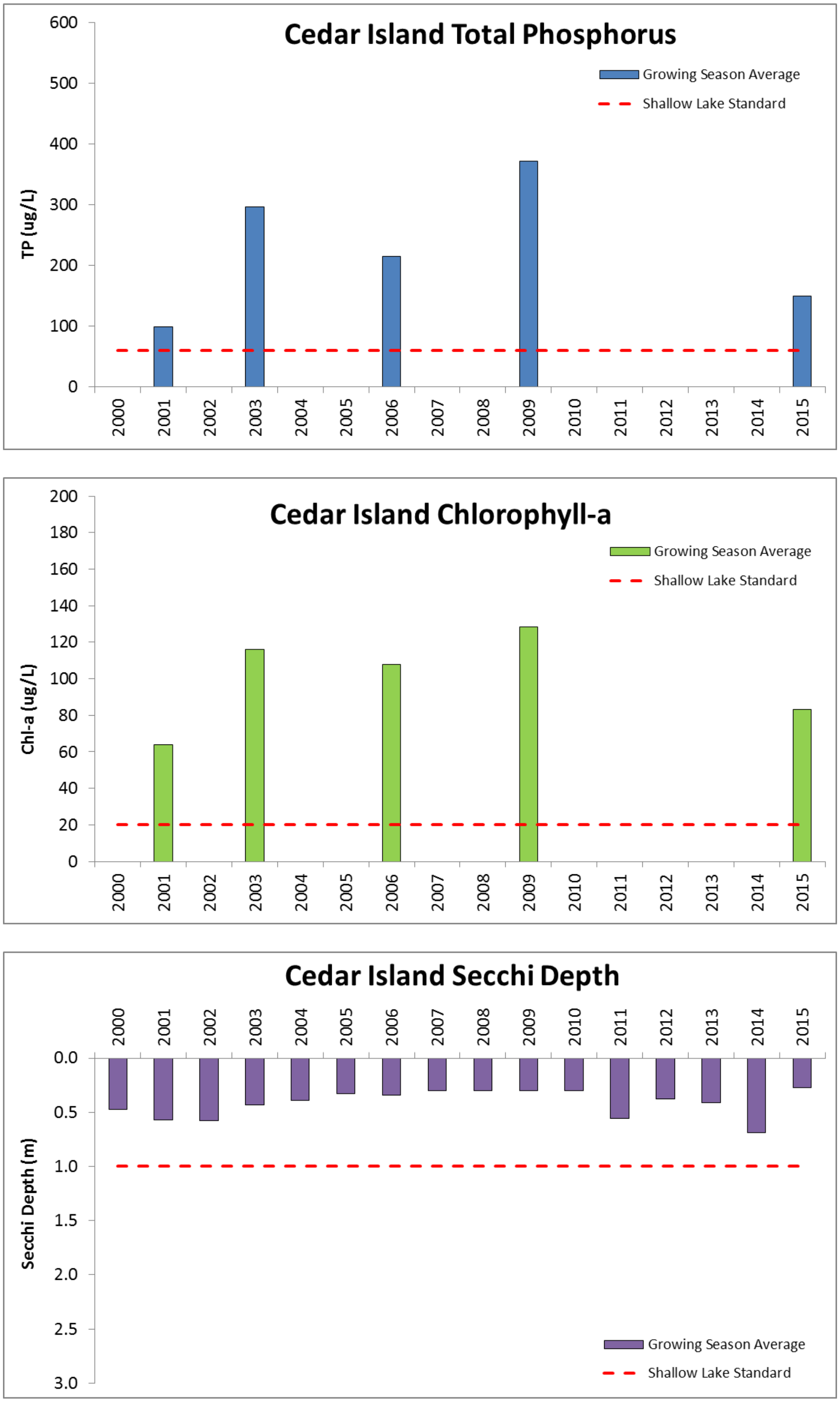


Figure 6.6. Cedar Island Lake historic TP, chlorophyll-a and Secchi depth data.

6.4 VEGETATION SURVEYS

Point-intercept surveys using methodology developed by the Minnesota Department of Natural Resources (DNR) were conducted on June 2, 2015 and August 25, 2015 on Eagle and Pike Lakes. Point-intercept sample points were established in GIS across the entire lake basin using a 50 x 50 meter grid file. The survey points during the August survey on Eagle Lake were spaced to 100 x 50 meters to expedite the surveying process, resulting in a total of 460 points and 231 survey points, respectively. A total of 90 points were surveyed on Pike Lake and were spaced 50 x 50 meters apart. The surveyed grid was downloaded onto a GPS unit that was used to navigate to each sample point during the survey. One side of the boat was designated as the sampling area. Water depth was recorded at each sample point using an electronic depth finder.

Wenck staff identified all plant species found within a one meter square sample site at each survey point. A weighted sampling hook attached to a rope was used to survey vegetation not visible from the surface. All vegetation species observed were identified to the species level where possible. Species abundance rankings were also visually assessed and recorded at each monitoring point using a 0-5 ranking scale (0 = no plants; 5 = heavy plant abundance). Water clarity was also recorded during each survey by measuring the depth at which a Secchi disk was visible when lowered into the water.

The late summer surveys were conducted to assess each lake's overall native plant community and diversity during the peak of the summer growing season. The early summer surveys were conducted to estimate the distribution and abundance of curly-leaf pondweed. Curly-leaf pondweed is a non-native plant species that can out-compete native plant species and disrupt lake ecosystems by changing the dynamics of internal phosphorus loading. Curly-leaf pondweed has the ability to grow slowly throughout the winter, even under thick ice and snow cover. Thus, by the time other species start growing in the spring, curly-leaf plants are large enough to block light penetration to the bottom. By late spring, curly-leaf pondweed can form dense surface mats which interfere with recreation activities. By mid-summer, these dense mats senesce and die back, releasing nutrients that can contribute to undesirable algae blooms. Before curly-leaf pondweed plants die back, they form hardened stem tips called turions, which serve the function of vegetative reproduction. These turions sprout in the fall and begin the plant's cycle again.

6.4.1 Eagle Lake Survey Results

Frequency of occurrence of each plant species observed in Eagle Lake is summarized in Table 6.1. Vegetation was found at 130 of 460 (28%) sampling sites during the June 2015 survey. In areas of the lake less than 15 feet deep, vegetation was found at 130 of 140 (93%) sites. Ten species of aquatic vegetation were documented at sample stations during this survey. The maximum depth at which vegetation was found during this survey was 14.7 feet. In general, vegetation occurrence and diversity decreased with depth, and most points shallower than 15 feet were vegetated. Secchi depth was measured at 2.6 meters (8.5 feet) during the survey.

Vegetation was found at 108 or 231 (47%) sampling sites during the August 2015 survey. In areas of the lake less than 15 feet deep, vegetation was found at 106 of 123 (86%) sites. Sixteen species of aquatic vegetation were documented at sample stations during the August 2015 survey. The maximum depth at which vegetation was found was 16 feet, with frequency of occurrence and diversity decreasing with depth. Secchi depth reading was taken on 8/17/2015 and was measured at 1.6 meters (5.2 feet) during this survey.

Figures 6.7 and 6.8 display the point occurrence of curly-leaf pondweed and Eurasian water milfoil, respectively, along with the relative vegetation biovolume during each survey.

Of the 130 vegetated locations the most common species observed during the June 2015 survey were curly-leaf pondweed (66%) and coontail (53%). Of the 108 vegetated locations the most commonly observed species during the August survey was coontail (74%). As expected, curly-leaf pondweed observation were low (5%) at survey locations during August. Eurasian milfoil, another non-native invasive species, was observed at 16% of stations during the June survey and 15% during the August survey.

Table 6.1. Frequency of species occurrence during Eagle Lake vegetation surveys.

Common Name	Percent Occurrence	
	2-Jun-15	25-Aug-15
Clasping Leaf	0%	3%
Coontail	53%	74%
Chara	24%	21%
Canada Waterweed	0%	2%
Northern Milfoil	1%	9%
Curly-leaf Pondweed	66%	5%
Narrowleaf Pondweed	0%	9%
Bushy Pondweed	0%	7%
Flat-stem Pondweed	34%	34%
Sago Pondweed	0%	5%
Greater Bladderwort	9%	14%
Leafy Pondweed	30%	5%
Wild Celery	0%	17%
Eurasian Water Milfoil	16%	15%
Yellow Waterlily	10%	22%
White Waterlily	4%	22%

Curly-leaf pondweed is a dominant plant species in Eagle Lake during the early growing season. Curly-leaf pondweed can out-compete and suppress development of native plant species. Treatment and/or removal of curly-leaf from the western shoreline of Eagle Lake is recommended. Eurasian watermilfoil observation and abundance was relatively low throughout the lake and does not appear to be a major concern or nuisance at this time (Figure 6.8).

Coontail is a native plant species to Minnesota lakes and wetlands. Coontail and native pondweed species have a more typical life cycle compared to curly-leaf pondweed. They typically begin growing in late spring and peak during the warm summer months before gradually dying back when water temperatures decrease in the fall. As a result, these species are not considered a source of nutrients or a water quality concern during the summer growing season. In fact, these species can be beneficial to water quality through nutrient uptake and stabilizing bottom sediments from re-suspension by wind and rough fish. Coontail thrives in nutrient rich environments and can reproduce rapidly to form thick stands of tangled stems and vegetation mats at or below the water's surface. In shallow areas, these vegetative mats can interfere with water recreation such as boating, fishing, and swimming. In high abundance, coontail can crowd out less-aggressive native species which can lead to lower species diversity.

Coontail was a dominant plant species during both the June (53%) and August (74%) surveys. Abundance rankings for coontail were high and consistently exceeded 2 throughout much of the lakes littoral area during both surveys. In shallow shoreline areas (North/ North East areas), coontail appeared to form dense floating and submerged mats which made navigating through these portions of the lake extremely difficult. While coontail is not believed to pose a threat to water quality in Eagle Lake, it may be a nuisance to property owners in certain areas of the lake.

6.4.1 Pike Lake Survey Results

Frequency of occurrence of each plant species observed in Pike Lake during each survey is summarized in Table 6.2. Vegetation was found at 43 of 90 (48%) sampling locations during the June 2015 survey. All vegetated areas were in waters less than 15 feet. Seven species of aquatic vegetation were documented throughout the lake survey stations with the maximum depth at which vegetation was observed being 12.3 feet. Secchi depth was measured at 0.8 meters (2.5 feet) during the survey.

Vegetation was found at 40 of 90 (44%) sampling sites during the August 2015 survey. All vegetated areas were in waters less than 15 feet. Eight species of aquatic vegetation were documented at sample stations during the August 2015 survey. The maximum depth at which vegetation was found was 10.2 feet, with frequency of occurrence and diversity decreasing with depth. Secchi depth reading was taken on 8/17/2015 and was measured at 1.0 meters (3.3 feet) during this survey.

Figures 6.9 and 6.10 show point occurrence of curly-leaf pondweed and Eurasian water milfoil and the relative vegetation biovolume during each survey. The most common species observed during the June and August surveys was coontail (48% and 95%, respectively). Curly-leaf pondweed was observed at 20% (June) and 15% (August) of survey locations. Eurasian water milfoil was not observed in June but had a 17% occurrence in August at vegetated sites.

Table 6.2. Frequency of species occurrence during Pike Lake vegetation surveys.

Common Name	Percent Occurrence	
	2-Jun-15	25-Aug-15
Coontail	48%	95%
Canada Waterweed	0%	5%
Curly-leaf Pondweed	20%	15%
Narrowleaf Pondweed	0%	7%
Flat-stem Pondweed	11%	32%
Sago Pondweed	3%	0%
Wild Celery	1%	0%
Eurasian Water Milfoil	0%	17%
Yellow Waterlily	17%	37%
White Waterlily	8%	51%

Curly-leaf pondweed was most abundant in the southwestern portion of the lake, while other portions of the lake were limited to a few small strands (Figure 6.9). At this time, curly-leaf pondweed is not abundant in Pike Lake during the early summer growing season.

Coontail was the dominant plant species during both the June (48%) and August (95%) surveys. Abundance rankings for coontail ranged between 1-5. Coontail formed dense floating and submerged mats in many shallower areas of the lake making navigating through these portions of the lake difficult. While coontail is not believed to pose a threat to water quality in Pike Lake, it is a potential nuisance species to lake recreators and shoreline property owners.

