



2015 Lakes Monitoring Report

MARCH 2016



Prepared By: CAPITOL REGION WATERSHED DISTRICT



Capitol Region Watershed District

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May 19, 2016

Dear Stakeholders and Interested Parties:

I am pleased to provide to you a copy of our *2015 Lakes Monitoring Report*. Capitol Region Watershed District's (CRWD) 2016 monitoring program was enhanced by the contributions of numerous agencies and individuals, most notably: Ramsey County Environmental Services Staff, John Manske; and Ramsey Conservation District, Laura Triplett.

Prior to 2013, CRWD reported District lake water quality data within the larger monitoring report that included stormwater data. For the third time in 2015, the District produced a stand-alone Lakes Monitoring Report. The report comprehensively reports chemical, physical, and biological data for each District lake, which provides a complete picture of factors influencing lake water quality and overall lake health. Data contained in this report will support ongoing future lake and watershed management decisions.

I would also like to recognize staff who assisted with the preparation of this report. Britta Suppes, Sarah Wein, Maddie Vargo, Joe Sellner, and Wyatt Behrends had a major role in analyzing and reporting the data.

The *2015 Lakes Monitoring Report* is available at the District's website:

www.capitolregionwd.org/press/crwd-reports. If you have any questions pertaining to this report, contact District Monitoring Coordinator, Britta Suppes at (651) 644-8888 or britta@capitolregionwd.org.

Sincerely,

A handwritten signature in blue ink, appearing to read "Bob Fossum".

Bob Fossum
Water Resource Program Manager

enc: Capitol Region Watershed District's *2015 Lakes Monitoring Report*

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ACRONYMS AND ABBREVIATIONS

ac	Acre
BMP	Best Management Practice
cBOD	5-day Carbonaceous Biochemical Oxygen Demand
cf	Cubic feet
cfs	Cubic feet per second
Chl-a	Chlorophyll-a
Cl	Chloride
CRWD	Capitol Region Watershed District
CS	Chronic Standard
DNR	Department of Natural Resources
DO	Dissolved Oxygen
<i>E. coli</i>	<i>Escherichia coli</i>
EPA	Environmental Protection Agency
ft	Foot/Feet
GPS	Global Positioning System
ha	Hectare
IBI	Index of Biological Integrity
in	Inch
kg	Kilogram
L	Liter
lb	Pound
m	Meter
MCES	Metropolitan Council Environmental Services
MCWG	Minnesota Climatological Working Group
mg	Milligram
mL	Milliliter
MnDOT	Minnesota Department of Transportation
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer System
MSP	Minneapolis-St. Paul International Airport
NA	Not Available
NCHF	North Central Hardwood Forest
NH ₃	Ammonia
NO ₂	Nitrite
NO ₃	Nitrate
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
OHWL	Ordinary High Water Level
Ortho-P	Ortho-phosphate

RCD	Ramsey Conservation District
RCLML	Ramsey County Lake Management Laboratory
RCPW	Ramsey County Public Works
sec	Second
SRP	Soluble Reactive Phosphorus
TB	Trout Brook
TBI	Trout Brook Storm Sewer Interceptor
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
UMN	University of Minnesota-St. Paul Campus
WD	Watershed District
WMO	Watershed Management Organization

DEFINITIONS

Anthropogenic – resulting from the influence of human beings on nature.

Bathymetric – the measurement of water depth in a body of water.

Benthic – the ecological region at the bottom of a body of water.

Biomanipulation – the deliberate alteration of an ecosystem by adding or removing species.

Class 2 Waters – waters of the State that are designated for aquatic life and recreational use.

Chlorophyll-a – a type of chlorophyll pigment found in plants used in oxygenic photosynthesis; used as a measure of phytoplankton production in lakes and streams.

Conductivity – the measure of the ability of water to pass an electrical current; affected by the presence of inorganic dissolved solids and temperature.

Designated Use – the water quality standards regulation requires that States and authorized Indian Tribes specify appropriate water uses to be achieved and protected. Appropriate uses are identified by taking into consideration the use and value of the water body for public water supply, for protection of fish, shellfish, and wildlife, and for recreational, agricultural, industrial, and navigational purposes.

Epilimnion – the top layer of water in a lake, characterized in the summer by warm, circulating water. MPCA lake standards are based on water sampled from this layer.

Eutrophic – a water body with high nutrient concentrations and primary biological productivity. These waters are murky and an extensive macrophyte population. Algal blooms are common.

Fingerling – fish harvested from rearing ponds after one summer of growth.

Fry – newly hatched fish ready to be stocked.

Hardness – the concentration of calcium and magnesium salts (e.g. calcium carbonate, magnesium carbonate) in a water sample.

Hypereutrophic – a water body with excessive nutrient concentrations and primary biological productivity. These waters are characterized by very murky water, frequent algal blooms and fish kills, foul odor, and rough (or less desirable) fish.

Hypolimnion – the part of a lake below the thermocline made up of water that is stagnant and of essentially uniform temperature except during the period of overturn.

Impaired Waters – waters that are not meeting their designated uses because of excess pollutants violating water quality standards.

Littoral Area/Zone – area of a lake that is less than 15 feet in depth where the majority of plants are found.

Mesotrophic – a water body that has intermediate nutrient concentrations and primary biological productivity. These waters are moderately clear and are characterized by late-summer algal blooms, moderate macrophyte populations, and occasional fish kills.

Morphometric – describing parameters relating to external form.

Oligotrophic – a water body that has low nutrient concentrations and primary biological productivity, and is characterized by clear water, few macrophytes, and salmonid fish.

Phytoplankton – the autotrophic plant members of the plankton (drifting organisms) community.

Secchi depth – a measure of the transparency of lake water using a Secchi disk.

Stormwater – water that becomes runoff on a landscape during a precipitation event.

Stormwater Best Management Practices – activities, practices, and structures designed to reduce stormwater pollution and runoff volume and increase groundwater recharge.

Subwatershed – a delineated area of land within a larger watershed where surface waters and runoff drain to a single point before ultimately discharging from the encompassing watershed.

Thermal stratification – refers to the changes in temperature at different depths in a lake as a result of the different densities of water at different temperatures.

Thermocline – the region in a thermally stratified body of water which separates warmer surface water from cold deep water and in which temperature decreases rapidly with depth.

Total Maximum Daily Load – the maximum amount of a substance that can be received by a water body while still meeting water quality standards. This may also refer to the allocation of acceptable portions of this load to different sources.

Turbidity – a measure of the relative clarity of a liquid. Turbidity measurements can provide a simple indicator of potential pollution in a sample. Turbid water will appear cloudy or hazy.

Watershed – a delineated area of land where surface waters and runoff drain to a single point at a lower elevation.

Zooplankton – the heterotrophic animal members of the plankton (drifting organisms) community.

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1 EXECUTIVE SUMMARY

1.1 CAPITOL REGION WATERSHED DISTRICT

Capitol Region Watershed District (CRWD) in Ramsey County, Minnesota is a special purpose unit of government that manages, protects, and improves water resources within its watershed boundaries. CRWD is a 41 square mile subwatershed nested in the Upper Mississippi River basin that contains portions of five cities, including: Falcon Heights, Lauderdale, Maplewood, Roseville, and Saint Paul. CRWD is highly urbanized with a population of 245,000 and 42% impervious surface coverage. All runoff from CRWD eventually discharges to the Mississippi River from 42 outfall locations within the District.

One goal of CRWD is to understand and address the presence of pollutants and their impacts on water quality within the District in order to better protect, restore, and manage local water resources. To address this goal, CRWD established a monitoring program in 2004 to begin assessing water quality and quantity of various District subwatersheds and stormwater best management practices (BMPs) over time. CRWD collects water quality and quantity data from major subwatersheds, lakes, ponds, and stormwater BMPs.

1.2 PURPOSE OF REPORT

This annual report focuses on the water quality of the five lakes (Como, Crosby, Little Crosby, Loeb, and McCarrons) in Capitol Region Watershed District during the 2015 monitoring season (April through October). Specific water quality data (total phosphorus, chlorophyll-a, and Secchi disk depth) for each lake from 2015 were compared to previous monitoring years. Additional biological and physical parameter results (i.e. phytoplankton, zooplankton, macrophytes, fisheries, lake morphometry, and water levels) are also included in this report.

The purpose of this report is to characterize overall lake water quality and health in 2015 and to examine trends over time, which in turn will inform lake management decisions for continued protection and improvement of District lakes. Previous annual monitoring reports (2005-2014) are available on the CRWD website at www.capitolregionwd.org.

1.3 LAKE MONITORING METHODS

Within CRWD, the five lakes are located in four of the sixteen major subwatersheds (Como, Crosby, McCarrons, and Trout Brook). CRWD organized the collection of water quality data for all of these lakes including information on chemical parameters (nutrients, pH, and conductivity), physical parameters (water clarity, dissolved oxygen, and temperature), and biological parameters (chlorophyll-a, aquatic vegetation type and abundance, phytoplankton, zooplankton, and fisheries populations).

CRWD partners with Ramsey County Public Works, Ramsey Conservation District, and the Minnesota Department of Natural Resources to collect lake data. Also, rainfall data was collected by CRWD from six precipitation gauges across the watershed.

1.4 2015 MONITORING RESULTS

The total amount of precipitation for the 2015 calendar year was 35.21 inches which was 4.60 inches greater than the 30-year normal of 30.61 inches. July 2015 was the wettest month of 2015, capturing the two largest storms recorded for the year on July 6 (1.95 inches) and July 12 (1.97 inches). Along with a wet July, May 2015 was also particularly wet with both months being well-above the monthly normal. In comparison to Fall 2014, Fall 2015 was very wet, with September, October, November, and December recording total precipitation above the monthly normal values.

In 2015, the water quality of the five District lakes (Como, Crosby, Little Crosby, Loeb, and McCarrons) varied by water body and by time of year. Based on the MPCA eutrophication numeric water quality standards, Loeb Lake and Lake McCarrons met the MPCA eutrophication water quality standards (for shallow/deep lakes) for all parameters during the 2015 growing season (May to September) (Table 1-1). Crosby and Little Crosby Lakes met both the chlorophyll-a (Chl-a) concentration and Secchi disk depth standards, but failed to meet the standard for total phosphorus (TP) (Table 1-1). Como Lake did not meet the MPCA shallow lake standards for TP and Chl-a concentrations, but met the standards for Secchi disk depth during the entire 2015 growing season (Table 1-1). Como Lake was the only District lake designated as impaired on the MPCA's 2014 303(d) proposed impaired waters list, and has been listed on the MPCA 303(d) list since 2002.

Table 1-1: CRWD 2015 average, historical average, and lake standards for TP/Chl-a/Secchi depth

Lake	2015 Averages			Historical Averages			State Lake Standards		
	TP (µg/L)	Chl-a (µg/L)	Secchi (m)	TP (µg/L)	Chl-a (µg/L)	Secchi (m)	TP (µg/L)	Chl-a (µg/L)	Secchi (m)
Como	215	42.8	1.2	174	33.9	1.5	<60	<20	≥1.0
Crosby	144	18.5	1.4	79	10.9	2.3	<60	<20	≥1.0
Little Crosby	76	12.9	1.9	92	10.2	2.5	<60	<20	≥1.0
Loeb	26	5.1	3.3	29	5.9	3.2	<60	<20	≥1.0
McCarrons	19	3.2	3.7	34	9.8	2.9	<40	<14	≥1.4
	Value does not meet the state standard								
	Value meets the state standard								

Lake grades were calculated for each lake based on the 2015 water chemistry data to provide a more understandable depiction of lake health and to better track lake water quality changes over time. The seasonal means of TP, Chl-a, and Secchi depth were examined for 2015 and previous

years and grades were based on scoring ranges for each parameter (Table 1-2). Based on the lake grading system, Lake McCarrons and Loeb Lake both received excellent lake grades with grades of 'A', which is at or above the historical average lake grade for each lake. Crosby Lake and Little Crosby Lake received 'C' grades, just under the historical average grade for these lakes of 'C+'. Como Lake received the lowest grade of 'D+', also the same as the historical average.

Table 1-2: CRWD 2015 lake grades and historical lake grades for TP/Chl-a/Secchi depth.

Lake	2015 Lake Grade			2015 Average	Historical Lake Grade			Historical Average
	TP	Chl-a	Secchi		TP	Chl-a	Secchi	
Como	F	C	C	D+	F	C	C	D+
Crosby	D	B	C	C	D	B	B	C+
Little Crosby	D	B	C	C	D	B	B	C+
Loeb	B	A	A	A	B	A	A	A
McCarrons	A	A	A	A	C	A	B	B

1.5 2016 RECOMMENDATIONS

Based on the results and findings of the *2015 Lakes Monitoring Report*, CRWD has several goals and recommendations for 2016 to continue improving the monitoring program and the water quantity and quality dataset. Specifically, CRWD aims to complete the following in 2016:

- Analyze additional chemical and physical parameters:** CRWD intends to expand the analysis of chemical and physical data previously collected but not fully analyzed in prior reports. Analysis of other water chemistry and physical attributes will allow a better understanding of overall lake health, such as total nitrogen, chloride, soluble reactive phosphorus (SRP), and temperature profiles.
- Continue to conduct fish surveys:** In 2016, CRWD will conduct fish population surveys on Crosby Lake, Little Crosby Lake, Loeb Lake, and Lake McCarrons.
- Complete an internal loading assessment of Lake McCarrons:** In 2016, CRWD will investigate the changes to internal loading in Lake McCarrons that have occurred since the 2004 alum treatment using sediment cores from the bottom sediments that were extracted in February 2016. The results of these sediment cores will be used to complete a phosphorus budget that will evaluate all internal and external sources to the lake, which will assist in determining future management strategies for Lake McCarrons.
- Complete an in-lake management analysis of Como Lake:** Como Lake has a long history of nutrient impairment due to excess phosphorus. The District has implemented several projects to address external phosphorus loading into the lake, including the Arlington-Pascal Stormwater Improvement Project. Despite efforts to control external sources, measurable water quality improvements have not been realized. Investigation into in-lake chemical and biological dynamics in Como Lake has been recommended.

2 INTRODUCTION

2.1 CRWD BACKGROUND

The Capitol Region Watershed District (CRWD) represents a small urban watershed nested in the Upper Mississippi River basin, located entirely in Ramsey County, Minnesota. All runoff from the watershed eventually discharges to the Mississippi River along a 13-mile reach in St. Paul, Minnesota through 42 storm tunnel outfall pipes. All surface water and stormwater runoff in the watershed is managed by CRWD, a special purpose unit of government founded in 1998 with the goal of managing, protecting, and improving all water resources within the watershed. CRWD contains portions of five cities, including: Falcon Heights, Lauderdale, Maplewood, Roseville, and Saint Paul (Figure 2-1). CRWD is highly developed and urbanized with a population of 245,000 and 42%+ impervious surfaces. Land use in CRWD is primarily residential and commercial with areas of industrial use and parkland.

2.2 CRWD WATER QUALITY ISSUES

Urban development in the watershed over time has significantly impacted the health and sustainability of the Mississippi River as well as CRWD lakes, wetlands, and streams. Impervious surfaces generate polluted stormwater runoff which causes poor water quality, increased peak storm flows, decreased groundwater recharge, increased flooding, and loss of biological habitat. Subsequently, stormwater runoff is one of the most significant sources of pollution to CRWD water resources. It delivers fertilizers, pesticides, pet and wildlife waste, nutrients, sediment, heavy metals, and other anthropogenic pollutants to lakes, ponds, and wetlands located in the District. As stormwater runs off the urban landscape, it is collected and conveyed through an extensive network of underground storm sewer pipes that eventually drain to the Mississippi River.

Both historical and current water quality data of CRWD lakes, ponds, and the Mississippi River indicate that these water bodies are impaired for various pollutants (including nutrients, bacteria, and turbidity) and are not meeting their designated uses for fishing, aquatic habitat, and recreation. The Mississippi River and Como Lake are listed on the Minnesota Pollution Control Agency (MPCA) 2014 303(d) proposed impaired waters list (MPCA, 2016). Impaired waters require a total maximum daily load (TMDL) study for pollutants of concern including nutrients, turbidity, metals, bacteria, and chloride.

The nutrient of primary concern in CRWD lakes is phosphorus. Phosphorus is a biological nutrient which limits the growth of algae in most lakes and streams and is often found in high concentrations in stormwater. Phosphorus occurs naturally in the environment, but in excess can cause the overgrowth of algae and aquatic plants in lakes and rivers which reduces dissolved oxygen levels and increases turbidity of the water column. Common sources of

phosphorous include fertilizers from lawns and gardens, leaves and grass clippings, pet and wildlife waste, and automobile emissions.

CRWD is within the Northern Central Hardwood Forest (NCHF) ecoregion. It is one of seven ecoregions in Minnesota and is characterized as an area with fertile soils with agriculture as the dominant land use in rural areas. In most lakes in the NCHF ecoregion, phosphorous is the least available nutrient; therefore, the concentration of phosphorous controls the extent of algal growth. Algal growth in turn affects the clarity and recreational potential of lakes.

Chlorophyll-a (Chl-a) is a pigment present in algae. Measuring Chl-a concentration is a proxy for measuring algal population. Algal blooms can make recreation unpleasant and prevent it entirely, and certain species of algae are toxic to humans and other animals. In addition, as algae die and decompose, oxygen is consumed from the water column and made unavailable for fish and other aquatic animals. Chronic low dissolved oxygen concentrations (<5 mg/L) may result in fish kills and low diversity of aquatic species (Kalff, 2002).

Water transparency, or water clarity, (determined using a Secchi disk) is another concern in area lakes. Lakes with high water clarity are generally considered healthier, and are characterized by more submerged aquatic plant growth, as clear water allows light to permeate to lower depth levels (Kalff, 2002). Increased plant growth also provides better habitat for aquatic organisms, including fish. Poor water clarity is a result of increased turbidity caused by suspended sediments, organic matter, and/or phytoplankton (algae).

Chloride in water bodies is a contaminant of concern for CRWD. High concentrations of chloride can harm fish and plant life by creating a saline environment. Also, once in dissolved form, chloride cannot be removed from a water body. Chloride is primarily sourced from road salt application for de-icing in the winter months.

2.3 CRWD LAKE MONITORING PROGRAM GOALS

CRWD was formed to understand and address these water quality impacts and to better protect and manage local water resources. In 2004, CRWD established a monitoring program to assess water quality and quantity of various District subwatersheds and stormwater best management practices (BMPs). Prior to the CRWD monitoring program, limited data was available on stormwater quantity and quality in the watershed. The objectives of the program are to identify water quality problem areas, quantify subwatershed runoff pollutant loadings, evaluate the effectiveness of BMPs, provide data for the calibration of hydrologic, hydraulic, and water quality models, and promote understanding of District water resources and water quality.

The *CRWD 2015 Lakes Monitoring Report* presents information on annual CRWD lake water quality monitoring, including data collection methods and results for water chemistry, physical parameters, and biological parameters. A climatological summary is also included to summarize the precipitation, snowpack, and notable climatic events from 2015. Previous annual monitoring reports (2005-2014) are available on the CRWD website at

www.capitolregionwd.org. Results and analysis of CRWD stormwater monitoring and stormwater BMPs are discussed in separate reports (CRWD, 2016; CRWD, 2015b; CRWD, 2014b; CRWD, 2012b), which are also available on the CRWD website.

2.4 OVERVIEW OF CRWD LAKES

There are five lakes within the boundaries of CRWD: Como Lake, Crosby Lake, Little Crosby Lake, and Loeb Lake in St. Paul, and Lake McCarrons in Roseville (Figure 2-1). The lakes are monitored by Ramsey County Public Works (RCPW) and CRWD to assess overall health and to determine if each lake supports their designated uses for swimming, fishing, and/or aesthetics. All of the lakes receive stormwater runoff (directly and/or indirectly) and are nested within the Mississippi River Basin.

Como Lake, Crosby Lake, Little Crosby Lake, and Loeb Lake are classified as shallow lakes and Lake McCarrons is classified as a deep lake. Shallow lakes have a maximum depth less than 15 ft, or more than 80% of the lake within the littoral zone (MPCA, 2014). The littoral zone is the near-shore area of the lake in which plants grow (Kalff, 2002). Deep lakes have a maximum depth greater than 15 ft, or less than 80% of the lake within the littoral zone (MPCA, 2014).

2.4.1 COMO LAKE

Como Lake (Chapter 6) is a 70.5 acre lake with a maximum depth of 15.5 ft and is located in the City of Saint Paul. The 1,856 acre Como Lake watershed land uses are primarily residential and parkland. Como Lake is classified as a shallow lake because nearly 100% of the lake is considered the littoral zone. The lake has been monitored since 1984, and although water quality has improved slightly over time, there has been an observed cyclical variation in water quality (Noonan, 1998). In an effort to improve water quality in the lake, the Como Lake Strategic Management Plan (CRWD, 2002) was developed in 2002 and can be found on the District website (www.capitolregionwd.org). Como Lake is listed on the MPCA's 2014 303(d) impaired waters draft list for chloride impairment (MPCA, 2016). Como lake was also listed as impaired by the MPCA for nutrients (2002) and mercury (1998).

2.4.2 CROSBY LAKE & LITTLE CROSBY LAKE

Crosby Lake (45 acres) and Little Crosby Lake (8 acres) (Chapters 7 and 8) are shallow lakes situated in the Mississippi River floodplain in Saint Paul and part of the Crosby Farm Regional Park and the Mississippi River National River and Recreation Area. The lakes are located within the 1,522 acres of Crosby Lake subwatershed; 197 acres of the subwatershed drain to Crosby Lake while 37 acres drain to Little Crosby Lake. The lakes are divided into two separate water bodies by a marsh/bog area 825 ft long. Crosby Lake is classified as a shallow lake because it has a maximum depth of 17 ft and the littoral zone covers 100% of the lake area. Little Crosby Lake is also considered a shallow lake even though it has a maximum depth of 34 ft, because it has a littoral area of 90% (<15 ft in depth). The watershed land uses for both water bodies are primarily parkland, single family residential, and industrial. A management plan for Crosby Lake (which included information regarding

Little Crosby Lake) was created in 2012 (CRWD, 2012a), and can be found on the District website (www.capitolregionwd.org). Crosby Lake has been monitored since 2005; Little Crosby Lake has been monitored since 2011. Water quality of both lakes can be greatly affected by the Minnesota and Mississippi Rivers, since it is located in the floodplain of their confluence. Both lakes are not currently on the MPCA 303(d) list.

2.4.3 LOEB LAKE

Loeb Lake (Chapter 9) is a 9.7 acre shallow lake with a maximum depth of 28 ft and has a littoral area of 81%. Located in Marydale Park in the City of Saint Paul, the predominant land uses in the surrounding drainage area (44 acres) are mixed residential and parkland. The lake has a small drainage area, with no outlets. Loeb Lake has been monitored since 2003 (with the exception of 2004). A management plan for the lake was created in 2009 (CRWD, 2009), and can be found on the District website (www.capitolregionwd.org). Loeb Lake is an unimpaired water body and is not currently on the MPCA 303(d) list.

2.4.4 LAKE MCCARRONS

Located in the City of Roseville, Lake McCarrons (Chapter 10) is a 74.7 acre lake with a maximum depth of 57 ft. It is considered a deep lake with less than a 34% littoral zone. Lake McCarrons has a watershed area of 1,070 acres, with land use of mainly mixed residential and open space, including the entire Villa Park wetland system, which outlets to the lake. Lake McCarrons has been monitored since 1988, and is the only District lake that allows swimming and has development (residential) directly on its shoreline. Lake McCarrons received an alum treatment in 2004 and water quality of the lake has shown improvement since this occurred. A management plan for the lake was created in 2003 (CRWD, 2003), and can be found on the District website (www.capitolregionwd.org). The lake is considered unimpaired and is not currently listed on the MPCA 303(d) list of impaired waters.

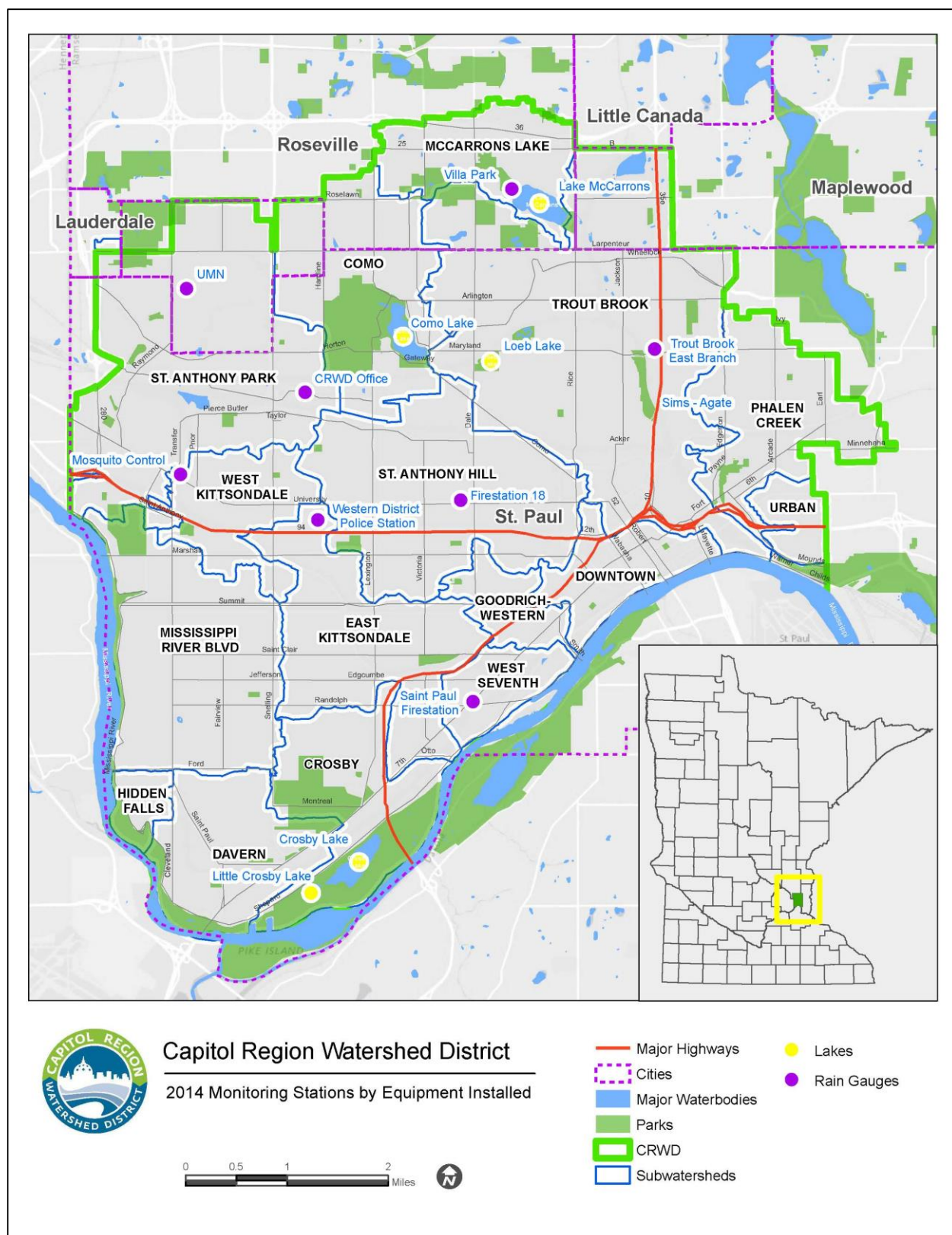


Figure 2-1: CRWD 2015 lake and rain gauge monitoring locations in Ramsey County, Minnesota.

3 METHODS

3.1 MONITORING METHODS

3.1.1 LAKE LEVEL

Lake elevation monitoring is organized by the Minnesota Department of Natural Resources (DNR) Lake Level Minnesota Program (DNR, 2015j). This program coordinates the monitoring by organizations and volunteers to gather weekly data of elevations on lakes throughout the state. Lake levels are measured using staff gages that are placed near the lakeshore in a stable and accessible location. Data on lake levels is collected by Ramsey County staff and provided to the DNR for inclusion in the LakeFinder database that can be accessed online to view historical lake levels for a particular lake (DNR, 2015i). Lake elevation monitoring by the DNR within CRWD occurs on Como Lake, Loeb Lake, and Lake McCarrons. CRWD collected lake level data from early spring to late fall in 2015 on Como Lake (March – November), Crosby Lake (April – November), and Lake McCarrons (June – October).

As this data continues to be compiled, a lake elevation graph is updated annually in order to view historical fluctuations in lake levels. The ordinary high water level (OHWL) is one other parameter that is shown on these graphs (where applicable). The OHWL is defined as the “highest water level that has been maintained for a sufficient period of time to leave evidence upon the landscape, commonly the point where the natural vegetation changes from predominantly aquatic to predominantly terrestrial” (Scherek, 1993). The OHWL is used to determine regulatory controls, with the Minnesota DNR regulating activity below the OHWL and local units of government regulating activity above the OHWL. By including this as a part of the lake elevation graph, observations can be made as to how current and past years compare to the “normal” lake level. This does not always mean that the lake level ever reaches or surpasses the OHWL, as this level is based on landscape evidence indicating the historical water level and is not an average of past monitored water levels.

3.1.2 CHEMICAL AND PHYSICAL DATA COLLECTION

Lake water quality data for 2015 and the preceding years was collected by RCPW throughout the growing season (May through October), resulting in an average of eight samples for each year (RCPW, 2009). In 2015, lakes were monitored beginning in early April and ending in late October, resulting in a total of ten samples for Como Lake, Loeb Lake, and Lake McCarrons. Crosby and Little Crosby Lakes were only sampled nine times from mid-April through late October. At each lake, RCPW staff anchored a watercraft over the deepest part of the lake, and monitored for various water quality parameters. The physical and chemical parameters of depth, temperature, dissolved oxygen, conductivity, and pH were measured at one-meter sampling intervals for the full depth profile of the lake using a multi-probe. From these recordings, the depths of the epilimnion, thermocline, and hypolimnion were recorded.

Additionally, at the lake sampling location, water chemistry samples were collected at multiple depths along the profile of the lake. At all lakes, two samples were obtained within the epilimnion, or mixed water layer. If RCPW staff was able to identify thermal stratification (where depths for the divisions between the epilimnion, thermocline, and hypolimnion can be identified), additional water samples from other depths were collected. One additional water sample was collected from within the thermocline and two were collected from within the hypolimnion. Any water samples collected were then stored and transported back to the RCPW lab and analyzed for the following parameters: Chl-a, TP, soluble reactive phosphorous (SRP) (i.e. ortho phosphorus), total Kjeldahl nitrogen (TKN), nitrate (NO₃), ammonia (NH₃), and chloride ion concentrations (Cl). Water transparency, or water clarity, was determined with the use of a Secchi disk. A Secchi disk is a black and white patterned disk that is connected to a line or pole. To take a measurement, the Secchi disk is lowered slowly into the water column until the pattern is no longer visible. The depth at which the disk is no longer visible is then recorded.

3.1.3 PHYTOPLANKTON AND ZOOPLANKTON COLLECTION

Phytoplankton and zooplankton data collection occurred at the same time as water quality data collection by RCPW for 2015 and previous monitoring years. For phytoplankton analysis, a composite sample was collected using a plastic tube that was inserted vertically 2 m into the upper layer of the water column. This sample was emptied into a bucket, thoroughly mixed, and a sub-sample was collected and preserved. This water sample was placed in an enclosed cooler and taken back to the lab for analysis (RCPW, 2012).

To collect a zooplankton sample, a net tow was lowered down to the observed thermocline in order to collect samples from the oxygenated layer of the lake.. The net tow was allowed to settle and then pulled back up to the water surface at a rate of 1 m/sec. The net and capture bucket were drained by swirling the capture bucket which allowed the water to drain out of the net and screen. Once the volume was reduced to 100 mL, the contents of the capture bucket were poured into another container and preserved in a 5% formaldehyde solution, then taken back to the RCPW lab for analysis (RCPW, 2012).

3.1.4 AQUATIC VEGETATION SURVEYS

Point-Intercept Survey Method

In 2015, all lakes were surveyed by the Ramsey Conservation District (RCD) for aquatic vegetation presence and abundance using the point-intercept method. This method consisted of using a GPS to pre-select specific monitoring points throughout the full area of the lake. At each evenly spaced (70 m distance) point, a double-tined metal rake was thrown out 1 m from the boat, dragged a distance of 1 m and brought back into the boat. Plant species were identified and given an abundance ranking based on the amount collected on the rake (Table 3-1). Any plants floating on the water surface were also identified. RCD surveyed all CRWD lakes three times throughout the course of the year: spring, summer, and early fall.

Table 3-1: Average abundance rating and description for aquatic vegetation (RCPW, 2009).

Percent Cover of Tines	Abundance Ranking
81-100	5
61-80	4
41-60	3
21-40	2
1-20	1

Biovolume Survey Method

To collect data on submerged aquatic vegetation as well as data about the lake bottom, RCD used a Lowrance HDS-5 GPS enabled depth finder to assess evenly spaced transects at a minimum distance of 40 meters. The sonar log data that was collected was then analyzed by CI BioBase software to determine the depth of the lake and the amount of aquatic vegetation (biomass) along each transect. These surveys also produced information estimating lake area, bathymetry, and lake water volume.

3.1.5 FISH STOCKING AND SURVEYS

Fish stocking occurs annually through the Minnesota DNR in an effort to improve fishing conditions on selected Minnesota lakes. Roughly 25% of Minnesota's 5,400 fishing lakes have a set stocking schedule (DNR, 2015f). Fish are stocked at different life stages depending on the desired effect in the lake. Table 3-2 describes the different types of fish used for stocking.

Table 3-2: Minnesota DNR fish stocking size definitions (DNR, 2015f).

Fry	Fish stocked in lakes shortly after hatching from eggs.
Fingerling	Fish harvested from rearing ponds after one summer of growth.
Yearling	Fish that are a year old at the time of stocking.
Adult	Fish more than 1 year old, usually transferred from other waters.

Fish surveys are conducted every 5-10 years by the DNR on the majority of Minnesota lakes. Surveys occur more frequently, however, on lakes of higher fishing importance. Through fish surveys, the DNR gains information on the species of fish in a lake in order to make management decisions and understand changes in lake water quality. Fish are collected using various field techniques based on the type and size of fish to be collected. These survey techniques include: gill netting (to capture larger, predator fish), trap netting (to capture smaller panfish), trawl and shoreline seines (to capture young fish), and electrofishing (to survey for bass, crappies and young walleyes). Once captured, information is recorded on the species, count, weight, and length, as well as how these measures compare to the normal expected range for the species (DNR, 2015f). In 2015, the DNR did not survey any CRWD lakes. CRWD contracted with Wenck Associates, Inc. to conduct surveys on Como Lake, Crosby Lake, and Little Crosby Lake

in 2015. These additional surveys by CRWD were conducted in 2015 in order to obtain more information about fish populations on all CRWD lakes. Wenck Associates staff followed DNR procedures for sampling of fish in these lakes.

3.2 DATA ANALYSIS METHODS

3.2.1 MORPHOMETRIC DATA

Morphometric data was compiled for each lake. This included information regarding lake surface area, mean and maximum depth, littoral area percentage, lake water volume, watershed area, and watershed-to-lake area ratio. The watershed-to-lake area ratio represents how large the watershed is compared to the size of the lake. A high ratio indicates a large portion of land for potential runoff to the lake, while a low ratio indicates a smaller area conducting runoff. In general, having a lower ratio in urban areas decreases external nutrient loading to lakes, which in turn can result in improved water quality.

3.2.2 WATER QUALITY STANDARDS COMPARISON

A lake is considered eutrophic if it has high nutrient levels, low dissolved oxygen concentrations, and frequent algal blooms. Although some lakes are naturally eutrophic, many have become eutrophic as a result of anthropogenic activities. In order to identify eutrophic water bodies in Minnesota, the MPCA establishes eutrophication numeric water quality standards in lakes for TP, Chl-a, and Secchi depth, which were updated in 2014 (Table 3-3) (MPCA, 2014). In the NCHF ecoregion, a different standard exists for shallow and deep lakes. Seasonal means were determined for each of these parameters based on the monitoring events that occurred between May and September of 2015. A lake is considered impaired under MPCA standards if it exceeds the standard for TP concentration and either the Secchi disk depth or Chl-a concentration. Lakes that do not meet the standards may be placed on the MPCA 303(d) list of impaired waters. To account for differences in natural trophic state, the standards vary by ecoregion and lake type.

Table 3-3: Deep and shallow lake state water quality standards (MPCA, 2014).

Parameter	Deep Lake Standard ^{a,b}	Shallow Lake Standard ^{a,c}	Units	Source
TP*	<40	<60	µg/L	Minn. Stat. § 7050.0222
Chlorophyll-a	<14	<20	µg/L	Minn. Stat. § 7050.0222
Secchi depth	≥1.4	≥1.0	m	Minn. Stat. § 7050.0222

^a Standards apply to Class 2B waters in the North Central Hardwood Forest ecoregion. Class 2B waters are designated for aquatic life and recreational use. All standard concentrations apply to chronic exposure.

^b A deep lake is defined as a lake with a maximum depth > 15 feet or one in which < 80% of the lake is in the littoral zone.

^c A shallow lake is defined as a lake with a maximum depth < 15 feet or one in which > 80% of the lake is in the littoral zone.

*MPCA standard for TP is listed in mg/L, but has been converted to µg/L.

In 2014, CRWD staff changed the calculation of summer averages for TP and Chl-a in comparison to previously reported data to meet MPCA protocols specified in the Guidance Manual for Assessing the Quality of Minnesota Surface Waters (MPCA, 2014). As described in the chemical monitoring methods above, water quality samples are collected at discrete depths in the water column. For previously reported (2005-2013) summer averages by CRWD, only the surface water quality sample was used for the calculation. If two samples were collected within the epilimnion, however, the average of these values should be used to find the daily average TP and Chl-a values, which can then be used to calculate the seasonal mean.

For the 2014 data and all historical TP and Chl-a data for all lakes, staff recalculated all annual averages to meet MPCA protocols. Where two samples were collected in the upper 2 m of the water column and both of these samples were considered to be in the epilimnion (i.e. the stratification depth on the day the samples were collected was deeper than 2 m), so the average of these values was calculated. To determine the seasonal mean, the average of the daily means from May – September (the growing season for CRWD lakes) was calculated. If the lake stratified higher than 2 m and only one sample was collected from the epilimnion, this value was taken as the respective TP or Chl-a value for that day. While these revised calculations slightly changed the seasonal average values for various years, no historical trends were altered significantly.

The 2015 summer averages for TP, Chl-a, and Secchi were also calculated using MPCA protocols utilized in 2014. However, in 2015 all summer average calculations were calculated using an automated script developed in Kisters WISKI water management software. CRWD worked with WISKI development staff to create scripts that calculate epilimnetic values using the guidelines outlined in the above paragraph. After script development, staff noted minor corrections to previously calculated data, which were updated in this report. Additionally, a script was developed to determine the hypolimnetic TP value for each sampling day for all lakes and all years monitored. This script selects the deepest point in the hypolimnion, then takes the average of all points from May – September (the growing season for CRWD lakes). This was developed in order to compare annual epilimnetic and hypolimnetic TP averages. All calculations made by the scripts in WISKI were compared to manual calculations of summer averages for validation and QA/QC.

3.2.3 LAKE GRADING SYSTEM

CRWD uses a lake grading system in order to give a qualitative measure to the water quality data and compare between years monitored (Table 3-4). This is based on the Metropolitan Council's lake grading system that is used to compare lakes across the metro region and to offer a non-technical value of lake water quality that is more understandable to a wide variety of audiences (Osgood, 1989). The seasonal means of TP, Chl-a, and Secchi depth were examined for 2015 and previous years and grades were based on ranges for each parameter. The range is weighted such that a certain percentage of Minnesota lakes fall into each grade. Each grade corresponds not only to ranges in the three lake eutrophication parameters (TP, Chl-a, and Secchi depth), but also to a recreational value for the lake that provides a description of user quality (MC, 2015). CRWD assigned each letter grade a numerical value (A = 5, B = 4, C = 3, D = 2, F = 1), and the average of these three values provided an overall lake grade (Table 3-5). The ranges in Table 3-5

are based off methods used by the Minnehaha Creek Watershed District in their monitoring reports (MCWD, 2015).

Table 3-4: Water quality parameter lake grade ranges, percentile ranges, and description of lake grade user quality (MC, 2015; Osgood, 1989).

Grade	Percentile	TP (µg/l)	Chl-a (µg/l)	Secchi (m)	Description of User Quality
A	<10	<23	<10	>3.0	Full recreational use capability
B	10-30	23-32	10-20	2.2-3.0	Very good water quality but some recreational use impairment
C	30-70	32-68	20-48	1.2-2.2	Average water quality but are recreationally impaired
D	70-90	68-152	48-77	0.7-1.2	Severly impaired recreational use
F	>90	>152	>77	<0.7	Extremely poor water quality; little to no recreational use

Table 3-5: CRWD overall lake grade ranges (MCWD, 2015).

Grade	Range
A	4.67 - 5.00
A-	4.34 - 4.66
B+	4.01 - 4.33
B+	3.67 - 4.00
B-	3.34 - 3.66
C+	3.01 - 3.33
C	2.67 - 3.00
C-	2.34 - 2.66
D+	2.01 - 2.33
D	1.67 - 2.00
D-	1.34 - 1.66
F	< 1.33

3.2.4 PHYTOPLANKTON AND ZOOPLANKTON LAB ANALYSIS

All methods for lab analysis of phytoplankton and zooplankton were obtained from Ramsey County Lake Management Laboratory (RCLML), a part of RCPW (RCPW, 2012). In the lab, the preserved phytoplankton sample was analyzed and identity/counts were recorded. The classes/phylums that were identified are listed and described in Table 3-6 (Kalff, 2002; UCMP, 2015).

Table 3-6: Phytoplankton types, taxonomic classification, description, and water quality significance.

Phytoplankton	Classification	Description	Water Quality Significance
Bacillariophyta	Class	Diatoms	Large populations suggest higher levels of dissolved silica needed to build external skeletons
Chlorophyta	Phylum	Green algae	Greatly contribute to freshwater lake species richness; contribute most significantly to biomass of eutrophic systems
Chrysophyta	Class	Golden-brown algae	Not overly abundant in eutrophic lakes; more plentiful in oligotrophic, clear-water lakes
Cryptophyta	Phylum	Cryptomonads	Most prevalent in oligotrophic and mesotrophic lakes; division does not contain an abundance of species types
Cyanophyta	Phylum	Blue-green algae	Indicative of highly nutrient-rich (eutrophic and hypereutrophic) lakes; large blooms are aesthetically displeasing and some can be toxic
Euglenophyta	Phylum	Euglenoids	Generally small contribution to overall biomass except in small, highly eutrophic bodies of water
Pyrrophyta	Phylum	Dinoflagellates	Typically contribute small portion of total biomass or species richness in temperate lakes

To analyze zooplankton, the preserved sample from the field was measured and a subvolume was analyzed for identity/counts. The zooplankton that were identified in this process are shown and described in Table 3-7 (Kalff, 2002). The Cladocerans identified during analysis consisted of *Daphnia*, *Bosmina*, *Chydorus*, *Ceriodaphnia*, *Diaphnosoma*, and *Leptodora*. These genus-level organisms were combined and grouped under the heading ‘Cladocera’ for analysis.

Table 3-7: Zooplankton types, taxonomic classification, description, and water quality significance.

Zooplankton	Classification	Description	Water Quality Significance
Cyclopoida	Order	Carnivorous copepods	Primarily carnivorous crustaceans; feed on other zooplankton and fish larvae but also eat algae, bacteria, and detritus
Calanoida	Order	Omnivorous copepods	Crustaceans that feed on ciliates as well as algae; change diet based on multiple variables including season and food availability
Nauplii	Genus	Juvenile copepods	Classified as <i>nauplii</i> during the first 5 or 6 molts (moltling occurs 11 times before adulthood) during the life span of a copepod
Rotifera	Phylum	Soft-bodied, multicellular invertebrates	Name originates from rotating wheel of cilia by mouth; important among invertebrates as many species can produce multi-generations per year
Cladocera	Suborder	Type of crustacean	Mainly important filter-feeders covered by a hard cover; specific species <i>Daphnia</i> are main food source for planktivorous fish

Techniques for creation of phytoplankton and zooplankton figures in the following individual lake results sections were based off methods used in the Minneapolis Park and Recreation Board 2012 Water Resources Report (MPRB, 2015). There are two figures for both phytoplankton and zooplankton. The first figure for phytoplankton compares total phytoplankton concentration and TP concentration from April to October. The first figure for zooplankton compares total zooplankton density and Chl-a concentration from April to October. The second figures depict the relative abundance of each type of phytoplankton and zooplankton in order to examine changes in their populations throughout the months monitored.

3.2.5 AQUATIC VEGETATION ANALYSIS

Biovolume Analysis

Sonar data was entered into CI BioBase software that generates aquatic vegetation and bathymetric maps (CIBB, 2015). The biovolume heat maps were coded by different color zones to highlight differences in cover of aquatic vegetation. Red indicates that 100% of the water column is being taken up by biovolume, or vegetation is growing to the water surface, and blue indicates 0%, or bare lake bottom. Statistics calculated along with the maps included plant biovolume (the percentage of the water column that is vegetation) and percent area covered (the amount of the lake area where vegetation exists) (CIBB, 2015).

Point-Intercept Analysis

Aquatic vegetation has been monitored infrequently in past years on CRWD lakes. Establishing a baseline of vegetation data for all lakes will be a key factor in making future monitoring decisions. Aquatic vegetation within a lake is dependent on many different factors, including: water clarity, water chemistry, and physical lake parameters (including depth, sediment substrate type, lake size/shape, and shoreline vegetation). Not only does aquatic vegetation stabilize bottom sediment, plants also provide habitat for aquatic animals and are usually the main primary producers in shallow lakes (Kalff, 2002). Collecting data on aquatic vegetation provides baseline information on what vegetation is in the lake, where it exists on the lake, and how much is present. Measuring annual changes in these factors can help identify trends in aquatic vegetation and water quality.

Collecting data on aquatic vegetation using the point-intercept method allowed for two primary analyses to occur: computation of percent occurrence and average abundance. Percent occurrence represents the number of times a plant species was observed divided by the number of total sample sites where vegetation was observed. This information gives a good picture of the most common species of aquatic vegetation found on the lake. Average abundance is calculated as the average of the abundance rankings (measured at each location found) for a species. This shows how much vegetation of each species is occurring at the locations where vegetation is noted. A high average abundance ranking indicates thick cover of a species where it is observed. Conversely, a low average abundance ranking indicates minimal growth of a species.

4 CLIMATOLOGICAL SUMMARY

4.1 PRECIPITATION DATA COLLECTION METHODS

CRWD utilizes climatological data collected by the Minnesota Climatology Working Group (MCWG) at the University of Minnesota-St. Paul and National Weather Service (NWS) at the Minneapolis-St. Paul International Airport (MSP) to assist in calculating annual precipitation, runoff, and loading.

MCWG records precipitation every fifteen minutes from an automatic rain gauge located approximately two miles west of the CRWD office. The MCWG rain gauge was used as CRWD's primary precipitation monitoring station for rainfall because of the gauge's close proximity to the District. The data is reported on a public website (<http://climate.umn.edu/>). Rainfall totals (15-minute and daily) were recorded by CRWD from the MCWG website (MCWG, 2016). Snow and ice totals were not accurately reported by MCWG due to equipment limitations.