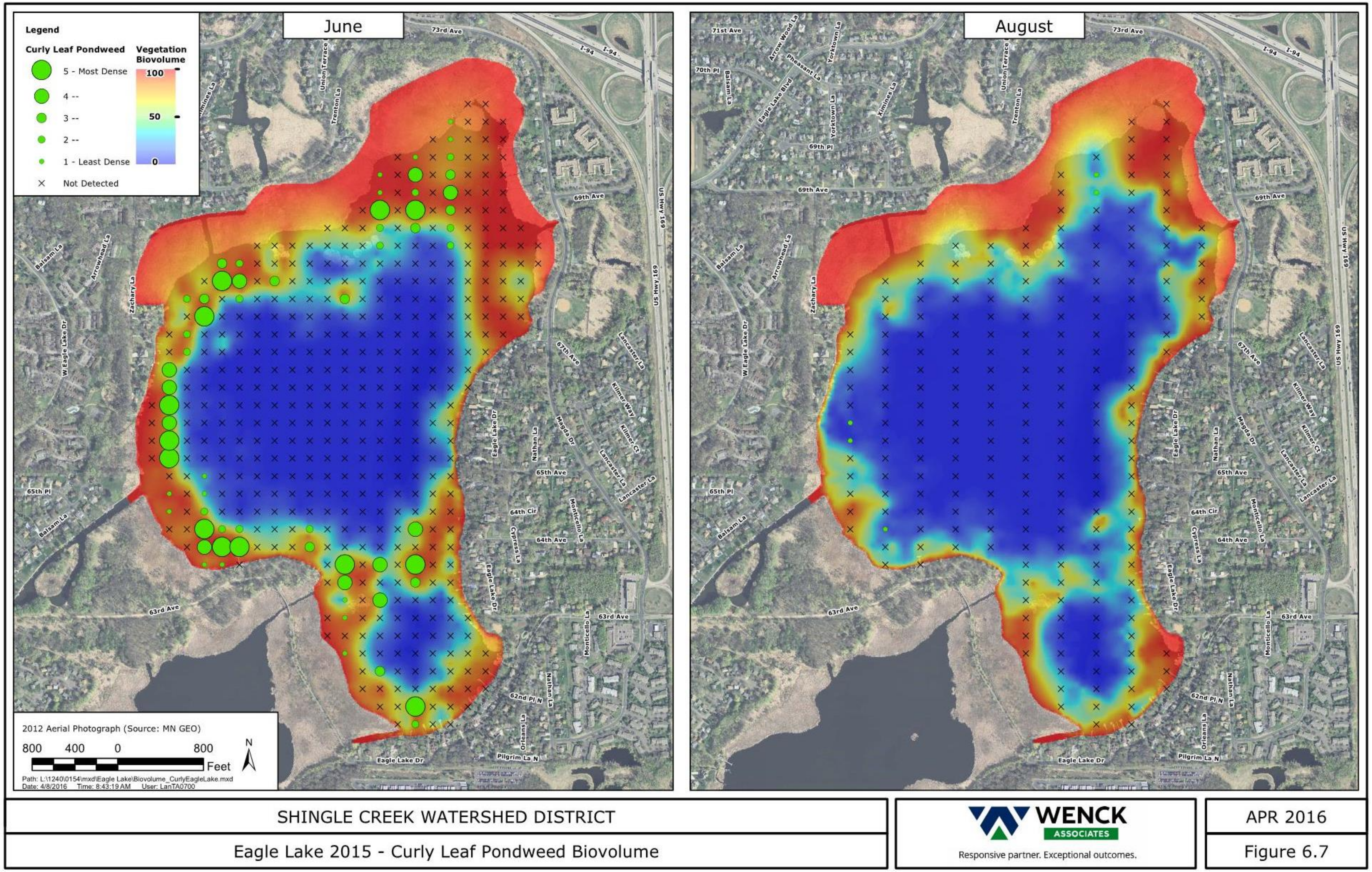


Figure 6.7. Eagle Lake total plant biovolume and curly-leaf pondweed locations.
Note: Left figure shows early summer and right figure lake summer conditions.

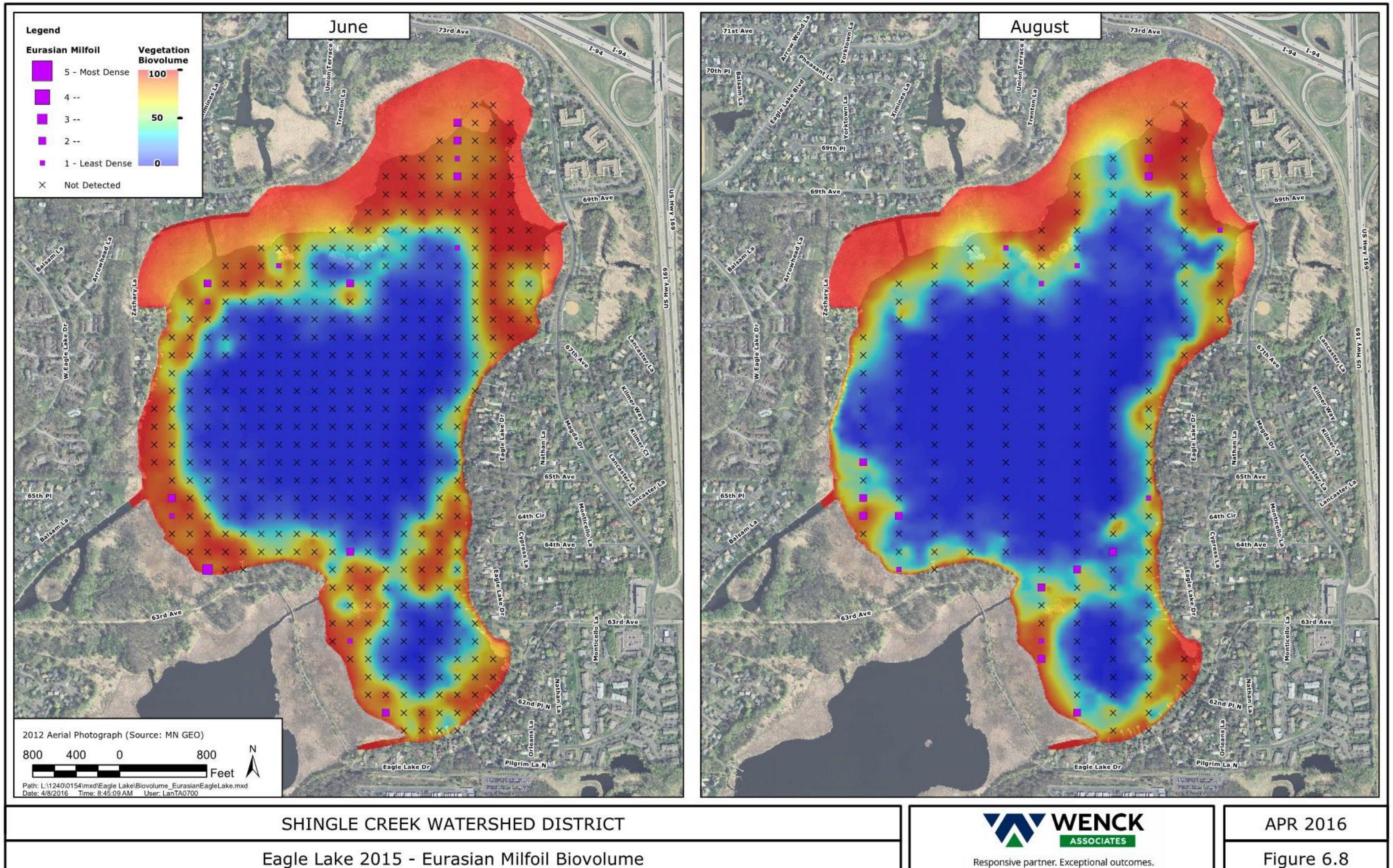


Figure 6.8. Eagle Lake total plant biovolume and Eurasian water milfoil locations.
Note: Left figure shows early summer and right figure lake summer conditions.

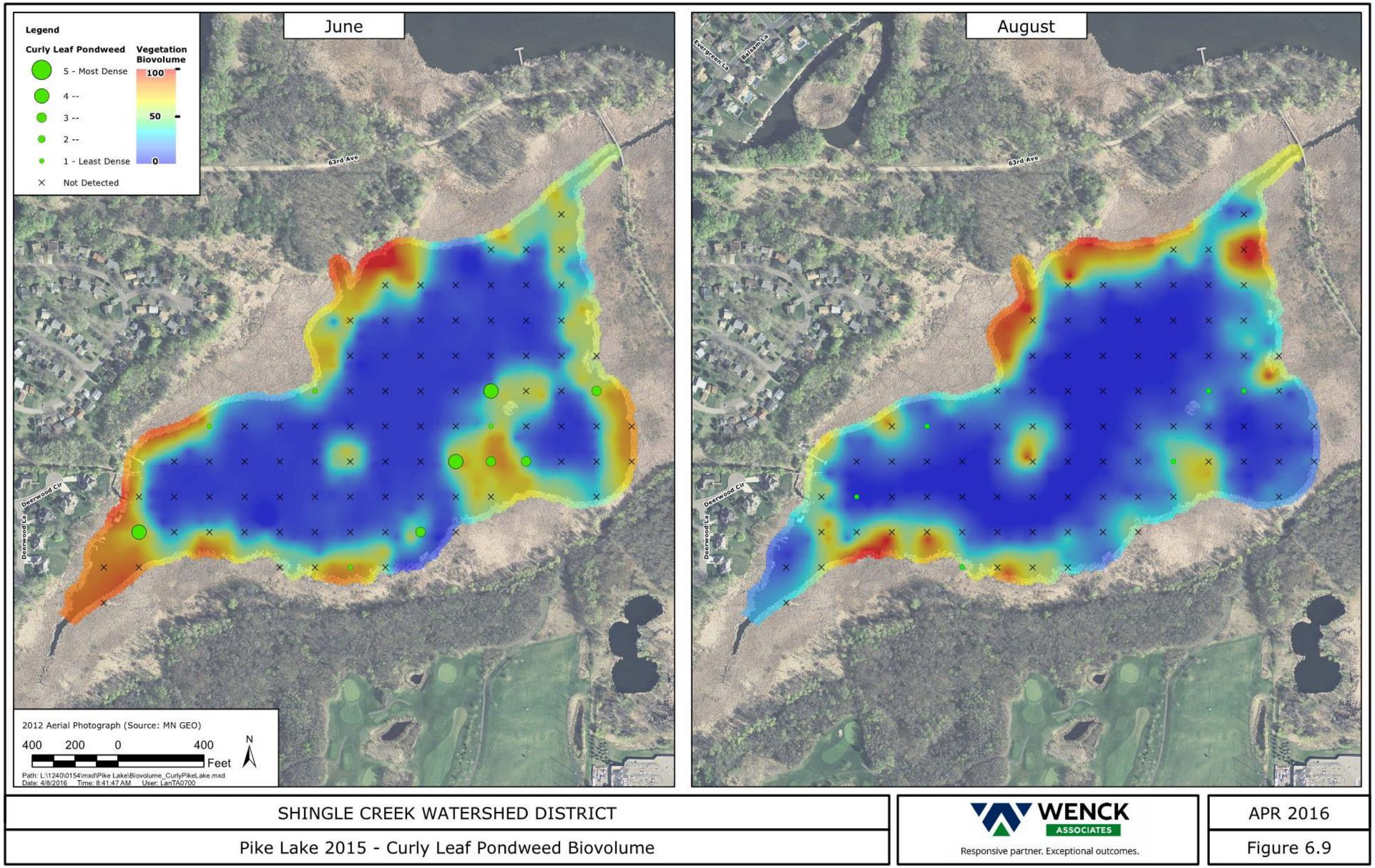


Figure 6.9. Pike Lake total plant biovolume and curly-leaf pondweed locations.
Note: Left figure shows early summer and right figure lake summer conditions.