The NWS weather station at MSP, located approximately ten miles south of the CRWD office, records many climate variables for each day, including: maximum, minimum, and average temperature; rainfall; snowfall and snow water equivalent; and depth of snowpack. Data is reported on a public website (<http://www.weather.gov/mpx/mspclimate>). If a snow or ice event occurred, the NWS daily precipitation totals were utilized by CRWD since their measurement equipment more accurately measures snow-water and ice-water equivalents than the MCWG gauge.

4.2 2015 PRECIPITATION RESULTS

Table 4-1 and Figure 4-1 compare the monthly precipitation totals to the 30-year monthly normal (NOAA, 2015). Table 4-2 lists 2015 daily precipitation totals, 2015 monthly precipitation totals, the 30-year monthly normal (1981-2010) (NOAA, 2015), and the 2015 departure from historical monthly normals.

In 2015, NWS data was used for the months of January, February, March, April, November and part of December, as the events during this time period exhibited frozen precipitation (Table 4-2). MCWG data was used for the remaining period (May through October and part of December), as rainfall events occurred during this time.

Annual precipitation data from 2005-2015 was compared to the 30-year normal for the Minneapolis-St. Paul region (Table 4-1; Figure 4-3). The 30-year normal is recalculated every 10 years. In 2010, the 30-year normal was recalculated for 1981-2010 to be 30.61 inches (formerly 29.41 inches (1971-2000)).

The total amount of precipitation recorded in CRWD in 2015 was 35.21 inches, which was 4.60 inches above the 30-year normal (Table 4-1 and 4-2; Figure 4-3). Figure 4-2 is a cumulative precipitation plot for 2015 which shows the total accumulated amount of precipitation throughout the entire year as well as fluctuations in precipitation trends and significant precipitation events. After a dry initial four months of 2015, precipitation steadily increased throughout the remainder of the year, producing a moderately wet summer and a fall with above normal precipitation.

Table 4-1: CRWD annual precipitation totals and departure from the 30-year normal.

Year	Precipitation (inches)^a	Departure from 30-Year Normal
2005	35.98	(+) 5.37"
2006	31.69	(+) 1.08"
2007	29.72	(-) 0.89"
2008	21.67	(-) 8.94"
2009	23.34	(-) 7.27"
2010	36.32	(+) 5.71"
2011	33.62	(+) 3.01"
2012	30.26	(-) 0.35"
2013	36.36	(+) 5.75"
2014	35.66	(+) 5.05"
2015	35.21	(+) 4.60"
30-Year Normal	30.61	--

^a Annual precipitation reported by the Minnesota Climatology Working Group (MCWG) and National Weather Service (NWS)

Very little snowfall was recorded from January to March 2015, amounting to only 4% of the total precipitation recorded for 2015. In total, 34.31 inches of snow fell during the winter of 2015, which was 20.1 inches less than the 30-year normal (Table 4-4; Figure 4-4).

This resulted in a less robust snowpack which did not contribute as much to spring groundwater recharge and surface runoff as previous winters.

July 2015 was the wettest month of 2015, capturing the two largest storms recorded for the year: 1.95 inches on July 6 and 1.97 inches on July 12. Only two summer months of May and July were above the monthly normal value for precipitation by 1.71 inches and 2.19 inches, respectively.

All months from September to December recorded precipitation totals above the monthly normal values. An abnormal 1.73 inch storm on November 11 was recorded as the fifth largest daily precipitation value for November in state records. This storm and a few other rain events in subsequent weeks caused November to report the most positive departure from the normal monthly temperatures in 2015.

Table 4-2: Daily and monthly precipitation totals for 2015 compared to the 30-year normal.

Day	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	0.00	0.02	0.00	0.26	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.09	
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	
3	0.00	0.06	0.13	0.00	0.25	0.94	0.00	0.00	0.00	0.00	0.00	0.00	
4	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
5	0.06	0.00	0.00	0.00	0.01	0.00	0.04	0.00	0.00	0.00	0.01	0.00	
6	0.00	0.00	0.00	0.18	0.00	0.64	1.95	0.22	0.69	0.00	0.00	0.00	
7	0.00	0.00	0.00	0.01	0.66	0.02	0.00	0.27	0.00	0.00	0.00	0.00	
8	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.37	0.00	0.08	
9	0.00	0.00	0.00	0.63	0.00	0.01	0.00	0.11	0.53	0.00	0.00	0.00	
10	0.00	0.13	0.00	0.08	0.79	0.00	0.00	0.00	0.06	0.00	0.00	0.16	
11	0.00	0.01	0.00	0.00	0.20	0.29	0.00	0.00	0.00	0.00	1.73	0.00	
12	0.00	0.00	0.00	0.65	0.07	0.00	1.97	0.00	0.00	0.00	0.37	0.00	
13	0.02	0.00	0.00	0.01	0.00	0.04	0.02	0.06	0.00	0.00	0.00	0.12	
14	0.01	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.63	
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	
16	0.00	0.01	0.00	0.00	0.19	0.01	0.12	0.64	0.08	0.00	0.17	0.37	
17	0.00	0.00	0.00	0.00	0.05	0.11	0.50	0.12	1.27	0.00	1.21	0.00	
18	0.00	0.00	0.00	0.07	0.00	0.00	0.37	0.96	0.34	0.00	0.50	0.00	
19	0.01	0.00	0.00	0.14	0.01	0.00	0.00	0.15	0.00	0.00	0.00	0.00	
20	0.05	0.07	0.00	0.02	0.00	0.43	0.00	0.00	0.05	0.00	0.00	0.00	
21	0.01	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	
22	0.00	0.00	0.20	0.00	0.00	0.43	0.00	0.34	0.00	0.00	0.00	0.00	
23	0.00	0.00	0.03	0.00	0.02	0.00	0.00	0.00	0.11	1.00	0.00	0.38	
24	0.00	0.01	0.12	0.34	0.53	0.00	0.18	0.00	0.21	0.18	0.00	0.00	
25	0.03	0.02	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.01	0.00	0.00	
26	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.00	0.00	0.02	0.12	0.09	
27	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.39	0.00	0.00	
28	0.00	0.00	0.00	0.00	0.00	0.11	1.08	0.00	0.02	0.52	0.00	0.21	
29	0.00		0.19	0.00	1.13	0.39	0.00	0.00	0.00	0.05	0.00	0.15	
30	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.41	0.00	
31	0.00		0.00		0.00		0.00	0.00		0.33		0.01	Total
Monthly Total	0.34	0.35	0.67	2.42	5.07	3.72	6.23	2.87	3.81	2.89	4.52	2.32	35.21
Monthly Normal	0.90	0.77	1.89	2.66	3.36	4.25	4.04	4.30	3.08	2.43	1.77	1.16	30.61
Departure from Normal	-0.56	-0.42	-1.22	-0.24	1.71	-0.53	2.19	-1.43	0.73	0.46	2.75	1.16	4.60
	Data supplied by NWS-MSP												
	Data supplied by UMN Climatological Observatory												
	No Date												

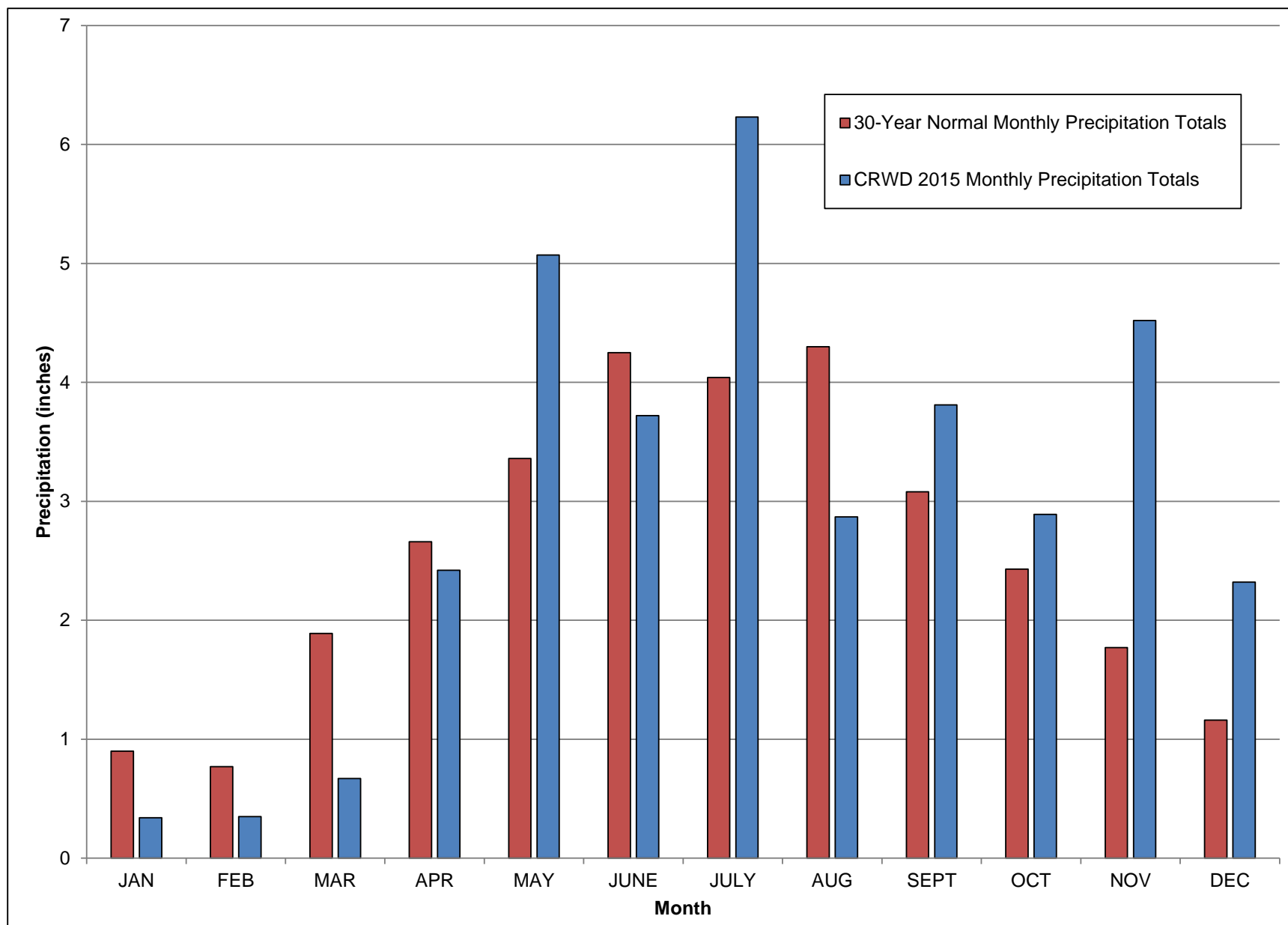


Figure 4-1: 30-year normal and 2015 monthly precipitation totals for CRWD.

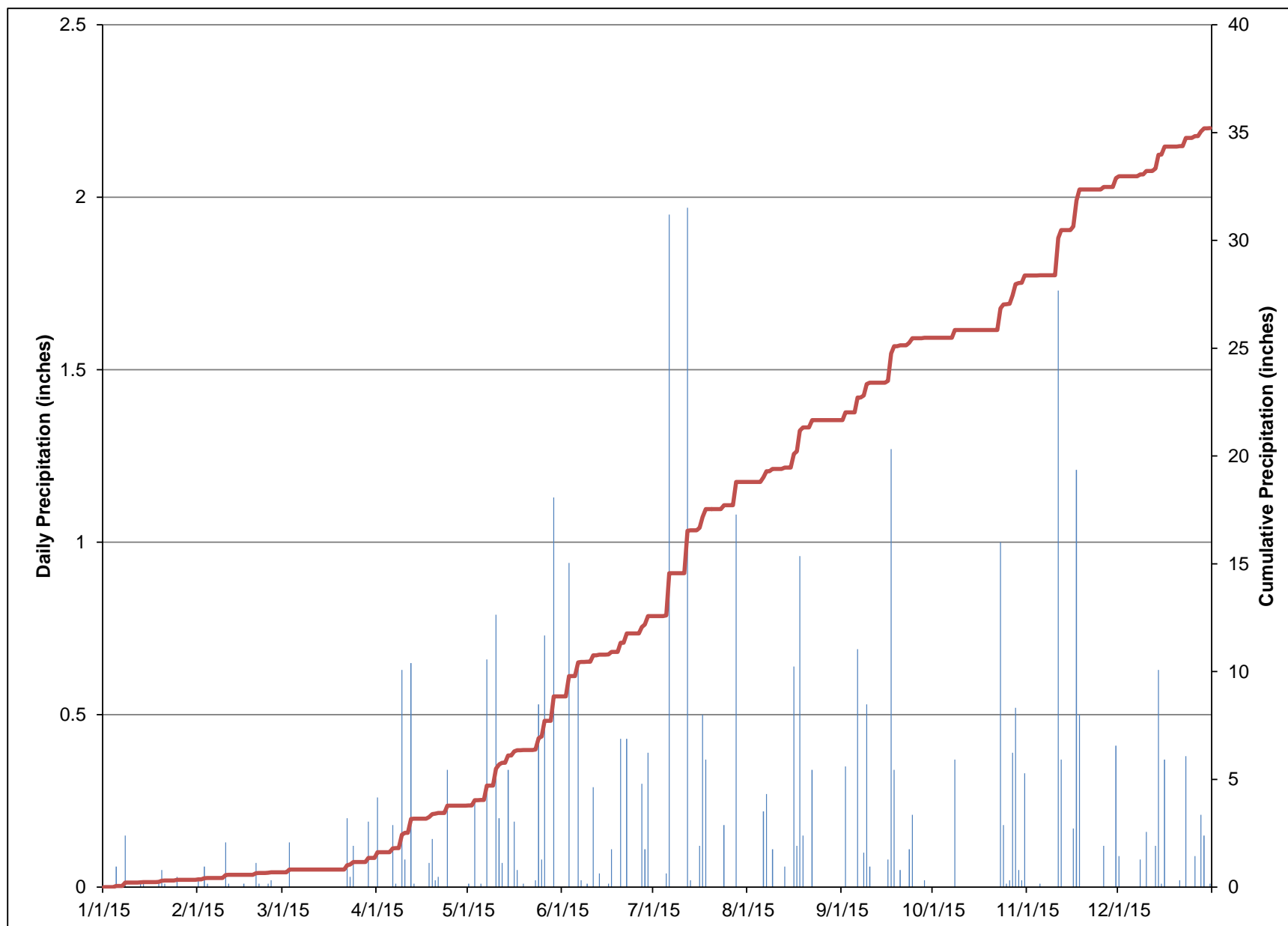


Figure 4-2: Daily precipitation totals and cumulative precipitation for January to December 2015.

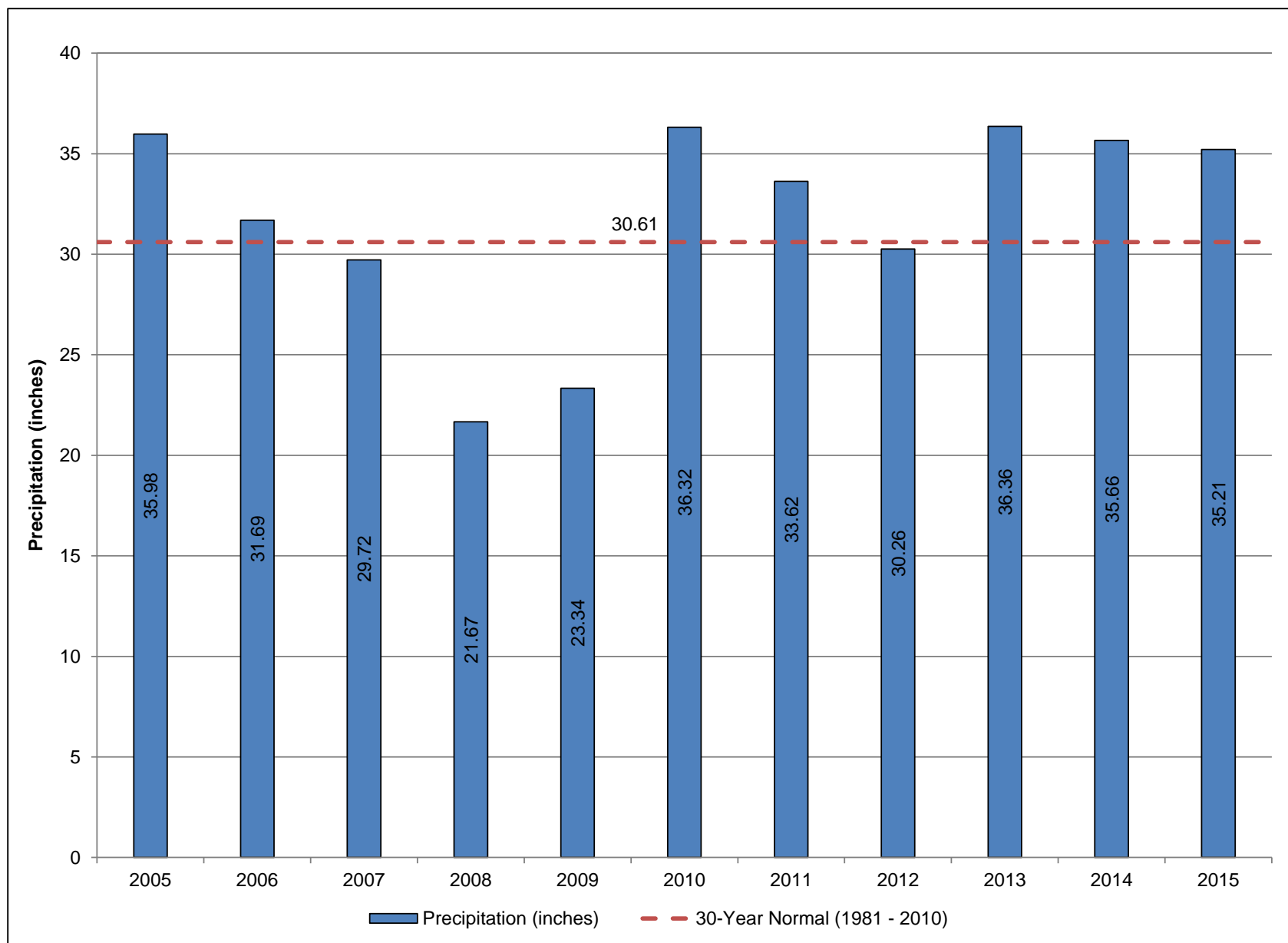


Figure 4-3: Annual precipitation totals (2005-2015) observed in CRWD by MCWG.

4.3 2015 NOTABLE CLIMATOLOGICAL EVENTS

While extrapolated data indicates a rather normal climatic year, 2015 exhibited unique seasonality by beginning with a dry winter, an unseasonably warm spring, and an extremely wet fall. There were very few notable summer rain and winter snow events. Also, the snowpack experienced four complete melt cycles before completely melting for the spring.

Table 4-3 shows the most intense rain events in 15-minute, 1-, 6-, and 24-hour intervals during 2015 as well as the corresponding Atlas 14 precipitation frequency ratings (NOAA, 2016). The precipitation event that occurred on July 12, 2015 produced the most intense 15-minute, 1-, 6-, and 24-hour intervals for the entire year (Table 4-3). During this event, 1.99 inches fell in 2.5 hours, with three 15-minute intervals recording over a quarter-inch of rain. When observed on a 1-hour interval, the July 12 storm categorized as a five-year rain event.

Table 4-3: Rainfall intensity statistics for 2015 from MCWG rain gauge data.

Rainfall Intensity			Atlas 14 Rating
Time Period	Date & Event End Time	Amount (in)	Frequency (yr)
15-minute	7/12/15 22:45	0.78	2
	7/17/15 0:00	0.5	1
	7/28/15 6:15	0.44	1
1-hour	7/12/15 23:00	1.7	5
	7/28/15 6:45	0.95	1
	7/18/15 0:45	0.73	1
6-Hour	7/13/15 0:30	1.99	1
	7/6/15 6:00	1.69	1
	11/11/15 21:15	1.56	1
24-Hour	7/6/15 12:00	1.99	1
	7/13/15 0:30	1.99	1
	11/11/15 22:45	1.79	1

Snowpack in CRWD was a less significant climatic variable in 2015 than in previous years. The 2015 snowfall total of 34.31 inches measured at MSP was 20.1 inches lower than the 30-year normal of 54.5 inches (Table 4-4). The last date with a 1 inch snowpack measured at MSP was March 25 (NWS, 2015), 8 days earlier than the normal date of March 31 (DNR, 2015k) (Figure 4-4).

Daily snowpack depths recorded at MSP were plotted against daily high temperature in Figure 4-4 (NWS, 2015). Three distinct periods of complete melt were observed from January 26 to March 1, each reset by three snowfall events. Another extensive melt period lasted from March 4 to March 22, during which temperatures rose to 70 degrees F. A four inch snowfall event occurred on March 23, resulting in a three day period of snowpack before melting away permanently for the spring. Snowpack reached a maximum depth of 5 inches on January 9, and

only stayed at a depth of 4 inches for a total of 8 days. Significant snowfall events for the year occurred on January 8 (3.0 inches) and March 22 (3.1 inches).

Snowmelt is a significant driver of hydrology in late winter and early spring and is dependent upon many factors such as the amount of snowpack and temperature. Snowpack levels remained at seasonally low levels as a result of record high spring temperatures and an overall lack of precipitation early in the winter months. Therefore, there was little hydrological storage on the landscape to contribute to spring snowmelt and runoff.

Table 4-4: Summary of 2015 climatological events in CRWD.

2015 Climate Summary			
Variable	2015	Average	Notes
Total Precipitation (inches)	35.21	30.61	4.60" higher than 30-yr normal
Total Snow (inches)	34.31	54.4	20.1" lower than 30-yr normal
Last Significant Snowfall	3/24 (1.2")	N/A	Variable - No data on averages
Last Spring date with greater than 1" snowpack	3/25	4/2	8 days earlier than normal
Spring Ice Out	3/27	4/5	9 days earlier than normal
Fall Leaf Off	10/21	N/A	Later than normal

With record high March temperatures, ice out on CRWD lakes occurred generally one week earlier than normal in 2015. Historical median ice out dates have not been established for any of the five CRWD lakes, nor were any observations made by CRWD on the lakes in 2014. However, the DNR has collected annual and historical median ice out dates for lakes nearby CRWD, including the five observed in Table 4-5 (DNR, 2016a; DNR 2016b).

Table 4-5: Summary of ice out dates for Twin Cities lakes nearby CRWD (DNR, 2016a; DNR, 2016b).

Lake Name	2015 Ice Out Date	Historical Median Ice Out Date
Lake Nokomis	March 25	April 5
Powderhorn Lake	March 25	April 4
Lake Josephine	N/A	April 7
Lake Owasso	N/A	April 6
Lake Phalen	April 1	April 5

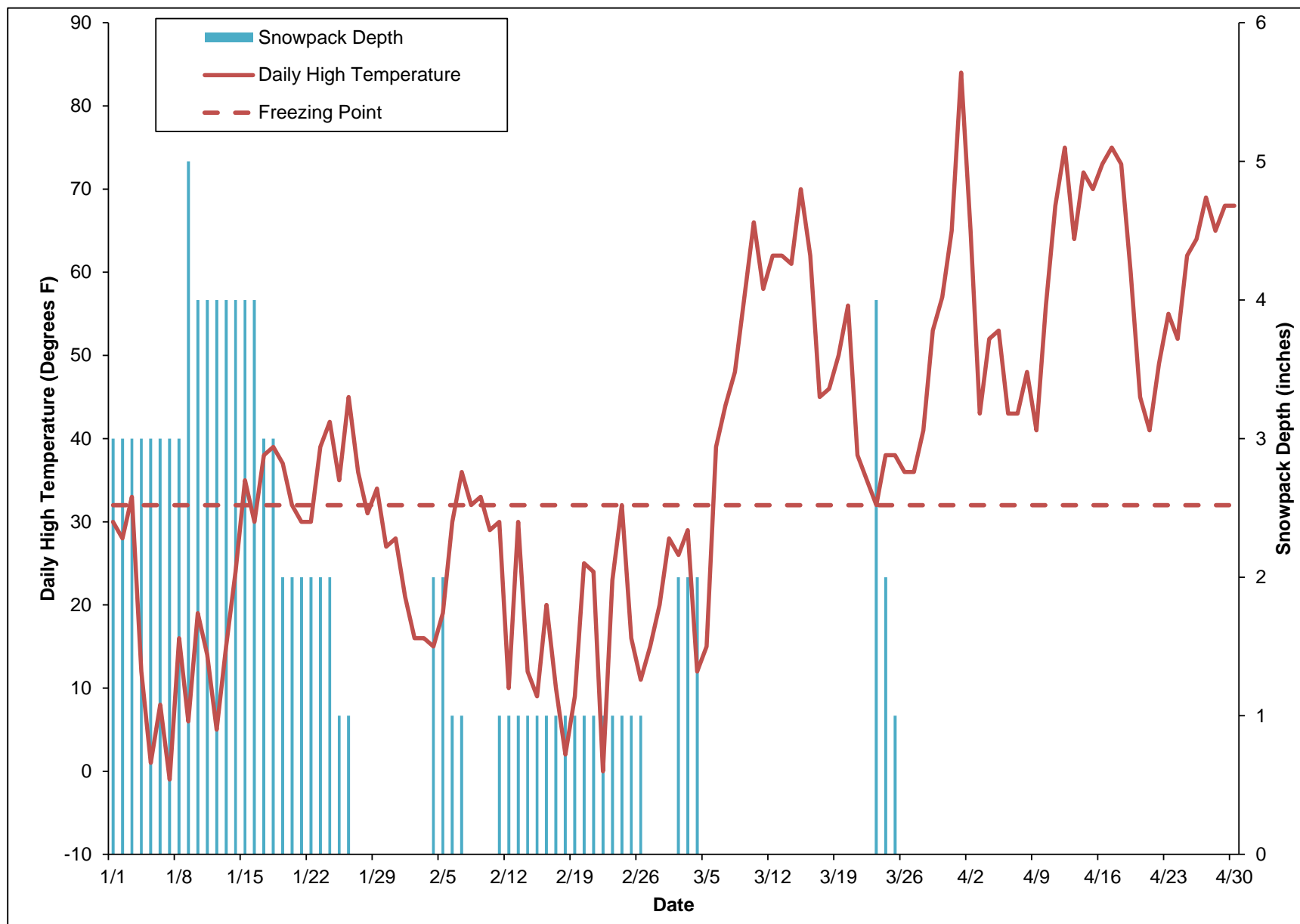


Figure 4-3: Daily temperature highs and snowpack depths from January to April 2015 as observed at MSP (NWS, 2015)

5 CRWD LAKES RESULTS SUMMARY

5.1 OVERALL DISTRICT LAKES RESULTS

Table 5-1 shows the 2015 averages, historical averages, and lake standards for TP and Chl-a concentrations and Secchi depth for each lake. The data is shown graphically in Figures 5-1, 5-2, and 5-3. In accordance with MPCA eutrophication standards for Class 2B waters, a lake is considered impaired if it does not meet the MPCA standard for TP and either Chl-a or Secchi disk depth. In 2015, Como Lake, Crosby Lake, and Little Crosby Lake did not meet MPCA standards for TP. Como Lake also did not meet the standard for Chl-a, so it was considered impaired in 2015. All other lakes met the standards for Chl-a. Loeb Lake and Lake McCarrons both met the MPCA eutrophication standards for all parameters. Crosby Lake, Little Crosby Lake, and Lake McCarrons all exhibited an increase in water quality compared to 2014. Como Lake exhibited a decline in water quality, while Loeb remained consistent with past years of stable water quality.

Table 5-1: CRWD 2015 average, historical average, and lake standards for TP/Chl-a/Secchi depth.

Lake	2015 Averages			Historical Averages			State Lake Standards		
	TP (µg/L)	Chl-a (µg/L)	Secchi (m)	TP (µg/L)	Chl-a (µg/L)	Secchi (m)	TP (µg/L)	Chl-a (µg/L)	Secchi (m)
Como	215	42.8	1.2	174	33.9	1.5	<60	<20	≥1.0
Crosby	144	18.5	1.4	79	10.9	2.3	<60	<20	≥1.0
Little Crosby	76	12.9	1.9	92	10.2	2.5	<60	<20	≥1.0
Loeb	26	5.1	3.3	29	5.9	3.2	<60	<20	≥1.0
McCarrons	19	3.2	3.7	34	9.8	2.9	<40	<14	≥1.4
	Value does not meet the state standard								
	Value meets the state standard								

In 2015, CRWD determined lake grades for each of its lakes based on the lake grade system created by the Metropolitan Council (Table 5-2) (Osgood, 1989). Loeb Lake and Lake McCarrons were the only two lakes that received good grades of “A” in 2015. An average water quality grade of ‘C’ was given to Crosby Lake and Little Crosby Lake. Como Lake received the lowest grade of ‘D+’. All five of the lakes were close to, if not higher than, their average historical grades in 2015 (Table 5-2). McCarrons increased by a full letter grade in 2015 compared to its historical average grade. Loeb and Como Lake received the same lake grade for 2015 as the historical average.

Table 5-2: CRWD 2015 and historical lake grades and averages for TP/Chl-a/Secchi depth.

Lake	2015 Lake Grade			2015 Average	Historical Lake Grade			Historical Average
	TP	Chl-a	Secchi		TP	Chl-a	Secchi	
Como	F	C	C	D+	F	C	C	D+
Crosby	D	B	C	C	D	B	B	C+
Little Crosby	D	B	C	C	D	B	B	C+
Loeb	B	A	A	A	B	A	A	A
McCarrons	A	A	A	A	C	A	B	B

5.2 SUMMARY OF INDIVIDUAL LAKES RESULTS

5.2.1 COMO LAKE

Como Lake has been monitored since 1984, so historical averages represent 31 years of data. Como Lake degraded in water quality for all three of the eutrophication parameters in 2015 in comparison to the historical average (Figures 5-1, 5-2, and 5-3). Como Lake has historically not met shallow lake state standards for TP and Chl-a concentrations. This was the case in 2015 as well. Como Lake has historically met shallow lake state water quality standards for Secchi depth, and did once again in 2015.

5.2.2 CROSBY LAKE

Crosby Lake has been monitored since 1999, so historical averages represent 16 years of data. Crosby Lake degraded in average Secchi disk reading in 2015 when compared to the historical average, and improved in the TP and Chl-a parameters (Figures 5-1, 5-2, and 5-3). While an improvement from 2014, the 2015 average TP concentration (144 µg/L) was 182% higher than the historical average (79 µg/L). Crosby Lake has historically been impaired for TP concentration, which was also the case in 2015. In concurrence with past trends, Crosby Lake met water quality standards for both Chl-a concentration and Secchi depth.

5.2.3 LITTLE CROSBY LAKE

Little Crosby Lake has been monitored since 2011, so historical averages represent only four years of data. In 2015, Little Crosby Lake improved in water quality when compared to the historical averages for TP and Secchi parameters (Figures 5-1 and 5-3). While an improvement from 2014, the 2015 Chl-a average was slightly below the historical average. With only 4 historical data points, comparisons to other historical averages are not as robust as they are for other lakes with a greater degree of longitudinal monitoring. Little Crosby Lake has never met the shallow lake standards for TP during its monitoring history, but met the standards for Secchi depth and Chl-a in 2015.

5.2.4 LOEB LAKE

Loeb Lake has been monitored annually since 2003, so historical averages represent 12 years of data. In 2014, Loeb Lake improved in water quality when compared to the historical averages of all three parameters (Figures 5-1, 5-2, and 5-3). Loeb Lake has met all of the shallow lakes standards throughout its sampling period to date. Loeb displayed improved water quality from the previous year, and maintained its position as exhibiting the best water quality of any of the District lakes.

5.2.5 LAKE MCCARRONS

Lake McCarrons has been monitored annually since 1988, so historical averages represent 27 years of data. When compared to the historical average, Lake McCarrons showed improved water quality as indicated by an improvement in all three parameters from the historical average (Figures 5-1, 5-2, and 5-3). TP improved by 45%, Chl-a by 78%, and Secchi disk depth by 30%. It should be noted that the historical averages are skewed towards worse water quality, as the monitoring period includes data in the average that was collected prior to the 2004 alum treatment. In 2015, Lake McCarrons still met all of the deep lake standards; the historical averages met all of the deep lake standards as well.

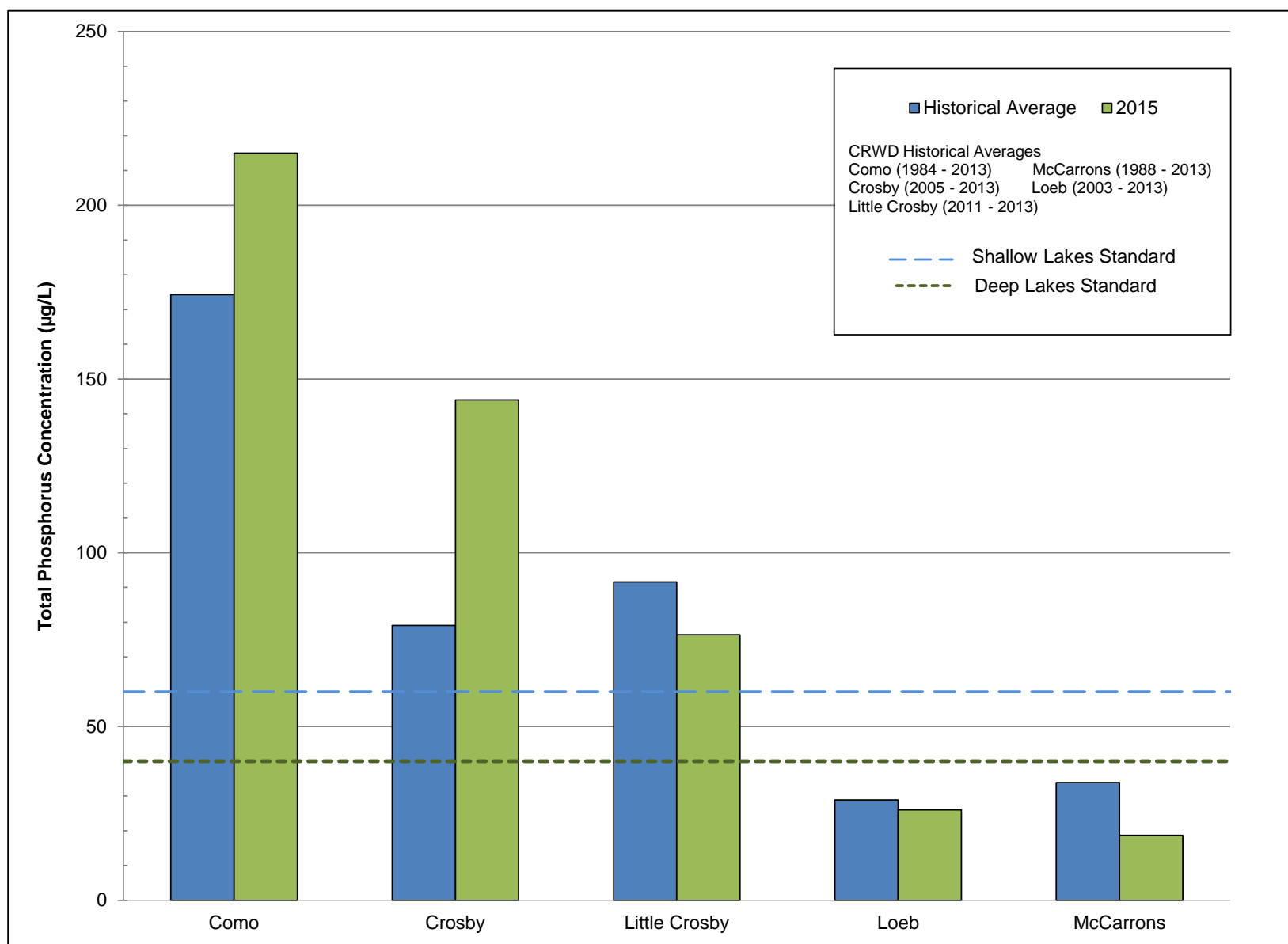


Figure 5-1: CRWD 2015 vs. historical average TP concentrations and lake standard comparisons.

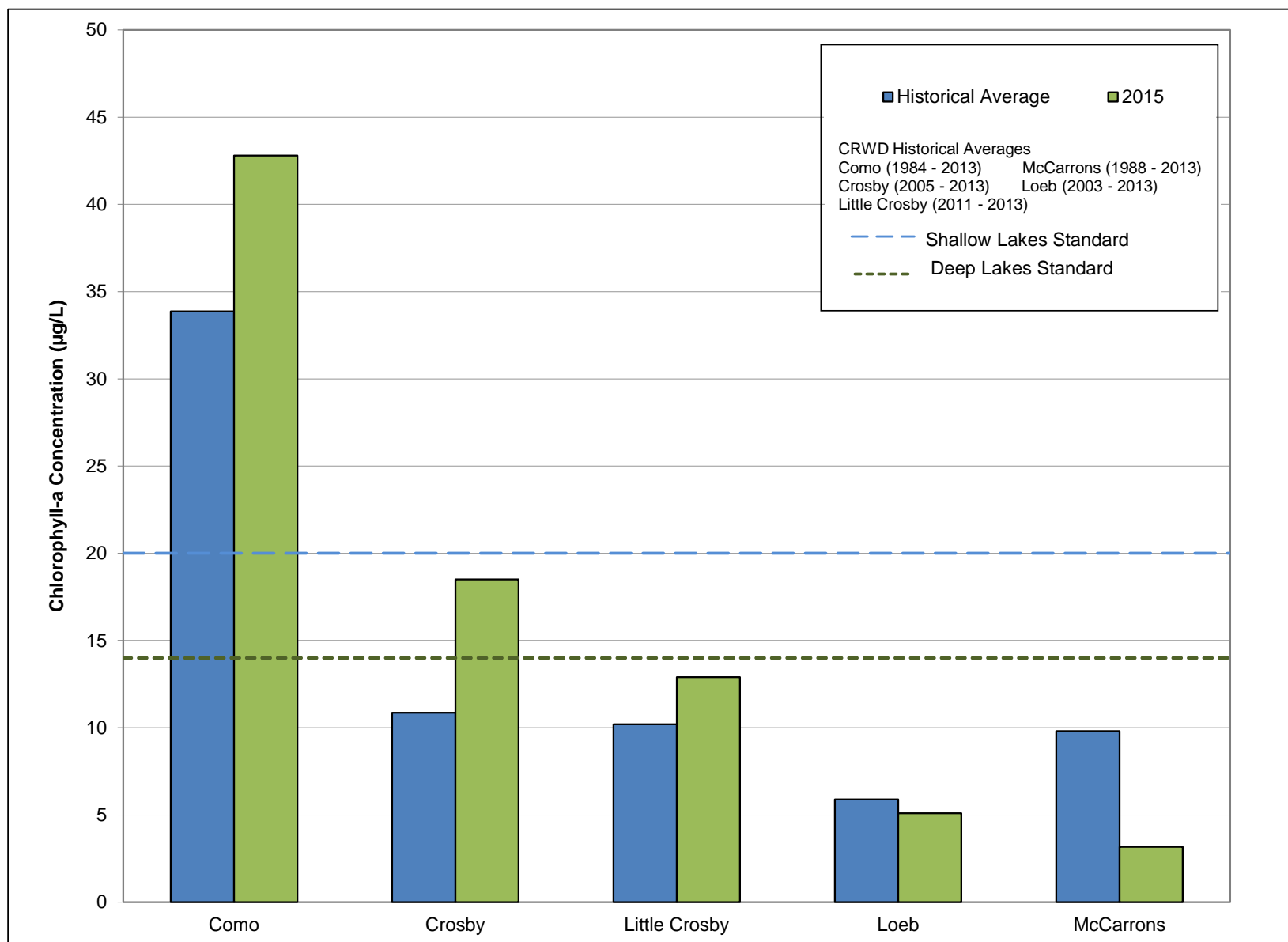


Figure 5-2: CRWD 2015 vs. historical average Chl-a concentrations and lake standard comparisons.

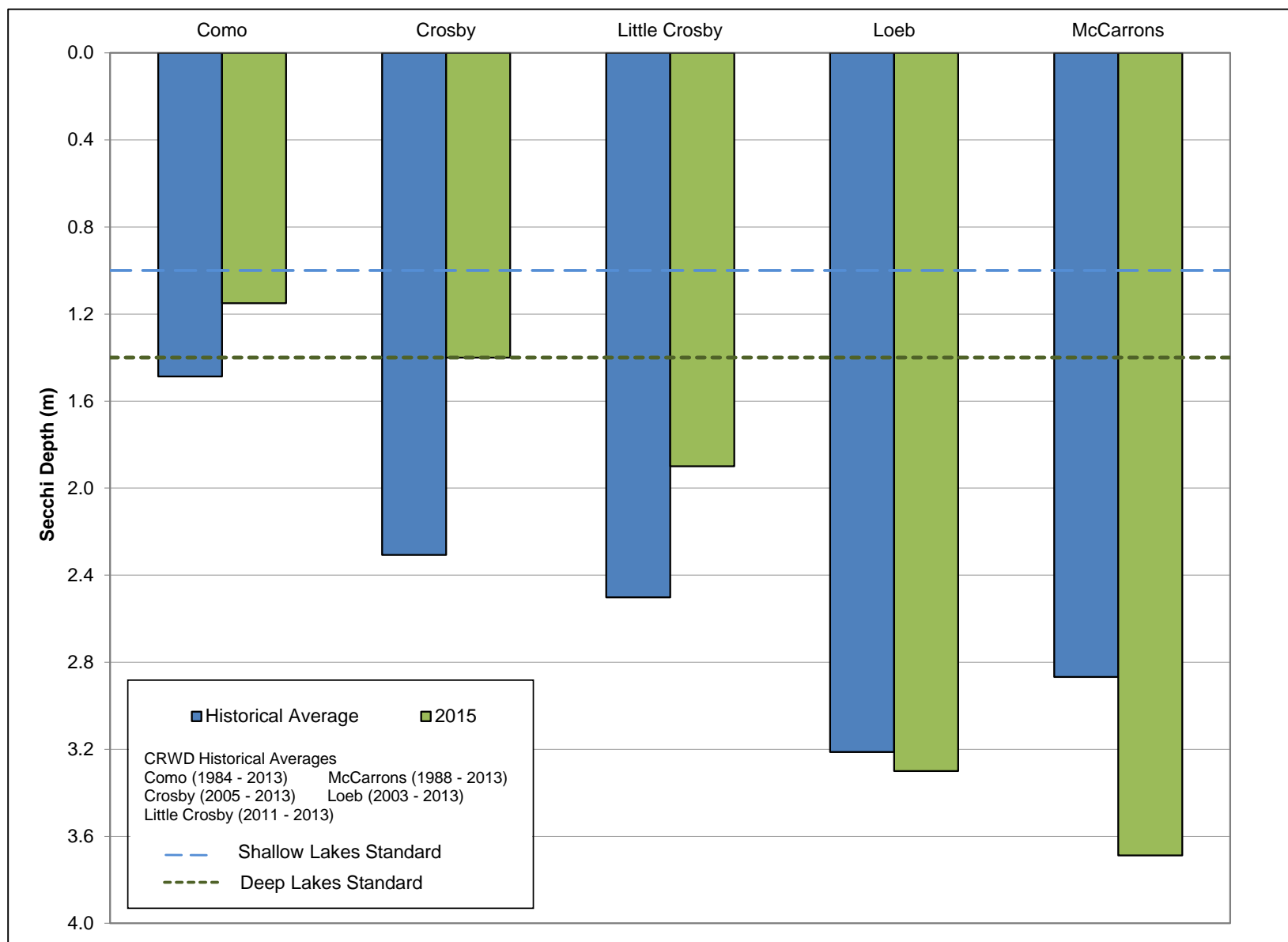


Figure 5-3: CRWD 2015 vs. historical average Secchi depths and lake standard comparisons.

6 COMO LAKE RESULTS

6.1 COMO LAKE BACKGROUND

Como Lake, a 70.5 acre shallow lake located in St. Paul's 348 acre Como Regional Park, is one of the most popular lakes in CRWD (Figure 6-1). In 2014, Como Regional Park was the second most frequently visited park in the Twin Cities Regional Parks System, with more than 4.3 million visits over the course of the year (MC, 2016). The lake is frequented by residents and visitors who come for various forms of outdoor recreation, including running/walking, fishing, and boating. The lake does not offer swimming opportunities and only allows non-motorized cartop-carried boats and electric trolling motors on the lake for fishing/recreation purposes.



Figure 6-1: View of the northwest shoreline of Como Lake.

Como Lake is a shallow urban lake with a volume of 468.8 acre-ft, a littoral area that covers 100% of the lake, and a maximum depth at 15.5 ft, (Table 6-1; Figure 6-2). Como Lake receives water from the surrounding watershed (1,856 acres), which consists of runoff from primarily residential areas, as well as from Como Regional Park and Golf Course (Figure 6-3). Runoff from the residential areas is directed to the lake through a system of stormwater pipes located

under the streets. Located upstream of Como Lake, Gottfried's Pit receives drainage from Roseville, Falcon Heights, Ramsey County right-of-ways, and the City of St. Paul before being pumped into Como Lake. Water occasionally outflows from the lake at the southeast corner, discharging into the Trout Brook storm sewer system which is routed to the Mississippi River (CRWD, 2002). The shallow depth of the lake, coupled with the large nutrient inputs from upland runoff sources, has had significant negative impacts to the lake's overall health.

Table 6-1: Como Lake morphometric data.

Surface Area (acres)	Maximum Depth (ft)	Littoral Area	Volume (acre-ft)	Watershed Area (acres)	Watershed: Lake Area (ratio)
70.5	15.5	100%	469	1,856	26.3



Figure 6-2: Como Lake bathymetric map.

One major water quality problem Como Lake faces is the excessive amount of sediment entering the lake from construction, roads, and general erosion. This has led to the formation of sediment deltas near stormwater inlets to the lake, which reduces overall lake volume, increases water turbidity, and decreases habitat value for the lake's fish populations. Sediment also provides a means by which other pollutants, including metals and hydrocarbons, can be transported to the lake. To address this problem, in 2001-2002, the lake was dredged to reduce the sediment deltas seen on the southwest side of the lake. This dredging reduced the amount of sediment that had accumulated in the lake and increased lake volume, giving the lake a higher capacity to absorb nutrient inflows.

In addition, low oxygen levels during winter months caused partial fish kills dating back to 1945, leading Ramsey County to install an aerator in 1985 (CRWD, 2002). Renovation and a complete restocking of the fish populations in the lake occurred in 1985 after installation of the aerator in an effort to improve water quality through biomanipulation. The original aerator was replaced in the winter of 2014-2015 by two floating aerators that improved the efficiency and breadth of aeration on the lake. Fish kills are now a rare occurrence in the lake, resulting only if there were to be equipment failure or an especially cold winter.

Como Lake's greatest water quality problem is excessive phosphorus. External and internal inputs of phosphorus have caused annual algal blooms and overgrowth, further reducing the integrity of the lake. Subsequently, Como Lake has historically not met the shallow lake state water quality standards for TP and Chl-a concentrations ($< 60 \mu\text{g/L}$ and $< 20 \mu\text{g/L}$, respectively), but has met the standards for Secchi disk depth ($\geq 1.0 \text{ m}$). The Como Lake Strategic Management Plan (CRWD, 2002) was published in 2002 to identify management issues surrounding Como Lake and develop goals to improve the lake's health. From this plan, a water quality goal of less than $59 \mu\text{g/L}$ for TP was developed, in order to reduce the number and severity of algal blooms (CRWD, 2002).