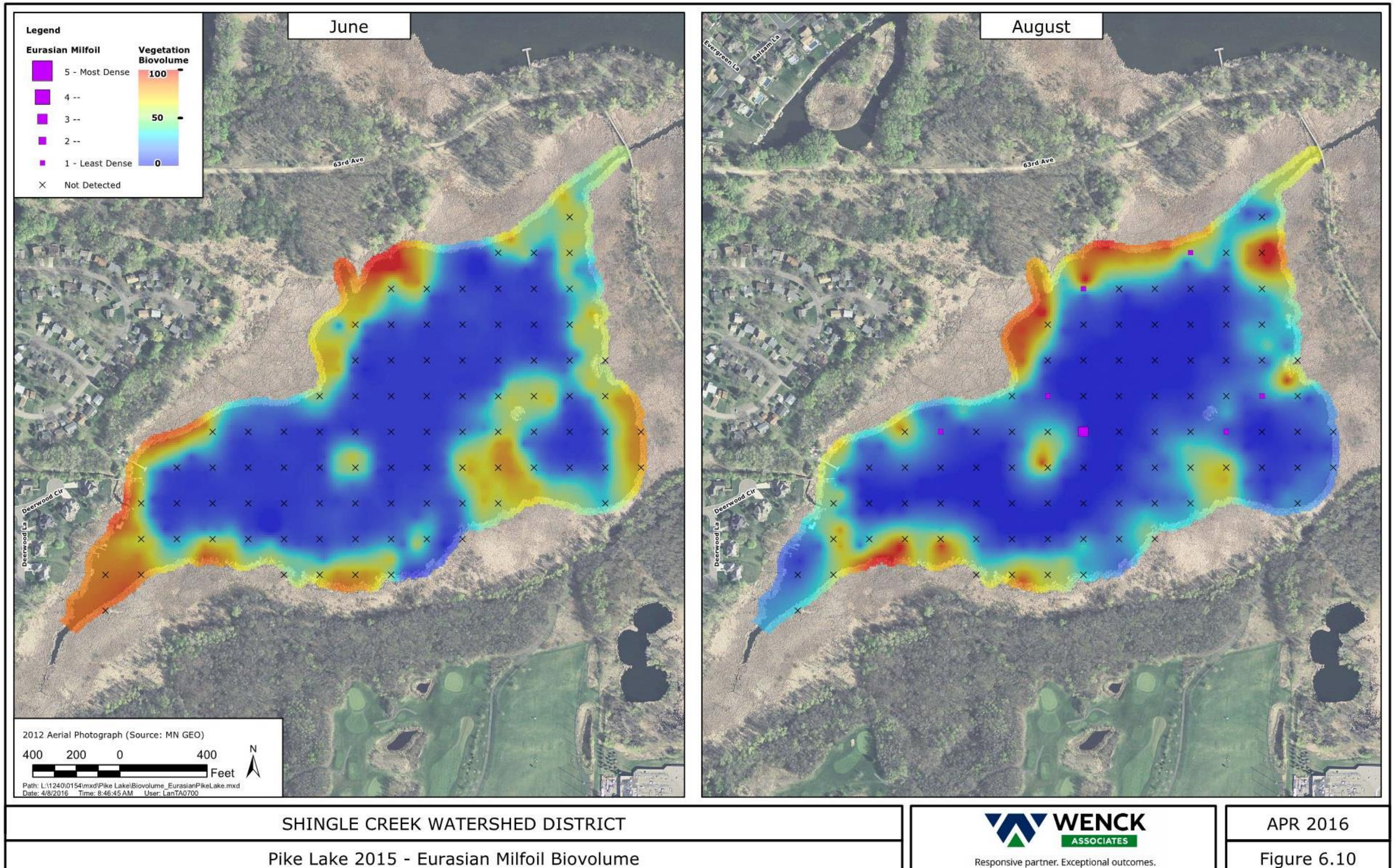


Figure 6.10. Pike Lake total plant biovolume and Eurasian water milfoil locations.
Note: Left figure shows early summer and right figure lake summer conditions.

7.0 Biological Monitoring

7.1 OVERVIEW

The Commission does not routinely undertake biological monitoring, but does obtain biological data by sponsoring volunteer monitoring through Hennepin County Department of Environment and Energy. High school students and their teachers monitor macroinvertebrates in streams through the River Watch program, and adult volunteers led by trained leaders monitor macroinvertebrates and vegetation in wetlands through the Wetland Health Evaluation Program (WHEP)

7.2 STREAM MACROINVERTEBRATE MONITORING

Routine stream macroinvertebrate monitoring in both watersheds is conducted by volunteers through Hennepin County's River Watch program. This program was initiated in 1995 to provide hands-on environmental education for high school and college students, promote river stewardship, and obtain water quality information on the streams in Hennepin County. It is a program of the River Network, a national non-profit organization that promotes community-based programs to restore and protect rivers and watersheds. Through the River Watch program, over 550,000 volunteers nationwide assist in watershed monitoring and assessment. Hennepin County coordinates student and adult volunteers who use the River Watch protocols to collect physical, chemical, and biological data to help determine the health of streams in the watershed.

One of the Commissions' goals is to track changes in streams. Examining the macroinvertebrate community provides a picture of the health of the stream. The results are qualitative and should be interpreted as one indicator of the rivers' health, not scientifically precise data. Another goal is to promote an understanding of the watershed and how water quality is related to land use. The water quality found in one short stretch of stream does not just reflect what is happening in one area. It reflects the water quality of all upstream areas draining into it.

The program began on Shingle Creek in spring 1996 and on Mattson Brook in West Mississippi in spring 1998. 2015 was the 19th year the site at Park Center High School was monitored. Mattson Brook was in the past regularly monitored, but has been irregularly monitored since 2013. Some other sites on Shingle Creek have been monitored for a few years and then for one reason or another dropped from the program.

Retention of volunteer groups is an ongoing issue for this program. Changes in the high school graduation standards, key teaching staff retirements, and school budget reductions all make it difficult to attract and retain school groups.

7.2.1 2015 Monitoring

In 2015, across the county 18 stream stretches were monitored in the spring and/or fall. Overall, two sites received an "A-" grade; three sites received a "B" grade; ten sites a "C" grade; and one site a "D" grade. The SCWM sponsored monitoring at two sites in Shingle Creek in 2015; no volunteer group was found for Mattson Brook in West Mississippi. The grading below shows annual variability that is likely related to precipitation and wet/dry periods. The site adjacent to Park Center High School has one of the longest data records of any of the Riverwatch sites in Hennepin County (Table 7.1). Because this site is currently under construction as part of the Connections at Shingle Creek project, in 2016 the monitoring will be completed upstream of the usual site. This is also where one of the public art reaeration structures will be placed in 2016, to improve dissolved oxygen levels that are currently stressing the biologic community.

Table 7.1. Riverwatch site Park Center High School, Brooklyn Park.
Monitored by Park Center High School.

Year	Grade	Year	Grade
2015	D+	2005	C
2014	D+	2004	D
2013	D+	2003	D+
2012	C-	2002	C
2011	C-	2001	D
2010	C	2000	D+
2009	C-	1999	D+
2008	C-	1998	D+
2007	C+	1997	C+
2006	C	1996	B-

Table 7.2. Riverwatch site Lions Park, Brooklyn Center.
Monitored by Calvin Christian High School.

Year	Grade	Year	Grade
2015	C-	2011	None
2014	C	2010	None
2013	C	2009	C+
2012	B-		

Sites monitored in previous years but not in 2015:

Table 7.3. Riverwatch site Mattson Brook, Brooklyn Park.
Monitored by Minneapolis South High School.

Year	Grade	Year	Grade
2014	C	2004	C
2013	None*	2003	C
2012	C-	2001	C
2010	C	2000	C
2009	C	1999	B
2008	C-	1998	B
2007	C-		

*Water levels too low

Table 7.4. Riverwatch site Webber Park, Minneapolis.
Monitored by Patrick Henry High School.

Year	Grade	Year	Grade
2012	D+	2004	C
2011	D+	2003	C-
2010	C	2002	C+
2009	C+	2001	C
2008	C		

Table 7.5. Riverwatch site North Hennepin Community College, Brooklyn Park.
Monitored by Metro Tech Academy.

Year	Grade	Year	Grade
2013	D+	2011	D+
2012	C		

Table 7.6. Riverwatch site Boone Avenue, Brooklyn Park.

Year	Grade	Year	Grade
2010	C	2007	C-
2009	Not monitored	2002	D+
2008	C-	2001	D

Table 7.7. Riverwatch site Brookdale Library, Brooklyn Center.

Year	Grade	Year	Grade
2009	C+		

7.2.2 Discussion

Based on the limited River Watch sampling, organisms found indicate average to impaired conditions for impacted urban streams. Variability is likely due to the amount of sustained flow in the streams.

7.3 WETLAND MONITORING

Both Commissions have participated in the Hennepin County Department of Environment and Energy Wetland Health Evaluation Program (WHEP) since 2006. The WHEP program uses trained adult volunteers to monitor and assess wetland plant and animal communities in order to score monitored wetlands on an Index of Biological Integrity for macroinvertebrates and for vegetation.

In 2015 volunteers assessed 33 sites across Hennepin County. On a scale of 1 to 30, the macroinvertebrate IBI scores ranged from a low of 8 (poor) to a high of 26 (excellent), with most of the sites in the 15-22 (moderate) range. On a scale of 1 to 35, the vegetation IBI scores ranged from 9 (poor) to 29 (excellent). This is unsurprising as most urban wetlands exhibit variable vegetative diversity due to their altered hydrology and pollutant and sediment conveyed by storm sewers. One site monitored in Timber Shores Park in Plymouth scored a 22 (top end of moderate) on macroinvertebrates but 11 (poor) on vegetation diversity, illustrating the difficulty of "rating" wetlands.

7.3.1 2015 Monitoring

Five sites were monitored in 2015: three in West Mississippi (two in Brooklyn Park, one in Champlin) and two in Shingle Creek (Plymouth and Brooklyn Park).

West Mississippi

A wetland in Brooklyn Park's Environmental Preserve has been monitored frequently, and serves as a reference and training site. This higher-quality wetland receives stormwater from a large area to the west that has developed in the last 10-15 years. This area is served by a number of detention ponds to treat runoff, and the health of BP-1 is one indicator of the effectiveness of that treatment in protecting downstream resources. In 2015 this site was monitored both by adult volunteers and by a QA/QC team. The QA/QC check of vegetative diversity was different than the volunteers; no explanation was given as to why.

Table 7.8. WHEP site BP-1, Environmental Preserve, Brooklyn Park.

Year	2006	2007	2008	2009	2010	2011	2015
Invertebrate	28 (excellent)	22 (moderate)	21 (moderate)	20 (moderate)	20 (moderate)	18 (moderate)	18/20 (moderate)
Vegetation	13 (poor)	19 (moderate)	22 (moderate)	19 (moderate)	19 (moderate)	20 (moderate)	23/27 (moderate/ excellent)

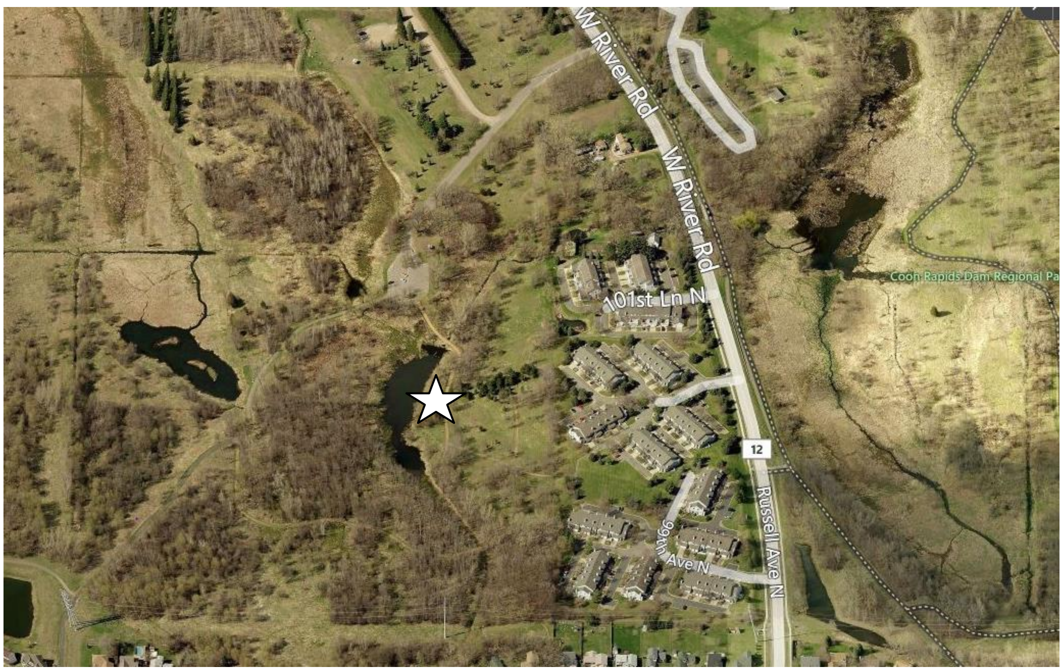


Figure 7.1. Monitored wetland in the Environmental Preserve.

The first of two new sites in 2015 is in Zane Sports Park, riparian to Century Channel in Brooklyn Park. It scored poorly for macroinvertebrates (Table 7.9), likely because the water levels in the wetland (Figure 7.2) fluctuate. Because it receives runoff through Century channel that is likely high in sediment and nutrients, plant diversity is low.

Table 7.9. WHEP site BP-7, Zane Sports Park, Brooklyn Park.

Year	2015
Invertebrate	8 (poor)
Vegetation	17 (moderate)

Figure 7.2. Zane Sports Park wetland, riparian to Century Channel.

The second new site in 2015 is in Bartusch Park in Champlin (Figure 7.3), in the northwest quadrant of 109th and Maryland Avenues N. this is a deeper wetland, so it is able to support more organisms (Table 7.10).

Table 7.10. WHEP site CH-3, Bartusch Park, Champlin.

Year	2015
Invertebrate	20 (moderate)
Vegetation	21 (moderate)

Figure 7.3. Bartusch Park wetland in Champlin.

Shingle Creek

One of the first sites monitored through this program was in Plymouth in Timber Shores Park in the wetland complex at the outlet of Bass Lake (Figure 7.4). This is the first time it has been monitored in five years (Table 7.11). In 2010 this site was monitored both by adult volunteers and by a QA/QC team. The QA/QC check of vegetative diversity was different than the volunteers; no explanation was given as to why.

Table 7.11. WHEP site PL-6, Timber Shores, Plymouth.

Year	2005	2006	2008	2009	2010	2015
Invertebrate	10 (poor)	16 (moderate)	22 (moderate)	24 (excellent)	18/22 (moderate)	22 (moderate)
Vegetation	15 (poor)	15 (poor)	17 (moderate)	15 (poor)	25/15 (mod/ poor)	13 (poor)

Figure 7.4. Wetlands in Timber Shores Park.

Site BP-5 is in Brookdale Park, in a series of wetlands just south of Shingle Creek, downstream of Noble Avenue and "monkey falls." Old records show that before the Creek was straightened and channelized through the park, it meandered through these wetlands. (Table 7.12 and Figure 7.5.) This wetland has some of the better scores of the WHEP wetlands in the watersheds.

Table 7.12. WHEP site BP-5, Brookdale Park, Brooklyn Park.

Year	2014	2015
Invertebrate	24 (excellent)	16 (moderate)
Vegetation	15 (moderate)	25 (moderate)

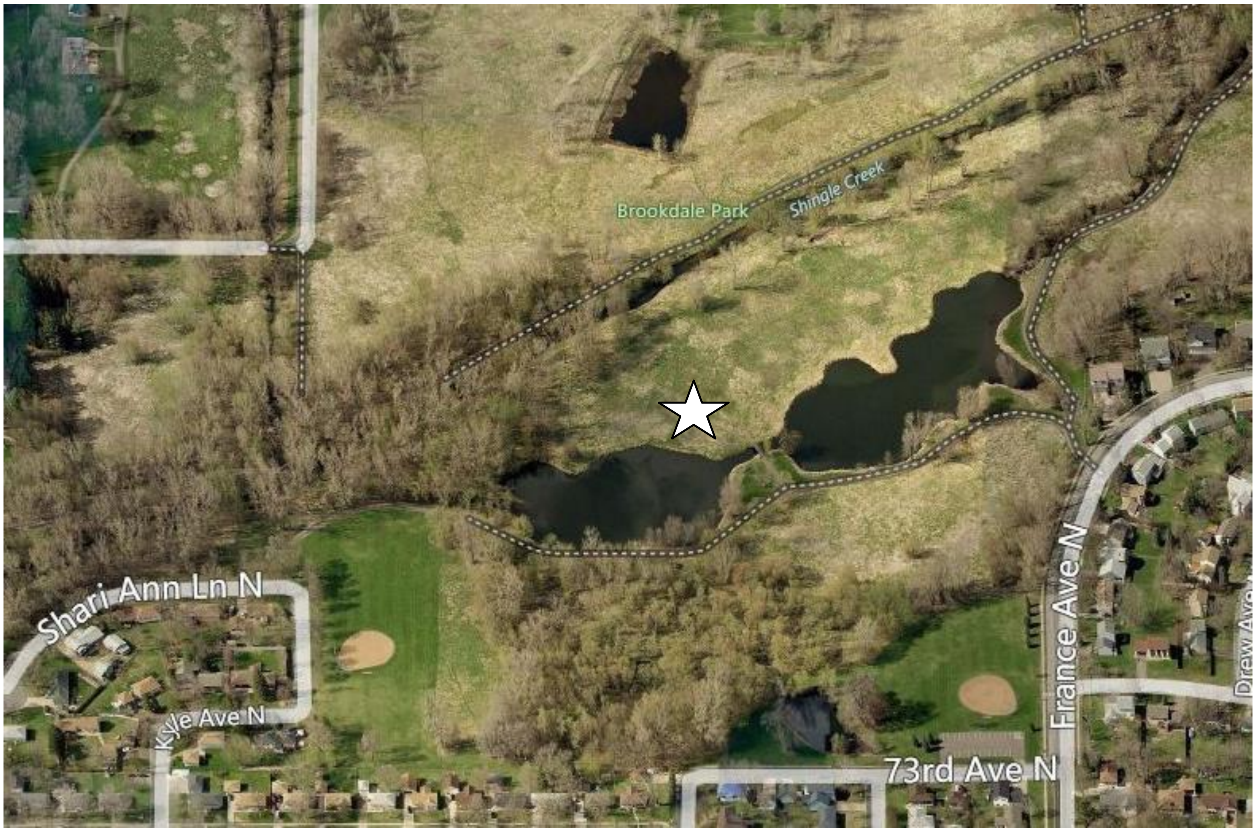


Figure 7.5. Wetlands in Brookdale Park, Brooklyn Park.

<u>Wetlands previously monitored by not in 2015 include:</u>

West Mississippi

The Oxboro Ponds site is in a series of ponds and remnant wetlands north of "Oxbow Lake" near Regent and 101st Avenues North related to the 2002 development of Oxbow Commons. This area has rapidly developed in the past ten years, contains protected and mitigation wetlands, and is in an area where other wetlands have lost their hydrology. This site scored moderately well on both metrics (Table 7.13).

Table 7.13. WHEP site BP-4, Oxboro Ponds, Brooklyn Park.

Year	2012	2013	2014
Invertebrate	16 (moderate)	16 (moderate)	24 (excellent)
Vegetation	16 (moderate)	21 (moderate)	21 (moderate)

In 2008 and 2009 a wetland in Brooklyn Park's Jewel Park was monitored (Table 7.14). Typical of small remnant wetlands in the watershed, this site is dominated by cattails and this monoculture greatly reduces both invertebrate and plant diversity.

Table 7.14. WHEP site BP-3, Jewel Park, Brooklyn Park.

Year	2008	2009
Invertebrate	10 (poor)	20 (moderate)
Vegetation	7 (poor)	10 (poor)

A mitigation wetland in Champlin was monitored for four years as site CH-1. It is a large pond/wetland east of TH 169 between 109th and 114th Avenues North. It scored poorly on vegetation (Table 7.15), which is a reflection of the stormwater discharged into it.

Table 7.15. WHEP site CH-1, Mitigation Wetland, Champlin.

Year	2010	2011	2012	2013
Invertebrate	8 (poor)	16 (moderate)	18 (moderate)	18 (moderate)
Vegetation	11 (poor)	15 (poor)	7 (poor)	15 (poor)

Shingle Creek

A wetland in Brooklyn Park just north of Palmer Lake was monitored in 2007-2009. The results (Table 7.16) illustrate how variable biotic health can be based on precipitation.

Table 7.16. WHEP site BP-2, Brookdale Drive Wetland, Brooklyn Park.

	2007	2008	2009
Invertebrate	16 (moderate)	20 (moderate)	13 (poor)
Vegetation	15 (poor)	7 (poor)	10 (poor)

A mitigation wetland in Palmer Lake Park just south of Palmer Lake was monitored for four years (Table 7.17). Biotic quality varied, likely due to variations in precipitation.

Table 7.17. WHEP site BC-1, South Palmer Lake, Brooklyn Center.

Year	2010	2011	2012	2013
Invertebrate	24 (excellent)	18 (moderate)	22 (moderate)	22 (moderate)
Vegetation	17 (moderate)	11 (poor)	19 (moderate)	17 (moderate)

Site BC-2 is a stormwater pond constructed in an upland area of the west side of the Palmer Lake Basin. This pond receives runoff from a large neighborhood to the west that had previously flowed untreated in the basin (Table 7.18.)

Table 7.18. WHEP site BC-2, West Palmer Lake, Brooklyn Park.

Year	2012	2013	2014
Invertebrate	14 (poor)	14 (poor)	16 (moderate)
Vegetation	17 (moderate)	19 (moderate)	19 (moderate)

Wetland 639W in Crystal has in the past been monitored. This site showed moderate invertebrate and vegetative diversity (Table 7.19).

Table 7.19. WHEP site CR-1, Wetland 639W, Crystal.

Year	2012	2013	2014
Invertebrate	16 (moderate)	16 (moderate)	22 (moderate)
Vegetation	13 (poor)	17 (moderate)	19 (moderate)

The site BP-6 is in Greenhaven Park in Brooklyn Park. This wetland is riparian to Shingle Creek. It is at this point that the Creek, which is flowing north, turns almost 90 degrees to the east and flows under Bottineau Boulevard and past Wal-Mart (Table 7.20).

Table 7.20. WHEP site BP-6, Greenhaven Park, Brooklyn Park.

Year	2014
Invertebrate	22 (moderate)
Vegetation	25 (moderate)