In addition, Como Lake is currently listed on the MPCA's 2012 303(d) list for nutrient impairment because of the hypereutrophic conditions (MPCA, 2012). Also, Como Lake is currently listed on the MPCA's 2014 303(d) proposed impaired waters list for chloride impairment (MPCA, 2016). Como Lake was first listed in 1998 for mercury in fish tissue (TMDL plan approved in 2008) and in 2002 for nutrient/eutrophication biological indicators (TMDL plan approved in 2010) (MPCA, 2012). Odor problems due to end-of-summer algal blooms also continue to be a problem and have been recorded since 1945. It is hypothesized that the water quality (referring to the TP, Chl-a, and Secchi disk depth) in Como Lake displays a cyclical trend, fluctuating every five to six years between fair and poor water quality (Figure 6-7) (Noonan, 1998). This suggests that the interactions among the biological, chemical, and physical parameters of the lake need to be better understood in order to make informed management decisions to improve the lake's health.

In effort to meet state nutrient standards and the goals defined in the management plan, various shoreline improvement projects have been completed on the lake since 2003 by the City of St. Paul and Ramsey Conservation District, with help from CRWD and other organizations. These projects have stabilized the shoreline, reduced erosion, increased habitat for wildlife, replaced non-native invasive plants with native species and improved the aesthetics of the shoreline for

visitors. Harvesting of aquatic plants has occurred at various times since the 1980s in order to enhance recreational opportunities.

Numerous BMPs have been installed by CRWD, the City of St. Paul, and others in the Como Lake subwatersheds to reduce external pollutant loading to the lake and to meet the state standards and management goals. Starting in 2007, the Arlington-Pascal Stormwater Improvement Project was constructed upland of Como Lake in the Como 7 subwatershed, which consisted of a series of BMPs including raingardens, infiltration trenches, an underground facility, and stormwater ponds. Improvements in water quality have been measured in the lake since the completion of the project. More information about these BMPs may be found in the *CRWD Stormwater BMP Performance Assessment and Cost-Benefit Analysis* (CRWD, 2012b).

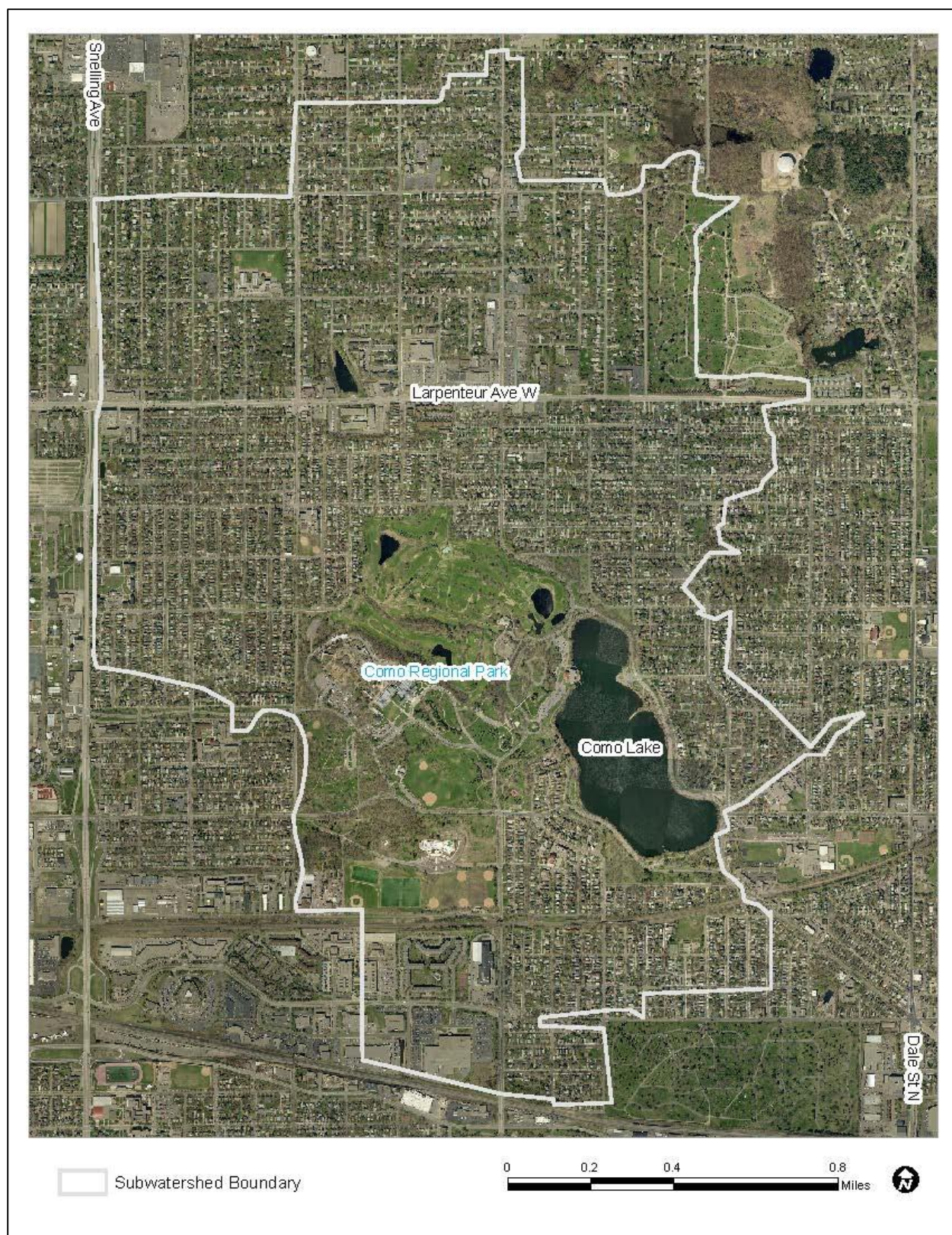


Figure 6-3: Como Lake and subwatershed boundary.

6.2 LAKE LEVEL

The level of Como Lake has fluctuated around the OHWL (881.4 ft) since monitoring of the lake level began in 1978 with a range of 4.3 ft, varying between 879.2 ft to 883.5 ft. The lowest of the range extremes occurred in June 1987, and the highest occurred in October of 2007 (Figure 6-4).

The 2015 lake level reported in Figure 6-5 was a combination of the weekly staff gauge readings completed by the DNR in January and February and the 15 min level logger data collected from April to November by CRWD. The average level for 2015 was 881.24 ft indicating that, on average, normal fluctuations in water level were seen for the lake in 2015. After ice off in late March, water level increased incrementally to mid-May when it reached its summer average hovering just below the OWHL (Figure 6-5). From early- to mid-summer, the level oscillated between spikes following rain events that exceeded the OHWL and prolonged declines to levels below the OWHL. From mid-July to mid-August, the level reached its summer low point at 880.64 ft. Heavy rains in November caused a late season increase in level before the lake froze by the end of December 2015 (Figure 6-5).

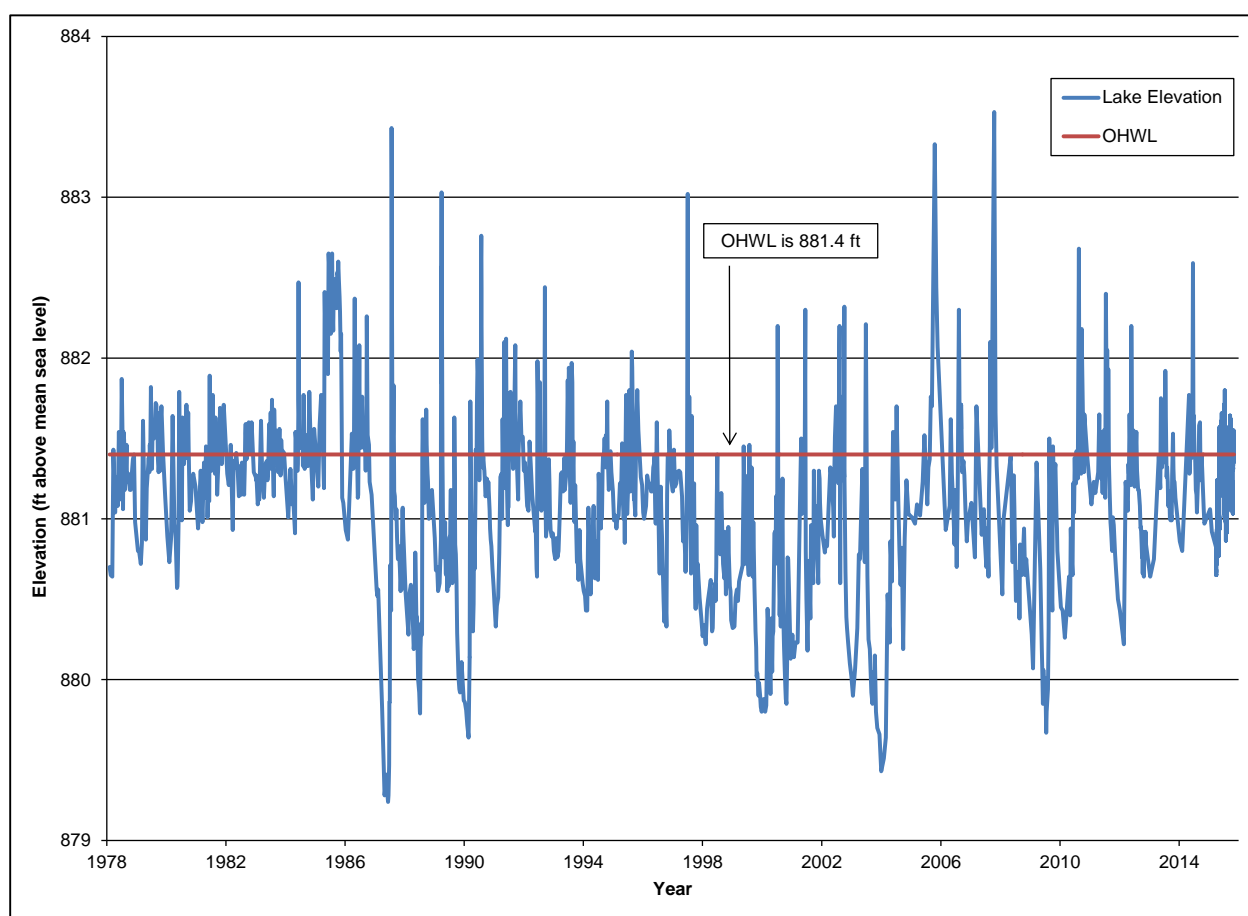


Figure 6-4: Como Lake historical lake elevations and the OHWL (DNR, 2015i).

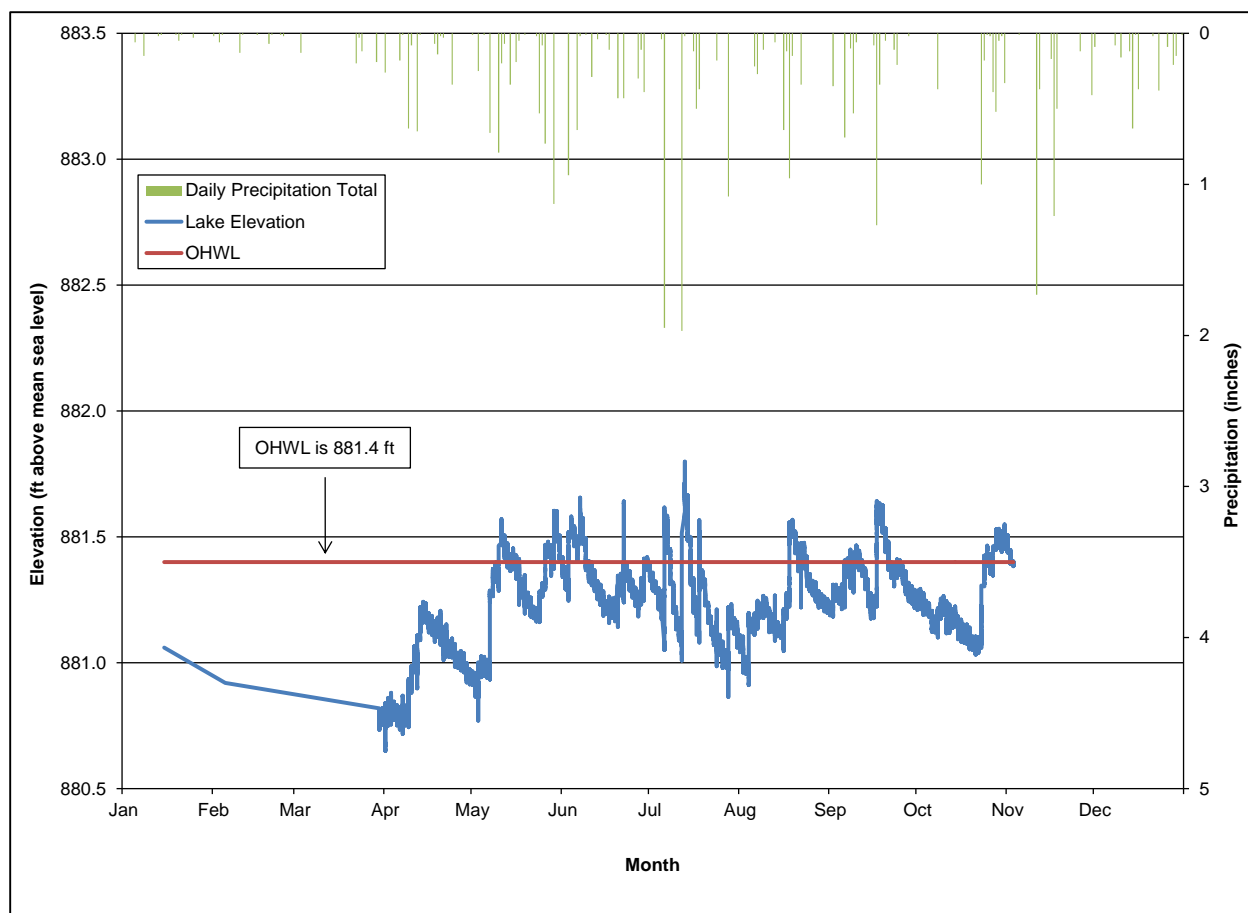


Figure 6-5: Como Lake 2015 lake elevations, OHWL, and daily precipitation events (DNR, 2015i; MCWG, 2016).

6.3 WATER QUALITY RESULTS

During 2015, Como Lake was sampled ten times from April 3 to October 19 (Figure 6-6). As in previous years, Como Lake was generally characterized by high TP and Chl-a concentrations, and low Secchi depths (Figure 6-7). Table 6-2 illustrates the differences observed in 2015 between the first five sample dates, the last five sampling dates, and the percent change from the former to latter.

Table 6-2: Differences between the first five sample dates, the last five sample dates, and the percent increase for Secchi/TP/Chl-a in Como Lake in 2015.

2015 Samples	First 5 sample dates	Last 5 sample dates	Percent Change
TP (µg/L)	120	295	+ 246%
Chl-a (µg/L)	29.6	55.9	+ 189%
Secchi (m)	1.7	0.4	- 79%

Sampling shows that TP and Chl-a concentrations were lower during the beginning of the season (the first 5 sample dates from early April to early July) than at the end of the season (the last 5 sample dates from late July to late October) (Table 6-2; Figure 6-6). Secchi disk readings met the state standard for water clarity during the first half of sampling events, and diminished greatly towards the end of the season. Similar to previous years, higher TP concentrations were generally correlated with higher Chl-a concentrations and lower Secchi depths. This suggests that phosphorus was a primary driver for water clarity in Como Lake during 2015.

Seasonally, Como Lake exhibits the best and least variable water quality during the month of May for TP, Chl-a, and Secchi disk depth (Figure 6-7). July, August, and September have the worst and most variable water quality for all three parameters. These months also have the greatest extremes of sampling values. From Figure 6-7, it is observed that water quality generally decreases throughout the summer season on Como Lake.

From 2009-2014, average annual epilimnetic TP appeared to be assuming the normal cycling pattern that has been observed (Figure 6-8). Following these observed trend assumptions, Como Lake was expected to exhibit falling TP values from 2014 to 2015. Instead, the lake produced moderately high TP values consistent with the past five years and little evidence of cycling. The hypolimnion displayed even more drastic fluctuations in phosphorus than the epilimnion, despite maintaining a similar 5-6 year cycle for the first 30 years on record (Figure 6-9). In eutrophic lakes, the hypolimnion is generally richer in phosphorus than the epilimnion, as bed sediments readily release phosphorus into the anoxic bottom layer, peaking in fall just prior to lake turnover (Kalff, 2002). Within the last 5 years, Como Lake hypolimnetic TP concentrations have increased more drastically in relation to the increase observed in epilimnetic TP during the same period. Data collected during future monitoring seasons will help determine if this phenomenon is an abnormality from its cycling pattern, or if it is an indicator of a new normal.

The average annual Chl-a concentration has remained relatively stable over the last five years (Figure 6-8). Average annual Secchi depth was within range of its deepest values in the last six years despite a poor water quality year in 2012 (Figure 6-8).

Yearly average historical TP concentrations, Chl-a concentrations, Secchi depths, and their comparisons to lake standards are shown in Table 6-3. Como Lake TP yearly average concentrations have exceeded the MPCA standards for all years of monitoring, including 2015. Chl-a concentrations have also exceeded the standard for 2015 and the majority of years monitored. Conversely, approximately 75% of the historical Secchi depth yearly averages met the standards. Similar to 2014, CRWD issued a 'D+' grade for Como Lake based on the average eutrophication parameters in 2015 (Table 6-4). The historical average grade for Como Lake is 'D+'. The lake received a 'B' grade only in 1998 and 1999.

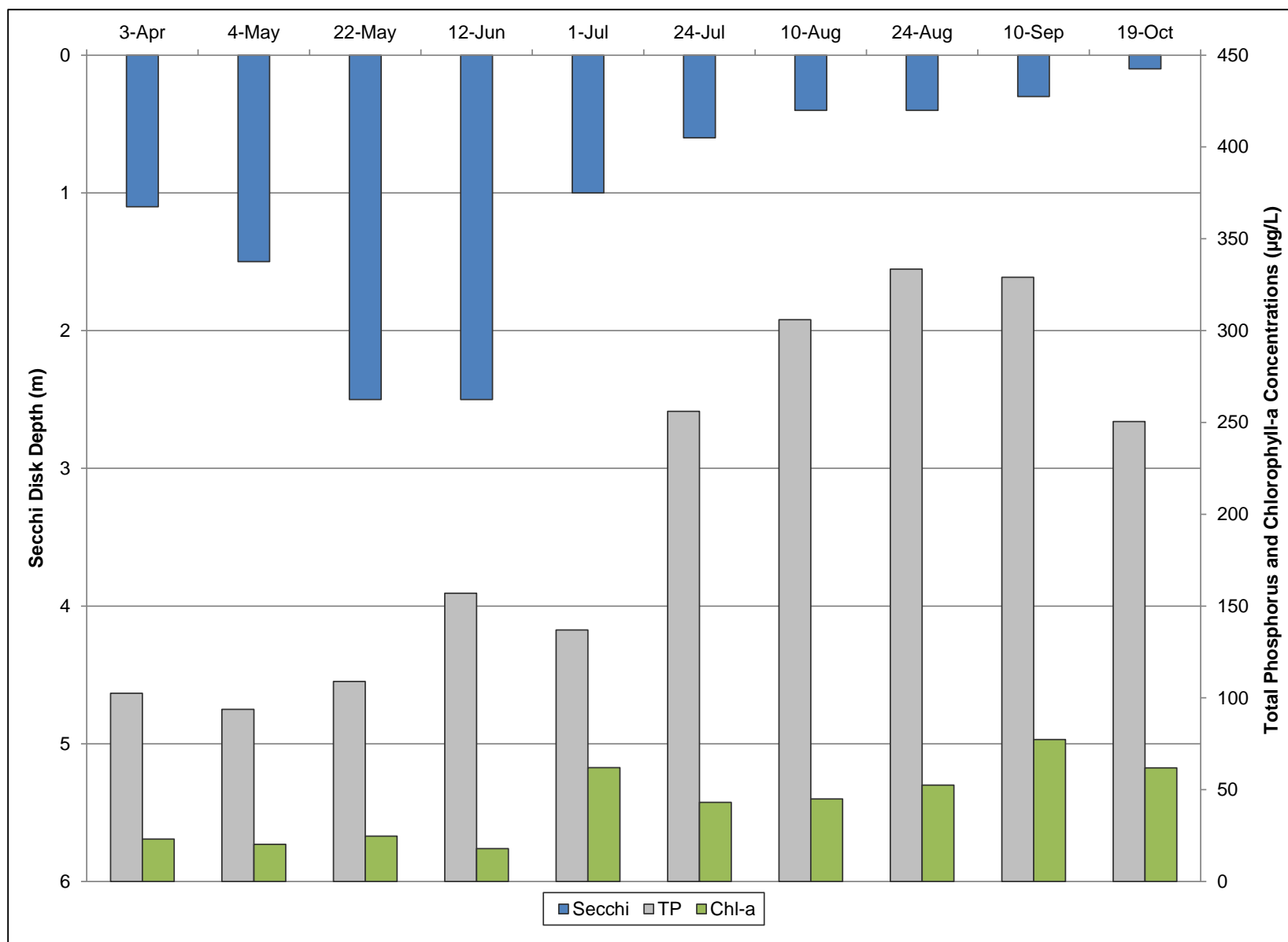


Figure 6-6: Como Lake 2015 Secchi/TP/Chl-a comparison.

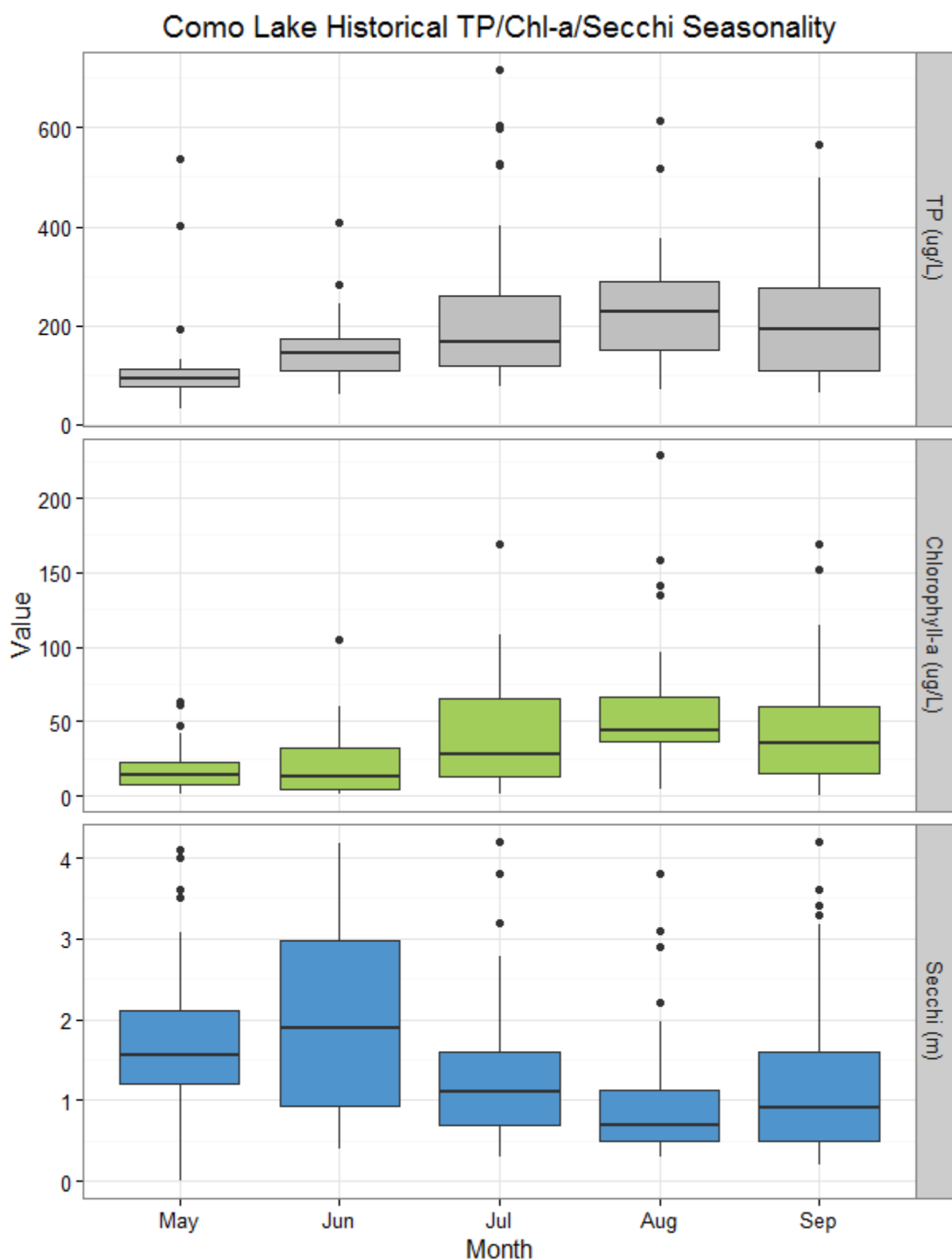


Figure 6-7: Como Lake seasonality boxplots of historical Secchi/TP/Chl-a samples.

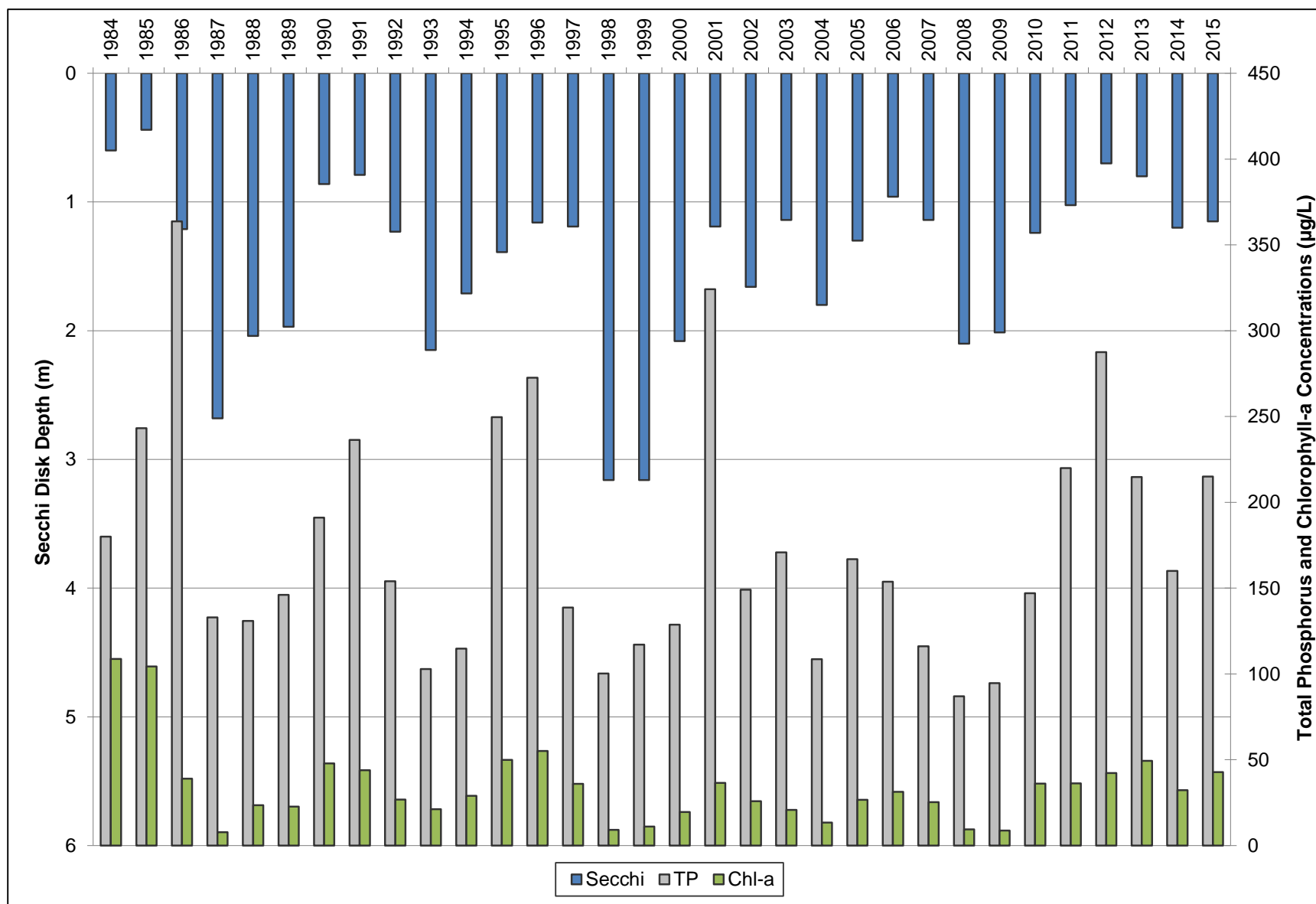


Figure 6-8: Como Lake historical annual average Secchi/TP/Chl-a comparison.

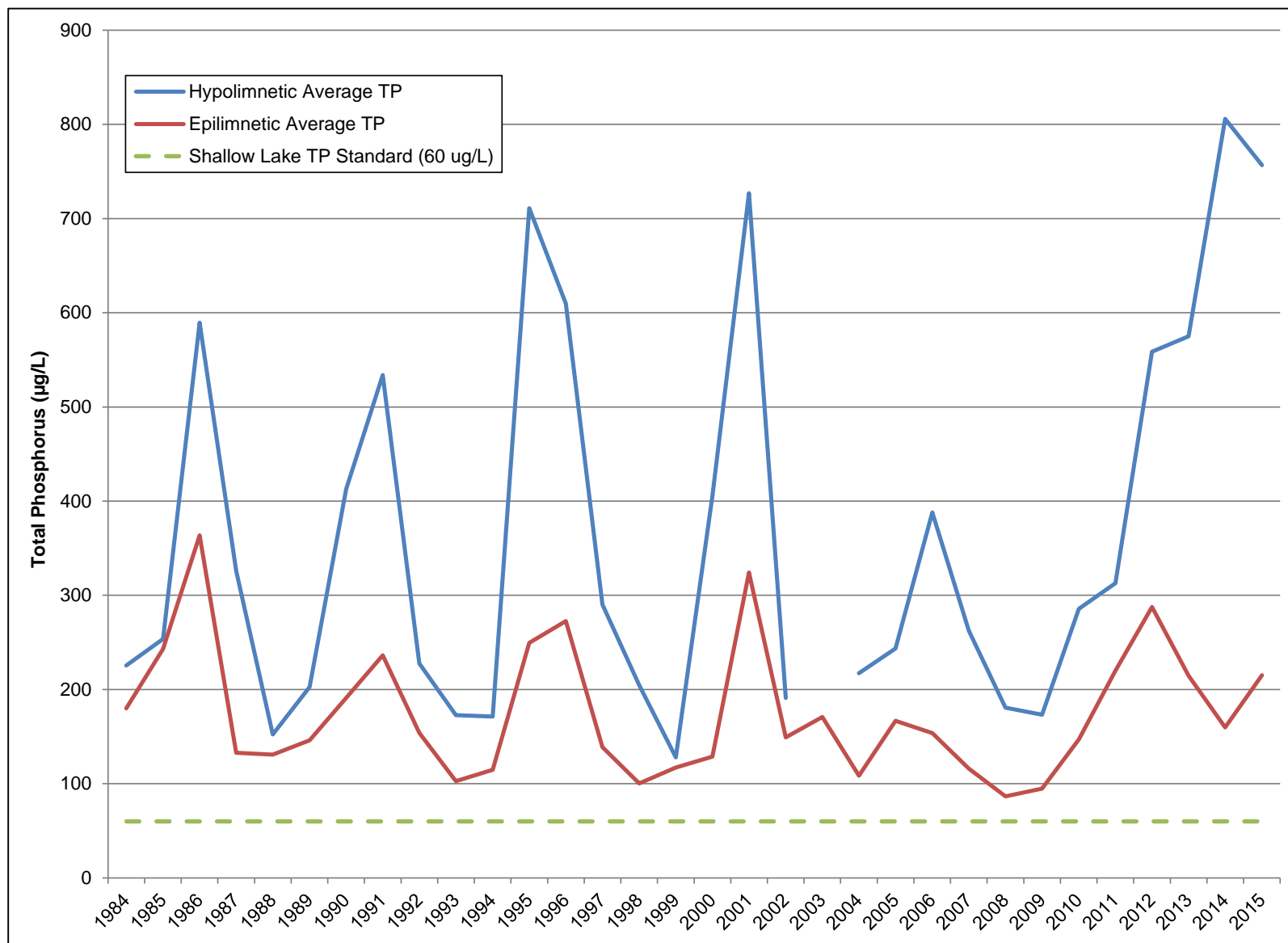


Figure 6-9: Como Lake historical annual hypolimnetic and epilimnetic total phosphorus values.

Table 6-3: Como Lake historical yearly TP/Chl-a/Secchi depth averages compared to shallow lake state standards.

Year	TP (µg/L)	Chl-a (µg/L)	Secchi (m)
1984	180	108.7	0.6
1985	243	104.4	0.4
1986	364	39.0	1.2
1987	133	7.8	2.7
1988	131	23.5	2.0
1989	146	22.7	2.0
1990	191	47.9	0.9
1991	236	43.9	0.8
1992	154	26.8	1.2
1993	103	21.2	2.2
1994	115	29.0	1.7
1995	250	50.0	1.4
1996	273	55.1	1.2
1997	139	35.9	1.2
1998	100	9.2	3.2
1999	117	11.0	3.2
2000	129	19.6	2.1
2001	324	36.5	1.2
2002	149	25.8	1.7
2003	171	20.8	1.1
2004	109	13.4	1.8
2005	167	26.7	1.3
2006	154	31.3	1.0
2007	116	25.4	1.1
2008	87	9.4	2.1
2009	95	8.8	2.0
2010	147	36.1	1.2
2011	220	36.2	1.0
2012	288	42.2	0.7
2013	215	49.4	0.8
2014	160	32.3	1.2
2015	215	42.8	1.2
	Value does not meet state standard*		
	Value meets state standard		

*MPCA shallow lake standards are not to exceed 60 µg/L for TP and 20.0 µg/L for Chl-a, with a Secchi disk depth of at least 1.0 m.

Table 6-4: Como Lake historical lake grades.

Year	TP Grade	Chl-a Grade	Secchi Grade	Overall Grade
1984	F	F	F	F
1985	F	F	F	F
1986	F	C	C	D+
1987	D	A	B	C+
1988	D	C	C	C
1989	D	C	C	C
1990	F	C	D	D
1991	F	C	D	D
1992	F	C	C	D+
1993	D	C	C	C
1994	D	C	C	C
1995	F	D	C	D
1996	F	D	D	D
1997	D	C	D	D+
1998	D	A	A	B
1999	D	B	A	B
2000	D	B	C	C
2001	F	C	D	D
2002	D	C	C	C
2003	F	C	D	D
2004	D	B	C	C
2005	F	C	C	D+
2006	F	C	D	D
2007	D	C	D	D+
2008	D	A	C	C+
2009	D	A	C	C+
2010	D	C	C	C
2011	F	C	D	D
2012	F	C	D	D
2013	F	D	D	D
2014	F	C	C	D+
2015	F	C	C	D+

6.4 PHYTOPLANKTON AND ZOOPLANKTON

During 2014, Como Lake was sampled for phytoplankton and zooplankton ten times from April 3 to October 19. The initial phytoplankton samples indicated a prolific community initially dominated by Euglenophyta (Figure 6-12). After Euglenophyta died off in April, Cryptophyta and subsequently Chlorophyta exhibited spikes and community dominance. A large Cyanophyta (blue-green algae) bloom began in early June and dominated the community for the remainder of the season, correlating with elevated TP during the same time period (Kalff, 2002) (Figure 6-10 and 6-12). The bloom decreased in density in August in September. A presence of Chlorophyta and Bacillariophyta contributed to the increase in phytoplankton density observed in the fall months.

Zooplankton communities in Como Lake were mainly dominated by Rotifers and Cladocerans during the month of April (Figure 6-13). Rotifer presence tapered out through May and Cladocerans continued to dominate the zooplankton community for the remainder of summer, contributing greatly to the overall density. Cladocerans, including the genus *Daphnia*, are important filter feeders and vital components of lower trophic levels in lake environments. Populations of nauplii were observed in moderate numbers from throughout the year. Cyclopoids spiked in May and June before tapering out for the year. Overall zooplankton density reached its highest peak in May, followed by a depression in density throughout the majority of summer before spiking again at the end of August (Figure 6-11). Zooplankton density did not strongly correlate with Chl-a concentrations in 2015.

Total zooplankton concentration followed overall phytoplankton concentration trends, with populations increasing and decreasing roughly 1.5 months following any phytoplankton high and low concentrations (Figures 6-10 and 6-11).

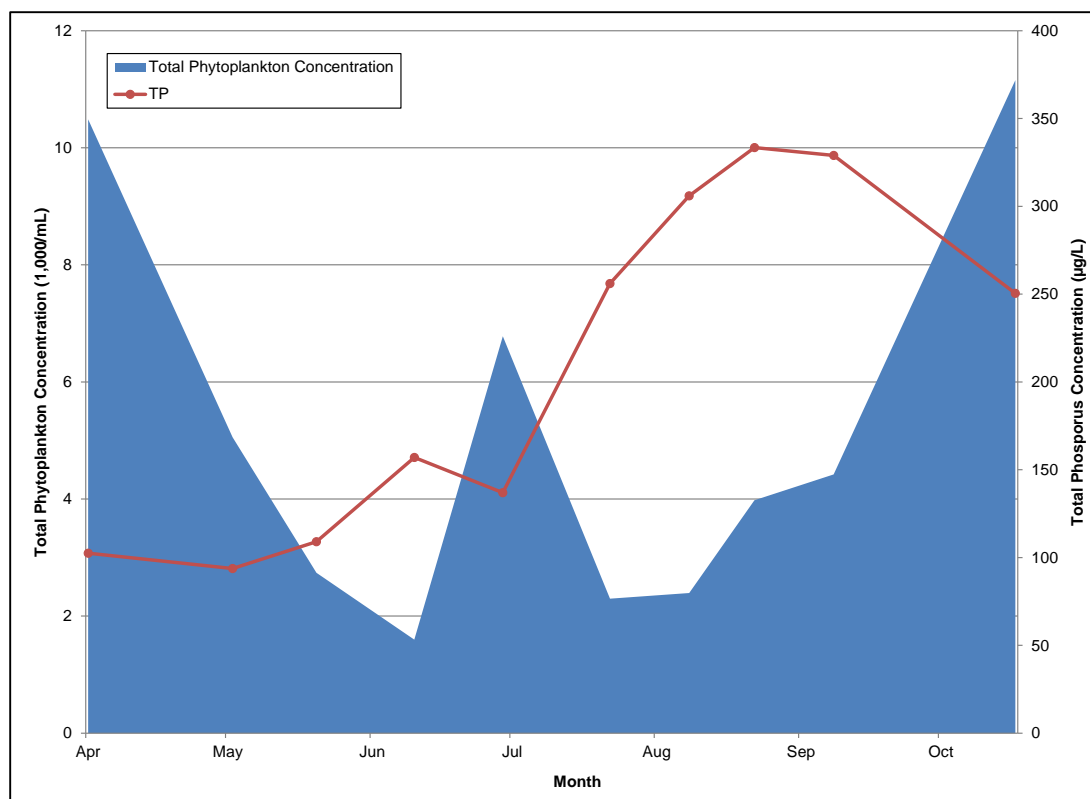


Figure 6-10: Como Lake 2015 total phytoplankton concentration and TP concentration.

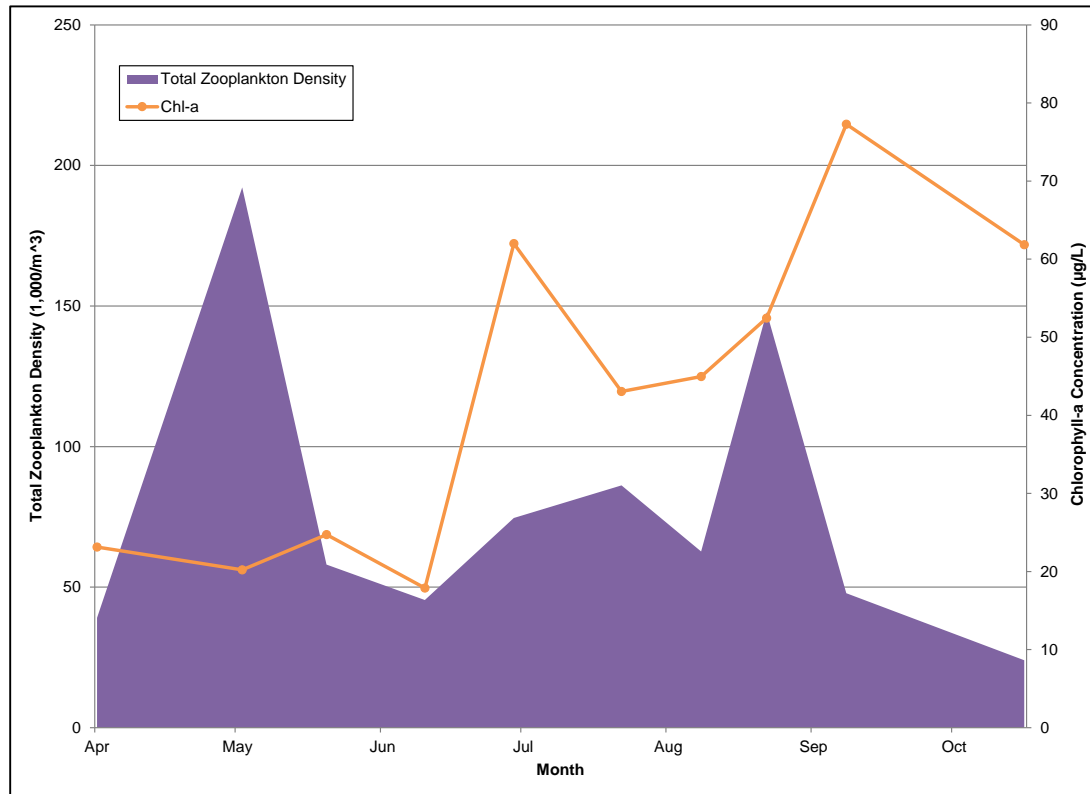


Figure 6-11: Como Lake 2015 total zooplankton density and Chl-a concentration.

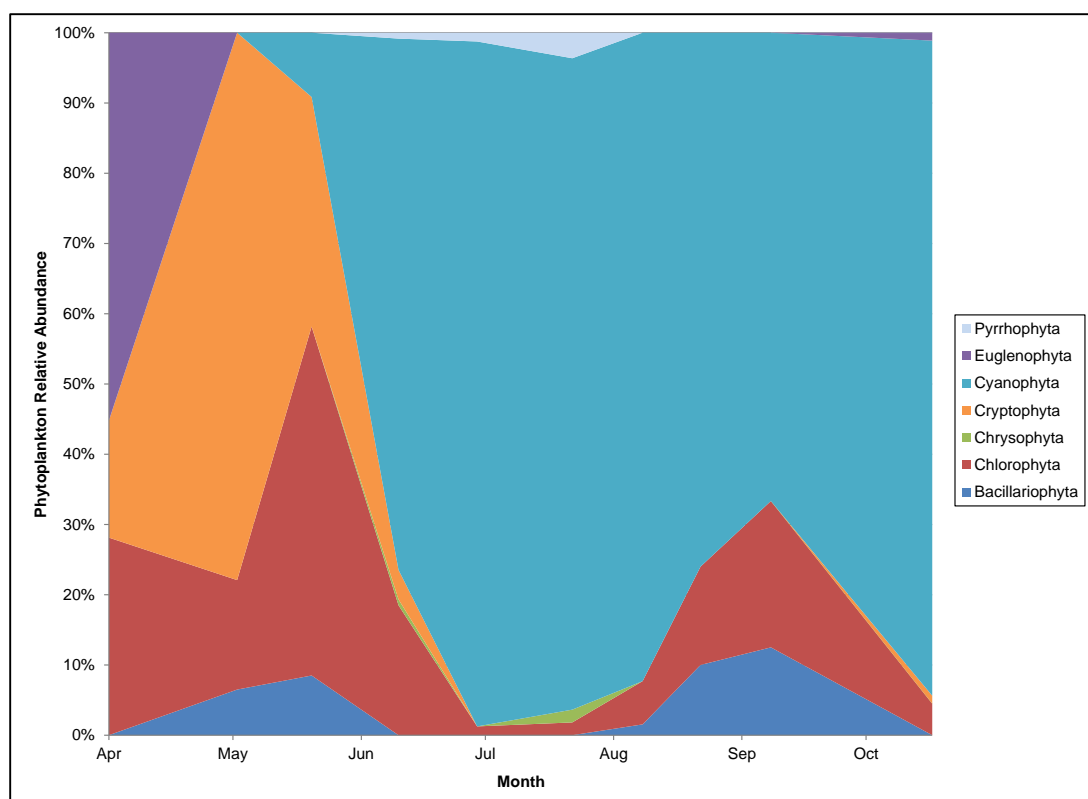


Figure 6-12: Como Lake 2015 phytoplankton relative abundance.

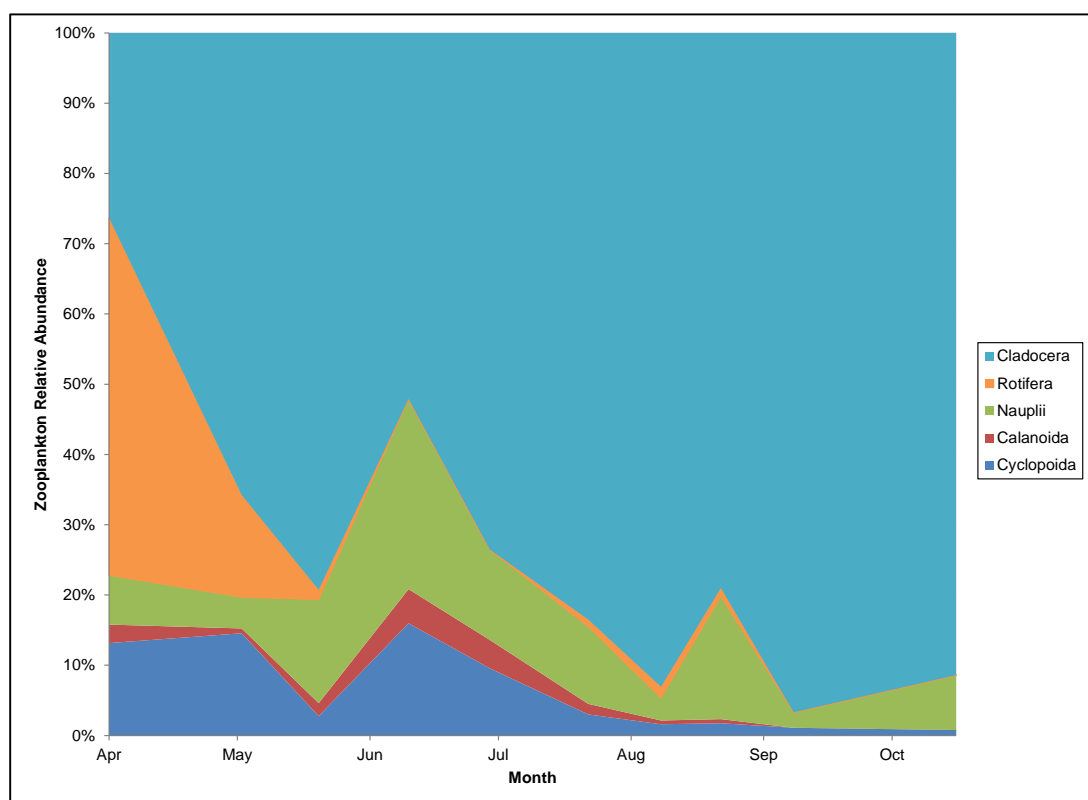


Figure 6-13: Como Lake 2015 zooplankton relative abundance.