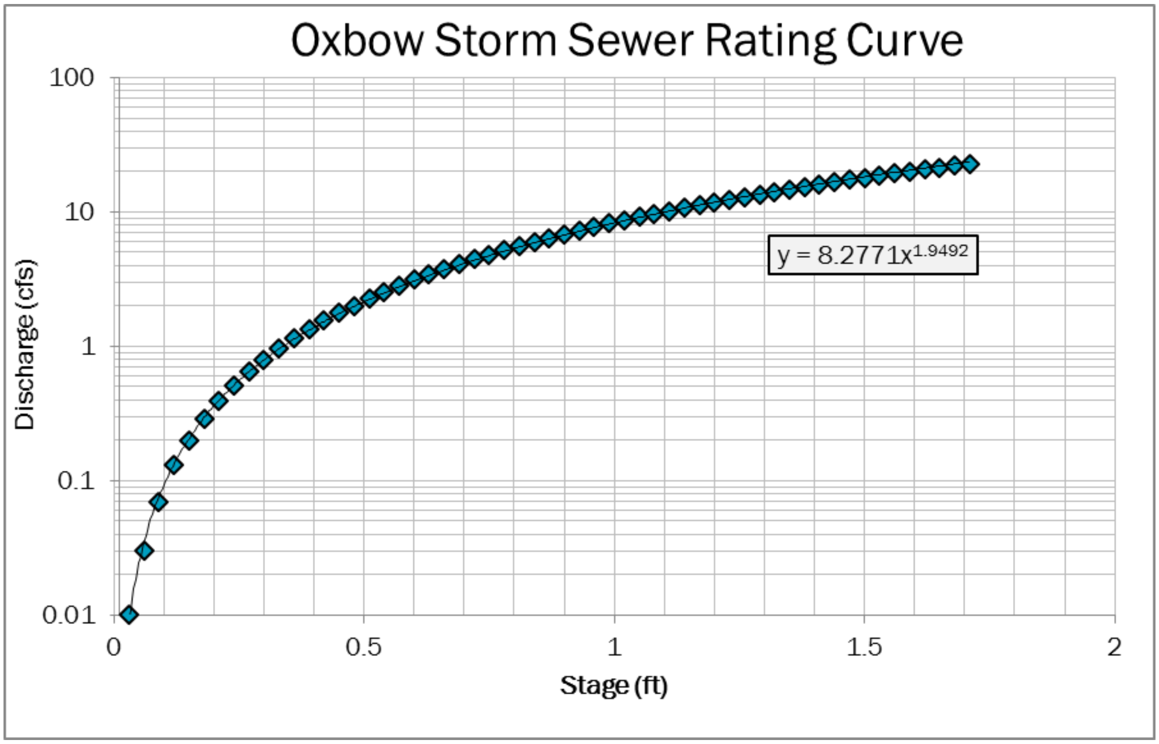
65th Avenue Outfall Monitoring 2015

Date	Time	Temp [C]	DO [mg/l]	pH	Sp. Cond	TP [mg/L]	Ortho-P [mg/L]	TSS [mg/L]	Chloride [mg/L]
4/14/2015	15:15	10.66	10.05	8.27	1808	0.076	0.017	4.6	1.03
4/18/2015	23:26					0.1	0.021	8.4	1.59
4/30/2015	15:15								
5/10/2015	12:26					0.341	0.141	43.6	
5/13/2015	13:50	11.7	9.87	7.60	1257	0.097	0.046	7.6	1.42
6/9/2015	11:00					0.144	0.1	3.2	
7/6/2015	10:30	22.03	7.56	7.55	443.2	0.068	0.067	12.4	
7/8/2015	11:45	18.91	7.79	7.59	602.9	0.114	0.077	9.5	0.888
7/13/2015	12:30					0.094	0.04	15.2	
8/5/2015	13:10	16.68	8.94	7.92	1723	0.082	0.046	7.6	0.821
8/6/2015	15:04					0.169	0.045	32.4	
8/17/2015	18:50					0.066	0.032	5.2	
8/31/2015	10:00	15.94	8.58	7.87	1664.5	0.063	0.039	3.8	
9/16/2015	14:45	18.07	7.72	7.94	1511.7	0.111	0.05	4.2	
10/30/2015	12:30					0.06	0.034	1.6	

Oxbow Outfall Monitoring 2015

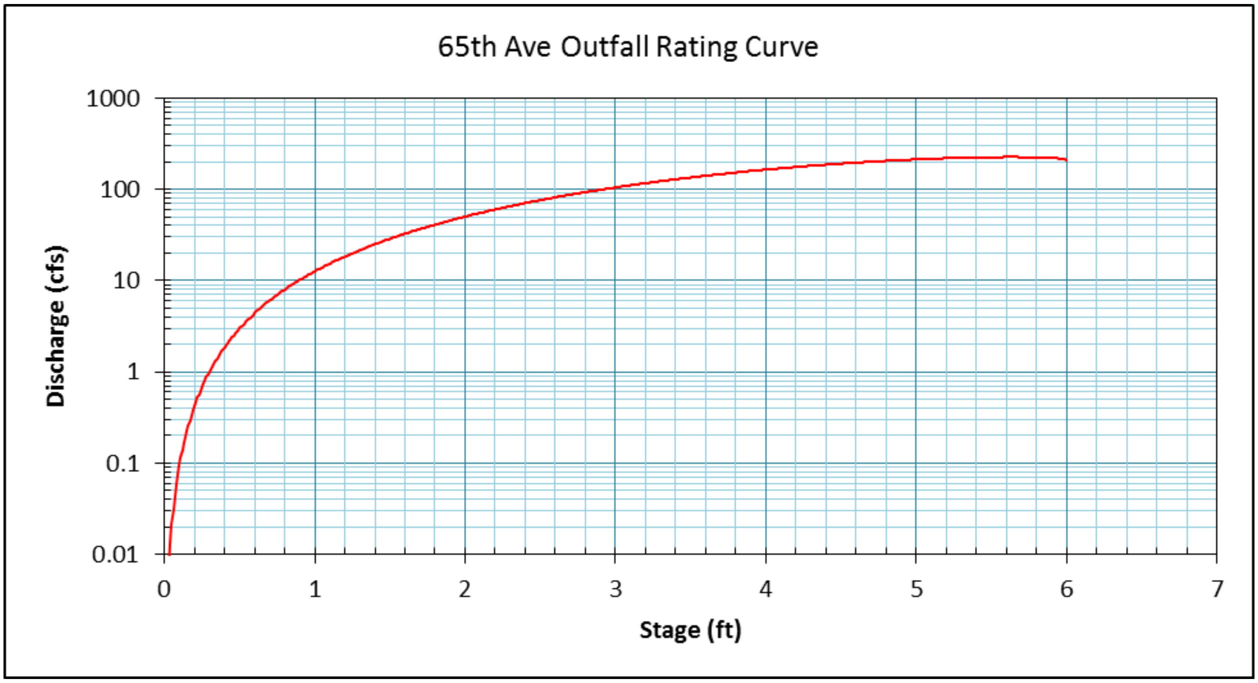
Date	Time	Temp [C]	DO [mg/l]	pH	Sp. Cond	TP [mg/L]	Ortho-P [mg/L]	TSS [mg/L]	Chloride [mg/L]
4/14/2015	15:45	9.51	9.94	8.16	856	0.028	0.019	1.60	272
4/19/2015	0:43					0.389	0.143	24	83.9
5/10/2015	13:10					0.396	0.069	77.6	49
5/13/2015	12:20	9.24	8.88	7.22	837	0.101	0.022	1.6	97
6/9/2015	11:30					0.061	0.021	1.2	101
6/6/2015	23:50					0.277	0.094	39.2	
7/6/2015	9:40	17.13	7.95	7.29	341.1	0.041	0.037	2	
7/8/2015	11:00	11.71	8.06	7.38	828.6	0.039	0.027	4.5	70
7/13/2015						0.507	0.191	74	
7/29/2015	6:23					0.231	0.16	40.4	
8/5/2015	12:30	12.92	8.16	7.35	867.3	0.049	0.027	5.2	
8/6/2015	11:28					0.272	0.228	101	
8/18/2015	12:06					0.107	0.055	30.6	
8/31/2015	10:45	13.58	7.84	7.48	858.2	0.043	0.026	<1	
9/16/2015		13.93		7.51	860.6	0.089	0.028	2.8	93.3
10/30/2015	12:00					0.031	0.024	<1	93.9

West Mississippi Outfall Rating Curves



Manning equation values used to calculate flow for station Oxbow Creek

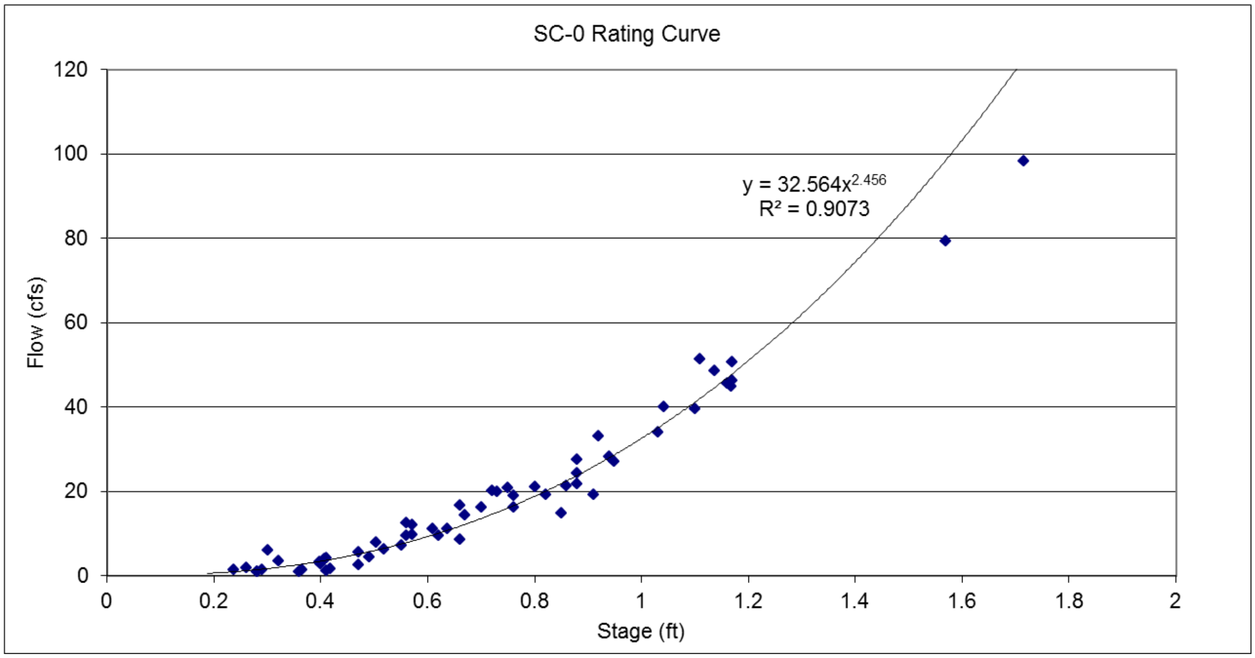
Parameter	**Value**	**Units**
Pipe diameter	4	ft
Pipe Length	520	ft
Pipe U/s invert Elevation	837.35	ft
Pipe D/s Invert Elevation	833.05	ft
Slope	.0083	ft/ft
roughness coefficient	0.011	NA