6.5 AQUATIC VEGETATION

6.5.1 BIOVOLUME ANALYSIS

As shown by the biovolume heat maps of seasonal vegetation changes in Como Lake, the majority of the lake vegetation in 2015 was observed along the shoreline in the littoral zone (Figure 6-14). Overall, Como Lake exhibited moderate aquatic vegetation growth in May, primarily in the northern bay. In July, plant coverage decreased throughout the majority of the littoral zone, besides a few spots of concentrated biomass along the southern shore, a spot that was not reported as vegetated in the May survey. Nearly all evidence of aquatic plant biomass had disappeared by the end of August. Aquatic plants stabilize bottom sediment which prevents re-suspension of sediments that decreases water clarity (DNR, 2015h). Aquatic plants also intake nutrients for growth, making those nutrients unavailable for use by algae, which reduces algal overabundance and improves water quality.

6.5.2 POINT-INTERCEPT SURVEYS

In May of 2015, plant species observed in Como Lake were curly-leaf pondweed, Canadian waterweed, filamentous algae, and leafy pondweed. (Figure 6-15). Coontail, greater duckweed, and wild celery were observed during the July survey. The species occurring at the most locations throughout the lake in July was Canada waterweed, with curly-leaf pondweed, filamentous algae, coontail, and flatstem pondweed all occurring at less than 50% of locations surveyed.

By the end of August, Canada waterweed increased in occurrence to over 90% of survey locations, followed by filamentous algae which occurred at about 25% of locations. Curly leaf pondweed was also observed at nearly 15% of survey locations, despite its normal die-back by mid-summer. All species throughout the summer received below average abundance rankings, indicating that where species were observed, none were overly abundant (Figure 6-16). The presence of Eurasian watermilfoil has not yet been observed in Como Lake. In general, observing Canada waterweed throughout the course of the growing season at higher percent occurrences is good overall for the health of the lake, as it is a native plant, a good producer of oxygen, and has a good structure for providing habitat to small aquatic organisms (DNR, 2015b).

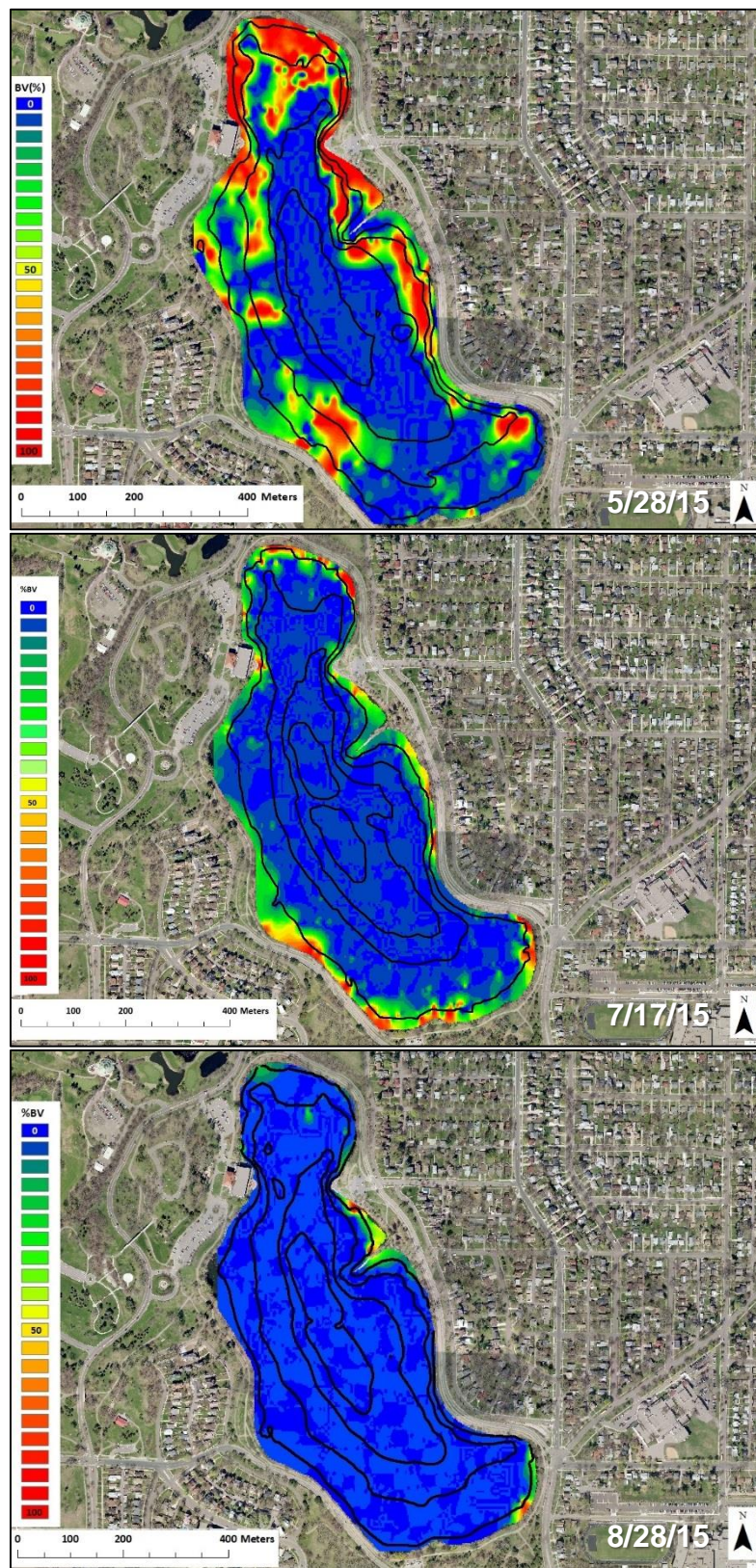


Figure 6-14: Como Lake 2015 seasonal vegetation changes (5/28/15, 7/17/15, 8/28/15).

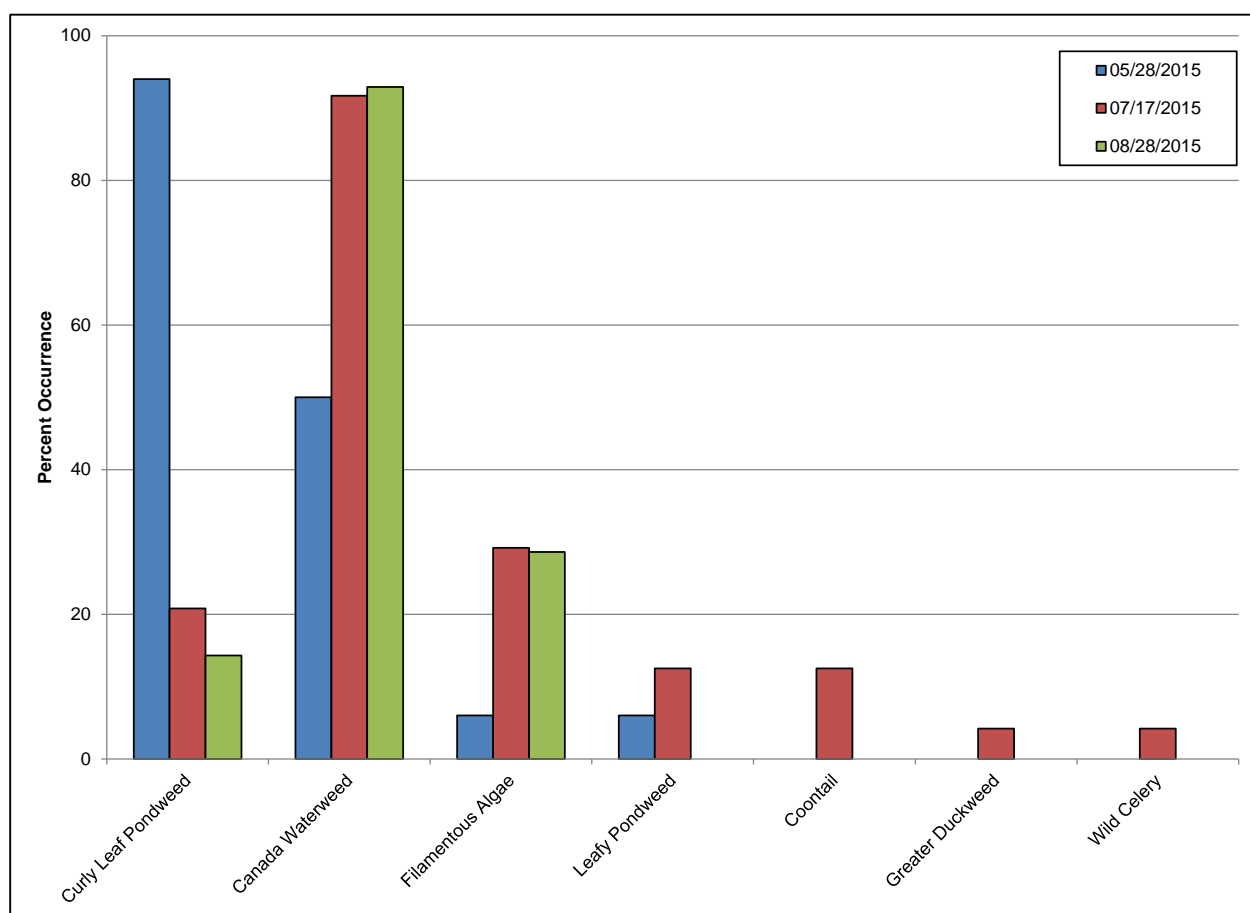


Figure 6-15: Como Lake 2015 percent occurrence of vegetation present.

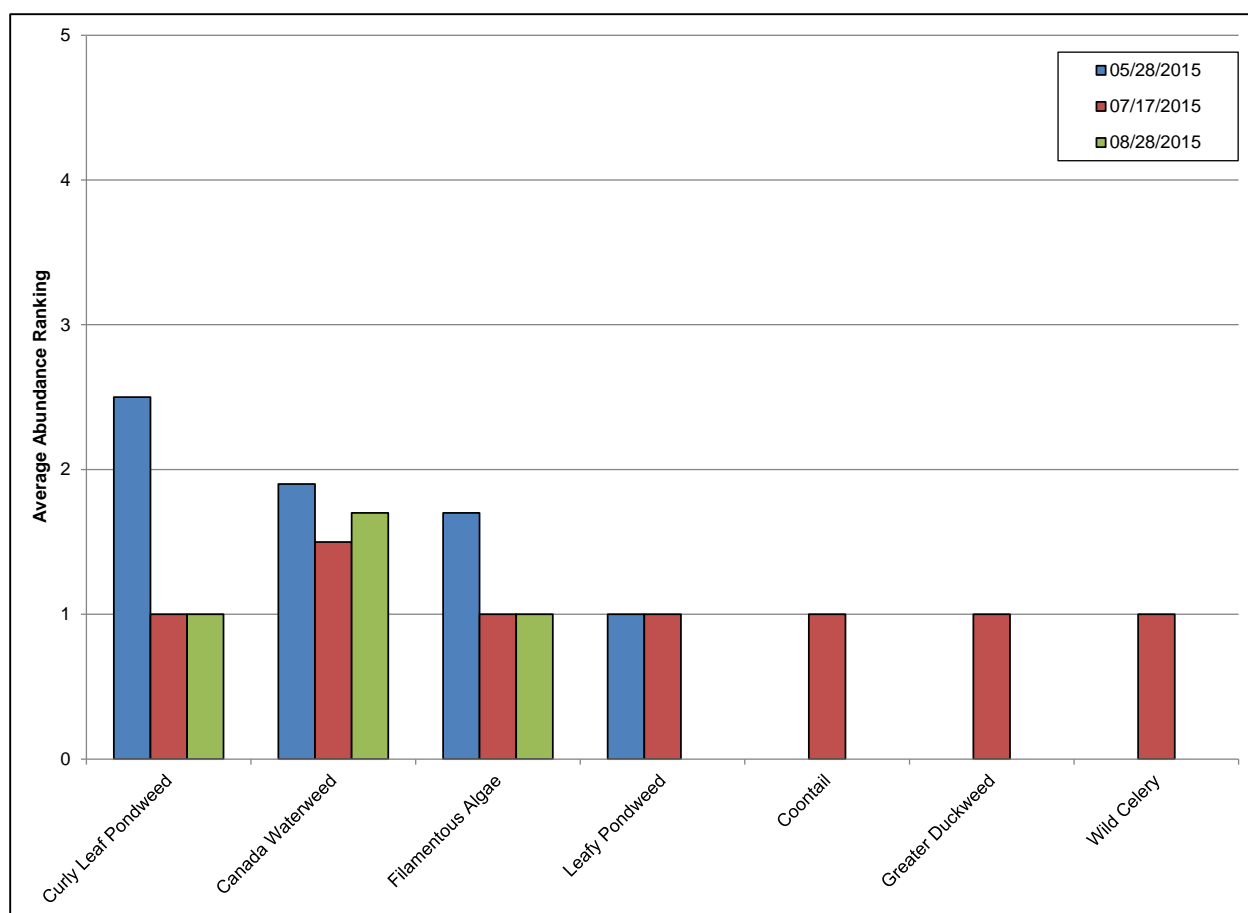


Figure 6-16: Como Lake 2015 average abundance ranking of vegetation present.

6.6 FISH STOCKING AND SURVEYS

While fish stocking in Como Lake has historically focused on bluegill and channel catfish because they are primary management species for the lake, channel catfish and walleye were the main species stocked in 2015 (Table 6-5). Como Lake is part of the Minnesota DNR’s “Fishing in the Neighborhood” program, which increases angling opportunities for residents in urban environments, encourages environmental stewardship, and improves knowledge of natural resources (DNR, 2015g). Therefore, these lakes are generally stocked with fish that are better for general angling activities.

In the 2015 fish survey (conducted by CRWD) of Como Lake, the most prevalent fish found were black crappie, which was similar to the previous survey completed in 2014 (Table 6-6) (Appendix A). Additional information regarding the 2015 survey and comparisons to the 2014 survey can be found in Appendix A: Technical Memo – Summary of 2015 Lake Fish Surveys. Varieties of panfish and planktivorous fish observed between the 2014 and 2015 surveys are similar. The 2015 survey, however, counted more than double the number of fish than the 2014 survey, and also identified 5 additional species not observed in the previous year. The northern

pike surveyed in both years were relatively large given the size and type of the lake, and were also found in similar numbers (Appendix A). The number of walleye was also greater in the 2015 survey than the 2014 survey. One concern is the large number of black bullhead observed in the 2015 survey, as these species can contribute to poor water quality (DNR, 2015a). Of note is the presence of common carp in Como Lake, which have not been observed in recent surveys. While only one carp was observed, the noted presence of common carp in a lake can be of concern, as they can be the cause of declines in water quality (DNR, 2015c) and are difficult to manage and remove. The next survey date by the DNR for Como Lake is set for 2016.

Table 6-5: Como Lake historical record of fish stocking.

Year	Bluegill	Channel catfish		Largemouth bass		Walleye			Yellow perch	
	Adult	Adult	Yearling	Adult	Yearling	Fry	Yearling	Fingerling	Adult	Yearling
2015		181					2,840			
2014			130	8		71,000		4,108	1211	
2013								486		
2011		124	3900					3593		
2010	24	91	3900				4			
2009			3457						816	1200
2008		155	4502							
2007	284	150	3864	179	414					
2006	1384									
2005										
2004	959									

Table 6-6: Como Lake 2015 fish populations.

Species	Number of fish caught in each category (inches)								Total
	0-5	6-8	9-11	12-14	15-19	20-24	25-29	30+	
Black bullhead	6	178	5	1	0	0	0	0	190
Black crappie	52	180	1	0	0	0	0	0	233
Bluegill	0	2	0	0	0	0	0	0	2
Brown Bullhead	0	0	1	0	0	0	0	0	1
Channel catfish	0	0	0	0	6	3	1	0	10
Common Carp	0	0	0	0	0	1	0	0	1
Golden shiner	0	6	0	0	0	0	0	0	6
Green Sunfish x Bluegill Hybrid	2	0	0	0	0	0	0	0	2
Northern pike	0	0	1	1	2	5	8	3	20
Walleye	0	1	5	5	5	3	0	0	19
White Sucker	0	0	0	0	3	0	0	0	3
Yellow bullhead	0	1	9	2	0	0	0	0	12
Yellow perch	0	0	1	0	0	0	0	0	1

6.7 OVERALL LAKE EVALUATION

Como Lake experiences a cyclic variation in water quality and biological response, fluctuating between poor and fair water quality generally every five to six years (Noonan, 1998). The period of record indicates that phosphorus has consistently been a primary driver for water clarity. It has historically received lower lake grades (including in 2015 when the lake received a “D+” grade), indicating lower user quality. The lake generally supports a fair variety of fish and contains a moderate amount of aquatic vegetation. In 2015, Como Lake showed degradation in water quality from 2014, exhibiting higher TP and Chl-a annual averages, and a stagnant average Secchi disk depth. Neither TP nor Chl-a met the MPCA state eutrophication standards in 2015.

7 CROSBY LAKE RESULTS

7.1 CROSBY LAKE BACKGROUND

Crosby Lake is situated within Crosby Farm Regional Park in Saint Paul and is also a part of the National Park Service's Mississippi National River and Recreation Area (CRWD, 2012a). The park itself is 736 acres and consists of floodplain and bluff areas. It offers various outdoor activities for fishing, canoeing, walking, hiking and winter cross-country skiing. The park has diverse wetland and forest habitats that support a large variety of plants, trees, and wildlife (Figure 7-1). Crosby Lake is 45 acres and has a maximum depth of 17 ft with a 100% littoral area (Table 7-1; Figure 7-2). It is located in the floodplain area of the park between a large bluff and the main channel of the Mississippi River.



Figure 7-1: View of the northeast shoreline of Crosby Lake.

Crosby Lake has a relatively small watershed area of only 197 acres (Table 7-1; Figure 7-3). Water flows into the lake during high water periods from wetlands on the east and north sides via culverts. Seepage from the base of the bluff (consisting of sandstone and limestone) is also an input to Crosby Lake. The major groundwater input to the lake comes from the St. Peter aquifer to the west.

Table 7-1: Crosby Lake morphometric data.

Surface Area (acres)	Maximum Depth (ft)	Littoral Area	Volume (acre-ft)	Watershed Area (acres)	Watershed: Lake Area (ratio)
45.0	17.0	100%	130	197	4.4



Figure 7-2: Crosby Lake bathymetric map.

CRWD developed a lake management plan for Crosby Lake that assessed the current condition of the Lake and characteristics of its watershed, identified the issues of greatest concern, and established management goals and an implementation plan for addressing identified issues (CRWD, 2012a). A key piece of understanding that came out of the plan was the interaction between Crosby Lake and the Mississippi River. As Crosby Lake sits within the floodplain of the Mississippi River, it is intermittently flooded during periods of high water. The normal water level (or ordinary water level) of the lake is 694 ft. The normal pool elevation of the river is 687 ft (CRWD, 2012a). Therefore, under normal, non-flood conditions, groundwater flows from the lake to the river. The lake does not normally directly output to the river. Under high water conditions, however, the river will overflow to the lake near the northeast corner.

CRWD determined that a 49,000 cfs flow (equivalent of a stage of 697 ft) would cause an exchange between the river and the lake to occur, equating to a 3-year storm event, meaning that this has a 33% chance of occurring each year (CRWD, 2012a). Looking at the historical record since 1982, only 2.5% of recorded river flows have been high enough for an exchange to occur. Table 7-2 shows the number of days the Mississippi River interacted with Crosby Lake during the historical monitoring period for the lake. During these exchanges, the water bodies interchange not only water, but nutrients, other pollutants, and biological organisms contained within.

Table 7-2: Historical record of Mississippi River interaction with Crosby Lake.

Year	Number of Days Mississippi River Interacts with Crosby Lake
1999	14
2000	0
2001	63
2002	0
2003	0
2004	0
2005	0
2006	19
2007	0
2008	0
2009	15
2010	36
2011	103
2012	10
2013	13
2014	50
2015	0

Crosby Lake has historically only met the shallow lake state water quality standards for TP concentration ($< 60 \mu\text{g/L}$) for half of the years monitored, but has consistently met the standards for Chl-a concentration ($< 20 \mu\text{g/L}$) and Secchi disk depth ($\geq 1.0 \text{ m}$) since monitoring began in 1999. The Crosby Lake management plan sets a similar goal of meeting the state standard for TP of $60 \mu\text{g/L}$ (CRWD, 2012a). Since the development of the Crosby Lake Management Plan, a number of water quality improvement projects have been implemented by CRWD, the City of Saint Paul and others to reduce stormwater runoff to Crosby Lake. In 2010, the City of Saint Paul installed filtration swales as part of the reconstruction of the Samuel Morgan pedestrian and bikeway trails along Shepard Road. CRWD provided the City of Saint Paul a grant in 2012 for the installation of a rain garden and swale during the reconstruction of the east end parking lot in Crosby Farm Regional Park. In addition, CRWD supports the Friends of the Mississippi River's efforts to restore the native prairie areas in Crosby Farm Regional Park. Lastly, as part of the reconstruction of the Madison-Benson Streets area near Crosby Lake in 2013, the City of Saint Paul constructed boulevard tree trench systems and rain gardens to treat street and sidewalk runoff.

Management efforts need to take into account the dynamic relationship between the lake and the river. Although water quality has been good in the past with TP concentrations below the state standards, recent years have shown increasing TP concentrations that have surpassed the standard (Figure 7-8; Table 7-3). The source of these high nutrient concentrations could be from high flow periods of the Mississippi River where large sediment loads enter the lake. For example, the lake was inundated by the river for 103 days in 2011 (CRWD, 2012a). Water quality data observed in the years following the inundation showed average TP concentrations well above the normal historical values (Figure 7-7; Table 7-3). In 2015, however, there were no documented days of river flooding, and water quality showed an improvement in TP and Chl-a over the previous year when moderate flooding occurred (Figure 7-7). From a management perspective, this relationship could make it hard to control and improve Crosby Lake water quality in the long-term.



Figure 7-3: Crosby and Little Crosby Lakes and subwatershed boundary.

7.2 LAKE LEVEL

The Minnesota DNR does not record or report historical lake level data for Crosby Lake, so CRWD began monitoring Crosby Lake level in June 2014. Figure 7-4 shows the fluctuation in Crosby Lake level from 2014-2015. During 2014, the lake level was greatly influenced by flooding from the Mississippi River. In 2015, there were no days in which flooding from the river occurred (Table 7-2).

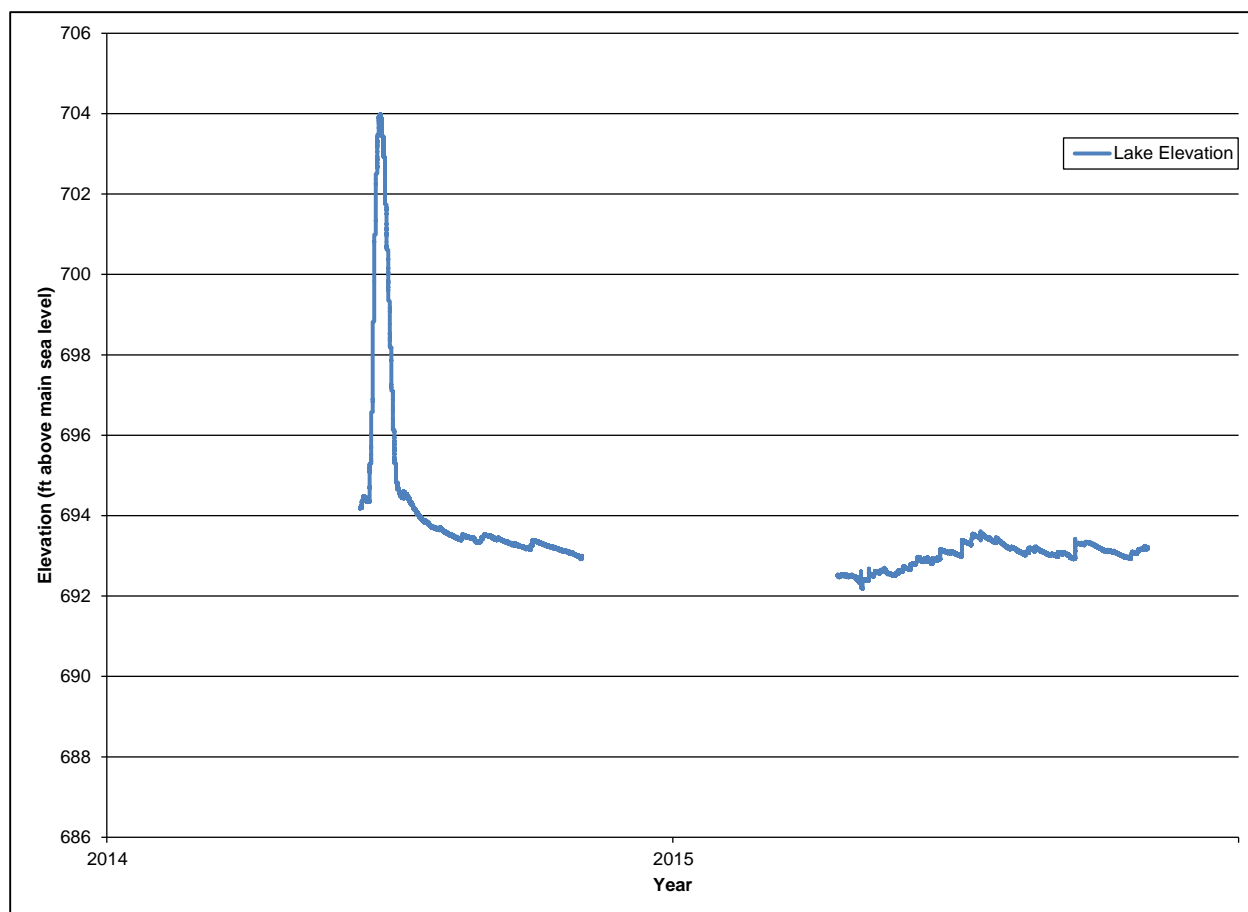


Figure 7-4: Crosby Lake historical lake elevations.

Figure 7-5 shows the continuous lake levels for Crosby Lake in 2015. Lake level did not fluctuate very drastically during the course of the year. Level increased from April until mid-July when it reached a maximum for the year after two significant rainfall events. After this peak, it generally decreased until late September, when it peaked again, then decreased until a final small increase following a late October rainstorm.

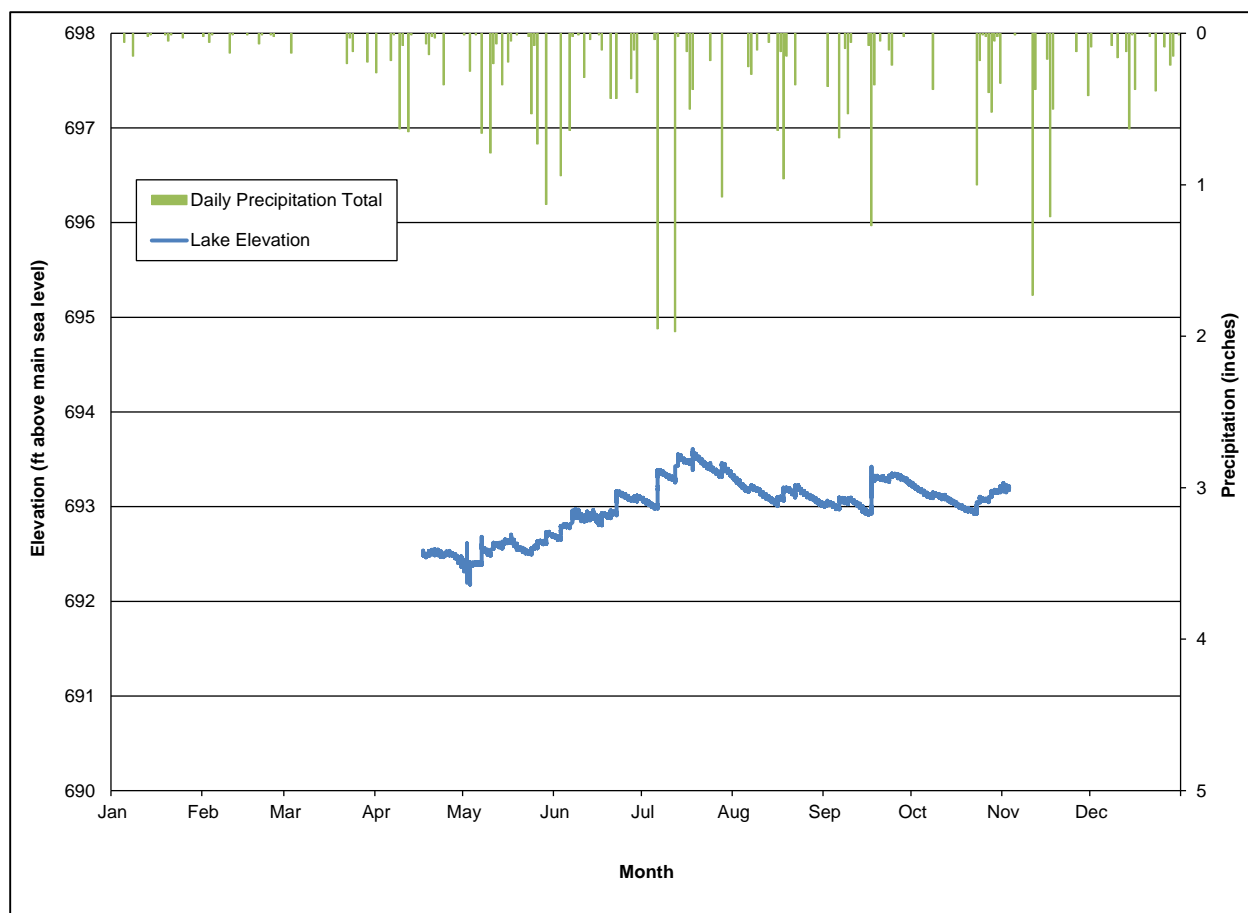


Figure 7-5: Crosby Lake 2015 lake elevations and daily precipitation events (MCWG, 2016).

7.3 WATER QUALITY RESULTS

Crosby Lake was sampled nine times during 2015, from May 18 to October 20 (Figure 7-6). As in previous years, Crosby Lake was characterized by high TP concentrations, but moderate Chl-a concentrations and Secchi depths (Figure 7-6).

Samples show TP concentrations in the lake exceeded state standards throughout the monitoring season but were lowest at the end of the season (September 4 – October 20) with an average of 68 µg/L. The six samples at the beginning of the season collected May 18 to October 20 averaged 164 µg/L; 241% higher than the end-of-the-season average.

Epilimnetic Chl-a concentrations varied throughout the year, with a peak in early August (Figure 7-6). Only four 2015 samples exceed the state standard for Chl-a. During 2015, fluctuations in Chl-a concentration were not generally associated with fluctuations in TP concentration, indicating that there could be other drivers of algae growth in the lake.

The highest degree of water transparency was observed during the first sample event on May 18 (3.5 m) and decreased to 0.7 m by the end of August before increasing gradually until the end of the growing season (Figure 7-6).

Seasonally, Crosby Lake exhibits the best and least variable TP and Chl-a values during the month of May (Figure 7-7). TP values do not exhibit any additional monthly trends from June through September. August shows the greatest variation in Chl-a values. The month of June shows the deepest Secchi disk depth median of all months (Figure 7-7).

Figure 7-8 shows yearly average historical TP concentrations, Chl-a concentrations, and Secchi disk depths graphically. Crosby Lake has been characterized by high epilimnetic TP concentrations over the last six years. The average TP concentration from 1999-2009 was 53.2 µg/L, while the average TP concentration from 2010-2015 was 139.0 µg/L, a 165% increase from the previous time period. Hypolimnetic TP annual averages followed a similar trend as epilimnetic TP, but with larger fluctuations and greater concentrations (Figure 7-9). In eutrophic lakes, the hypolimnion is generally richer in phosphorus than the epilimnion, as bed sediments readily release phosphorus into the anoxic bottom layer, peaking in fall just prior to lake turnover (Kalff, 2002).

Chlorophyll-a concentrations have exhibited elevated concentrations since 2007 (Figure 7-8). Figure 7-8 shows that water clarity is principally affected by Chl-a concentration over the period of record. In the first year Crosby Lake was monitored (1999) the Secchi depth average was the deepest on record at 3.8 m. Since then, Secchi depths have fluctuated annually but have generally decreased as Chl-a concentrations increased and vice versa. It is noteworthy that despite a record TP concentration average in 2012, the yearly average Chl-a concentration and Secchi depths were similar to historical values (years with lower TP concentrations).

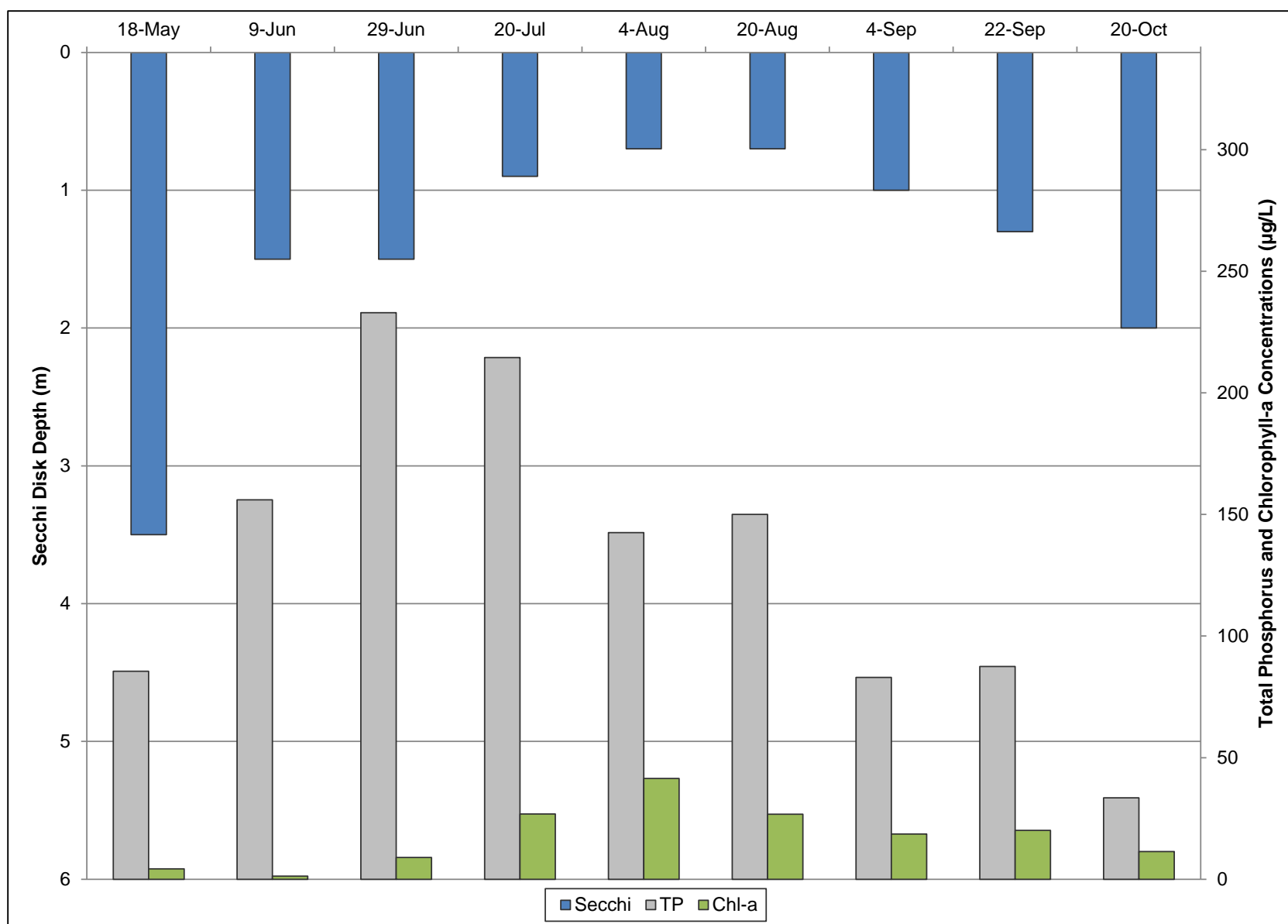


Figure 7-6: Crosby Lake 2015 Secchi/TP/Chl-a comparison.

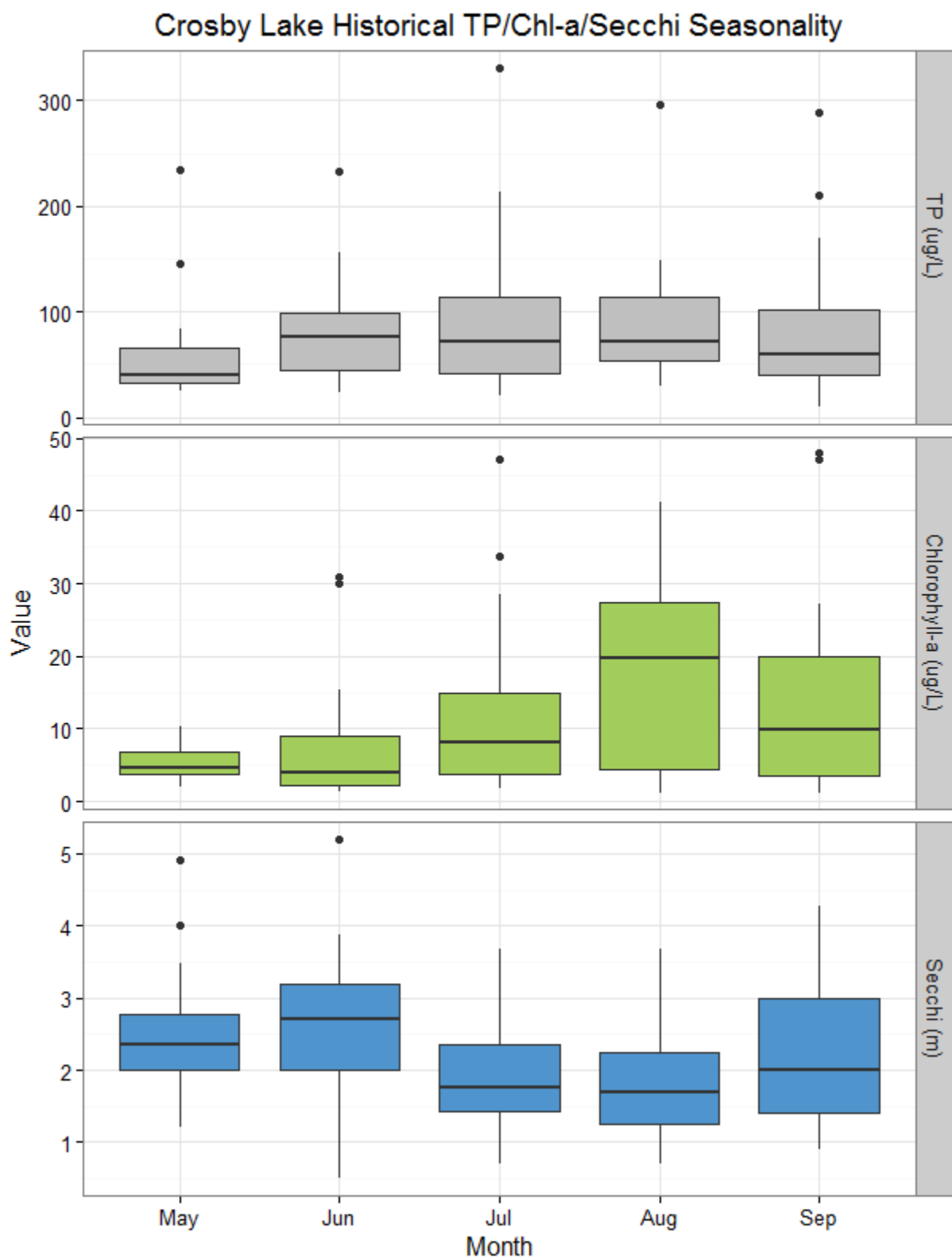


Figure 7-7: Crosby Lake seasonality boxplots of historical Secchi/TP/Chl-a samples.

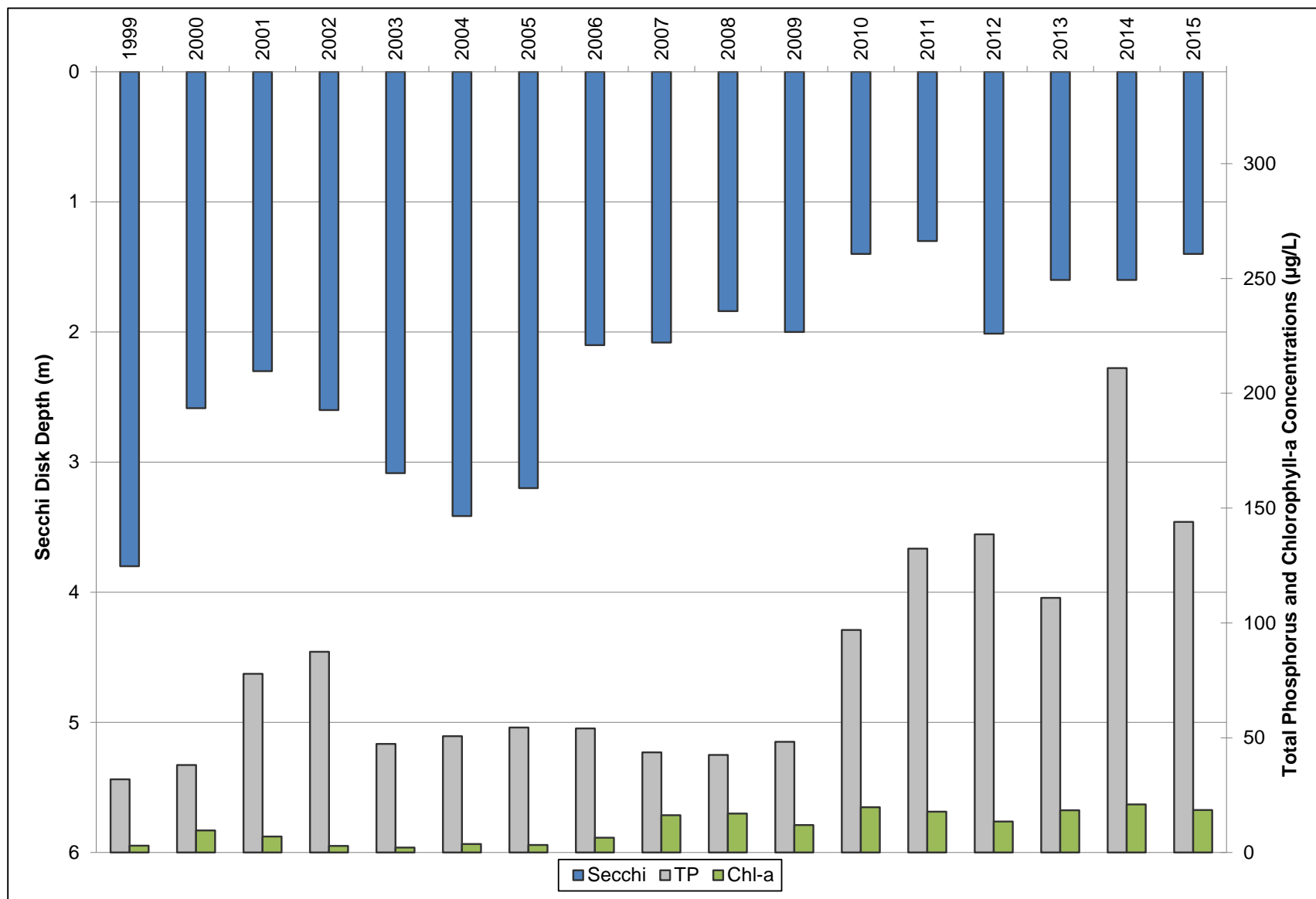


Figure 7-8: Crosby Lake historical annual average Secchi/TP/Chl-a comparison.

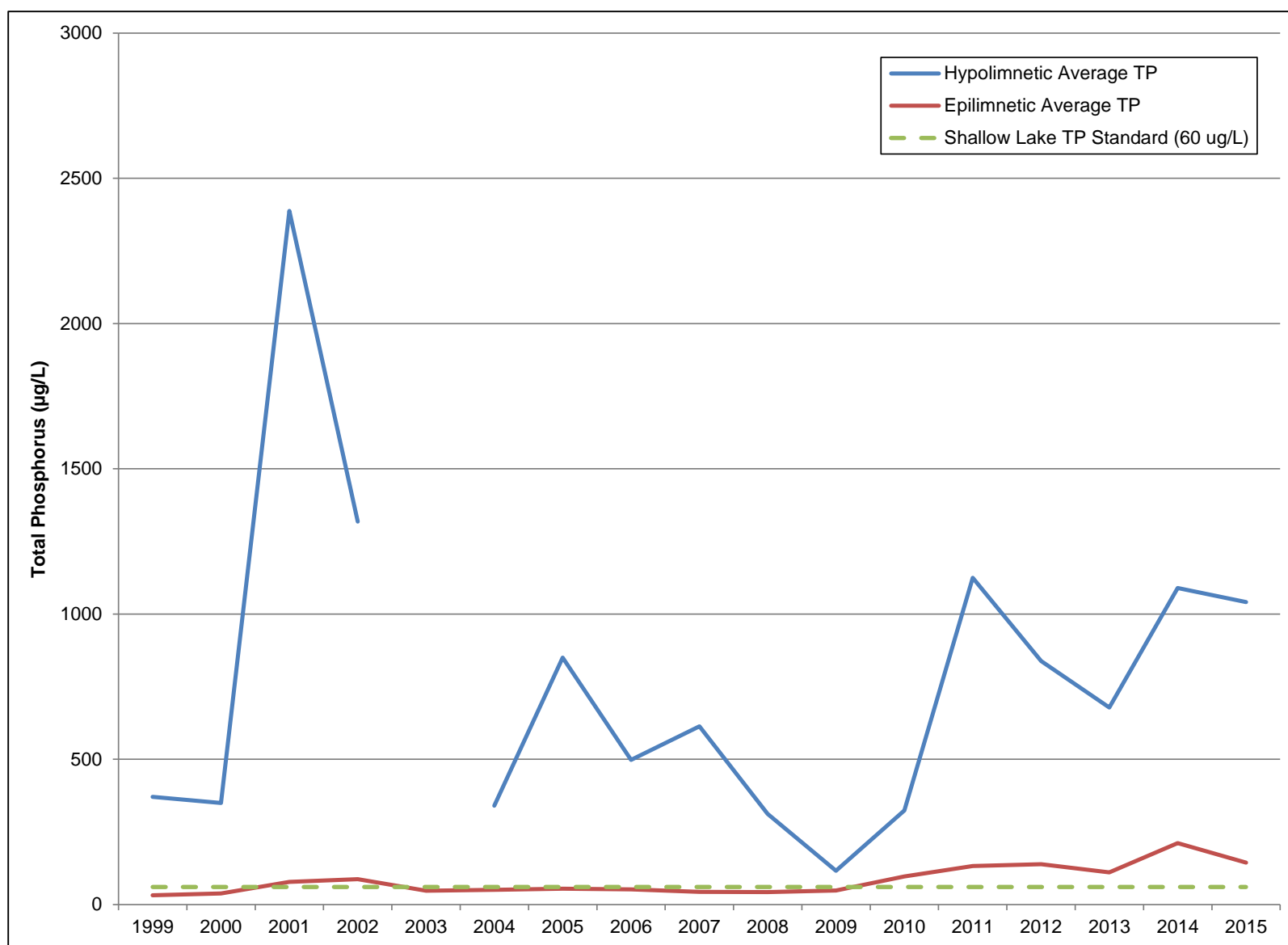


Figure 7-9: Crosby Lake historical annual average hypolimnetic and epilimnetic total phosphorus.

Yearly average historical TP concentrations, Chl-a concentrations, Secchi depths, and their comparisons to lake standards are shown in Table 7-3. Historically, Crosby Lake has met the standards for Chl-a and Secchi depth, with only two years exceeding TP standards, from 1999-2009 (Table 7-3). Since 2010, however, it has consistently exceeded the standards for TP, which was also the case in 2015 even though TP improved between 2014 and 2015. In 2015, Crosby Lake received a grade of “C,” an improvement upon the previous year and consistent with the average since 2010 (Table 7-4). While all water quality parameters have been degrading, the most notable has been the steadily increasing TP concentration.

Table 7-3: Crosby Lake historical yearly TP/Chl-a/Secchi depth averages compared to shallow lake state standards.

Year	TP (µg/L)	Chl-a (µg/L)	Secchi (m)
1999	32	3.0	3.8
2000	38	9.6	2.6
2001	78	7.0	2.3
2002	87	2.9	2.6
2003	47	2.2	3.1
2004	51	3.7	3.4
2005	54	3.2	3.2
2006	54	6.5	2.1
2007	44	16.3	2.1
2008	43	17.0	1.8
2009	48	12.0	2.0
2010	97	19.7	1.4
2011	132	17.8	1.3
2012	139	13.5	2.0
2013	111	18.4	1.6
2014	211	21.0	1.6
2015	144	18.5	1.4
	Value does not meet state standard*		
	Value meets state standard		

*MPCA shallow lake standards are not to exceed 60 µg/L for TP and 20.0 µg/L for Chl-a, with a Secchi disk depth of at least 1.0 m.

Table 7-4: Crosby Lake historical lake grades.

Year	TP Grade	Chl-a Grade	Secchi Grade	Overall Grade
1999	B	A	A	A
2000	C	A	B	B
2001	D	A	B	B
2002	D	A	B	B
2003	C	A	A	B+
2004	C	A	A	B+
2005	C	A	A	B+
2006	C	A	C	B
2007	C	B	C	C+
2008	C	B	C	C+
2009	C	B	C	C+
2010	D	B	C	C
2011	D	B	C	C
2012	D	B	C	C
2013	D	B	C	C
2014	F	C	C	D+
2015	D	B	C	C

7.4 PHYTOPLANKTON AND ZOOPLANKTON

Crosby Lake was sampled for phytoplankton and zooplankton nine times during 2015 from May 18 to October 20. Total 2015 phytoplankton concentrations can be seen in Figure 7-10. Overall, there was a diverse phytoplankton community observed throughout the year (Figure 7-12).

In May and June, concentrations of phytoplankton were low, but consisted of primarily Cryptophyta and Chlorophyta (green algae) (Figure 7-12). Overall density rose in July, as a result of a Cyanophyta (blue-green algae) bloom. Starting in early August, Cryptophyta and Chlorophyta alternated in spikes until September, when Cryptophyta dominated the phytoplankton community through the end of the year. Cryptophyta bloom when waters represent oligotrophic conditions, as evidenced by the falling total phosphorus concentrations during this time. Euglenophyta experienced a small spike in late-August. Phytoplankton concentration moderately followed the TP concentration pattern during the first half of 2015 (Figure 7-10).

Total zooplankton density can be seen in Figure 7-11. The Crosby Lake zooplankton community was predominately comprised of Cladoceran, Cyclopoids and Nauplii (juvenile crustacean) in 2015 (Figure 7-13). Nauplii and Cyclopoids accounted for a nearly equal portion of the zooplankton community, spiking in early August. Cladoceran (important lake filter-feeders including the order *Daphnia*) populations also spiked during this same sampling event. The remainder of the samples indicated a continuance of Nauplii and Cyclopoida zooplankton dominance. Very few numbers of Rotifers and Calanoids were observed. Zooplankton density generally followed the Chl-a concentration pattern during 2015 (Figure 7-11).

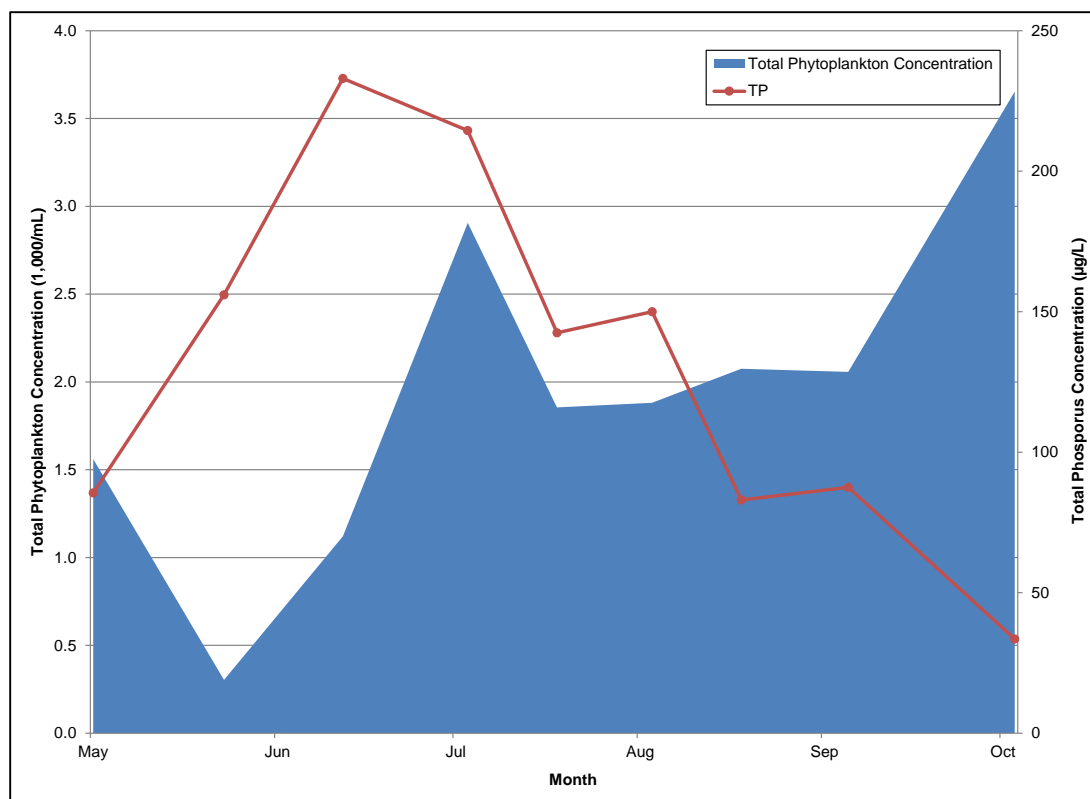


Figure 7-10: Crosby Lake 2015 total phytoplankton concentration and TP concentration.

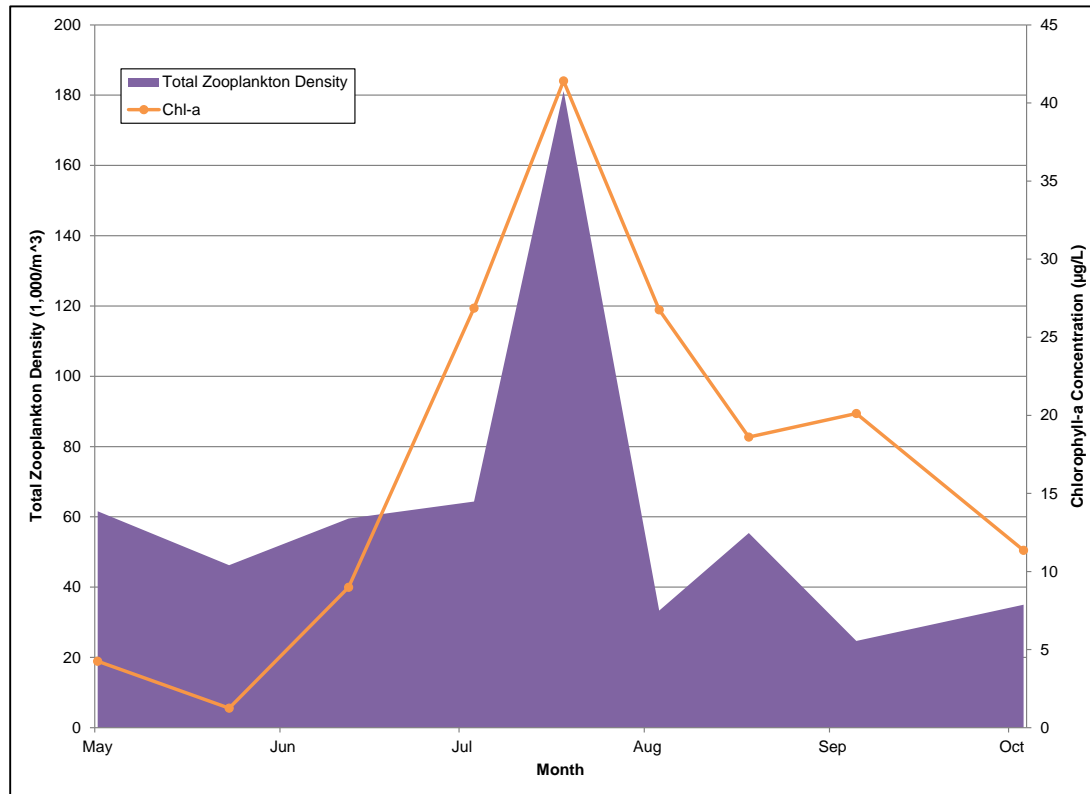


Figure 7-11: Crosby Lake 2015 total zooplankton density and Chl-a concentration.

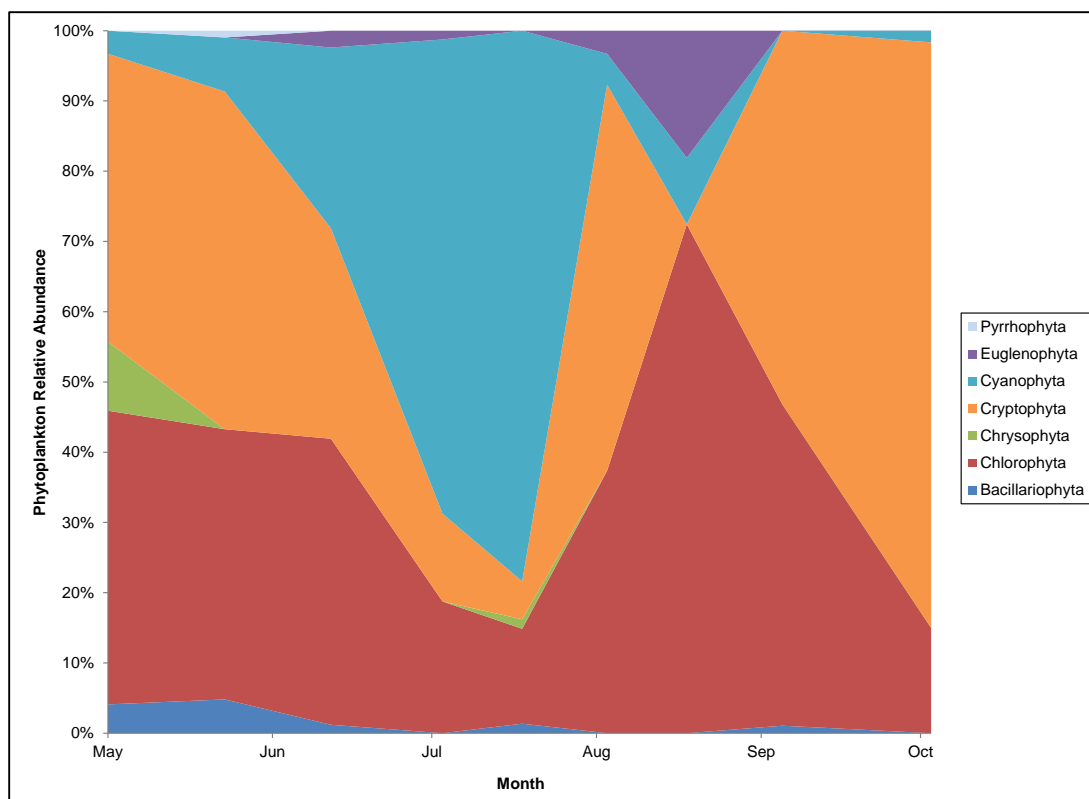


Figure 7-12: Crosby Lake 2015 phytoplankton relative abundance.

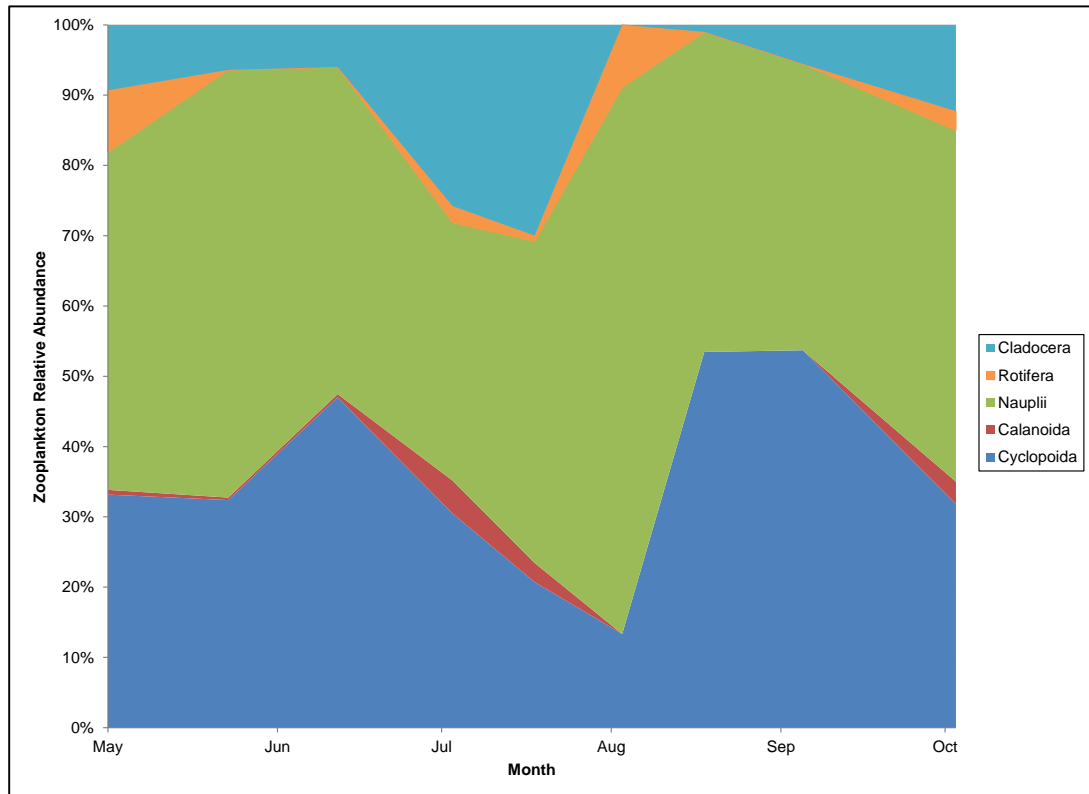


Figure 7-13: Crosby Lake 2015 zooplankton relative abundance.

7.5 AQUATIC VEGETATION

7.5.1 BIOVOLUME ANALYSIS

The 2015 biovolume heat maps of submerged aquatic vegetation for Crosby Lake are shown in Figure 7-14. Since 100% of the lake area lies within the littoral zone, submerged biomass was observable at nearly all points in the lake. The 2015 biovolume analysis indicates an increase in aquatic plant growth from previous years, especially at depths greater than 10 ft. There is a general decrease in aquatic biomass present from the initial survey in June to the final survey in August.

7.5.2 POINT-INTERCEPT SURVEYS

A diverse aquatic plant community was observed in Crosby Lake in 2015, with 18 distinct species observed throughout the season (Figure 7-15). The following plants were observed at mid-to-high percent occurrence during all three survey events: sago pondweed, star duckweed, white water lily, and coontail (Figures 7-15 and 7-16). Six floating aquatic plant species were observed at varying levels of occurrences in Crosby Lake: three species of duckweed, watershield, white water lily, and white water crowfoot. Curly leaf pondweed also was observed at a moderate level of occurrence in June and July, but was not observed in August due to its seasonal mid-summer die off. Curly leaf pondweed is an aquatic invasive species and was only first found in the lake in the 2013 survey.

Eurasian water milfoil was observed in Crosby Lake during the August survey, the first recorded occurrence of the invasive species in the lake. Unlike native northern watermilfoil, Eurasian watermilfoil forms dense mats at the surveys of the water, impeding recreational accessibility and decreasing light available to other aquatic plants beneath its canopy (DNR 2015d). Eurasian watermilfoil does not easily become established in lakes with previously well-established and diverse populations of native plants.

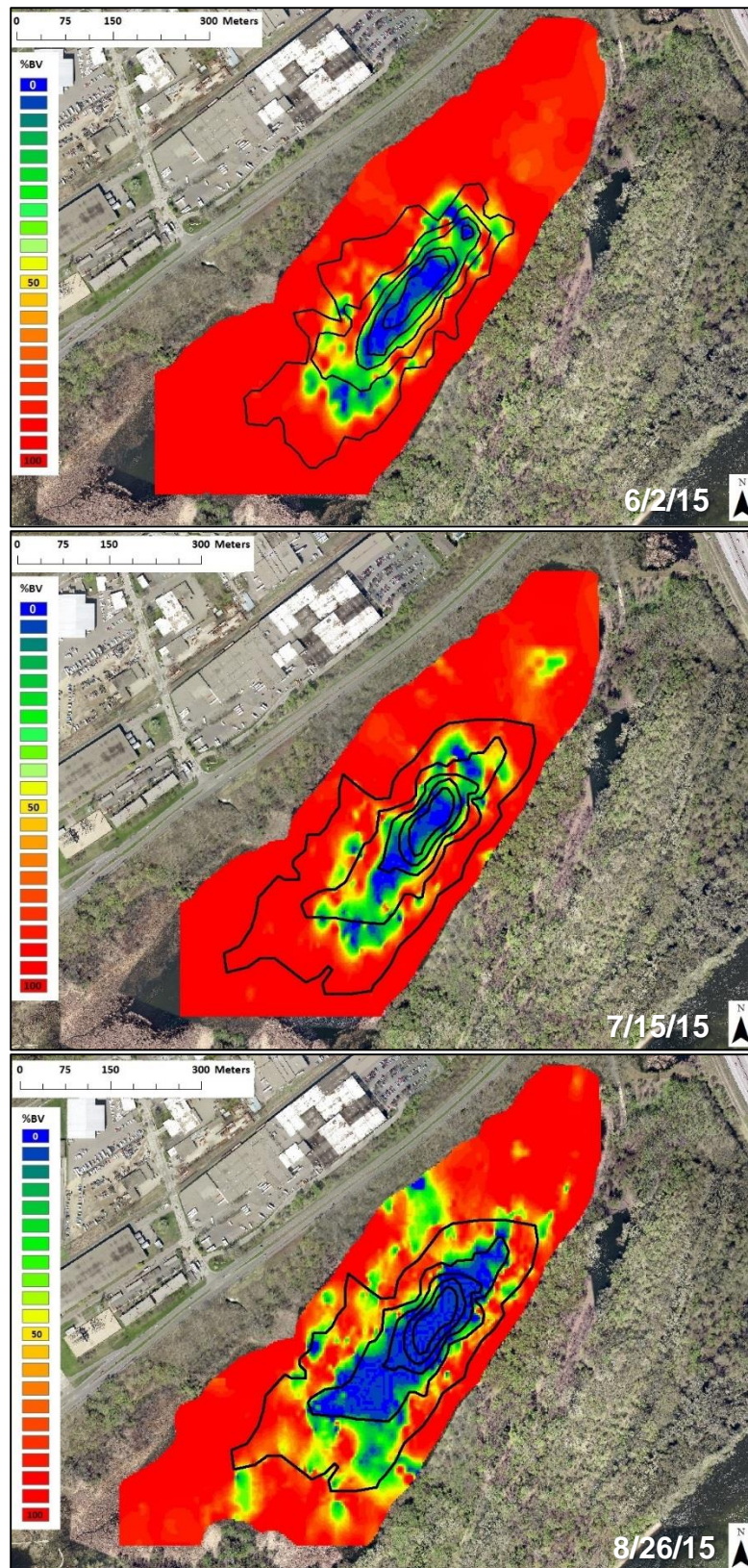


Figure 7-14: Crosby Lake 2015 seasonal vegetation changes (6/2/15, 7/15/15, 8/26/15)

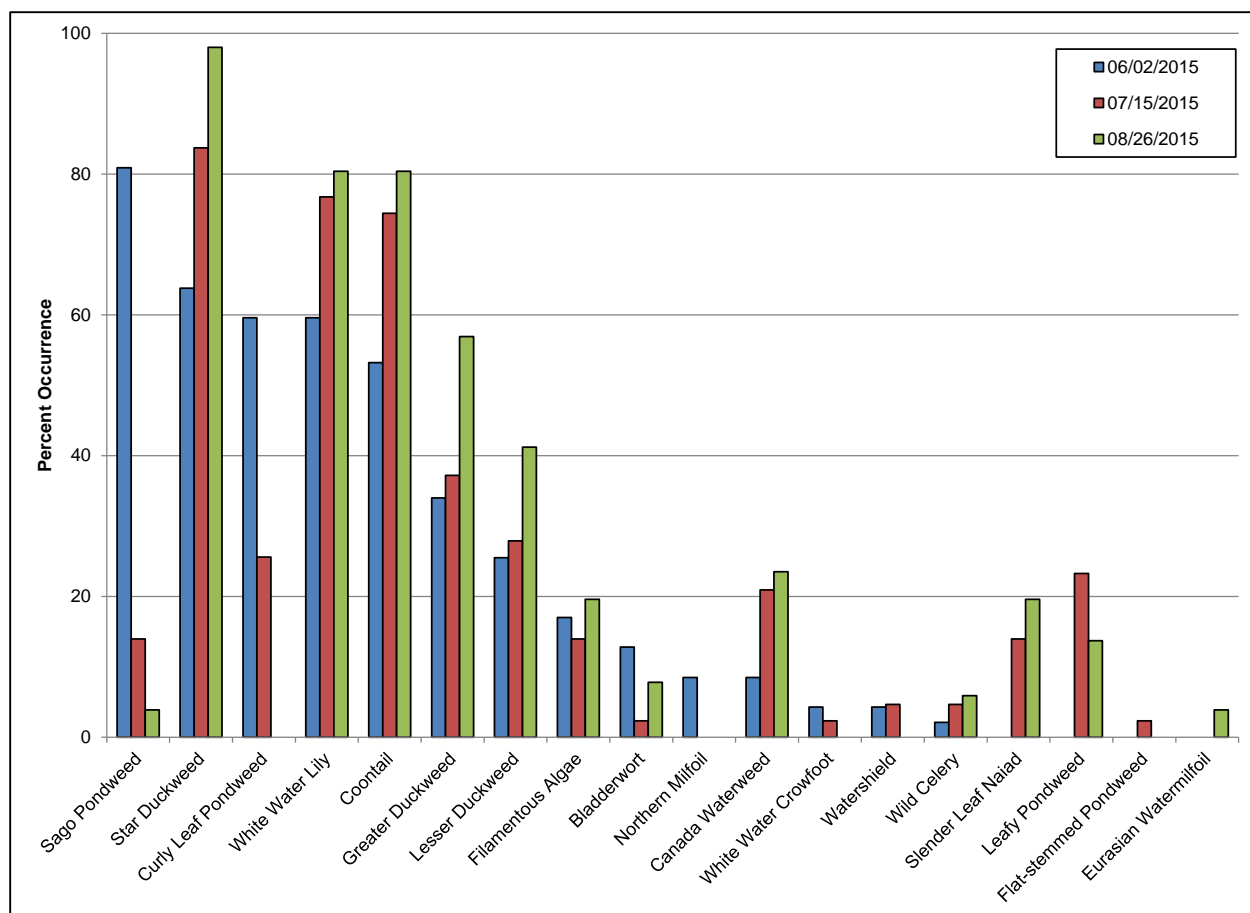


Figure 7-15: Crosby Lake 2015 percent occurrence of vegetation present.

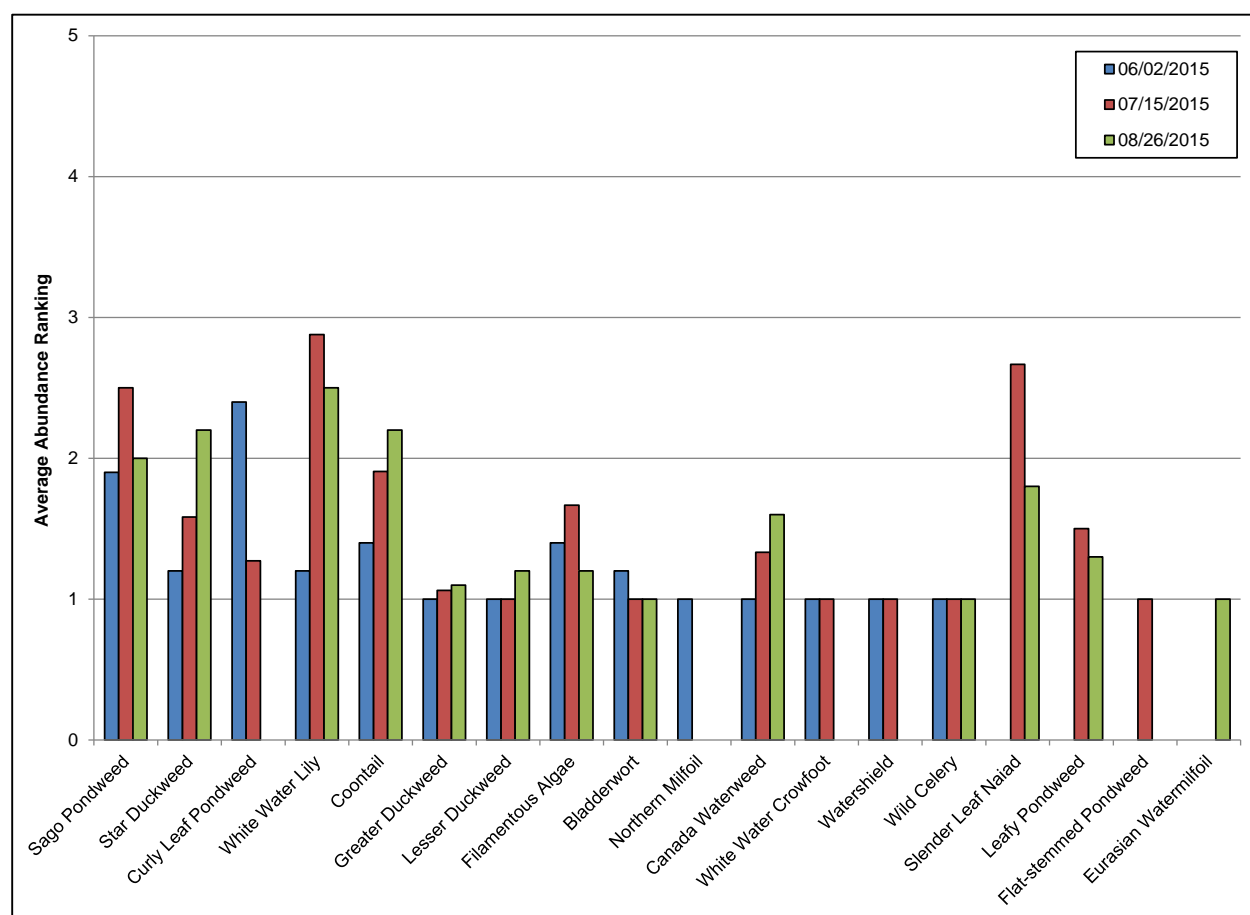


Figure 7-16: Crosby Lake 2015 average abundance ranking of vegetation present.

7.6 FISH STOCKING AND SURVEYS

The last survey of fish populations completed by the Minnesota DNR in Crosby Lake was in 2014. In 2015, the fish survey in Crosby Lake was conducted by CRWD (Table 7-5). The DNR does not stock this lake, so populations observed are naturally present in the lake and are influenced by overflow from the Mississippi River during high water levels. The largest population of fish observed in 2015 were bluegills, followed by pumpkinseed sunfish. The 2015 survey contained half of the overall total number of fish, and also had fewer species observed. This could be the result of the lack of flooding that occurred in 2015 as compared to 2014, where there were potentially not as many fish entering Crosby Lake from the Mississippi River. Northern pike were observed, but not in high abundance. Of note is the decrease in total numbers of bluegill and black crappie in the 2015 survey as compared to 2014: in 2014 these two species constituted roughly 75% of the catch. Crosby Lake is scheduled to be surveyed again in the summer of 2016 by CRWD.

Table 7-5: Crosby Lake 2015 fish populations.

Species	Number of fish caught in each category (inches)								Total
	0-5	6-8	9-11	12-14	15-19	20-24	25-29	30+	
Black bullhead	6	1	1	0	0	0	0	0	8
Black crappie	1	2	1	0	0	0	0	0	4
Bluegill	13	18	0	0	0	0	0	0	31
Bowfin (Dogfish)	0	0	0	2	0	2	0	0	4
Largemouth bass	0	0	0	1	0	0	0	0	1
Northern pike	0	0	0	0	1	0	2	0	3
Pumpkinseed sunfish	5	11	0	0	0	0	0	0	16
Yellow bullhead	0	2	0	0	0	0	0	0	2
Yellow perch	3	1	0	0	0	0	0	0	4

7.7 OVERALL LAKE EVALUATION

In 2015, while TP decreased from the highest annual average on record in 2014, Crosby Lake exhibited a much higher TP annual average than the historical average. Also, Crosby Lake exhibited similar Chl-a concentration and Secchi Disk depth to previous years. TP and Chl-a improved in Crosby Lake from 2014-2015, which could potentially be related to there being zero days of floodplain inundation by the Mississippi River. The lake grade in 2015 was a “C”, just below the historical grade of “C+”. Crosby Lake has historically received average lake grades, indicating that it generally has average water quality, with the exception of the more recent years of monitoring (2011-present) which have exhibited poorer water quality for all three eutrophication parameters. The lake contained a large variety of vegetation during the 2015 vegetation surveys, with extensive vegetation covering the majority of the lake from early June through late August. Crosby Lake contained average populations of planktivorous fish in 2015, with only two species of predator fish observed.

8 LITTLE CROSBY LAKE RESULTS

8.1 LITTLE CROSBY LAKE BACKGROUND

Little Crosby Lake is 8 acres with an average depth of 7 ft and a maximum depth of 34 ft (Figure 8-1; Table 8-1). Little Crosby Lake is a shallow lake with a littoral area of 88% and has a small watershed area of only 37 acres (Table 8-1). Little Crosby Lake is hydrologically connected to Crosby Lake through a small marsh area 825 ft long, and thus shares the same subwatershed (Figure 8-2). For information on Little Crosby Lake Background, see Crosby Lake Background (page 59).



Figure 8-1: View facing northwest from the southern shoreline of Little Crosby Lake.

Table 8-1: Little Crosby Lake morphometric data.

Surface Area (acres)	Maximum Depth (ft)	Littoral Area	Volume (acre-ft)	Watershed Area (acres)	Watershed: Lake Area (ratio)
8.0	34.0	88%	59	37	4.6

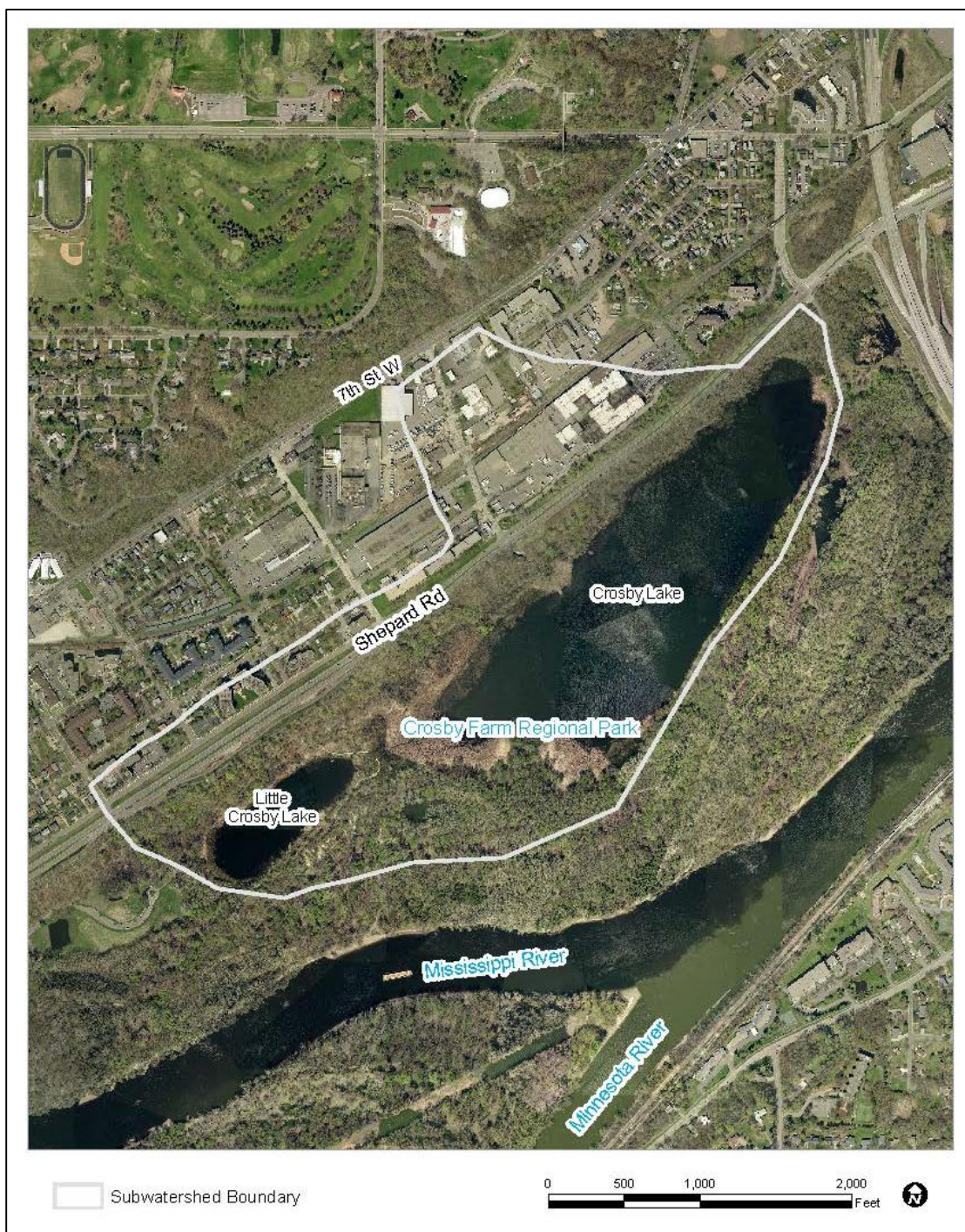


Figure 8-2: Crosby and Little Crosby Lakes and subwatershed boundary.

Little Crosby Lake has only been monitored since 2011. In the past five years of monitoring for TP, it exceeded the state standards for all four years (Table 8-2). A potential source of these high nutrient concentrations could be from high flow periods of the river, bringing large sediment loads into the lake.

8.2 LAKE LEVEL

There is no historical lake level data for Little Crosby Lake from the Minnesota DNR. CRWD began monitoring Crosby Lake level in 2014. General trends in lake level can be seen by looking at Crosby Lake level (Figure 7-4), as these two bodies of water are hydrologically connected and reside at the same elevation on the Mississippi River floodplain.

8.3 WATER QUALITY RESULTS

Little Crosby Lake was sampled nine times in 2015, from May 18 to October 20 (Figure 8-3). Samples indicate that all parameters exhibit the poorest state of water quality in late June, with a gradual trends towards improved water quality later in the season (Figure 8-3). TP values exceeded the state standard throughout the entire monitoring season. The Chl-a and Secchi disk readings were more comparable to years with poorer water quality than years with high water quality.

Historically, Little Crosby Lake exhibits the lowest level of water quality during July, which exhibits the highest medians of TP and Chl-a and the lowest Secchi disk readings than any other month (Figure 8-4). This could be related to typically dryer weather and higher temperatures, which contributes to more stagnant water and more primary productivity. During periods of high precipitation, the Mississippi River may flood and mix with Little Crosby Lake water, which can also impact the seasonality of water quality.

Figure 8-5 shows yearly average historical TP concentrations, Chl-a concentrations, and Secchi disk depths graphically. Since monitoring on Little Crosby Lake began in 2011, only five years of records exist for comparison. Little Crosby Lake had improved with respect to TP and Chl-a concentrations between each year for the first three years of monitoring, but saw higher concentrations for TP and Chl-a and shallower Secchi depths for 2014 than any other year. The lake improved again in 2015. Throughout the last five years, high water transparency has been associated with lower TP and Chl-a concentrations.

While 2012 and 2013 exhibited the lowest epilimnetic TP concentrations and overall highest water quality in the historical record (Figure 8-5), these years produced the highest hypolimnetic TP concentrations yet recorded (Figure 8-6). In eutrophic lakes, the hypolimnion is generally richer in phosphorus than the epilimnion, as bed sediments readily release phosphorus into the anoxic bottom layer, peaking in fall just prior to lake turnover (Kalff, 2002). Little Crosby Lake can be affected by seasonal flooding from the Mississippi River, which can influence mixing in the lake.

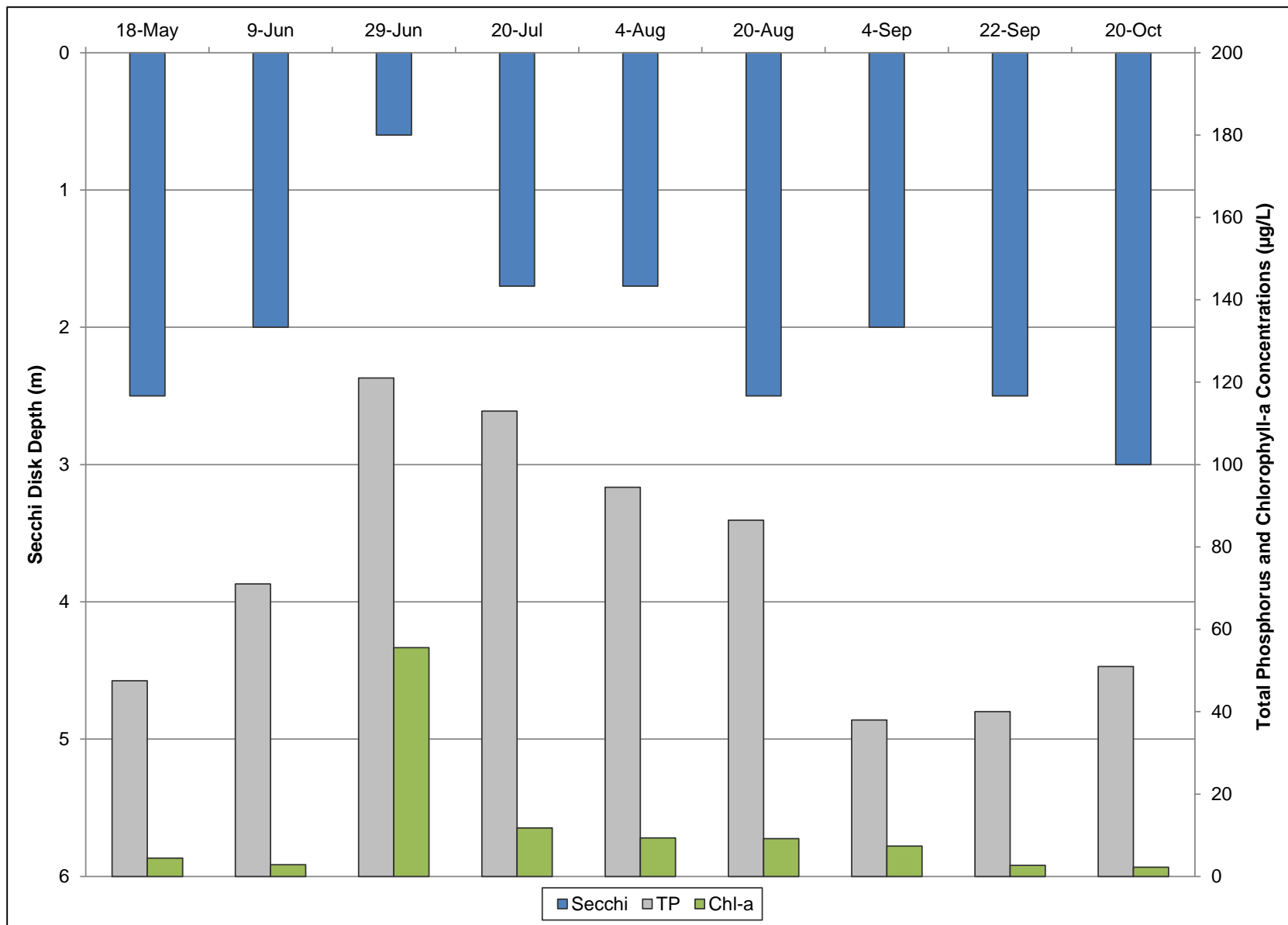


Figure 8-3: Little Crosby Lake 2015 Secchi/TP/Chl-a comparison.

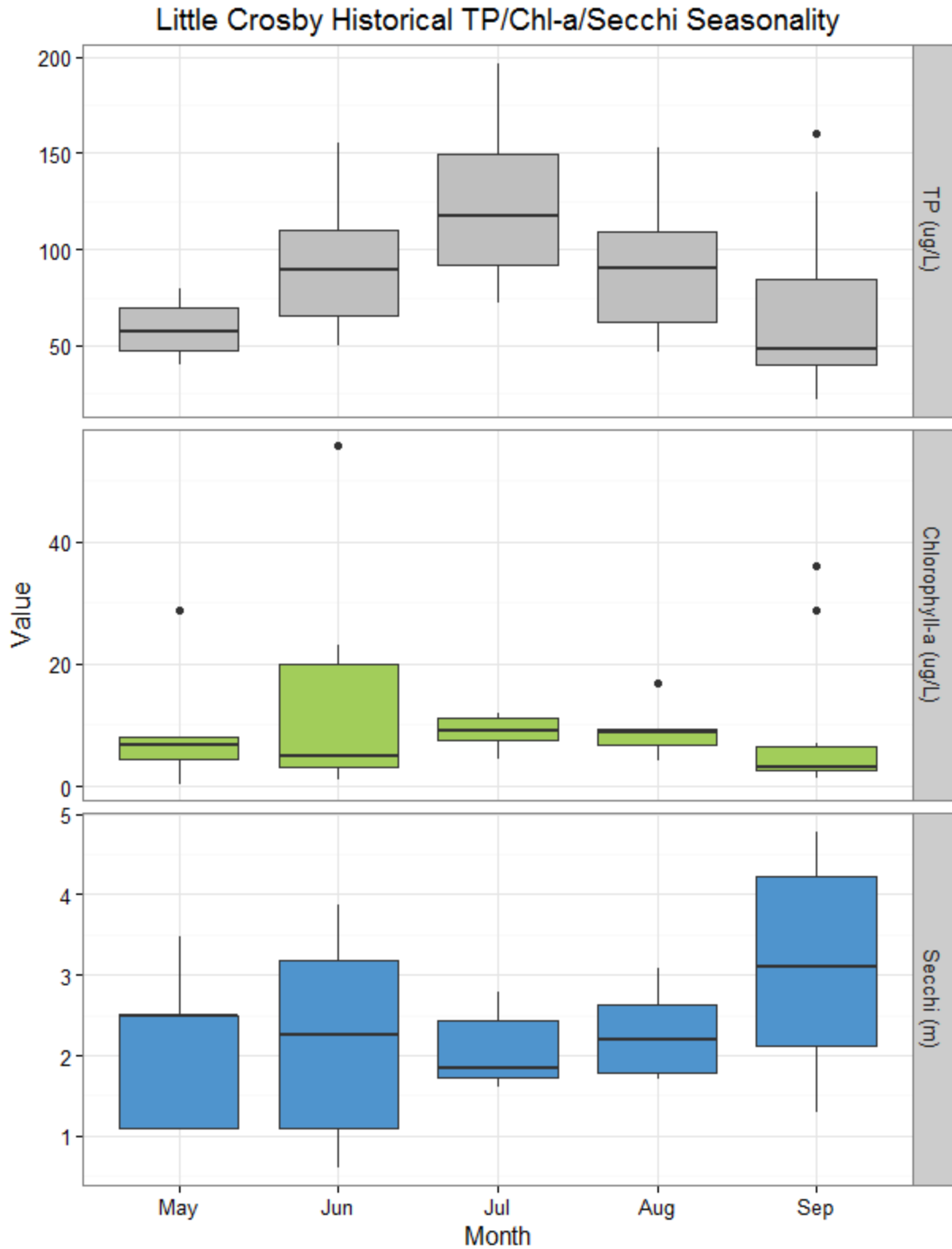


Figure 8-4: Little Crosby Lake seasonality boxplots of historical Secchi/TP/Chl-a samples.