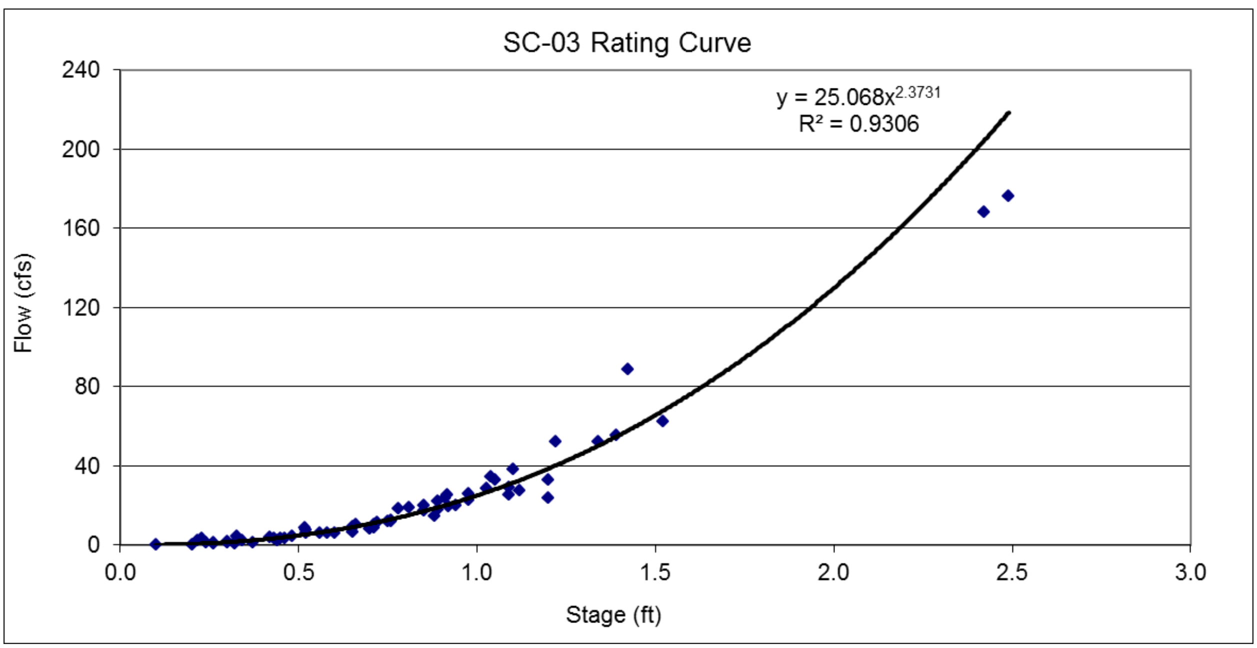


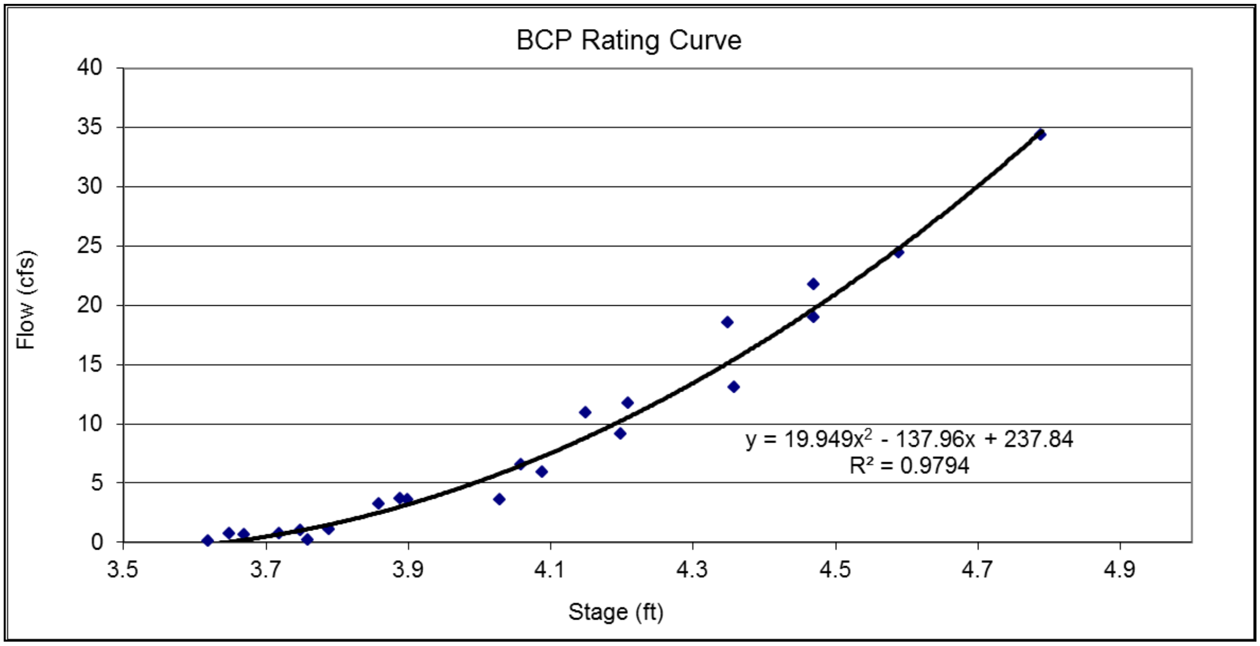
Manning equation values used to calculate flow for station Oxbow Creek

Parameter	**Value**	**Units**
Pipe diameter	6	ft
Pipe Length	320	ft
Pipe U/s invert Elevation	818.77	ft
Pipe D/s Invert Elevation	817.99	ft
Slope	0.0024375	ft/ft
roughness coefficient	0.013	NA

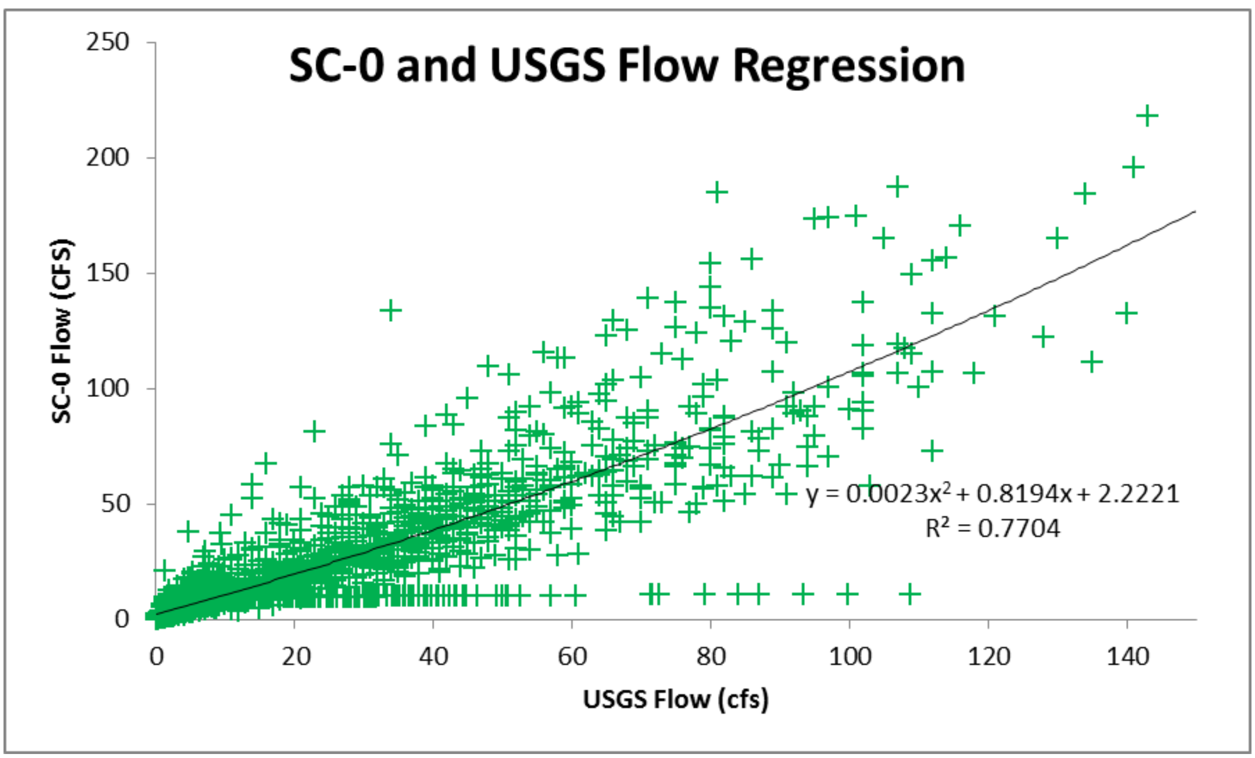
Shingle Creek Rating Curves

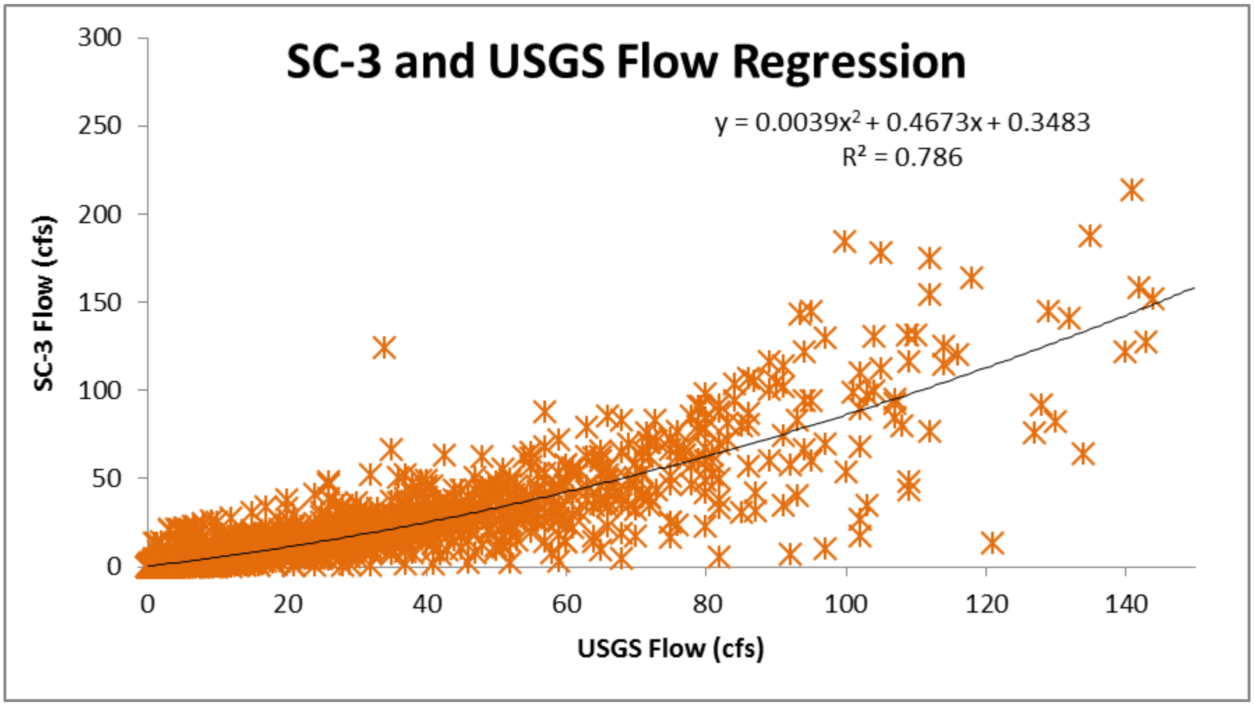




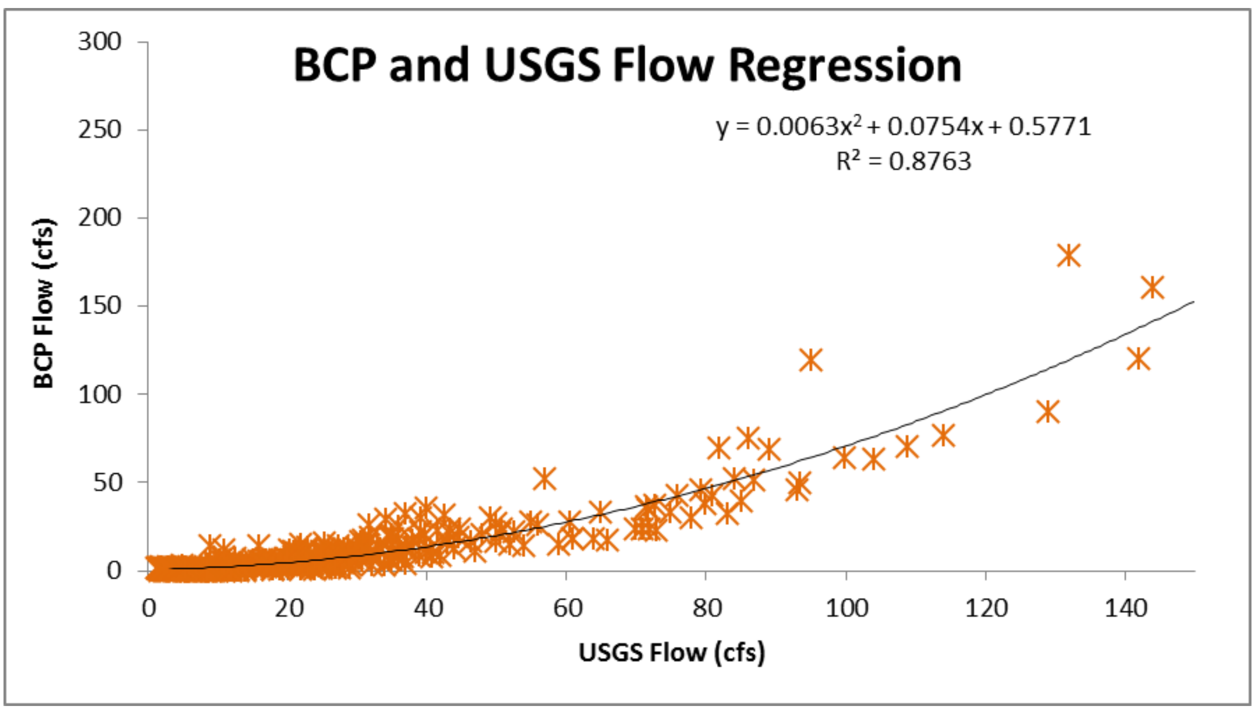


Shingle Creek Flow Regressions





SC-3 and USGS Flow Regression
y = 0.0039x² + 0.4673x + 0.3483
R² = 0.786
SC-3 Flow (cfs)
USGS Flow (cfs)
0
50
100
150
200
250
300
0
20
40
60
80
100
120
140



BCP and USGS Flow Regression
y = 0.0063x² + 0.0754x + 0.5771
R² = 0.8763
BCP Flow (cfs)
USGS Flow (cfs)
0
50
100
150
200
250
300
0
20
40
60
80
100
120
140