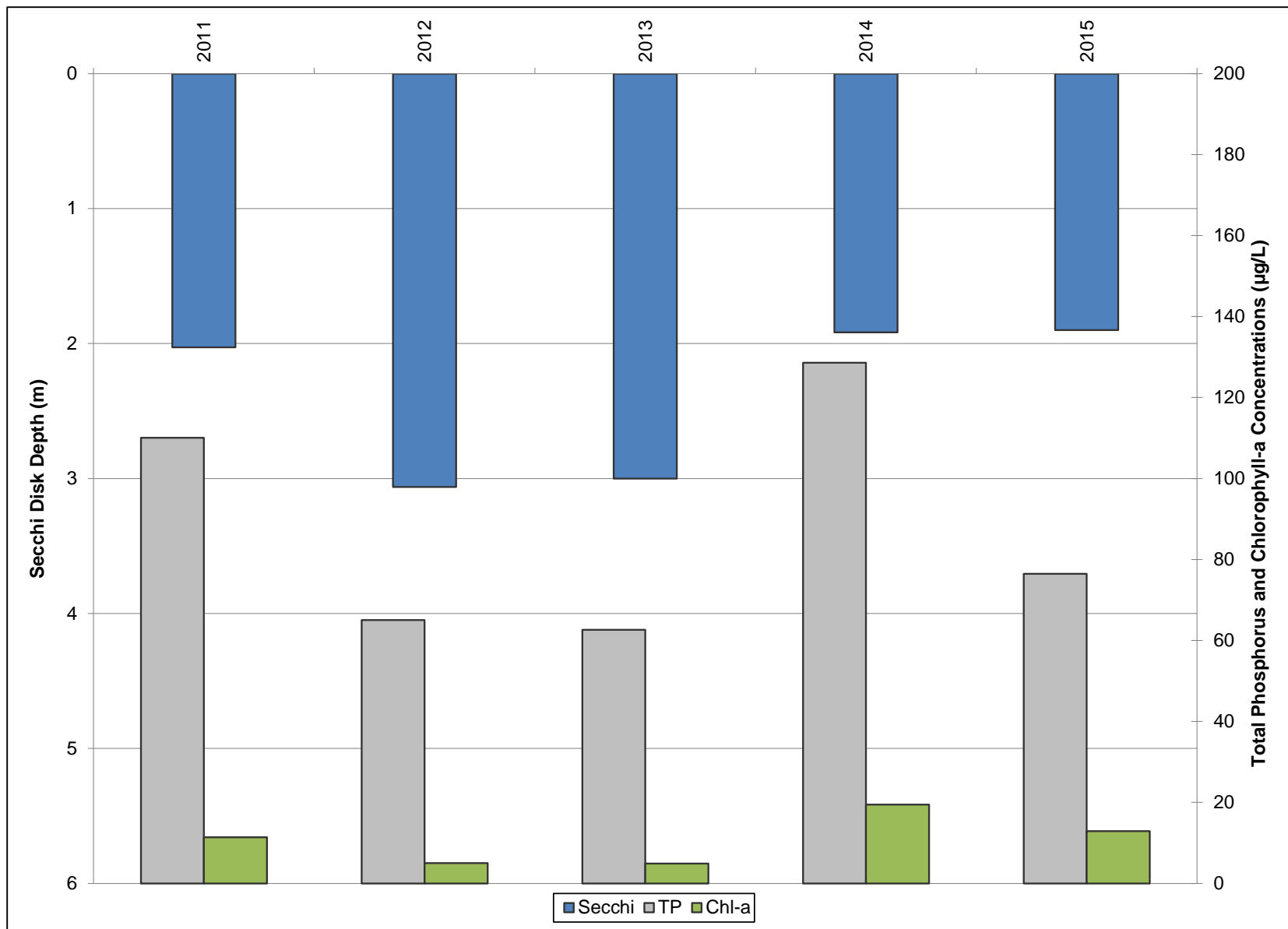


Figure 8-5: Little Crosby Lake historical annual average Secchi/TP/Chl-a comparison.

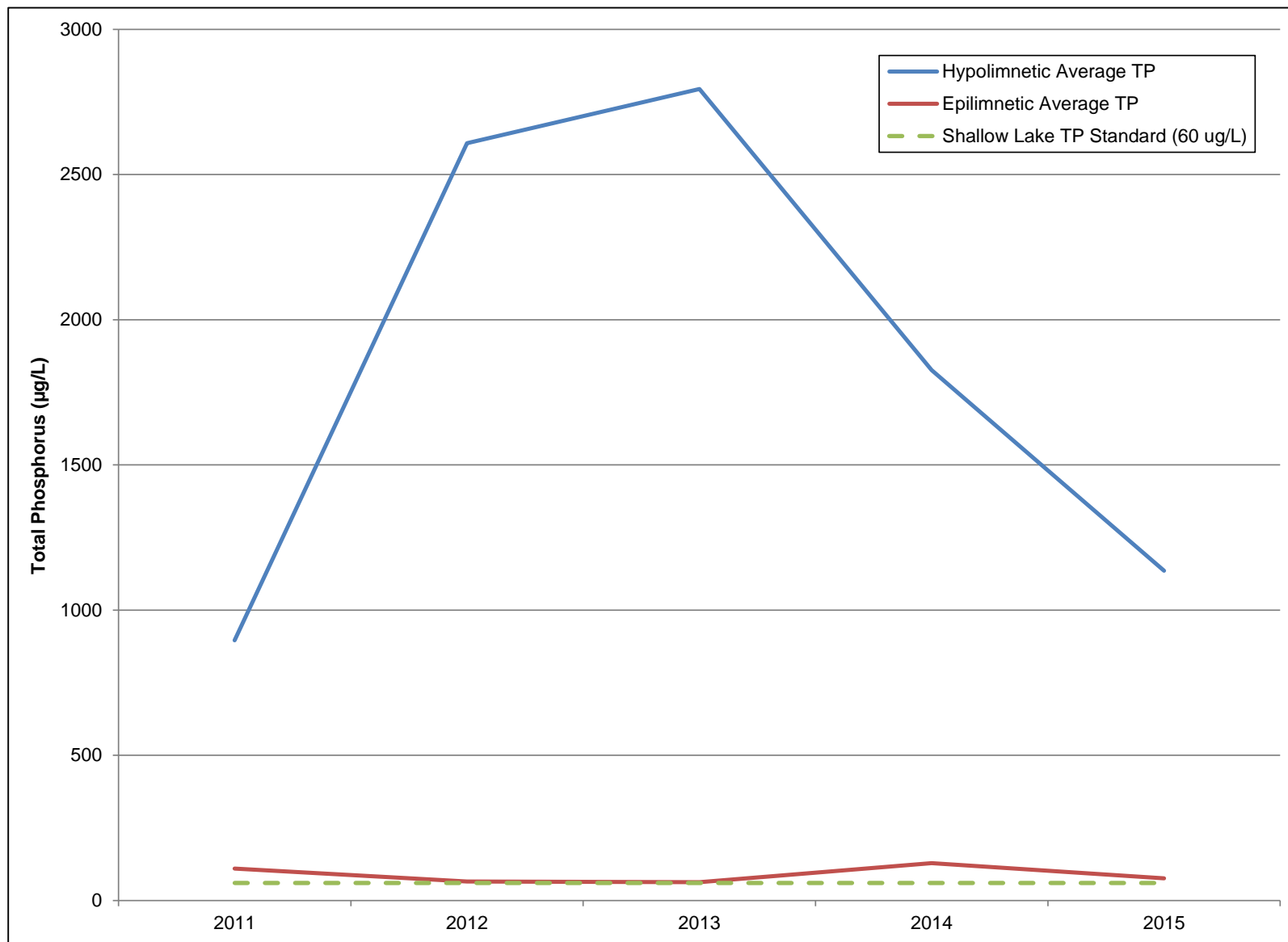


Figure 8-6: Little Crosby Lake historical annual average hypolimnetic and epilimnetic total phosphorus.

Yearly average historical TP concentrations, Chl-a concentrations, Secchi depths, and their comparisons to lake standards are shown in Table 8-2. Little Crosby Lake TP concentrations exceeded the MPCA standards from 2011-2015, while Chl-a and Secchi depth both met the lake standards. The lake has an average grade of 'B' over the five years of record. In 2015, Little Crosby Lake was evaluated with an overall grade of 'C'. Little Crosby received grades of 'A' for both Chl-a and Secchi depth in 2012 and 2013, but as a result of a lower TP grade, received an overall grade of 'B+' for these years (Table 8-3). Overall, Little Crosby Lake exhibited moderate water quality for the years monitored. In the future, a larger data set with more monitoring seasons will provide better information to interpret trends in water quality.

Table 8-2: Little Crosby Lake historical yearly TP/Chl-a/Secchi depth averages compared to shallow lake state standards.

Year	TP (µg/L)	Chl-a (µg/L)	Secchi (m)
2011	110	11.4	2.0
2012	65	5.0	3.1
2013	63	4.9	3.0
2014	129	19.4	1.9
2015	76	12.9	1.9
	Value does not meet state standard*		
	Value meets state standard		

*MPCA shallow lake standards are not to exceed 60 µg/L for TP and 20.0 µg/L for Chl-a, with a Secchi disk depth of at least 1.0 m.

Table 8-3: Little Crosby Lake historical lake grades.

Year	TP Grade	Chl-a Grade	Secchi Grade	Overall Grade
2011	D	B	C	C
2012	C	A	A	B+
2013	C	A	A	B+
2014	D	B	C	C
2015	D	B	C	C

8.4 PHYTOPLANKTON AND ZOOPLANKTON

Little Crosby Lake was sampled for phytoplankton and zooplankton nine times in 2015, from May 18 to October 20 (Figure 8-7). The phytoplankton remained diverse throughout the year, wavering through multiple spikes of most listed groups. Cryptophyta were the dominant type of phytoplankton during the month of May (Figure 8-9). Spikes in Cyanophyta were observed in June and late-August. Cryptophyta spiked in mid-July followed by a spike in Chlorophyta. Pyrrophyta spiked in early September, followed by another spike in Cyanophyta. The year wrapped up with Cryptophyta dominating the phytoplankton community. Phytoplankton concentrations were highest during the summer months, and moderately correlated to TP concentrations (Figure 8-7). A dip in phytoplankton concentration observed in July corresponds to an increase of zooplankton during the same sampling period (Figures 8-7 and 8-8).

Zooplankton densities remained low throughout the sampling season, except for a spike in July, predominately contributed to by Cyclopoids, Cladocerans, and Nauplii (Figure 8-8; Figure 8-10). These three groups substantiated most of the zooplankton community in 2015. A small presence of Calanoids became apparent in late summer and early fall. A small spike in Rotifers was observed in October. Density closely shadowed Chl-a concentration during the year (Figure 8-8).

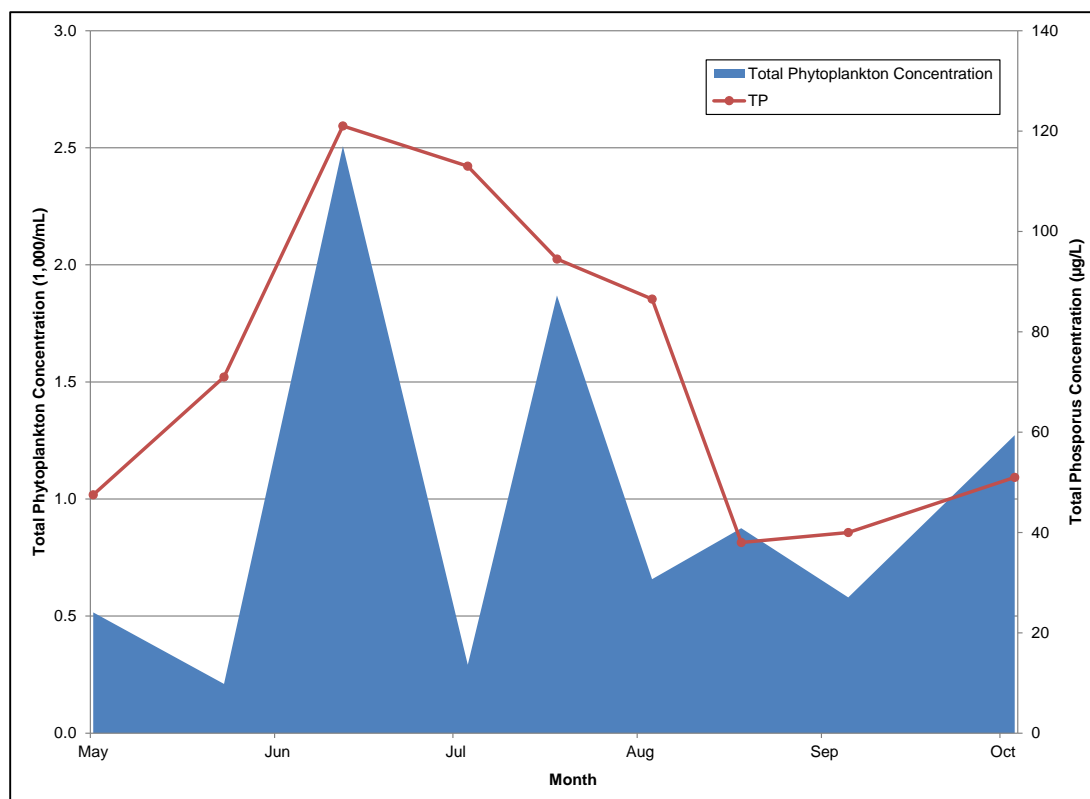


Figure 8-7: Little Crosby Lake 2015 total phytoplankton concentration and TP concentration.

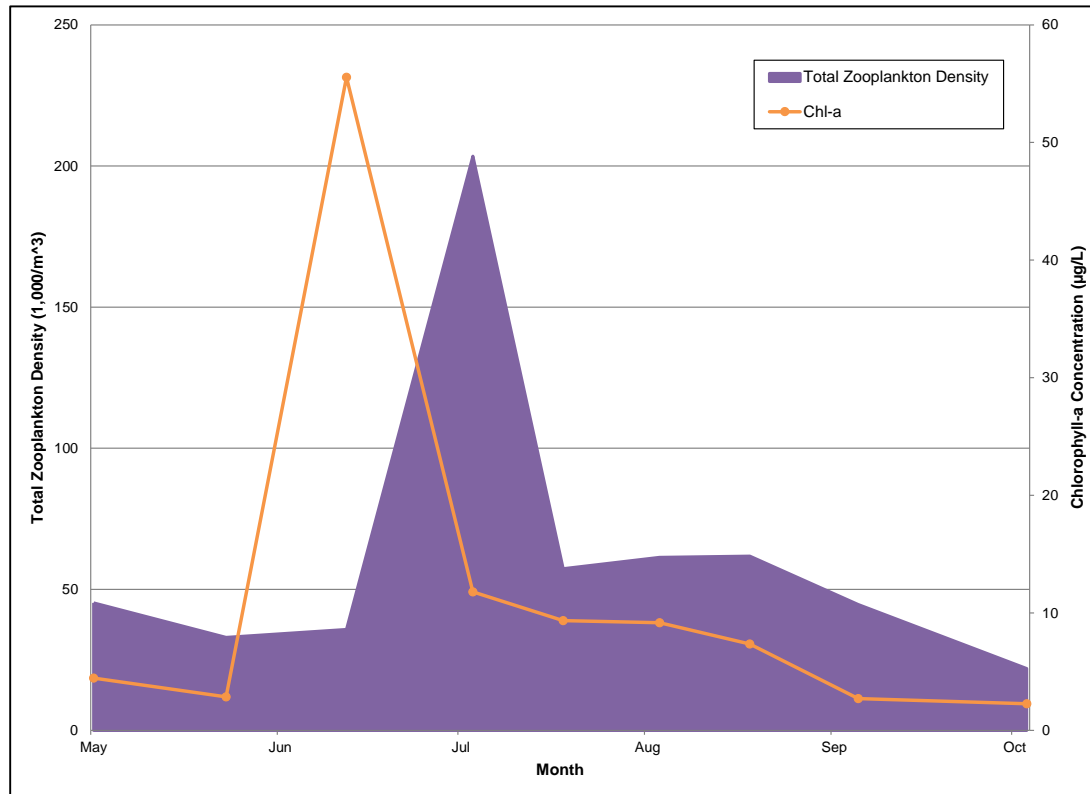


Figure 8-8: Little Crosby Lake 2015 total zooplankton density and Chl-a concentration.

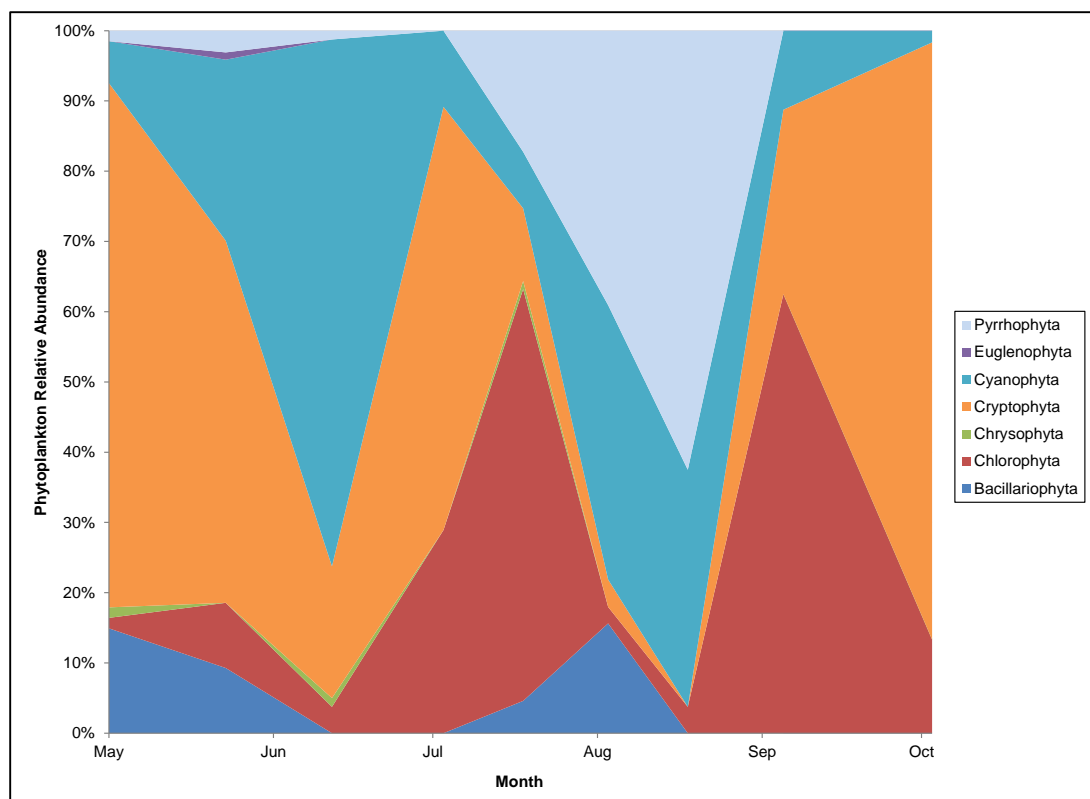


Figure 8-9: Little Crosby Lake 2015 phytoplankton relative abundance.

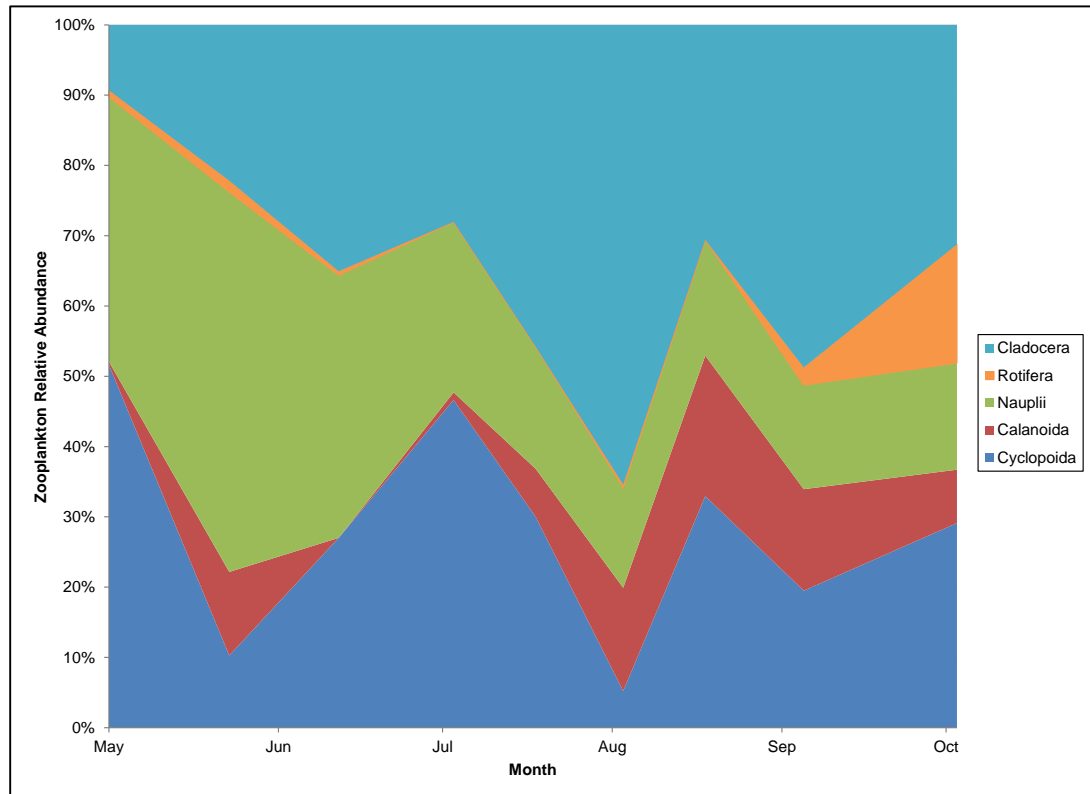


Figure 8-10: Little Crosby Lake 2015 zooplankton relative abundance.

8.5 AQUATIC VEGETATION

8.5.1 BIOVOLUME ANALYSIS

Figure 8-11 shows the results of the June, July, and September 2015 biovolume analyses of Little Crosby Lake. Vegetation growth was generally limited to the 15 foot littoral zone. Aquatic plant biovolume decreased from June to July, but increased from July to September in depths from 5 to 15 feet. Spatial biovolume growth patterns generally mirrored the results from previous years' surveys.

8.5.2 POINT-INTERCEPT SURVEYS

Twelve distinct species were observed in Little Crosby Lake during 2015. All species found in Little Crosby Lake were also found to be present in Crosby Lake. The following plants were observed at mid- to high-level occurrences throughout all three survey sessions: white water crowfoot, filamentous algae, leafy pondweed, and greater duckweed (Figures 8-12 and 8-13). Coontail and star duckweed were also observable at mid- to high-level occurrences, however only during the July and September surveys.

Curly leaf pondweed was observed in Little Crosby Lake during the initial June survey at 50% occurrence and low density. It was not observed during the July and September surveys. Curly-leaf pondweed is an invasive plants that has a biological advantage of beginning its growth cycle early while ice still covers the lake. Thus, it causes problems by displacing other native plants during early open-water season and forming thick mats on the surface of a lake that disrupt boating and recreation. Additionally, when the plants die back in mid-summer, the resulting decomposing plant material increases phosphorus levels, which can lead to disruptive algal blooms (DNR, 2005).

The presence of Eurasian watermilfoil has not yet been observed in Little Crosby Lake; however, Eurasian watermilfoil was first observed in Crosby Lake in September 2015. As the lakes are hydrologically connected through a marsh area and seasonally flooding via the Mississippi River, it is possible that Eurasian watermilfoil will be observed in Little Crosby Lake in future years. Eurasian watermilfoil can propagate from stem and rhizome fragments on the inch scale (DNR, 2015d).

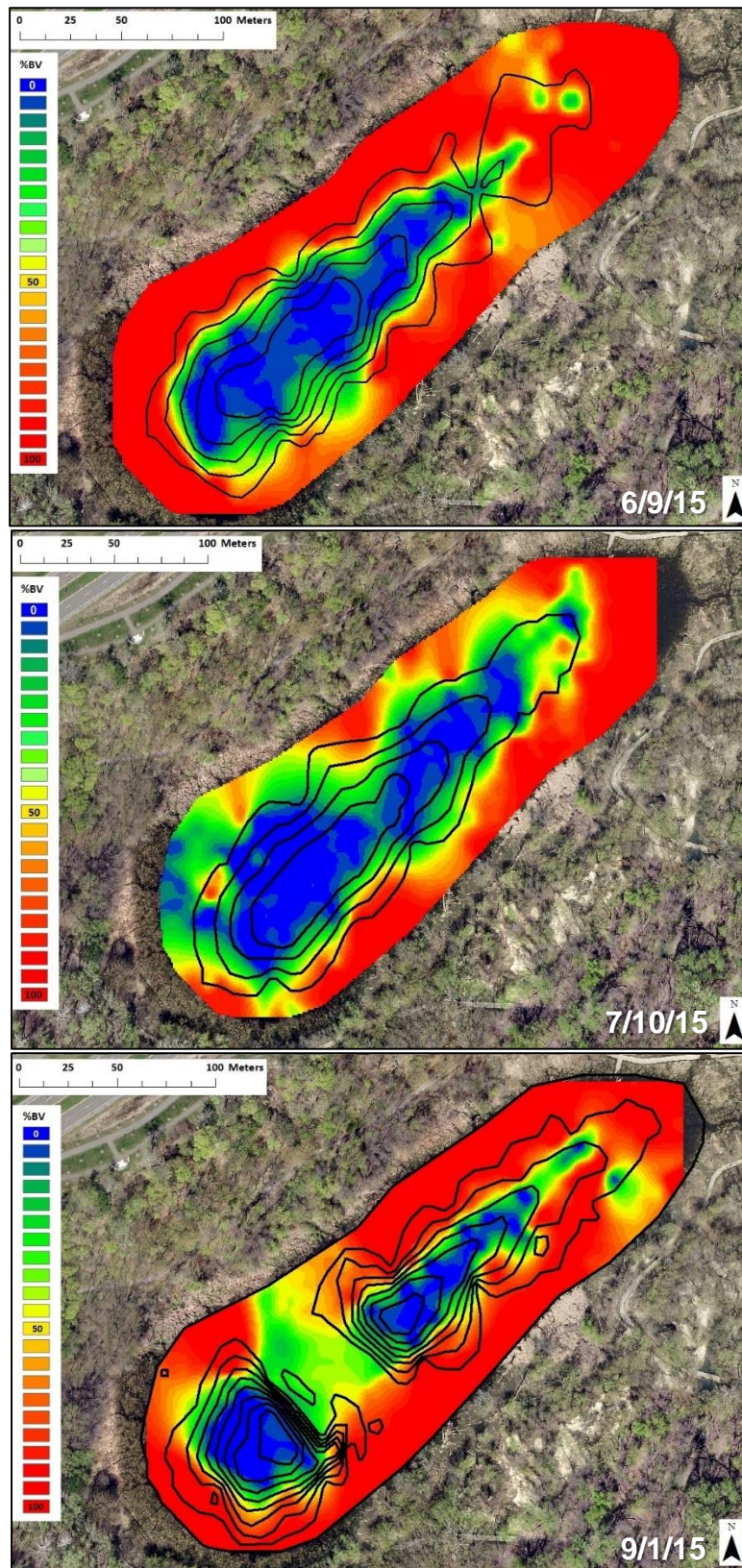


Figure 8-11: Little Crosby Lake 2015 seasonal vegetation changes (6/9/15, 7/10/15, 9/1/15).

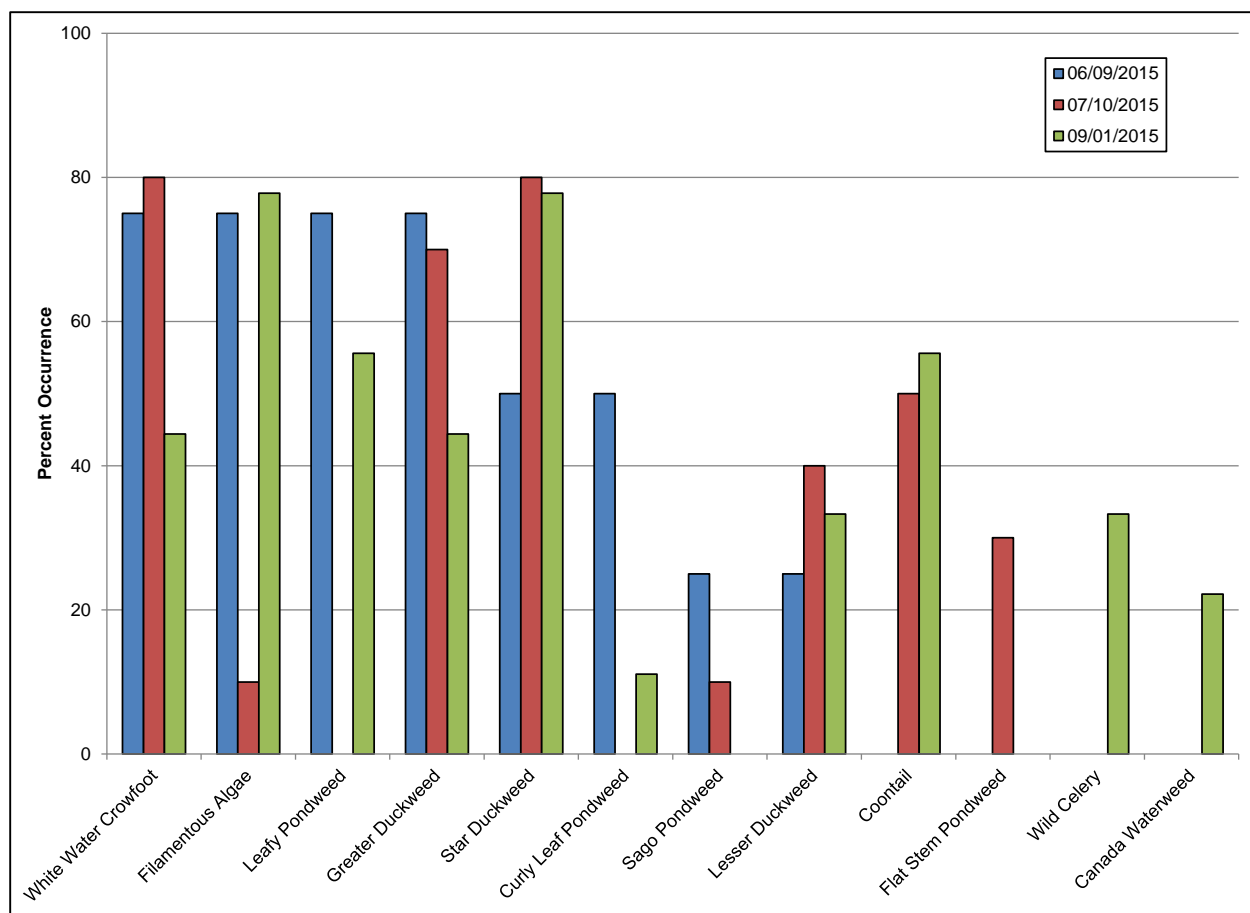


Figure 8-12: Little Crosby Lake 2015 percent occurrence of vegetation present.

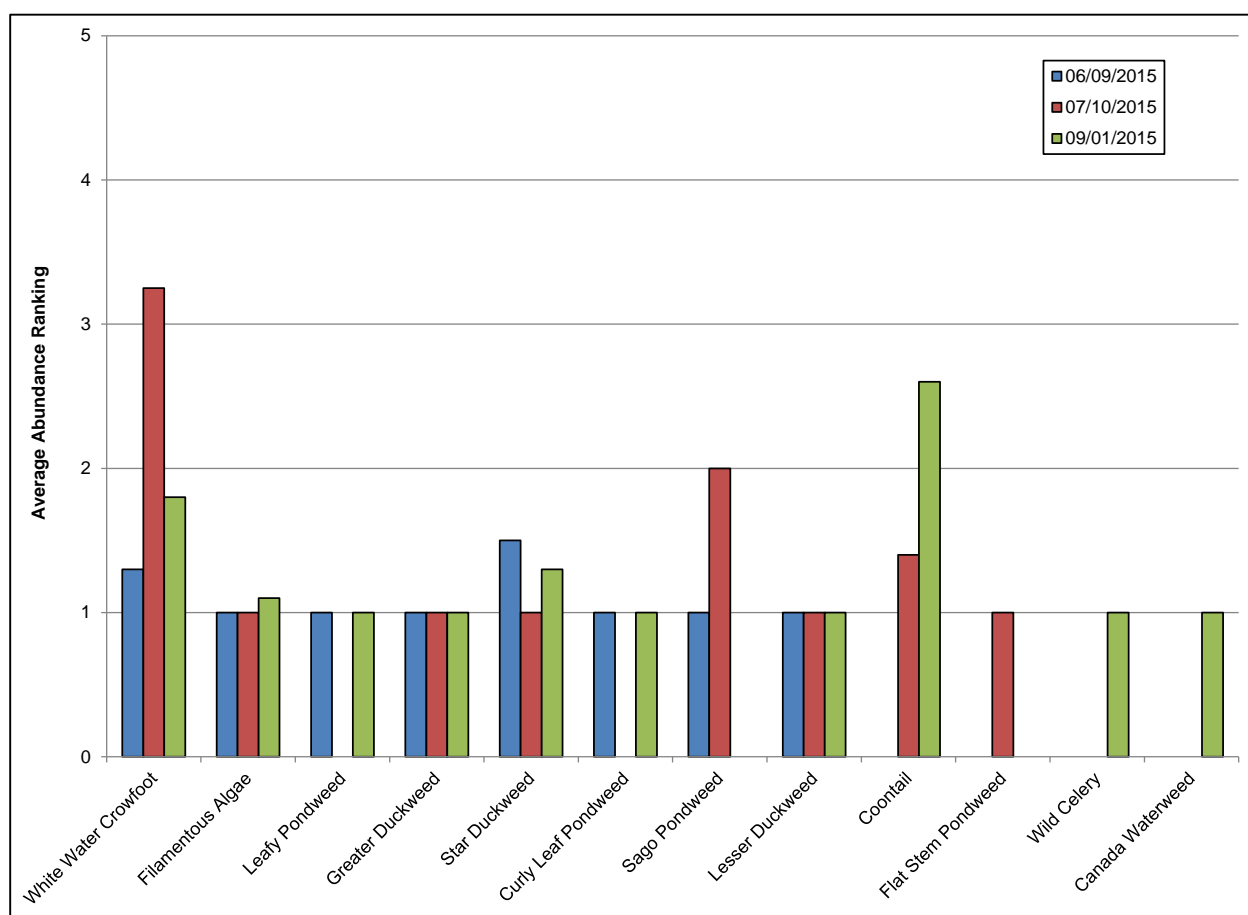


Figure 8-13: Little Crosby Lake 2015 average abundance ranking of vegetation present.

8.6 FISH STOCKING AND SURVEYS

There is no history of fish stocking for Little Crosby Lake by the Minnesota DNR. CRWD conducted fish surveys on Little Crosby Lake in 2014 and 2015.

In the 2014 fish survey on Little Crosby Lake, the largest population of fish observed (55) were black bullhead. In 2015, however, only one black bullhead was observed during the survey, representing a significant decrease in population (Table 8-4). All of the species observed were also observed in the 2015 Crosby Lake fish survey (Table 7-5), which is expected given that they are hydrologically connected. There were more species of fish, however, observed in the Crosby Lake survey, which could be a result of its larger size and hydrology.

Only six types of species were observed in the lake in 2015 and the total catch was low (34 fish). Little Crosby Lake is scheduled to be surveyed again in the summer of 2016 by CRWD.

Table 8-4: Little Crosby Lake 2015 fish populations.

Species	Number of fish caught in each category (inches)								Total
	0-5	6-8	9-11	12-14	15-19	20-24	25-29	30+	
Black bullhead	1	0	0	0	0	0	0	0	1
Bluegill	6	3	0	0	0	0	0	0	9
Northern pike	0	1	0	0	0	1	2	0	4
Pumpkinseed sunfish	6	1	0	0	0	0	0	0	7
Yellow perch	3	0	0	0	0	0	0	0	3

8.7 OVERALL LAKE EVALUATION

Little Crosby Lake has a relatively short monitoring record when compared to the other District lakes. From 2011-2013, it exhibited relative improvements in TP and Chl-a concentrations and deeper Secchi disk depths, but 2014 had the highest TP and Chl-a concentrations and shallowest Secchi Disk depth on record as a result of flooding from the Mississippi River. In comparison, TP and Chl-a averages showed large improvements in 2015, most likely as a result of the absence of any river flooding. Much of the lake area was covered by moderate vegetation in 2015, with the heaviest coverage occurring in early June. The lake contained a moderate diversity of plant species by early fall. Fish populations exhibited low diversity and low abundance in 2015, and the number of black bullhead caught significantly decreased between the 2014 and 2015 surveys.

9 LOEB LAKE RESULTS

9.1 LOEB LAKE BACKGROUND

Loeb Lake (Figure 9-1), located in Marydale Park in the northwestern portion of the City of St. Paul, is a 9.7 acre lake with a maximum depth of 28 feet and an 81% littoral area (Table 9-1). The area has a walking path, children's play area, picnic areas, a fishing pier, and a boat launch. The surrounding area is primarily residential land use.



Figure 9-1: View of the northwest shoreline from the dock of Loeb Lake.

Table 9-1: Loeb Lake morphometric data.

Surface Area (acres)	Maximum Depth (ft)	Littoral Area	Volume (acre-ft)	Watershed Area (acres)	Watershed: Lake Area (ratio)
9.7	28.0	81%	84	44	4.5

The watershed area contributing inflow to the lake is 44 acres (Table 9-1; Figure 9-2). Water enters the lake from the north half of the watershed through sheet flow traveling through Marydale Park, as well as a storm sewer that collects runoff from Mackubin Street between Maryland and Jessamine Avenues (CRWD, 2009). Runoff from the south half of the watershed enters Loeb Lake through two different storm sewers. The storm sewers drain streets on the south and east sides of the lake, discharging to a stormwater pond on the southeast corner. A pipe directly connects this pond to Loeb Lake. There are no direct outlets from Loeb Lake.

Loeb Lake has been monitored since 2003 and has had relatively stable TP, Chl-a, and Secchi disk depth values that have consistently met the state standards. Therefore, lake conditions have appeared to remain stable in the past nine years. Because of the lake's stable and high quality conditions, the Loeb Lake management plan recommends a phosphorus goal for non-degradation, or maintaining water quality at current levels.

Previous winter kills of fish have been observed in Loeb Lake, but have not occurred since 2000, when an aerator was installed in the lake (CRWD, 2009). Future management efforts on Loeb Lake should focus on reduced loading in the surrounding watershed and naturalizing the shoreline (CRWD, 2009). Both of these actions would reduce the subsequent influx of nutrients into the lake. While water quality is currently stable, good management efforts around the lake to prevent further increases in nutrient inputs will be key in preventing lake degradation.



Figure 9-2: Loeb Lake and subwatershed boundary.

9.2 LAKE LEVEL

Loeb Lake level has been monitored since 2003, with the exception of May 2004 through February 2006 when level data was not available (Figure 9-3). Loeb Lake does not have an OHWL to compare the current year to historical “normal” lake levels. The lowest recorded water level of the lake occurred in May 2009 at a level of 848.6 ft. In July 2014, the lake reached the highest level on record at 852.32 ft following a record-setting storm event. The previous record high was in August of 2011 at a height of 851.63 ft. In 2015, lake level fluctuated very little around a level of 851 ft, just above the historical average of 850.57 ft (Figure 9-4).

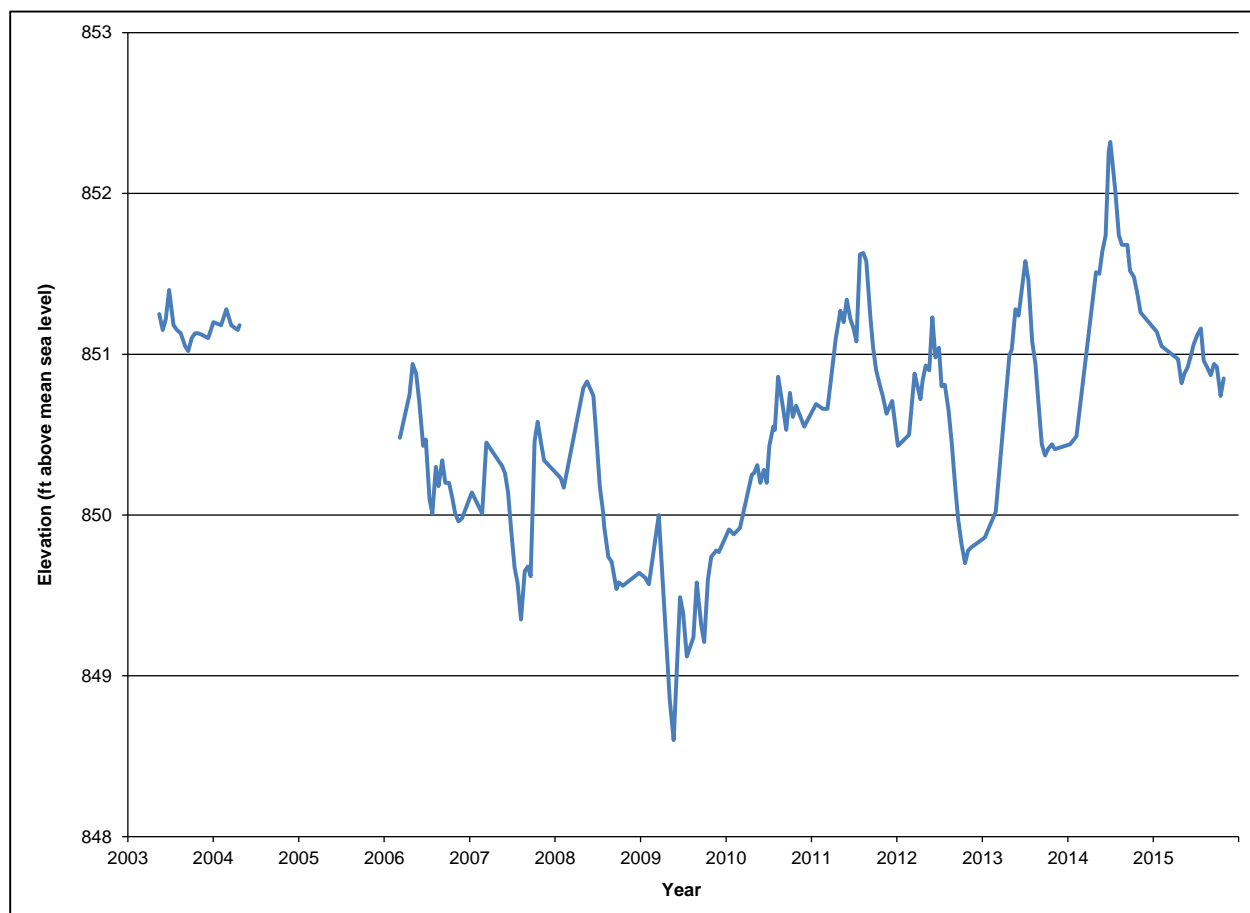


Figure 9-3: Loeb Lake historical lake elevations (DNR, 2015i).

The lake level for Loeb Lake in 2015 slowly declined from its early season high to its end of season low, with little fluctuation. The level responded to storm events throughout summer and fall, but the response was minimal compared to other lakes with more stormwater inputs.

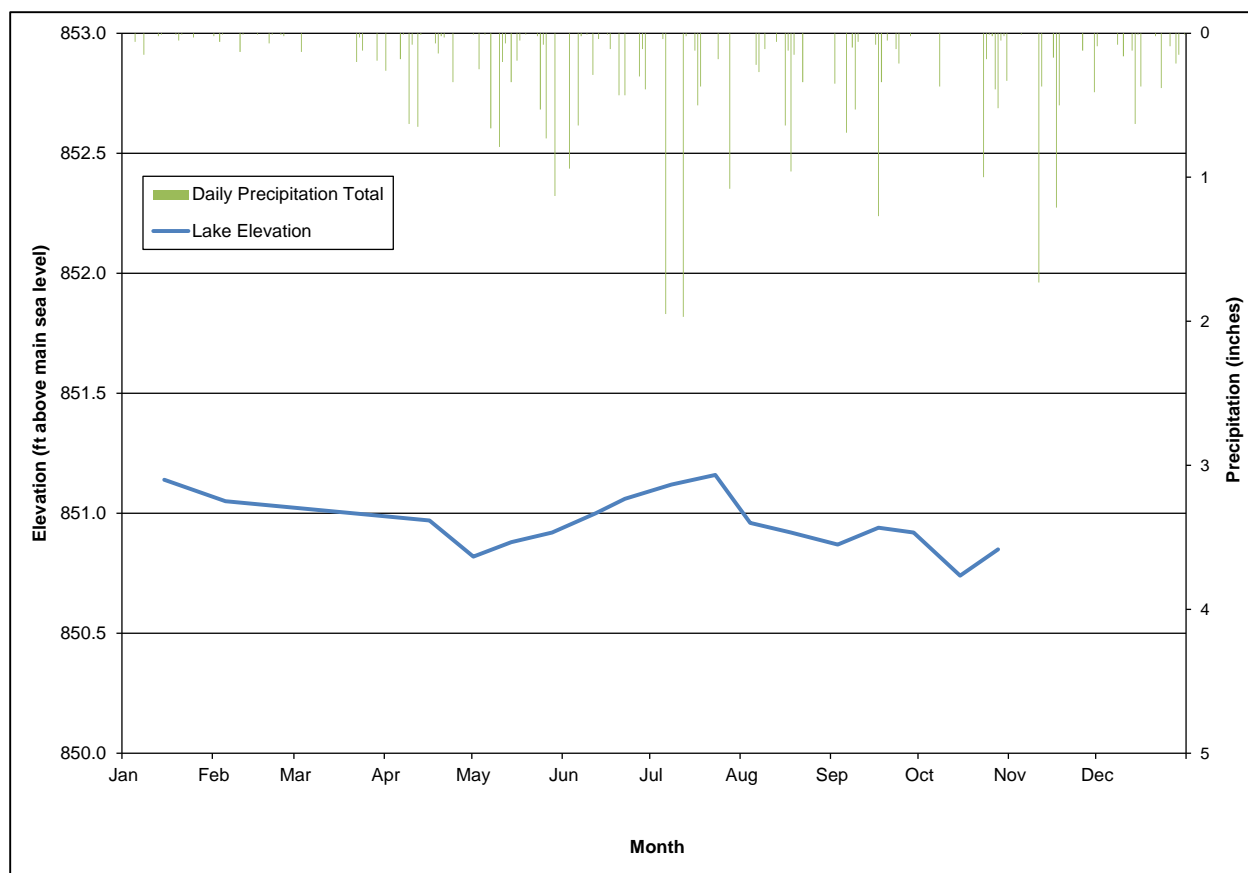


Figure 9-4: Loeb Lake 2015 lake elevations and daily precipitation events (DNR, 2015i; MCWG, 2016).

9.3 WATER QUALITY RESULTS

Loeb Lake was sampled ten times during 2015 from April 3 to October 19 (Figure 9-5). As in previous years, Loeb Lake was characterized by low TP and Chl-a concentrations, and deep Secchi depths. TP levels were highest (39 $\mu\text{g/L}$) during the first sampling event on April 3. TP spiked again (37 $\mu\text{g/L}$) again in early July and maintained a steady level through the end of the season.

Chlorophyll-a concentrations also began with a season high value of 8.7 $\mu\text{g/L}$ on April 3 and followed a similar pattern as TP concentrations. Secchi depths were generally deepest earlier in the season (average 4.5 m, excluding April 3) and shallower as the season continued (average 2.8 m). The data suggests that during 2015, higher water clarity was associated with lower TP and Chl-a concentrations.

Loeb Lake does not exhibit much seasonal variation throughout the historical record for TP, Chl-a or Secchi disk depth (Figure 9-6). All three parameters are typically indicative of the highest level of water quality during June, closely followed by May. Water quality generally decreases

slightly throughout July, August, and September, but the lake still consistently meets the shallow lake standards for each parameter.

Figure 9-7 shows yearly average historical TP concentrations, Chl-a concentrations, and Secchi disk depths graphically. Based on the historical data since 2003, Loeb Lake has demonstrated a high degree of consistency. TP concentrations decreased from 2003-2009 and while TP increased in 2010, concentrations have since remained relatively constant. Overall TP concentrations, however, are the lowest of any District Lake, and also low compared with other area lakes (Table 5-1) (DNR, 2015i).