Shingle Creek SC-0 Monitoring 2015

Date	Time	Temp [C]	DO [mg/l]	pH	Sp. Cond	TP [mg/L]	Ortho-P [mg/L]	TKN [mg/L]	Nitrate [mg/L]	TSS [mg/L]	Chloride [mg/L]
1/16/2015	16:00	-0.05	7.11	7.09	1780						313
1/28/2015	15:45	0	10.52	7.94	1958						434
2/12/2015	15:40	-0.03	9.77	7.54	1903						421
3/9/2015	10:00	-0.03	9.89	7.76	2214						566
4/14/2015	12:00	13.51	10.76	8.60	950	0.068	0.019	0.749	0.276	3.8	319
4/30/2015	14:45	17.24	17.02	8.11	1331	0.088	0.036	0.703	0.073	6	234
5/10/2015	22:54					0.242	0.075	1.63	0.185	28.4	106
5/13/2015	11:00	12.47	7.64	7.22	837	0.097	0.066	0.829	0.248	2.8	182
5/28/2015	14:00	21.39	7.18	8.14	706	0.102	0.052	0.721	0.064	7.6	146
6/9/2015	8:45	21.59	3.02	6.96	793	0.173	0.142	0.84	0.069	2.4	168
6/22/2015	17:00	24.02	5.36	7.52	642	0.107	0.055	0.661	0.258	8.4	
7/6/2015	12:15	22.73	4.10	7.41	328.7	0.145	0.101	0.822	0.137	22.4	
7/8/2015	10:10	20.19	4.37	7.36	443.7	0.117	0.081	0.922	0.14	6	38.6
7/23/2015	9:30					0.12	0.093	0.822	0.212	2.4	125
7/28/2015	6:34					0.329	0.162	1.54	0.188	92.4	50.4
7/29/2015	12:20	22.63	4.39	7.33	366						
8/5/2015	11:45	21.88	5.14	7.55	899.5	0.073	0.096	0.796	0.219	1.2	140
8/6/2015	15:24					0.1	0.057	0.97	0.363	28.4	140
8/18/2015	12:31					0.176	0.103	0.945	0.245	38.2	
8/19/2015	11:30	19.47	4.72	7.90	346.5	0.109	0.091	0.814	0.216	10	58.4
9/16/2015	14:00	21.62	4.93	7.61	922.8	0.068	0.048	0.849	0.34	2	154
9/28/2015	11:30	19.64	5.04	7.46	830	0.089	0.059	0.558	0.373	7	139
10/16/2015	9:30					0.074	0.05	0.696	0.403	6	159
10/16/2015	9:35					0.073	0.049	0.662	0.441	6.1	163
10/30/2015	11:15	7.93	8.26	7.47	419						
11/20/2015	11:30	2.98	10.60	6.96	445.9						

Shingle Creek SC-3 Monitoring 2015

Date	Time	Temp [C]	DO [mg/l]	pH	Sp. Cond	TP [mg/L]	Ortho-P [mg/L]	TKN [mg/L]	Nitrate [mg/L]	TSS [mg/L]	Chloride [mg/L]
1/16/2015	16:50	1.68	6.90	7.26	2740						647
1/28/2015	15:00	1.92	8.56	7.68	2350						584
3/9/2015	9:45	1.98	10.11	7.96	2859						717
4/12/2015	22:16					0.206	0.074	1.63	0.547	50.8	374
4/14/2015	13:00	12.06	9.91	8.09	1517	0.094	0.032	1.06	0.38	4	464
4/30/2015	14:00	13.44	9.59	7.68	1552	0.048	0.024	0.624	0.187	4.8	356
5/10/2015	19:54					0.222	0.058	1.61	0.203	39.6	295
5/11/2015	12:00										
5/13/2015	9:30	10.46	7.75	7.10	1164	0.089	0.048	0.774	0.169	2.8	389
5/28/2015	13:00	19.27	7.36	7.94	938	0.112	0.069	0.987	0.071	4.4	213
6/6/2015	23:36					0.514	0.145	4.09	0.272	83.2	
6/9/2015	8:15	20.25	3.08	6.91	850	0.155	0.12	0.862	0.375	<1.0	178
6/22/2015	8:15					0.202	0.116			18.4	
6/22/2015	16:00	23.37	4.79	7.47	359	0.127	0.082	0.729	0.214	4.4	
7/6/2015	11:40	22.64	5.84	7.40	332	0.157	0.115	0.822	0.173	18	
7/8/2015	8:50	17.94	4.99	7.01	574.8	0.168	0.124	1.11	<0.03	9.5	64
7/23/2015	10:30					0.154	0.115	0.911	0.09	4	130
7/28/2015	6:51					0.182	0.131	0.844	0.072	36	84.4
7/29/2015	11:30	22.32	4.77	7.01	464.9						
8/5/2015	9:50	20.05	4.21	7.43	735.2	0.132	0.096	0.685	0.064	10.8	145
8/6/2015	11:08					0.169	0.092	1.49	0.404	32.8	145
8/18/2015	11:55					0.107	0.075	0.825	0.119	18.6	
8/19/2015	10:30	18.79	5.87	7.10	301	0.111	0.072	0.901	0.079	33.3	58.4
9/16/2015	13:30	21.23	4.54	7.52	697.2	0.095	0.067	0.976	0.102	7	145
9/28/2015	12:00	19.69	5.19	7.49	597	0.098	0.04	0.956	0.094	8	115
10/30/2015	10:30	7.68	8.19	7.41	482						
11/20/2015	9:45	-3.57	9.33	7.16	469.6						

Shingle Creek BCP (Bass Creek Outlet) Monitoring 2015

Date	Time	Temp [C]	DO [mg/l]	pH	Sp. Cond	TP [mg/L]	Ortho-P [mg/L]	TKN [mg/L]	Nitrate [mg/L]	TSS [mg/L]	Chloride [mg/L]
1/28/2015	15:30	-0.16	9.67	7.51	4475						1930
3/9/2015	8:30	-0.16	13.40	7.73	5047						1621
4/12/2015	22:24					0.206	0.071	1.55	0.426	22	424
4/14/2015	14:45	14.5	12.94	8.32	1592	0.111	0.051	1.19	0.17	6.2	464
4/30/2015	13:30	15.14	11.82	7.85	2351	0.076	0.027	0.917	<0.030	4.8	692
5/10/2015	22:32					0.271	0.131	1.75	0.34	<2.0	318
5/13/2015	8:30	8.44	6.33	6.85	1398	0.103	0.072	0.895	0.103	2.8	389
5/28/2015	12:00	20.01	8.46	8.10	1041	0.117	0.077	0.754	0.082	4.33	246
6/9/2015	7:30	17.48	3.47	6.58	1066	0.171	0.142	0.971	0.051	4.8	250
6/22/2015	15:05	22.89	4.01	7.21	570	0.214	0.17	0.956	0.253	13.2	
7/6/2015	11:20	21.37	2.41	7.00	408.2	0.171	0.199	1.29	0.148	56.4	
7/8/2015	8:00	16.28	4.23	7.19	752.7	0.166	0.138	0.822	0.061	10	112
7/23/2015	8:30					0.136	0.105	0.734	<0.030	6	123
7/28/2015	6:23					0.37	0.225	1.52	0.047	76.8	43.6
7/29/2015	10:40	21:48	3.83	7.15	545.3						
8/5/2015	8:55	17.84	3.57	7.29	770	0.218	0.177	1.29	0.092	15.6	143
8/6/2015	11:10					0.216	0.121			21.6	
8/18/2015	21:59					0.196	0.166	1.11	0.216	11.7	
8/19/2015	9:30	18.26	3.48	7.07	567.3	0.172	0.127	0.825	0.046	14	123
9/16/2015	12:30	21.17	6.31	7.58	720.5	0.135	0.078	1.02	0.103	5.33	145
9/28/2015	12:15	19.36	6.35	7.51	697	0.127	0.105	0.763	0.127	5.5	139
10/16/2015	8:15					0.071	0.046	0.651	0.076	4	211
10/30/2015	9:30	7.52	7.12	7.19	690						
11/20/2015	8:30	-2.37	10.40	7.02	570.9	0.079					

Pollutant Load Methodology

FLUX pollutant loading analysis software (Walker 1999) was used to analyze data and calculate each pollutant's total loading. The FLUX method uses daily average flow rates and monitored pollutant concentrations to calculate loads with six different methods. The analyst then selects the most appropriate method based on estimate variability, residuals distribution, stratification schemes, and knowledge of methods.

Sites were analyzed over 12 months in 2015**.** Flows occurring during winter months when monitoring equipment was not installed were estimated using regression relationships with the USGS site. Some caution is needed in these relationships since winter flows may be affected by ice and backwater.

The first step in the data analysis was to correlate pollutant concentration and flow. If correlation exists and is left uncorrected, the loading estimate may be biased. To minimize bias, the following criteria are applied to the selection of appropriate data stratification and load calculation method:

1. Data stratification is required if results are not reasonably independent of flow and time.
2. The stratification scheme provides a robust estimate (i.e., insensitive to method).
3. The method selected provides the smallest coefficient of variation.

Data found to correlate with flow were divided into two groups: those above the mean flow rate and those below the mean flow. The tables below present the data stratification schemes and load calculation methods used for the 2015 stream monitoring data analysis.

2015 FLUX pollutant load methods for SC-0.

Pollutant	Load Calculation Method	Coefficient of Variation	Stratification scheme
TP	Method 2	0.08	0-8 cfs 8-16 cfs >16 cfs
Ortho-phosphate	Method 2	0.14	0-10 cfs 10-20 cfs >20 cfs
TSS	Method 2	0.45	0-7 cfs 7-27 cfs >27 cfs
Nitrate	Method 2	0.07	none
TKN	Method 2	0.15	0-8 cfs 8-17 cfs >17 cfs

2015 FLUX pollutant load methods for SC-3.

Pollutant	Load Calculation Method	Coefficient of Variation	Stratification scheme
TP	Method 2	0.12	0-10 cfs 10-20 cfs >20 cfs
Ortho-phosphate	Method 2	0.08	0-5 cfs 5-15 cfs >15 cfs
TSS	Method 2	0.12	0-12 cfs >12 cfs
Nitrate	Method 2	0.30	none
TKN	Method 2	0.20	none

2015 FLUX pollutant load methods for BCP.

Pollutant	Load Calculation Method	Coefficient of Variation	Flow interval(s) used to stratify data (cfs)
TP	Method 2	0.10	0-3 cfs 3-13 cfs >13 cfs
Ortho-phosphate	Method 2	0.07	0-4 cfs 4-13 cfs >13 cfs
TSS	Method 2	0.23	0-1 cfs 1-13 cfs >13 cfs
Nitrate	Method 2	0.23	0-1 cfs 1-5 cfs > 5 cfs
TKN	Method 2	0.06	0-0.3 cfs 0.3-5 cfs >5 cfs

SC-0 Pollutant Load Trends

Year	Flow	TP		Ortho-P		TSS		VSS		Nitrate		TKN	
	Acre-ft	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)
2004	8,612	3,748	160	882	38	749,572	32	308,647	13	4,409	0.19	--	--
2005	15,367	6,820	163	1,320	32	1,577,400	38	1,031,800	25	13,420	0.32	52,800	1.26
2006	13,255	5,060	140	1,540	43	1,095,600	30	459,800	13	--	--	39,600	1.10
2007	11,239	3,960	130	880	29	811,800	27	431,200	14	9,240	0.30	38,720	1.27
2008	7,950	3,080	142	660	31	367,400	17	248,600	12	6,380	0.30	25,080	1.16
2009	3,917	880	83	220	21	231,000	22	92,400	9	1,320	0.12	5,720	0.54
2010	7,634	3,300	159	660	32	561,000	27	233,200	11	3,740	0.18	22,000	1.06
2011	18,023	5,814	119	1,255	26	1,098,478	22	465,297	9	14,807	0.30	54,294	1.11
2012	7,943	3,384	157	579	27	648,520	30	286,019	13	--	--	21,219	0.98
2013	9,916	4,382	163	511	19	660,628	24	583,448	22	--	--	36,177	1.34
2014	17,483	5,945	125	1,131	24	1,239,189	26	--	--	--	--	55,102	1.16
2015	8,630	2,187	113	1,679	71	683,057	29.1	--	--	4,680	0.073	23,688	1.01