Chl-a concentrations have been low and varied only slightly throughout the period of record. Concentrations for Chl-a were lowest from 2005-2012 and 2014-2015, whereas 2003, 2004, and 2013 were characterized by slightly higher Chl-a concentrations (Figure 9-7). Secchi depths were shallowest in 2003 (2.7m), deepest in 2005 and 2006 (3.8 m and 3.7 m) and have been generally getting shallower since.

Despite exhibiting low epilimnetic TP concentrations, Loeb Lake has produced very high annual average hypolimnetic TP concentrations early in its sampling record (Figure 9-8). In 2005, Loeb Lake exhibited the lowest TP and Chl-a and highest Secchi disk readings in its record (Figure 9-7). The highest hypolimnetic TP reading, however, was also recorded during this year (1,036 µg/L) (Figure 9-8). In eutrophic lakes, the hypolimnion is generally richer in phosphorus than the epilimnion, as bed sediments readily release phosphorus into the anoxic bottom layer, peaking in fall just prior to lake turnover (Kalf, 2002).

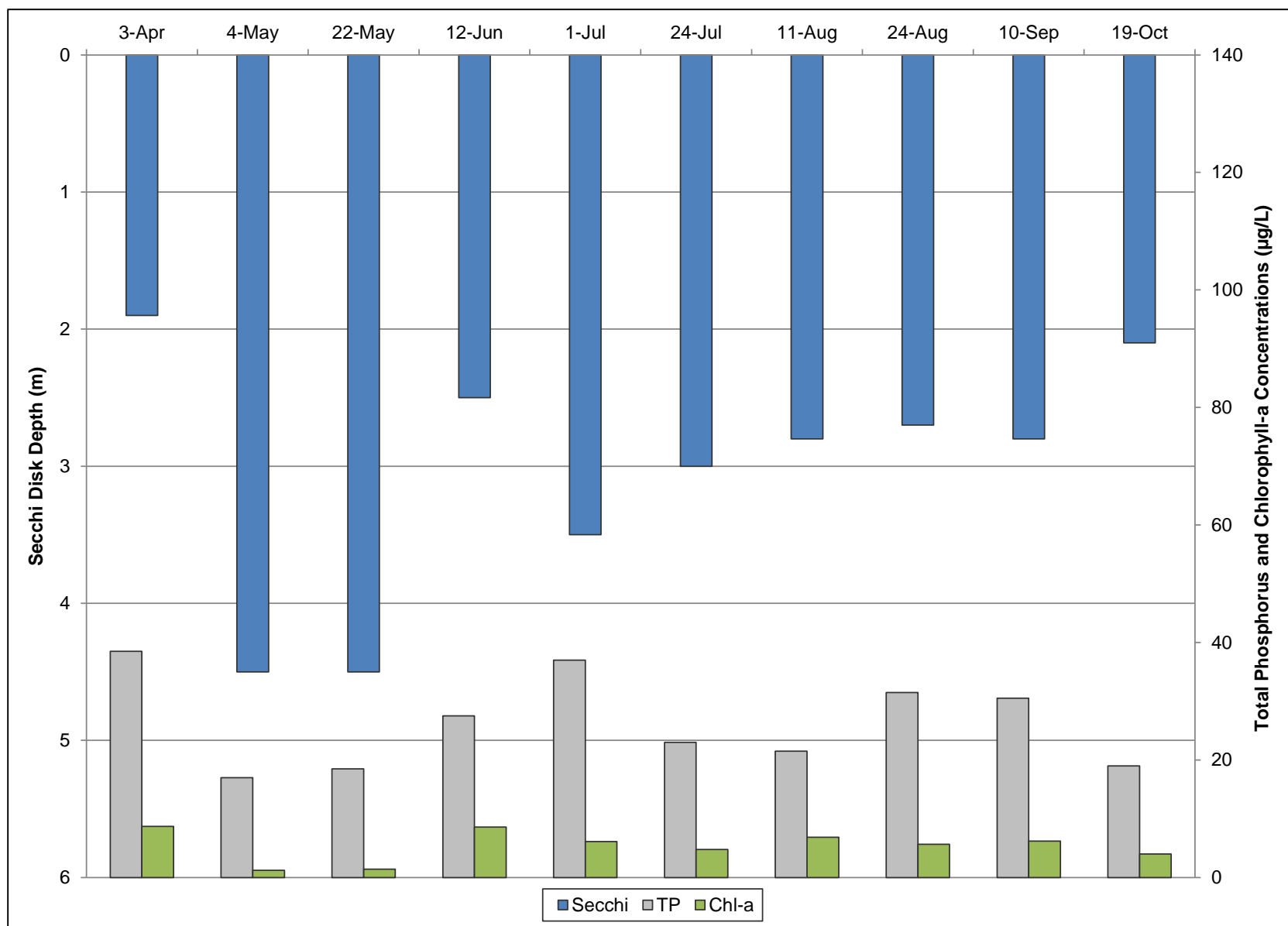


Figure 9-5: Loeb Lake 2015 Secchi/TP/Chl-a comparison.

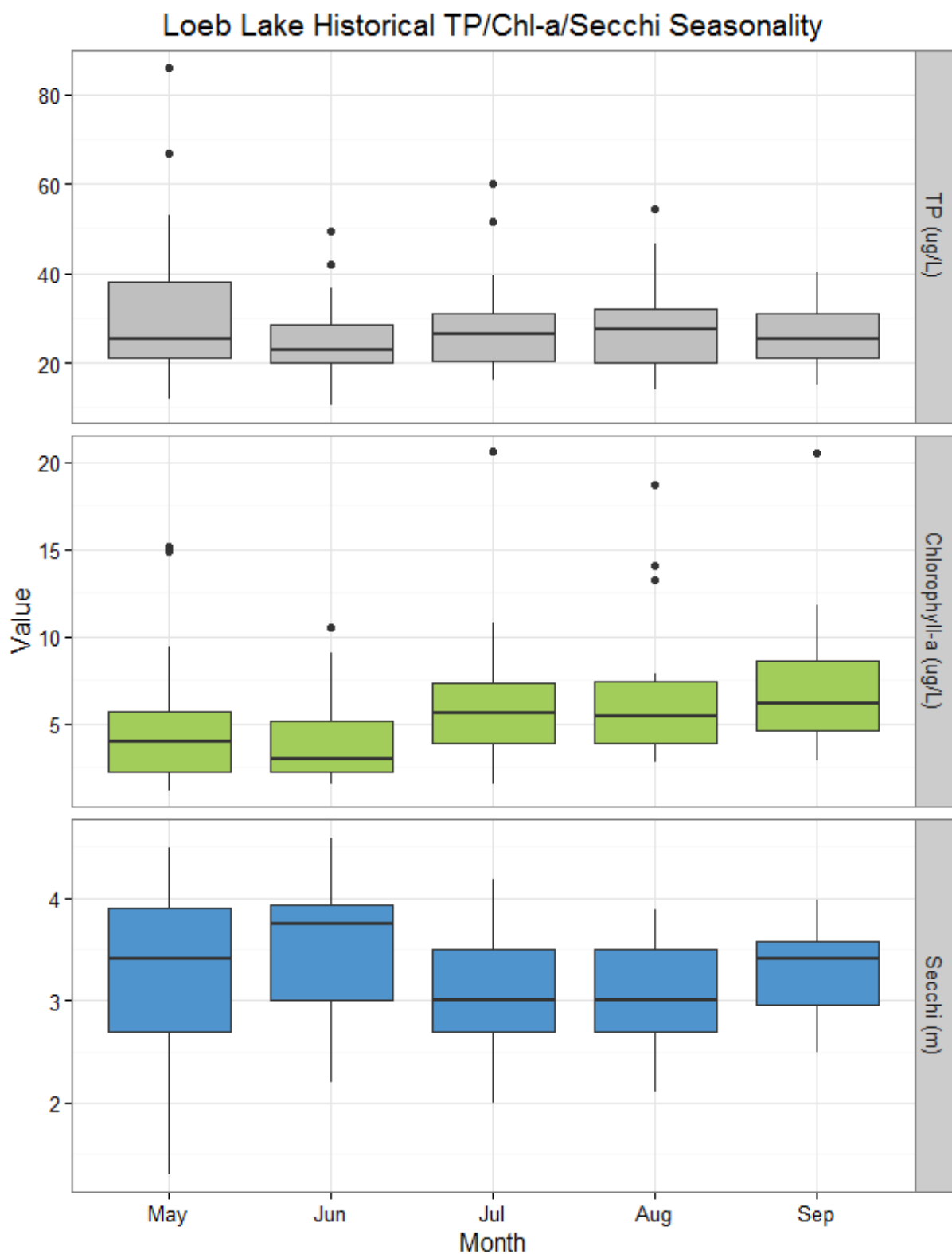


Figure 9-6: Loeb Lake seasonality boxplots of historical Secchi/TP/Chl-a samples.

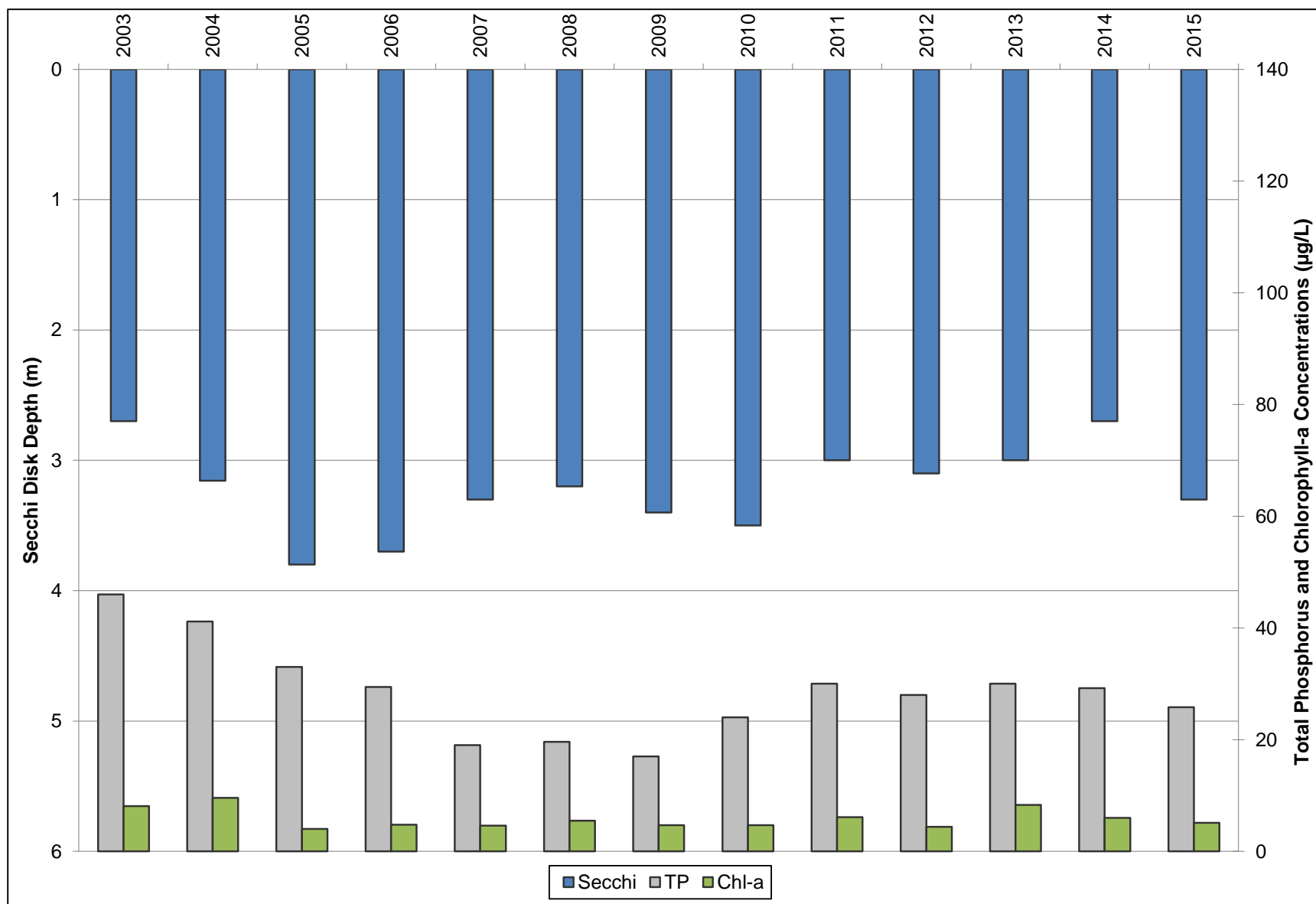


Figure 9-7: Loeb Lake historical annual average Secchi/TP/Chl-a comparison.

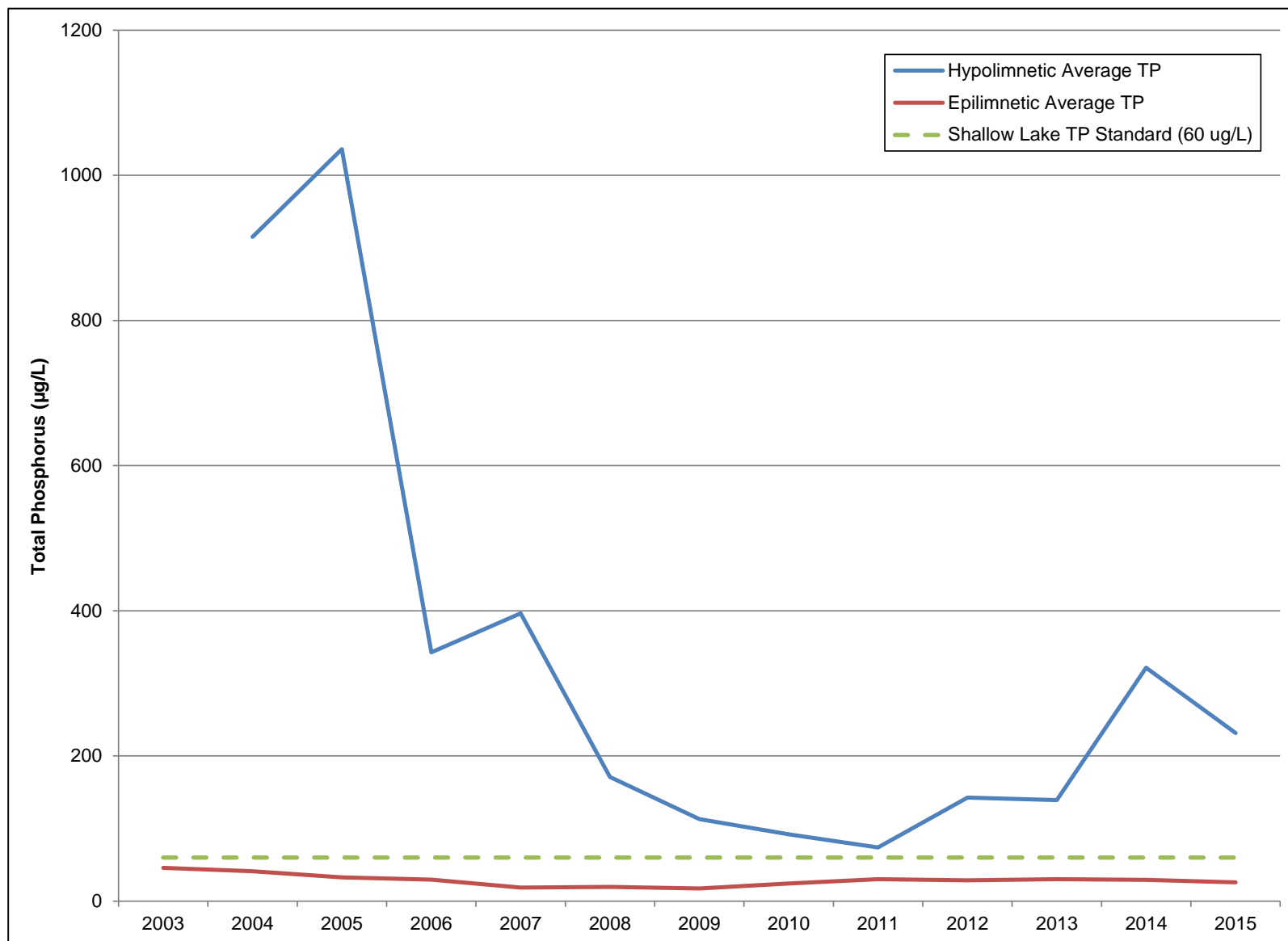


Figure 9-8: Loeb Lake historical annual average hypolimnetic and epilimnetic total phosphorus.

Yearly average historical TP concentrations, Chl-a concentrations, Secchi depths, and their comparisons to lake standards are shown in Table 9-2. Loeb Lake has had a stable and consistent water quality history. It has not exceeded the average summer TP, Chl-a or Secchi disk depth water quality standards in its monitoring history.

The overall lake grade has historically been an 'A', with only one 'B' grade occurring in 2003 and three 'B+' grades in 2004, 2005, and 2014 (Table 9-3). The drop from an 'A' grade in 2013 to a 'B+' grade in 2014 was the result of the slight decrease in Secchi disk depth observed between the two years. The high water quality lake grades associated with Loeb Lake indicate that it continues to be one of the highest water quality lakes in the District.

Table 9-2: Loeb Lake historical yearly TP/Chl-a/Secchi depth averages compared to shallow lake state standards.

Year	TP (µg/L)	Chl-a (µg/L)	Secchi (m)
2003	46	8.1	2.7
2004	41	9.6	3.2
2005	33	4.0	3.8
2006	29	4.8	3.7
2007	19	4.6	3.3
2008	20	5.5	3.2
2009	17	4.7	3.4
2010	24	4.7	3.5
2011	30	6.1	3.0
2012	28	4.4	3.1
2013	30	8.3	3.0
2014	29	6.0	2.7
2015	26	5.1	3.3
	Value does not meet state standard*		
	Value meets state standard		

*MPCA shallow lake standards are not to exceed 60 µg/L for TP and 20.0 µg/L for Chl-a, with a Secchi disk depth of at least 1.0 m.

Table 9-3: Loeb Lake historical lake grades.

Year	TP Grade	Chl-a Grade	Secchi Grade	Overall Grade
2003	C	A	B	B
2004	C	A	A	B+
2005	C	A	A	B+
2006	B	A	A	A
2007	A	A	A	A
2008	A	A	A	A
2009	A	A	A	A
2010	B	A	A	A
2011	B	A	A	A
2012	B	A	A	A
2013	B	A	A	A
2014	B	A	B	B+
2015	B	A	A	A

9.4 PHYTOPLANKTON AND ZOOPLANKTON

During 2015, Loeb Lake was sampled for phytoplankton and zooplankton ten times from April 3 to October 18. From April to early-June in Loeb Lake, concentrations of Chlorophyta, Chrysophyta, and Cryptophyta were the dominant groups (Figure 9-11). Two large Cyanophyta (blue-green algae) bloom events occurred in mid-summer, the first of which contributed greatly to the overall phytoplankton concentration during that time. The blue-green algae blooms were interrupted by a smaller Chlorophyta (green algae) bloom. After the summer algal blooms, Cryptophyta then Chrysophyta made up a large part of zooplankton concentration, albeit small. Pyrrophyta were present in low concentrations in late spring. Total phytoplankton concentrations did not mirror total phosphorus concentrations in 2015 (Figure 9-9).

Cyclopoids dominated the zooplankton community during the first two months of sampling in 2015 and remained predominant in smaller levels throughout the season (Figure 9-12). Nauplii had a small presence during the first two months and another larger spike in July. Cladocerans also had a prolonged spike in July, and remained dominant throughout the remainder of the season. Calanoids and Rotifers were present in small spikes beginning in mid-summer throughout the remainder of the season. Overall zooplankton density roughly shadowed trends in Chl-a during the latter half of the year, but were opposite during the beginning half of the year (Figure 9-10).

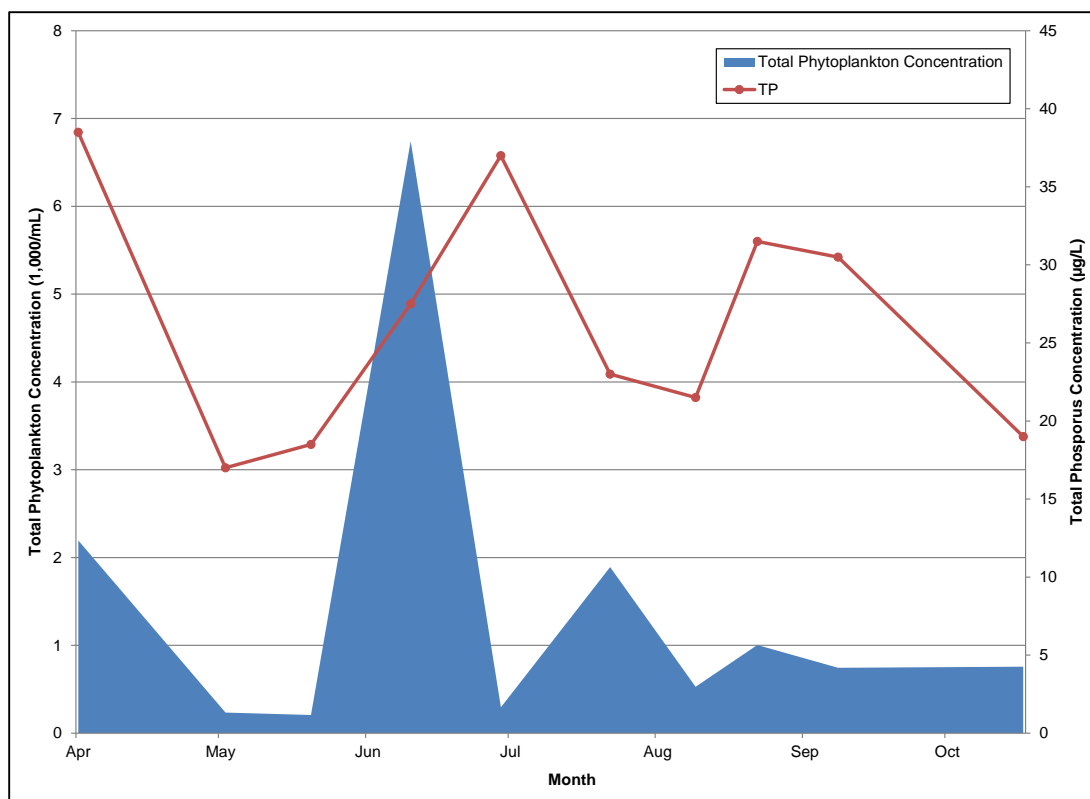


Figure 9-9: Loeb Lake 2015 total phytoplankton concentration and TP concentration.

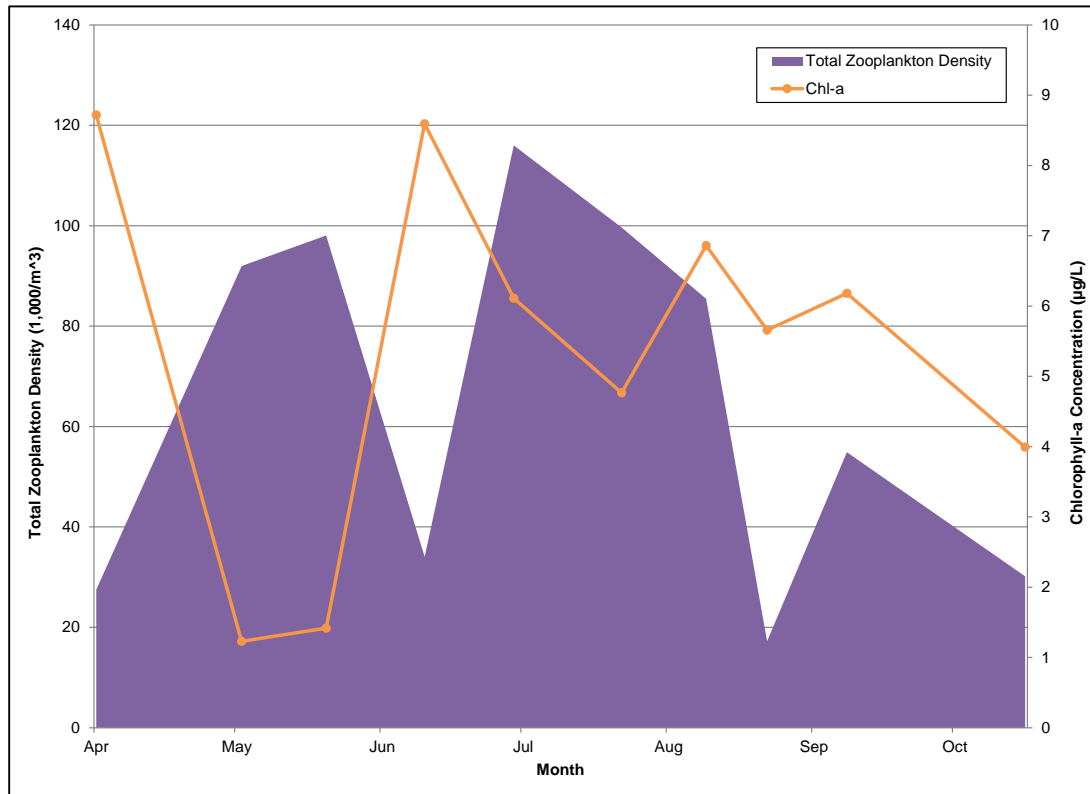


Figure 9-10: Loeb Lake 2015 total zooplankton density and Chl-a concentration.

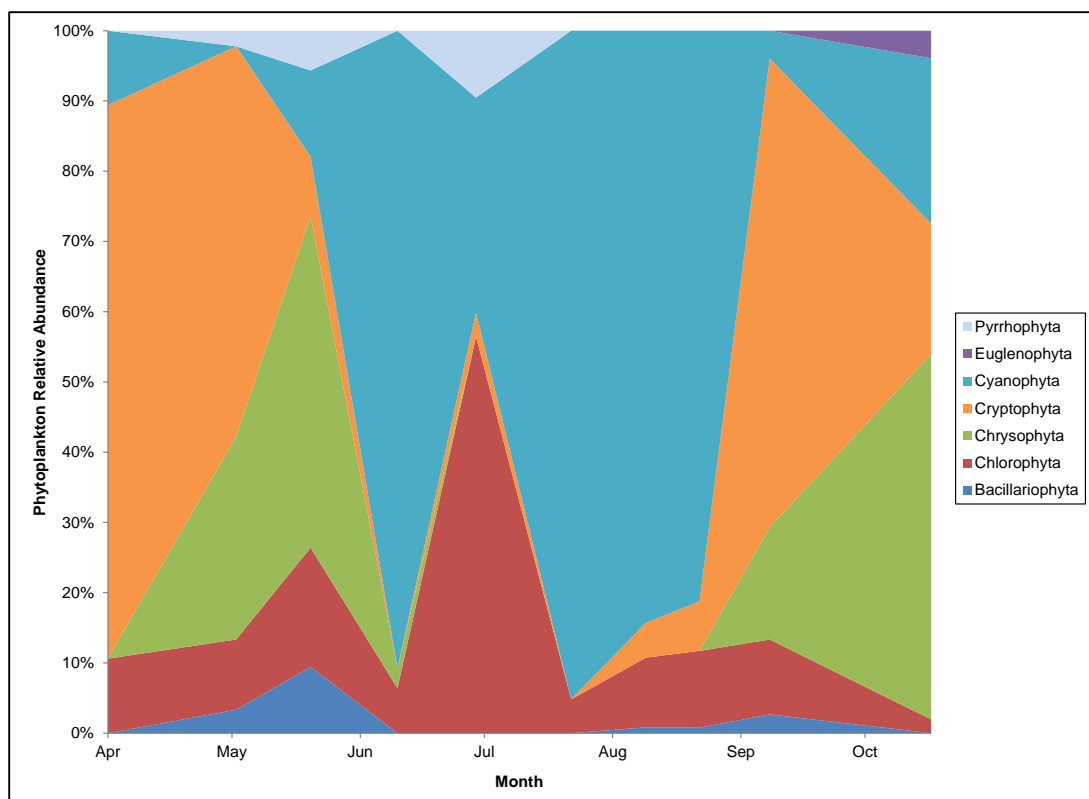


Figure 9-11: Loeb Lake 2015 phytoplankton relative abundance.

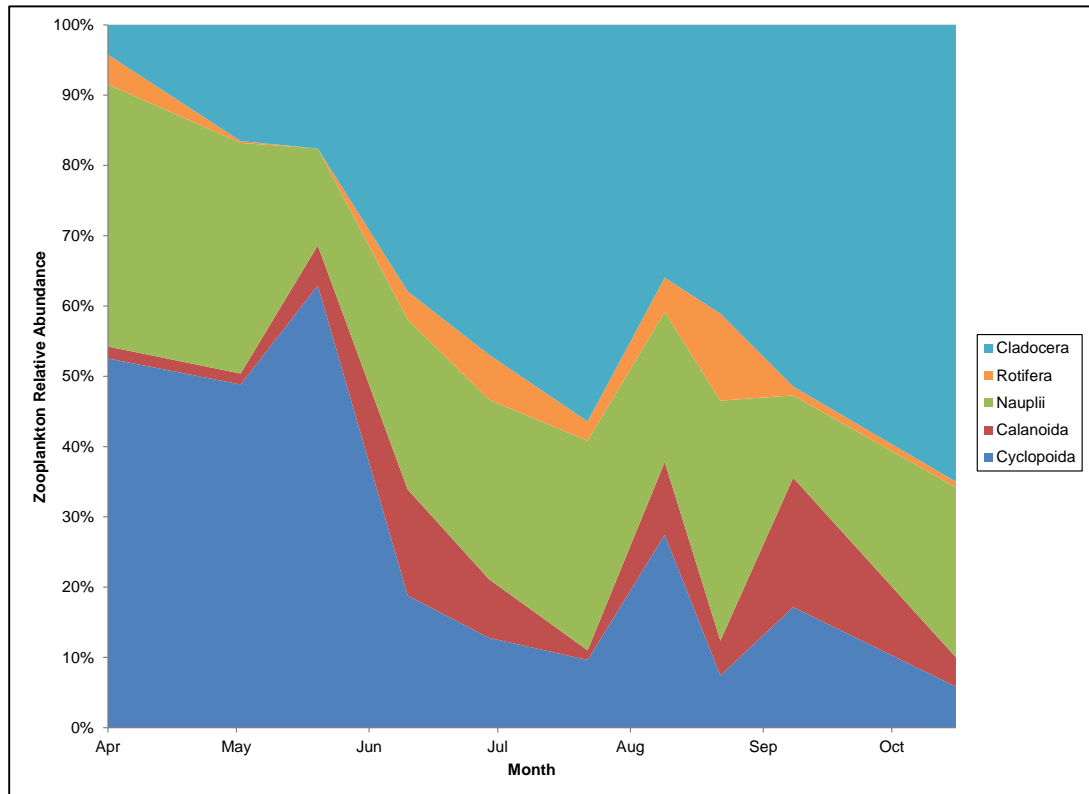


Figure 9-12: Loeb Lake 2015 zooplankton relative abundance.

9.5 AQUATIC VEGETATION

9.5.1 BIOVOLUME ANALYSIS

Figure 9-13 shows the 2015 aquatic plant biovolume survey results of Loeb Lake. Early season biovolume was lower than biovolume surveyed in previous years. The July survey showed that the littoral zone recorded nearly 100% biovolume throughout with small patches decreasing in density on the eastern portion of the lake in August.

9.5.2 POINT-INTERCEPT SURVEYS

Few species (a total of seven throughout the summer) of aquatic plants were observed in Loeb Lake in 2013 (CRWD, 2014a). Since 2013, subsequent point-intercept surveys in 2014 and 2015 have demonstrated plant communities that indicate a healthier lake habitat than in 2013. In 2014 and 2015, a total of ten plants species were observed over the course of the growing season in each year (CRWD, 2015a). The lake is widely dominated by the native coontail community (Figures 9-14 and 9-15). Invasive Eurasian watermilfoil and curly leaf pondweed were present throughout the surveys, but remained at low level abundance and occurrence levels. Leafy pondweed was found at high abundances during both the July and August surveys. Slender leaf naiad was also found at moderately high abundance levels in August.

The presence of both curly-leaf pondweed and Eurasian watermilfoil in Loeb Lake presents potential problems for future management decisions. Curly-leaf pondweed and Eurasian watermilfoil are both non-native invasive species, causing problems by displacing other native plants, and forming thick mats on the surface of a lake that disrupt boating and recreation (DNR, 2015d; DNR, 2005). In addition, when curly-leaf pondweed plants die back in mid-summer, the resulting increase in phosphorus from the decomposing plant material can cause disruptive algal blooms (DNR, 2005). The spreading of Eurasian watermilfoil makes it an especially difficult plant to manage, as a new plant can grow from just a tiny piece of an original plant. This makes it easy to float and grow quickly in other areas of a lake, as well as be transported between lakes on boat trailers and fishing gear (WSDE, 2015). Both species have been observed in Loeb Lake since 2005.

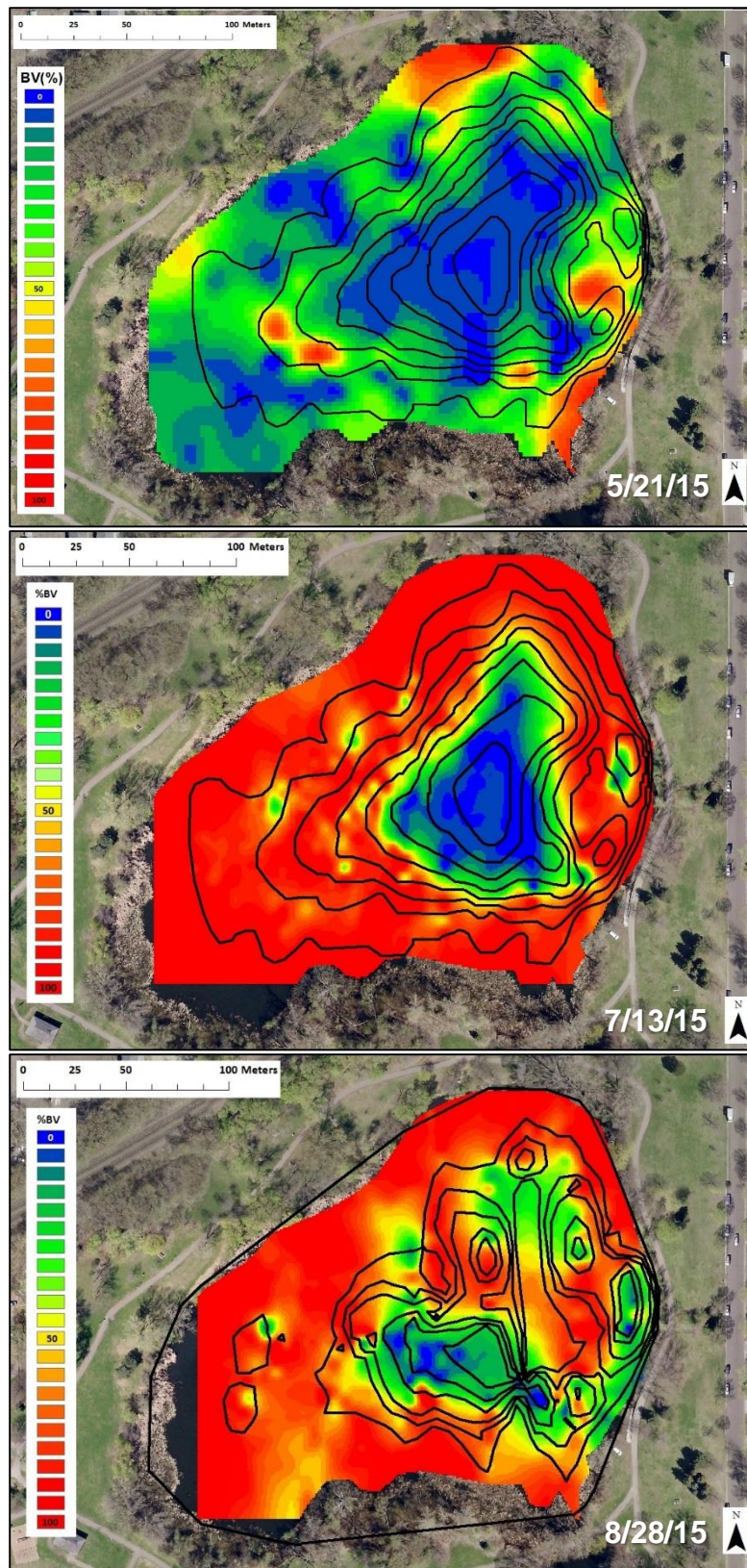


Figure 9-13: Loeb Lake 2015 seasonal vegetation changes (5/21/15, 7/13/15, and 8/28/15).

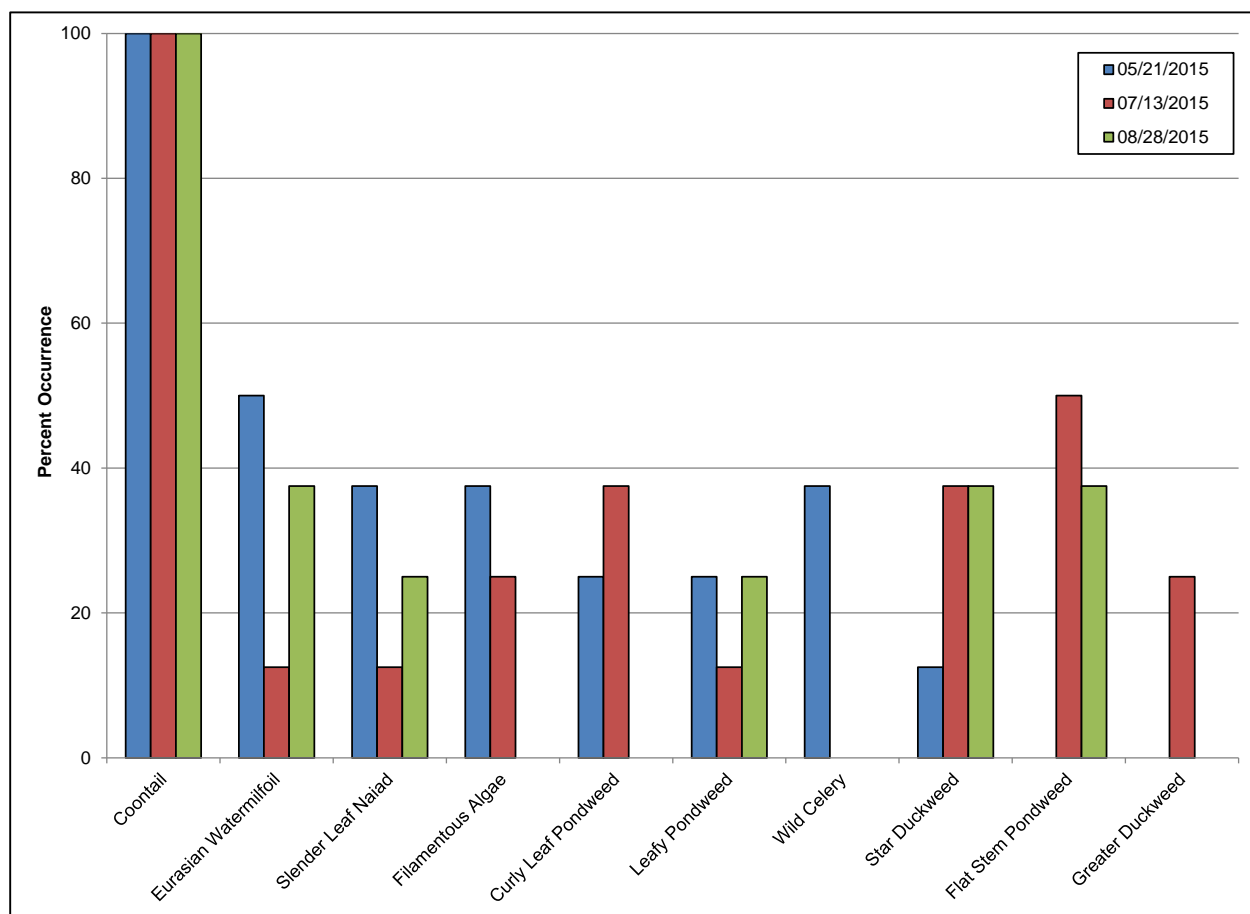


Figure 9-14: Loeb Lake 2015 percent occurrence of vegetation present.

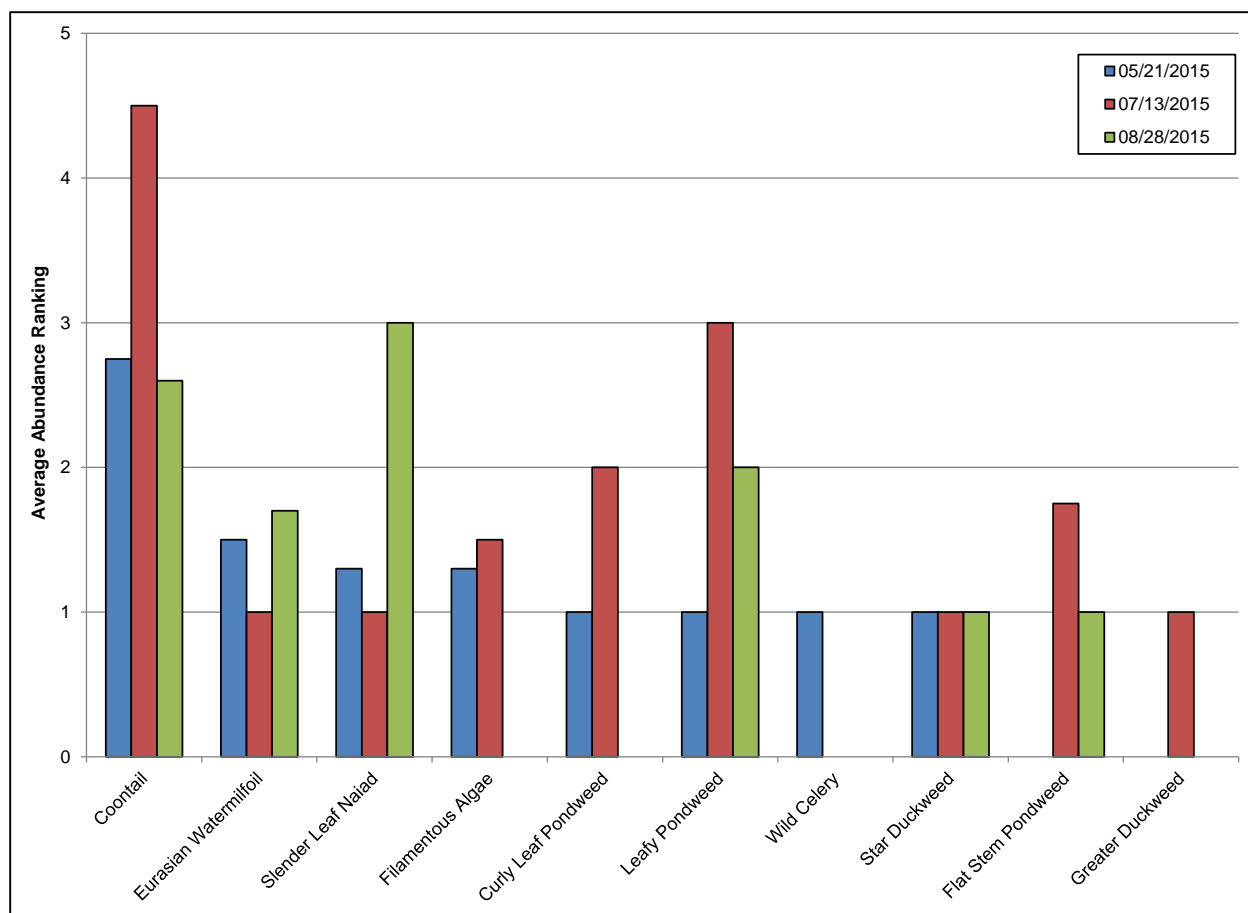


Figure 9-15: Loeb Lake 2015 average abundance ranking of vegetation present.

9.6 FISH STOCKING AND SURVEYS

Loeb Lake is part of the Minnesota DNR's "Fishing in the Neighborhood" program which provides angling opportunities for children and families in urban environments, encourages environmental stewardship, and improves knowledge of natural resources (DNR, 2015g). Therefore, these lakes are stocked with fish that are better for general angling activities. As seen in Table 9-4, the main fish types stocked in Loeb Lake in recent years are bluegill and walleye. There was no fish survey conducted on Loeb Lake in 2015. In general, the fish populations on the lake are stable and are affected mainly by stocking activity. Loeb Lake is scheduled to be surveyed again by CRWD in 2016.

Table 9-4: Loeb Lake historical record of fish stocking.

Year	Black crappie	Bluegill		Channel catfish		Largemouth bass		Walleye		
	Adult	Adult	Yearling	Adult	Yearling	Adult	Yearling	Yearling	Fingerling	Fry
2015		176						960		
2014		289							380	
2013		185							610	
2012		152								
2011	26	144			689				709	
2010		74		50	1211					
2009	207	106		47	622					
2008	244	380		55	1290					
2007	69	1018		38	1040	138	630			13,000
2006		524							34	10,000
2005	9	242	627						19	10,000
2004		444						3	149	10,000

9.7 OVERALL LAKE EVALUATION

Loeb Lake exhibits the best water quality of any District lake, and has historically received an ‘A’ lake grade, indicating high water quality and user quality. In 2015, the lake received an ‘A’ lake grade, which is in line with the historical average grade. All historical years of monitoring have met the MPCA state standards for TP, Chl-a, and Secchi disk depth. Hypolimnetic TP was highest in 2005, but has remained relatively low since 2008. Loeb Lake had a variety of aquatic vegetation in 2015, but most species monitored (aside from coontail) only showed low to moderate abundance throughout the lake.

10 LAKE MCCARRONS RESULTS

10.1 LAKE MCCARRONS BACKGROUND

Lake McCarrons is a 74.7 acre, deep lake located in the City of Roseville (Figure 10-1). With a maximum depth of 57 ft and a 36% lake littoral area, it supports a variety of activities including swimming, boating, and fishing (Table 10-1; Figure 10-2). Lake McCarrons County Park, located on the east shore of the lake, supports visitors to the lake with a beach building, picnic shelter, and boat access with car/trailer parking.



Figure 10-1: View of the public beach on the southeast shoreline of Lake McCarrons.

Table 10-1: Lake McCarrons morphometric data.

Surface Area (acres)	Maximum Depth (ft)	Littoral Area	Volume (acre-ft)	Watershed Area (acres)	Watershed: Lake Area (ratio)
74.7	57.0	34%	1,892	1,070	14.3



Figure 10-2: Lake McCarrons bathymetric map.

The 1,070 acre watershed of Lake McCarrons consists of residential properties, commercial and public areas, highway, wetland/grassland/woodland areas, and a park bordering it on the east side (Figure 10-3). The primary source of water inflowing to Lake McCarrons is stormwater from surrounding subwatersheds. The outlet of the Villa Park Wetland Treatment System located on the western edge of the lake is the primary inlet to Lake McCarrons. A secondary inlet enters on the north side of the lake via William Street Pond. It has one main outlet at the east end of the lake. This outlet is the headwaters of the Trout Brook-West Branch Subwatershed, where water enters the Trout Brook Storm Sewer Interceptor (CRWD, 2003).