Note: Annual flows presented in acre-feet/year, pollutant loads in pounds/year, and pollutant flow weighted mean concentrations in mg/L

SC-3 Pollutant Load Trends

Year	Flow	TP		Ortho-P		TSS		VSS		Nitrate		TKN	
	Acre-ft	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)
2004	7,355	4,189	209	1,543	77	599,657	30	255,736	13	6,173	0.31	--	--
2005	10,616	5,500	191	2,640	92	464,200	16	215,600	7	8,800	0.30	35,200	1.22
2006	3,843	2,200	211	880	84	451,000	43	138,600	13	--	--	20,240	1.94
2007	6,270	2,200	129	880	52	391,600	23	105,600	6	3,960	0.23	24,200	1.42
2008	2,962	880	109	220	27	85,800	11	92,400	11	1,540	0.19	8,580	1.07
2009	961	220	84	--	--	33,000	13	15,400	6	440	0.17	1,320	0.51
2010	4,799	1,980	152	660	51	391,600	30	147,400	11	4,180	0.32	17,820	1.37
2011	10,099	3,192	116	719	26	591,218	22	211,470	8	3,326	0.12	25,419	0.93
2012	5,147	2,024	145	615	44	287,380	21	108,114	8	--	--	12,572	0.90
2013	7,033	4,110	215	1,012	53	633,717	33	395,899	21	--	--	43,336	2.27
2014	11,736	5,042	158	1,594	54	983,344	31	--	--	8,865	0.28	34,023	1.07
2015	5,159	2,334	166	1,289	75	293,355	20.9	--	--	2,101	0.15	15,950	1.14

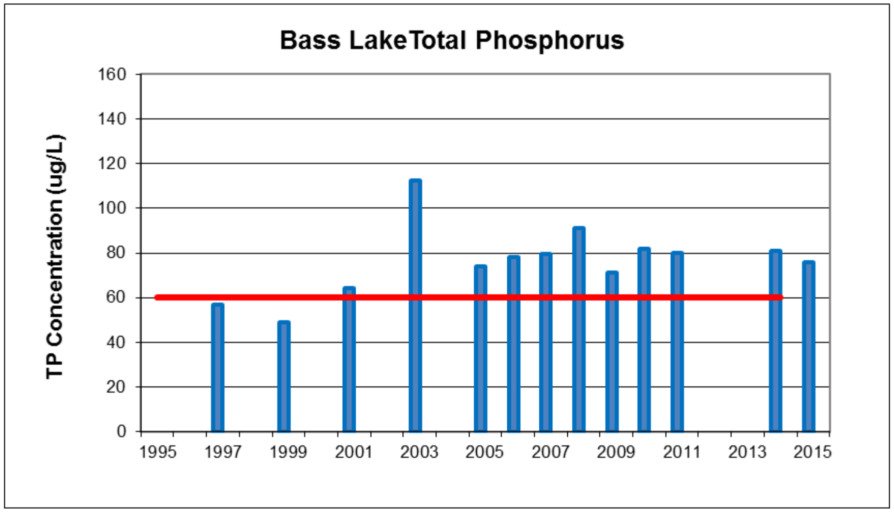
BCP Pollutant Load Trends

Year	Flow	TP		Ortho-P		TSS		VSS		Nitrate		TKN	
	Acre-ft	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)
2004	--	--	--	--	--	--	--	--	--	--	--	--	--
2005	--	--	--	--	--	--	--	--	--	--	--	--	--
2006	--	--	--	--	--	--	--	--	--	--	--	--	--
2007	--	--	--	--	--	--	--	--	--	--	--	--	--
2008	--	--	--	--	--	--	--	--	--	--	--	--	--
2009	--	--	--	--	--	--	--	--	--	--	--	--	--
2010	--	--	--	--	--	--	--	--	--	--	--	--	--
2011	--	--	--	--	--	--	--	--	--	--	--	--	--
2012	--	--	--	--	--	--	--	--	--	--	--	--	--
2013	--	--	--	--	--	--	--	--	--	--	--	--	--
2014	6,837	1,881	101	776	42	106,971	6	--	--	4,281	0.23	13,736	0.74
2015	1,493	792	192	531	129	107,640	23.1			1,856	0.148	5,123	1.14

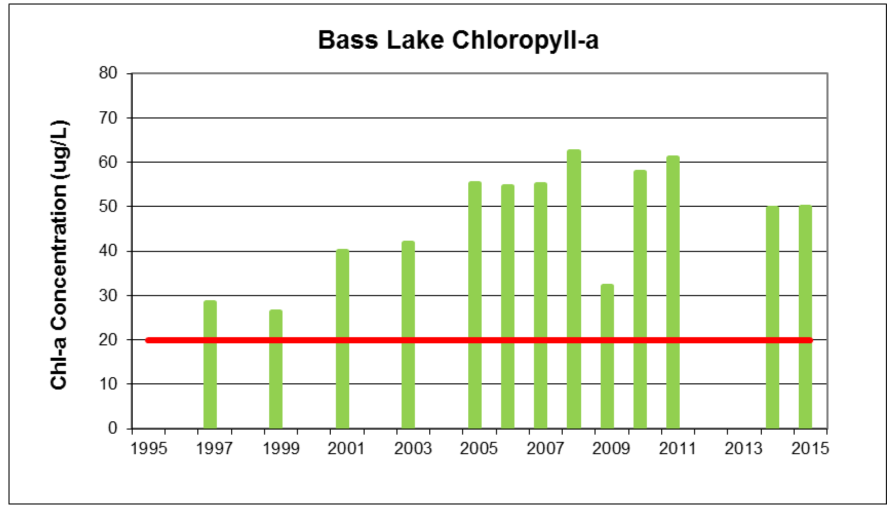
Appendix D

Historical trends data for Bass and Magda Lake.

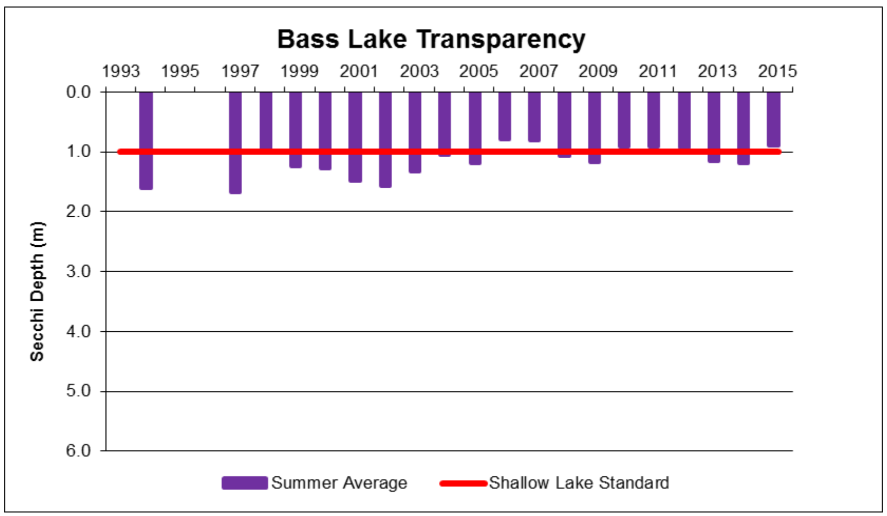
Bass Lake



Bass LakeTotal Phosphorus
TP Concentration (ug/L)
160
140
120
100
80
60
40
20
0
1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015

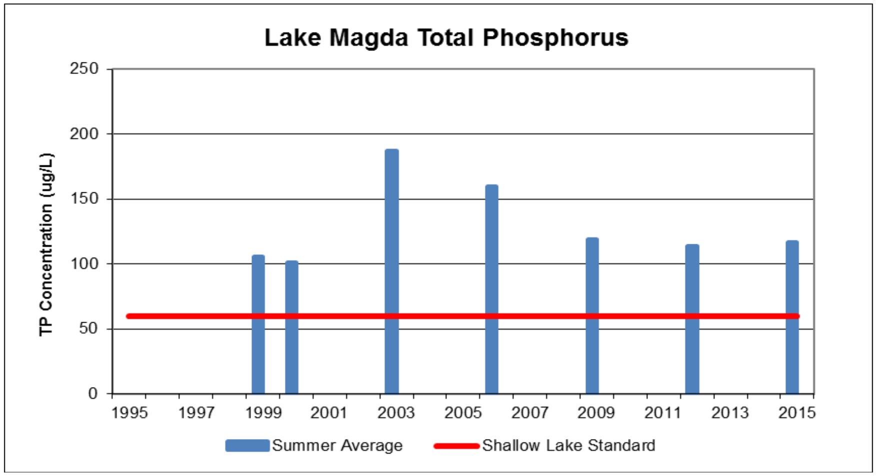


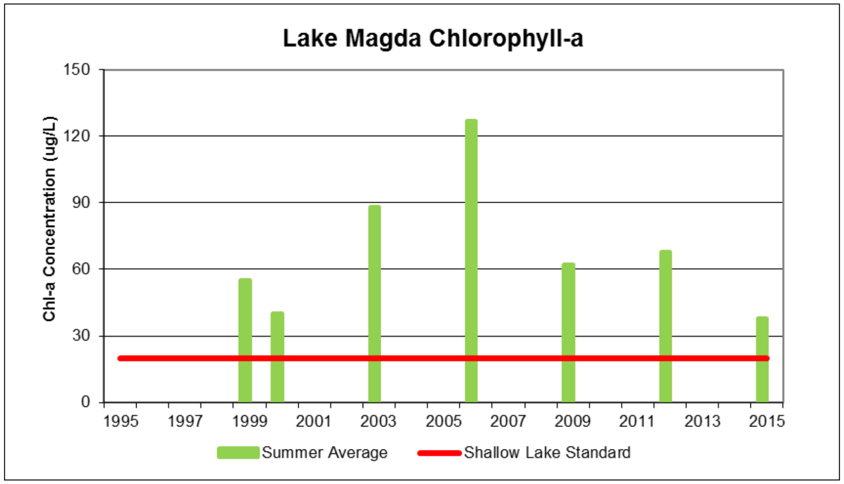
Bass Lake Chloropyll-a
Chl-a Concentration (ug/L)
80
70
60
50
40
30
20
10
0
1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015

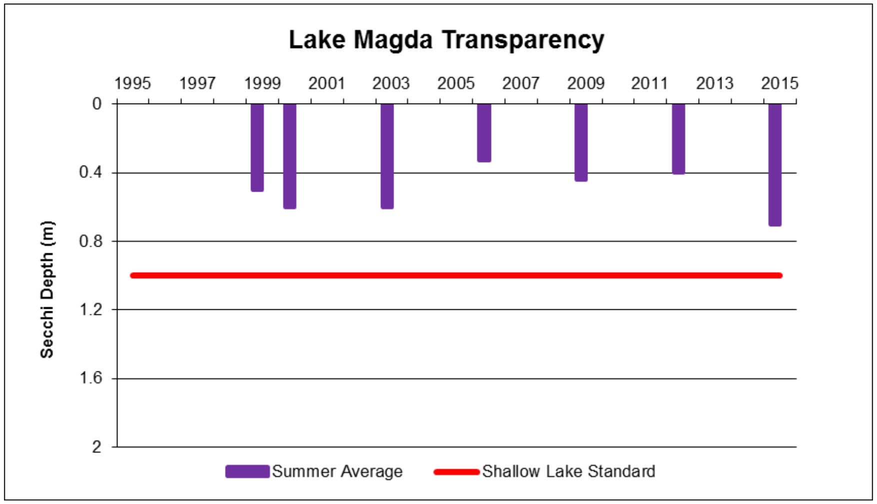


Bass Lake Transparency
1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Secchi Depth (m)
Summer Average
Shallow Lake Standard

Lake Magda


Lake Magda Total Phosphorus
TP Concentration (ug/L)
250
200
150
100
50
0
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
Summer Average
Shallow Lake Standard


Lake Magda Chlorophyll-a
Chl-a Concentration (ug/L)
150
120
90
60
30
0
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
Summer Average
Shallow Lake Standard


Lake Magda Transparency
Secchi Depth (m)
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
0
0.4
0.8
1.2
1.6
2
Summer Average
Shallow Lake Standard