One of the primary water quality concerns in Lake McCarrons is phosphorus. Currently, Lake McCarrons is considered unimpaired and is not listed on the MPCA 303(d) list of impaired waters. The Lake McCarrons Management Plan (CRWD, 2003) was developed in 2003 and created a goal of minimizing summer algae blooms by managing summer TP levels at or below 33 µg/L (CRWD, 2003). While this management goal is less than the deep lake state standard (40 µg/L), it is still attainable and presents the best achievable goal to continue to improve lake water quality.

In order to achieve the phosphorus goals outlined in the Lake McCarrons Management Plan, several projects have been implemented to improve lake water quality. Most notably, CRWD completed an alum treatment on Lake McCarrons in October 2004 in order to reduce the amount of total phosphorus in the lake. In this type of treatment, aluminum sulfate is applied below the lake surface and binds to free phosphorus particles causing them to drop out of the water column and settle on the bottom of the lake (Kennedy and Cook, 1982). This removes phosphorus from the water column, as well as prevents additional phosphorus release from the bottom sediments (CRWD, 2003). Water quality in Lake McCarrons after the alum treatment showed improvements when compared to pre-alum treatment water quality.

In addition, the Villa Park subwatershed has been a high-priority focus area for management efforts in the Lake McCarrons subwatershed because it has the largest drainage area to the lake (753 acres, or 70% of the watershed area of the lake) (CRWD, 2010). At the outlet of the Villa Park subwatershed, the Villa Park Wetland Treatment System was constructed in 1987 to receive and treat runoff at the subwatershed outlet before flowing into Lake McCarrons. The wetland system consists of a series of wetland cells that channel stormwater to decrease flow velocity and allow sediments and bound nutrients to settle before entering the lake. This system reduced the amount of TP and dissolved phosphorus entering the lake (CRWD, 2003). In 2004, improvements (i.e. timber weirs) were made to the system to enhance nutrient retention. In 2013, CRWD dredged several of the wetland cells in the Villa Park System. A total of more than 17,000 cubic yards of sediment was removed from the system to improve stormwater treatment and residence time before water flows into Lake McCarrons.

While Lake McCarrons currently exhibits overall good water quality and is still considered unimpaired, the lake is dynamic and should be evaluated annually to monitor change in integrity. For example, Lake McCarrons exhibited higher-than-normal early-May TP and Chl-a values in 2014, which prompted an evaluation of potential drivers of these high observed values. Subsequently, it was recommended in the *2014 Lakes Monitoring Report* to complete an internal loading assessment of the lake (CRWD, 2015a).

Another on-going management issue is the presence of invasive species on the lake including carp, Eurasian watermilfoil, and curly-leaf pondweed, all of which have been observed in recent years. Excessive aquatic vegetation growth on the west end of the lake has become a management concern, and CRWD coordinated plant removal on this area of the lake twice in 2014 and again in June and August of 2015. Plant removal in future years will be evaluated as needed.



Figure 10-3: Lake McCarrons and subwatershed boundary.

10.2 LAKE LEVEL

Lake McCarrons level has been consistently below the OHWL of 842.2 ft throughout the historical lake level record (Figure 10-4). The water level came close to the OHWL in 1984 and 1997. A significantly low water level period occurred from 1932-1939. The water level has consistently stayed within 840-842 ft for the past 35 years. The 2015 lake level reported in Figure 10-5 was a combination of the weekly staff gauge readings completed by the DNR in January and February and the 15 min level logger data collected from April to October by CRWD. In 2015, lake level decreased slowly from the beginning of the open-water season in April until August, responding to larger rain events (Figure 10-5). A wet fall curtailed the downward seasonal trend from dipping below 840.5 ft.

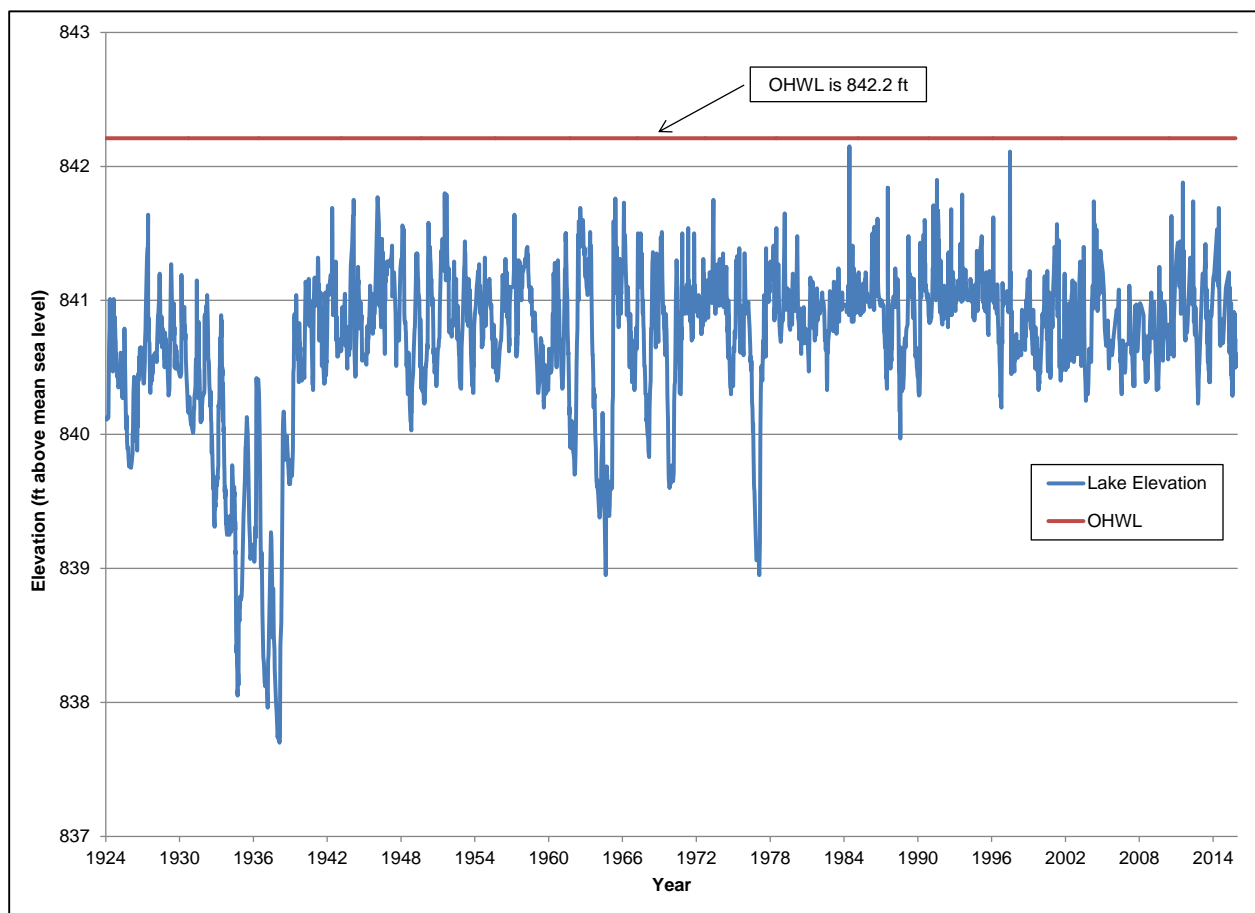


Figure 10-4: Lake McCarrons historical lake elevations and the OHWL (DNR, 2015i).



Figure 10-5: Lake McCarrons 2015 lake elevations, OHWL, and daily precipitation events (DNR, 2015i; MCWG, 2016).

10.3 WATER QUALITY RESULTS

Lake McCarrons was sampled ten times in 2015 from April 3 to October 19 (Figure 10-6). Sampling shows the highest epilimnetic TP concentration (50 µg/L) during the first sampling event on April 3, which then dropped significantly to an average of 18 µg/L through the remainder of the season. Chl-a concentrations followed the same trend as TP by beginning the season with a high concentration of 26.0 µg/L and decreasing to an average of 3.2 µg/L through the remainder of the season.

Water transparency was highest in May with an average of 5.0 m (Figure 10-6). Water transparency then decreased throughout the rest of the season with an average of 3.2 m. High water transparency is generally associated with low TP and Chl-a concentrations throughout the season. That trend was not strongly observed in Lake McCarrons in 2015; but based on other years in the historical record, TP is generally a major driver of water transparency.

Figure 10-7 displays the seasonal variation in Lake McCarrons for TP, Chl-a, and Secchi disk readings throughout the historical record using box-and-whisker plots. Chl-a and Secchi disk

readings indicate the highest level of water quality in May and the lowest in August. These parameters are not closely correlated with TP, likely due to the 2004 alum treatment which stratified the historical TP data into two categories, thus affecting generalizations that could be gathered. From Figure 10-7, it is observed that water quality generally decreases throughout the summer season.

Figure 10-8 shows yearly average historical TP concentrations, Chl-a concentrations, and Secchi disk depths graphically. Throughout the period of record, high Chl-a concentrations have generally been associated with high TP concentrations (Figure 10-8). Low Secchi depths have generally been associated with high Chl-a and TP concentrations, indicating that they are primary drivers for water clarity in Lake McCarrons. Since the 2004 alum treatment, the lake has experienced a significant improvement in water quality. Table 10-2 illustrates the differences between the average TP/Chl-a/Secchi values for the years 1988-2004 and 2005-2015, and the percent change from the former to latter.

Table 10-2: Differences between the 1988-2004 average, 2005-2015 average, and the percent change for TP/Chl-a/Secchi in Lake McCarrons.

Parameter	1988-2004 Average	2005-2015 Average	Percent Change
TP (µg/L)	42.9	18.5	- 57%
Chl-a (µg/L)	12.9	4.4	- 66%
Secchi (m)	2.4	3.7	+ 54%

Overall, the alum treatment is still effective in maintaining water quality in the lake in 2015. However, 2014 was the first year following the alum treatment that a decline in water quality was observed as evidenced by higher TP and Chl-a concentrations as well as shallower Secchi disk readings than other years since the alum treatment. The efficacy of an alum treatment can vary between 8-20 years, which CRWD will continue to monitor on Lake McCarrons into the future.

Figure 10-9 displays the annual average hypolimnetic and epilimnetic TP in Lake McCarrons thought the period of record. In addition to the epilimnion, the hypolimnion experienced a drastic drop in TP after the 2004 alum treatment. In eutrophic lakes, the hypolimnion is generally richer in phosphorus than the epilimnion, as bed sediments readily release phosphorus into the anoxic bottom layer, peaking in fall just prior to lake turnover (Kalff, 2002). Since 2004, the annual hypolimnetic TP concentrations have gradually increased, but still remain below pre-treatment concentrations. Also, the annual epilimnetic average has gradually increased since 2004, but is still meeting the deep lake standard for phosphorus (40 µg/L).

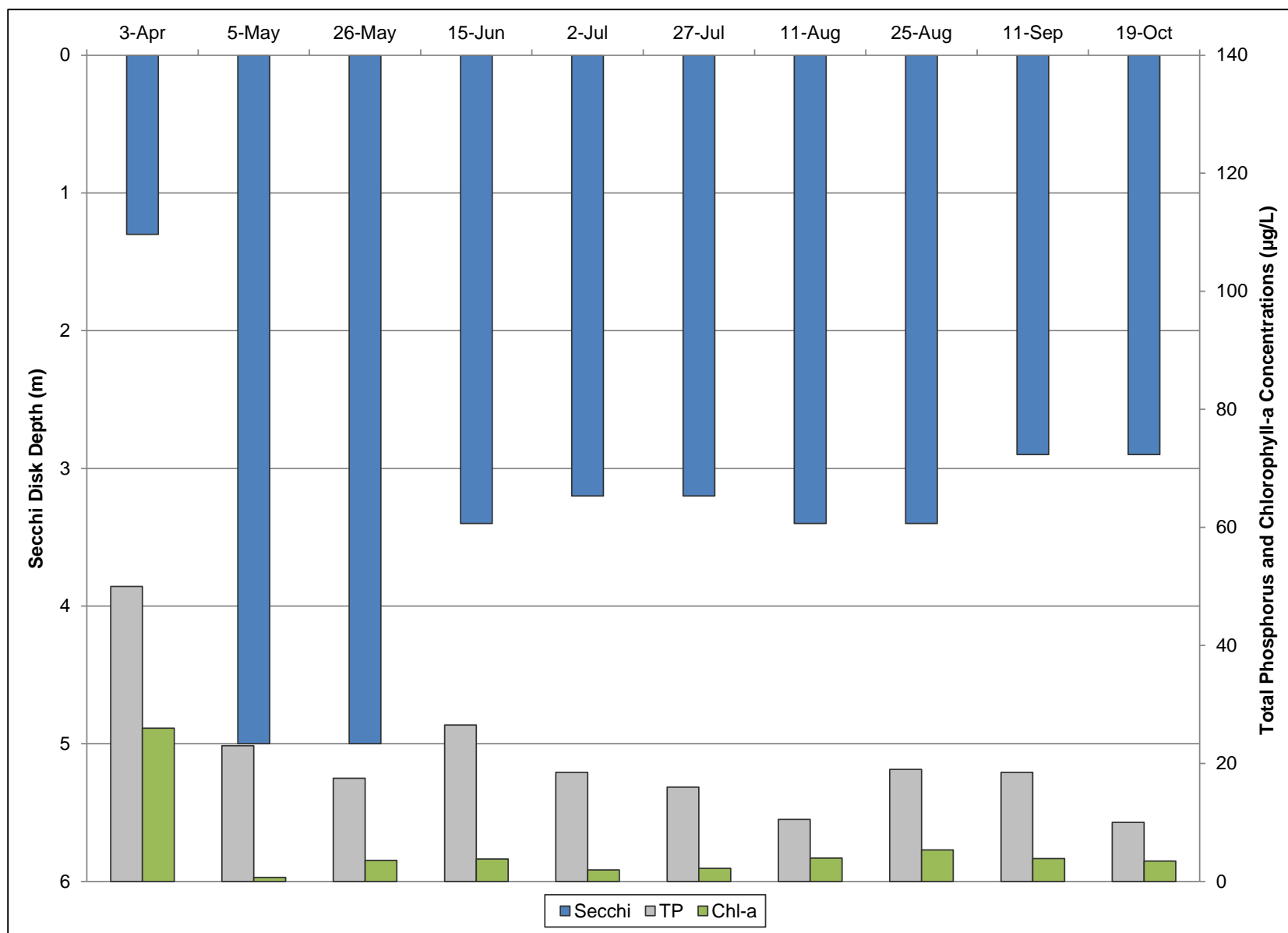


Figure 10-6: Lake McCarrons 2015 Secchi/TP/Chl-a comparison.

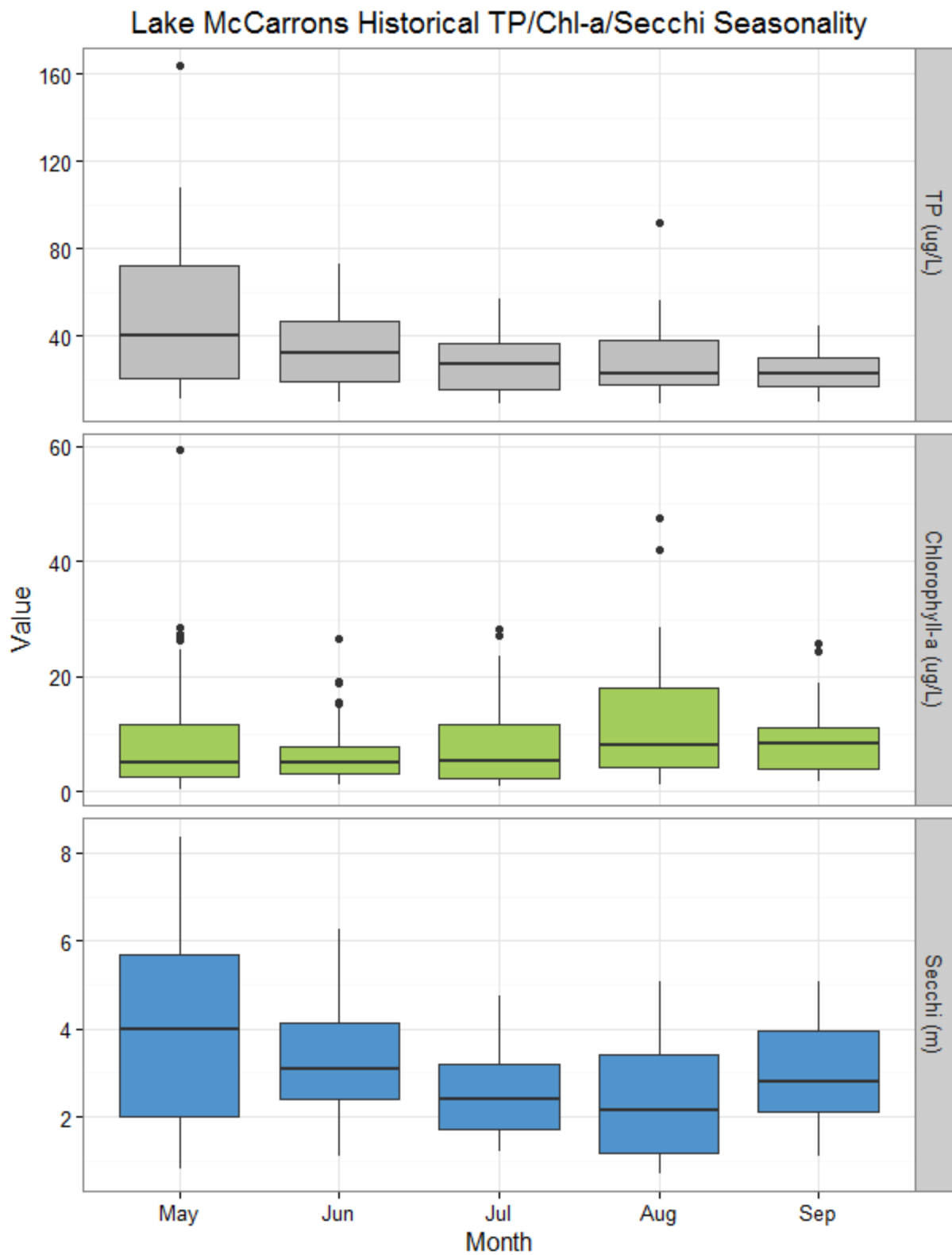


Figure 10-7: Lake McCarrons seasonality boxplots of historical Secchi/TP/Chl-a samples.

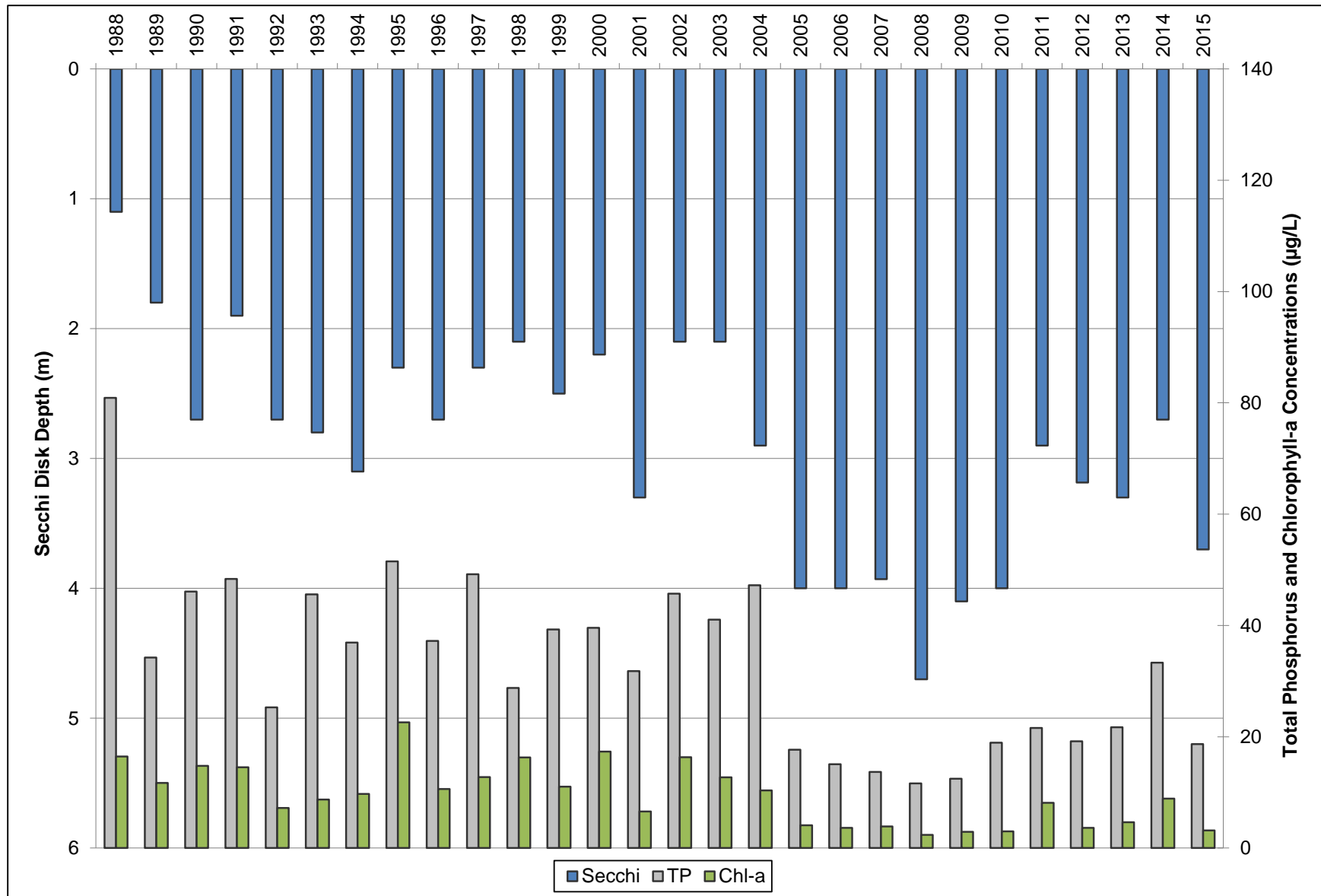


Figure 10-8: Lake McCarrons historical annual average Secchi/TP/Chl-a comparison.

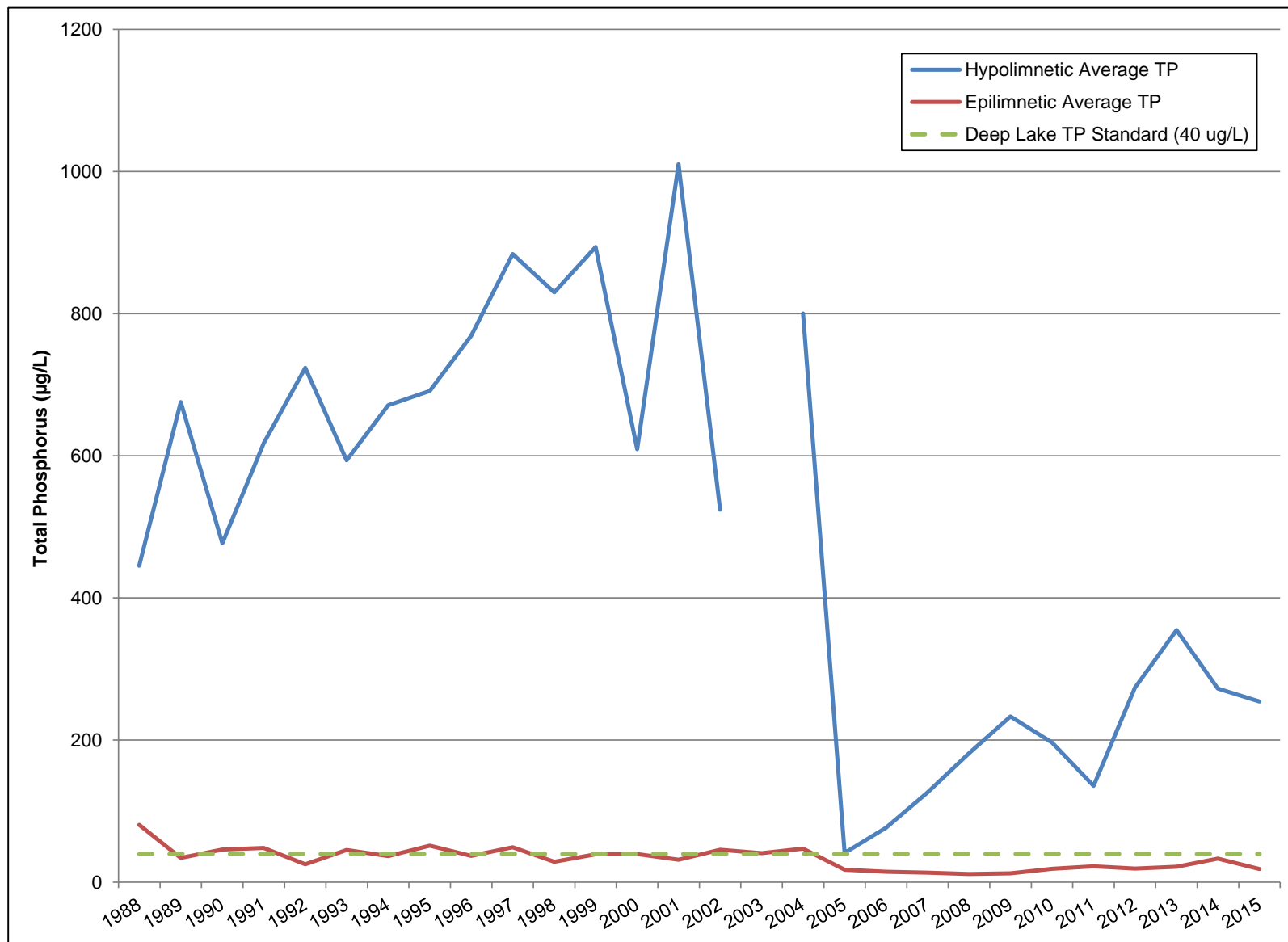


Figure 10-9: Lake McCarrons historical annual average hypolimnetic and epilimnetic total phosphorus.

Table 10-3 shows yearly average historical concentrations for TP, Chl-a, Secchi depths, and their comparisons to MPCA lake standards. Lake McCarrons has exceeded the state standards for TP for one-third of the years monitored and for 25% of the years monitored for Chl-a, all prior to the alum treatment in 2004. It has never exceeded the deep lake standard for Secchi disk depth. With the exception of 2014 when the lake received a 'B' due to the high May samples for TP and Chl-a, the lake has received an 'A' lake grade since the 2004 alum treatment (Table 10-4).

Table 10-3: Lake McCarrons historical yearly TP/Chl-a/Secchi depth averages compared to deep lake state standards.

Year	TP (µg/L)	Chl-a (µg/L)	Secchi (m)
1988	81	16.4	1.1
1989	34	11.7	1.8
1990	46	14.8	2.7
1991	48	14.5	1.9
1992	25	7.2	2.7
1993	46	8.7	2.8
1994	37	9.7	3.1
1995	52	22.6	2.3
1996	37	10.6	2.7
1997	49	12.8	2.3
1998	29	16.3	2.1
1999	39	11.0	2.5
2000	40	17.3	2.2
2001	32	6.6	3.3
2002	46	16.3	2.1
2003	41	12.7	2.1
2004	47	10.4	2.9
2005	18	4.1	4.0
2006	15	3.6	4.0
2007	14	3.9	3.9
2008	12	2.4	4.7
2009	12	2.9	4.1
2010	19	3.0	4.0
2011	22	8.1	2.9
2012	19	3.6	3.2
2013	22	4.6	3.3
2014	33	8.9	2.7
2015	19	3.2	3.7
	Value does not meet state standard*		
	Value meets state standard		

*MPCA deep lake standards are not to exceed 40 µg/L for TP and 14.0 µg/L for Chl-a, with a Secchi disk depth of at least 1.4 m.

Table 10-4: Lake McCarrons historical lake grades.

Year	TP Grade	Chl-a Grade	Secchi Grade	Overall Grade
1988	D	B	D	C
1989	C	B	C	C+
1990	C	B	B	B
1991	C	B	C	C+
1992	B	A	B	B+
1993	C	A	B	B
1994	C	A	A	B+
1995	C	C	B	C+
1996	C	B	B	B
1997	C	B	B	B
1998	B	B	C	B
1999	C	A	B	B
2000	C	B	B	B
2001	B	A	A	A
2002	C	B	C	C+
2003	C	B	C	C+
2004	C	B	B	B
2005	A	A	A	A
2006	A	A	A	A
2007	A	A	A	A
2008	A	A	A	A
2009	A	A	A	A
2010	A	A	A	A
2011	A	A	B	A
2012	A	A	A	A
2013	A	A	A	A
2014	C	A	B	B
2015	A	A	A	A

10.4 PHYTOPLANKTON AND ZOOPLANKTON

Lake McCarrons was sampled ten times for phytoplankton and zooplankton in 2015 from April 3 to October 19. In the spring, phytoplankton populations were dominated by Chlorophyta and Cryptophyta (Figure 10-12). As summer began, Cyanophyta bloomed and became very dominant throughout the remainder of the season, although overall phytoplankton concentrations were low. Bacillariophyta and Chlorophyta bloomed in July and late-August, respectively. There was a small presence of both Pyrrophyta and Euglenophyta observable in June and August. The early spring bloom of phytoplankton was likely a result of high nutrient availability (as seen by a peak in TP concentration) and increased light availability (Figure 10-10) (Kalff, 2002; UWE, 2004). The phytoplankton concentrations closely followed TP trends for the monitoring season, indicating that algal blooms were driven by phosphorus in the system, a pattern assumed by Lake McCarrons in previous years (Figure 10-10).

The zooplankton population of Lake McCarrons was divided among populations of Cyclopoids, Calanoids, Nauplii, and Cladocerans for the entire monitoring season (Figure 10-13). A small amount of Rotifers were observed during the month of June. The overall zooplankton population peaked in May at a time when Chl-a values neared zero (Figure 10-11). Total zooplankton concentration generally did not follow the Chl-a concentration fluctuations observed in 2015.

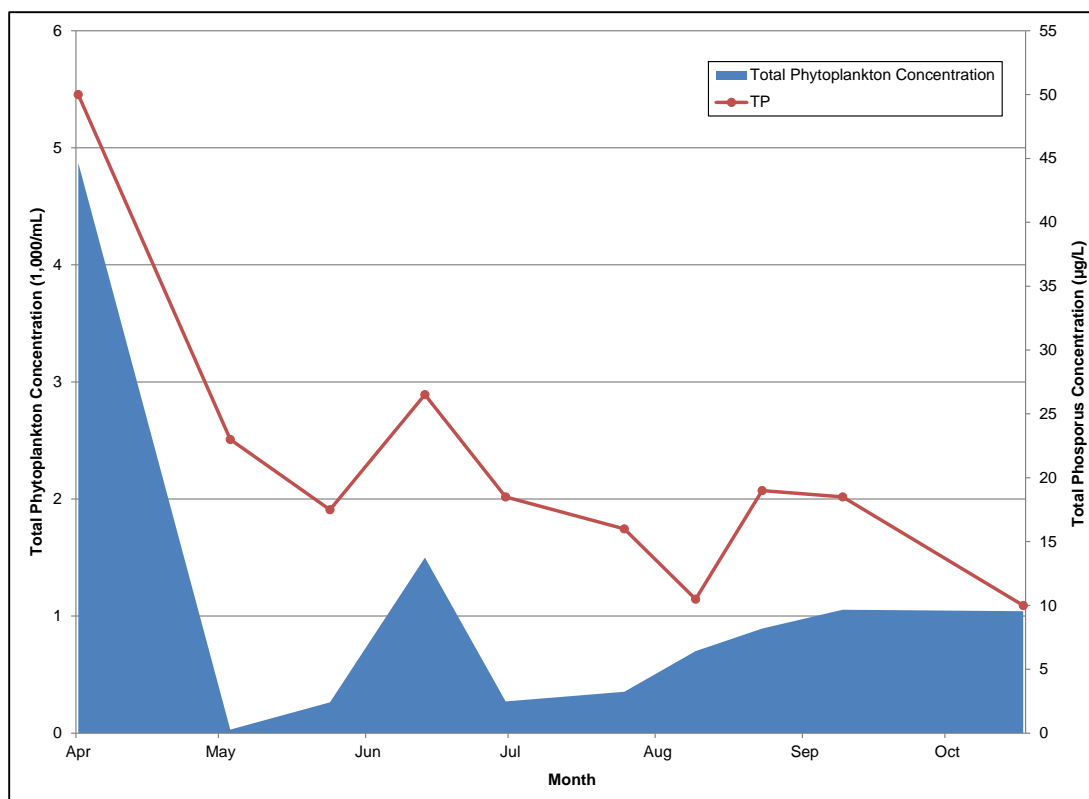


Figure 10-10: Lake McCarrons 2015 total phytoplankton concentration and TP concentration.

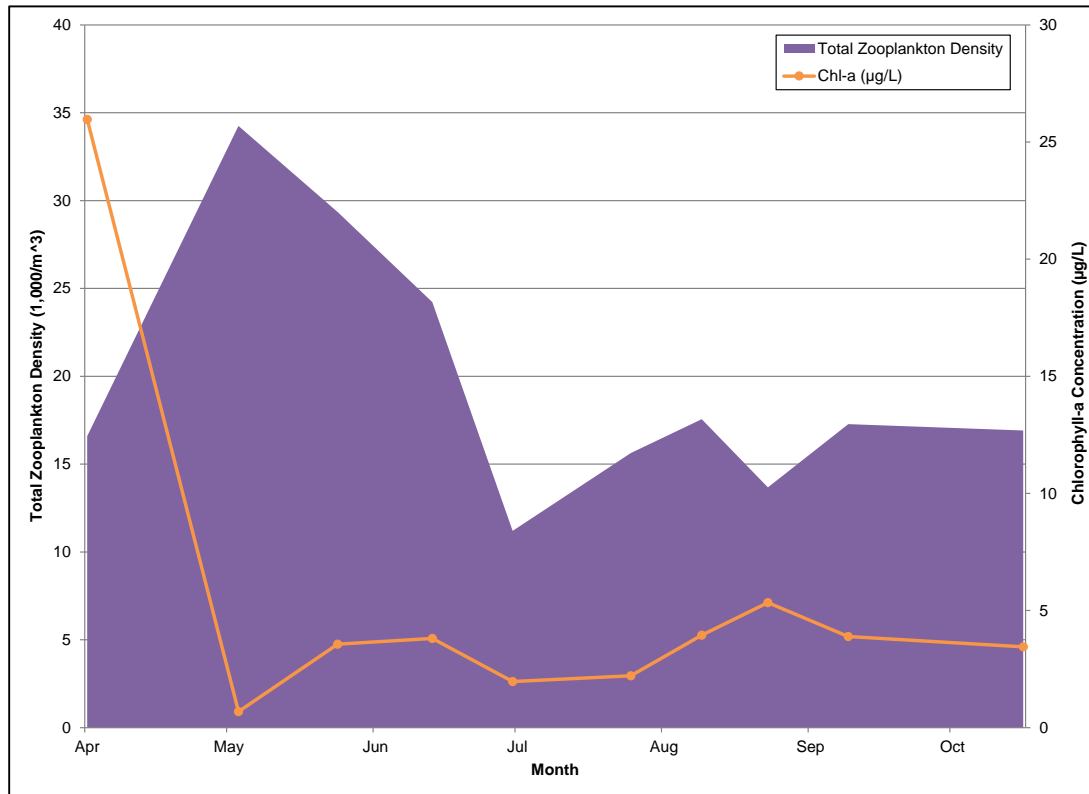


Figure 10-11: Lake McCarrons 2015 total zooplankton density and Chl-a concentration.

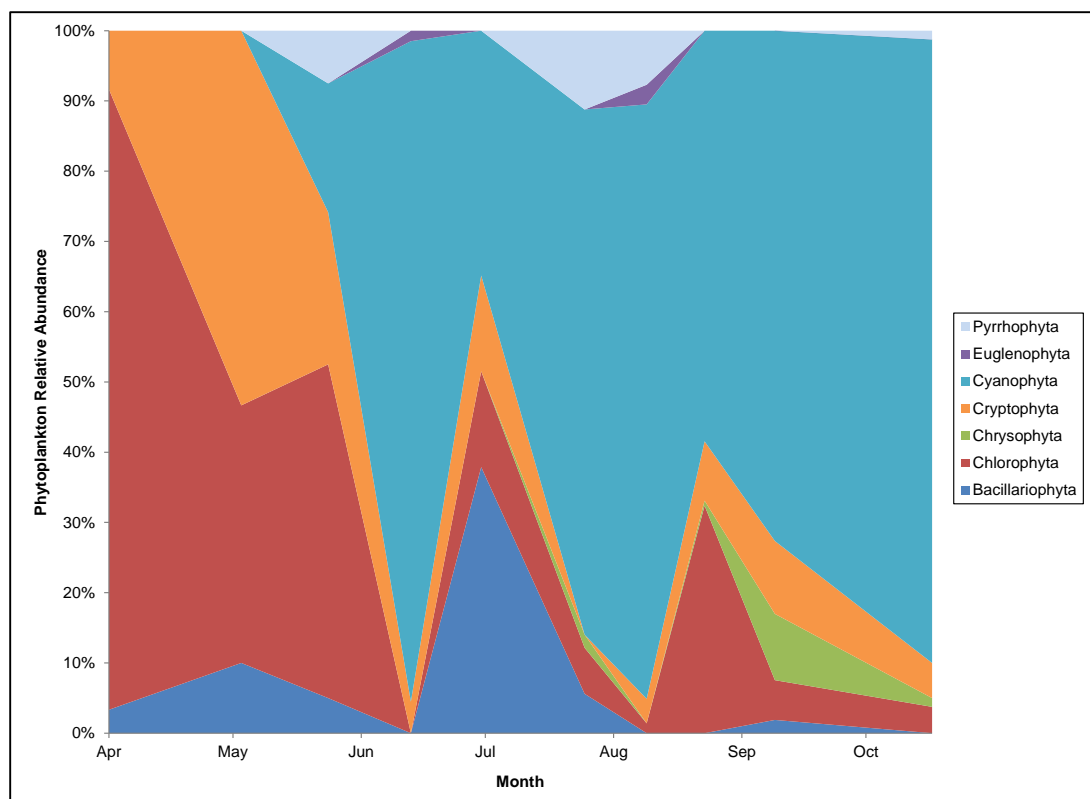


Figure 10-12: Lake McCarrons 2015 phytoplankton relative abundance.

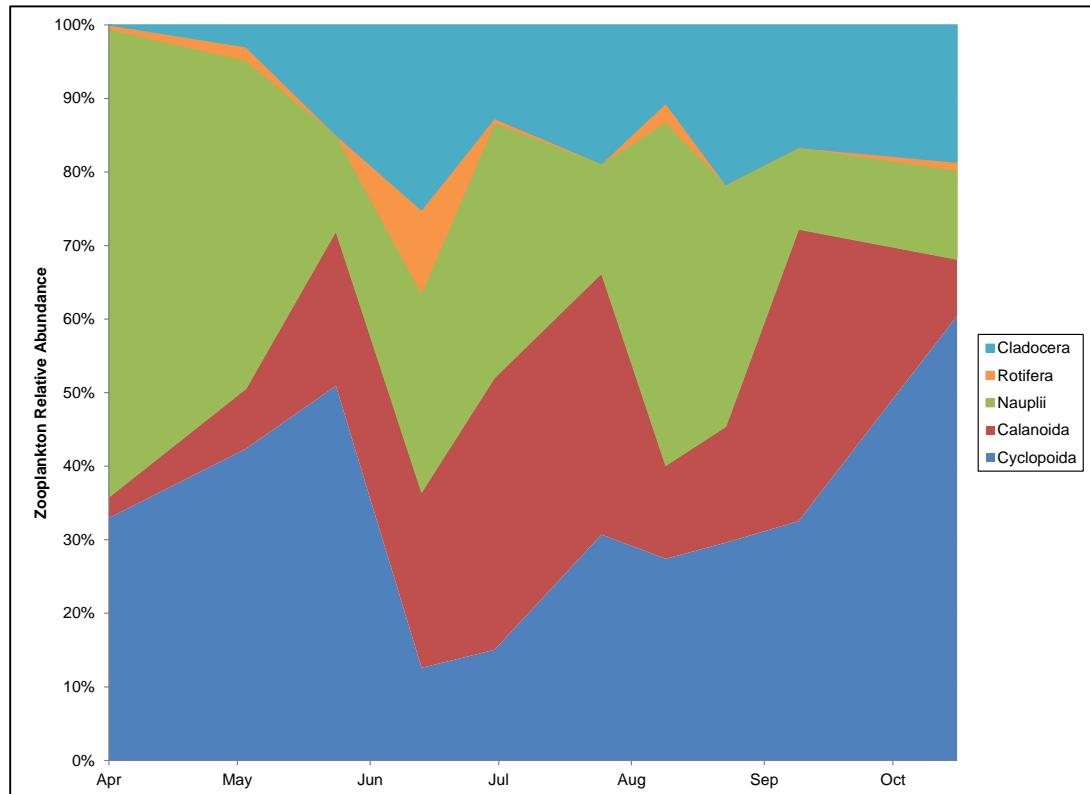


Figure 10-13: Lake McCarrons 2015 zooplankton relative abundance.

10.5 AQUATIC VEGETATION

10.5.1 BIOVOLUME ANALYSIS

The biovolume heat maps of Lake McCarrons show that the majority of the aquatic vegetation in the lake in 2015 occurred in the littoral areas (less than 15 ft) near the shoreline (Figure 10-14). Aquatic plants were most abundant along the western end of the lake, where the red color indicates that 100% of the water column contained aquatic vegetation. Overall plant abundance generally stayed consistent from May through August.

In June and August of 2015, CRWD partnered with Lake McCarrons homeowners to hire a contractor to perform vegetation harvesting on the west end of the lake. The goal of harvesting was to remove some of the nuisance plant growth observed by homeowners and improve recreational access to the lake. The July plant biovolume survey shows less biovolume on the west end of the lake as a result of the vegetation harvesting, while the August removal does not appear to have made a significant impact on overall plant biovolume.

10.5.2 POINT-INTERCEPT SURVEYS

Eurasian watermilfoil was the most frequently occurring plant in Lake McCarrons in 2015 with respect to the number of locations in which it was observed, increasing in frequency from previous years' surveys (Figure 10-15). Coontail increased in presence throughout the growing season to nearly match Eurasian watermilfoil. Despite having a high occurrence rate, Eurasian watermilfoil was less abundant than some native plants (Figure 10-16). None of the most frequently occurring species observed, however, were found in high abundance in 2015 (Figure 10-16). Ten species of aquatic plants were represented in Lake McCarrons during the July survey, but only seven species were present during the May and August survey.

Filamentous algae was just as abundant as Eurasian watermilfoil and coontail throughout the survey period (Figure 10-16). Filamentous algae can become a nuisance species when in high abundance as it forms thick, green mats on the water surface that can impede lake activities. It is also indicative of the presence of excessive nutrients (especially phosphorus) in a lake, which is common in urban lakes like Lake McCarrons (DNR, 2015e).

Eurasian watermilfoil and curly leaf pondweed have been observed in surveys since 2005. Curly leaf pondweed and Eurasian watermilfoil are both non-native invasive species, causing problems by displacing other native plants and forming thick mats on the surface of a lake that disrupt boating and recreation (DNR, 2015d; DNR, 2005). Curly leaf pondweed begins its lifecycle earlier than other plants underneath the ice and subsequently dies back earlier than others in mid-summer. This results in an increase in phosphorus from the decomposing plant material which can contribute to disruptive algal blooms (DNR, 2005). Eurasian watermilfoil spreads easily, as a small fragment of the stem or rhizome can propagate a new plant. It can easily float and grow quickly in other areas of a lake, as well as be transported between lakes on boat trailers and fishing gear (WSDE, 2015).

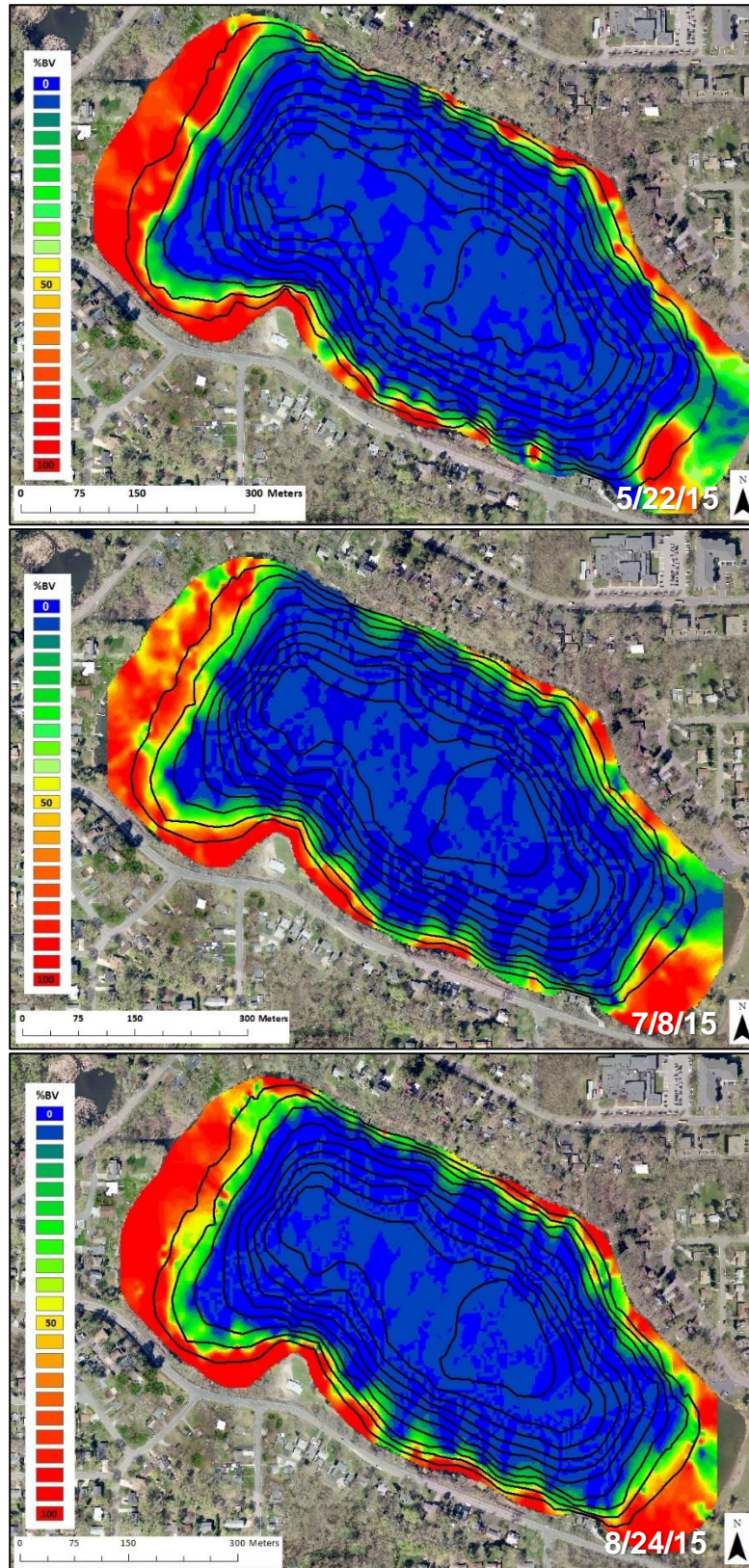


Figure 10-14: Lake McCarrons 2015 seasonal vegetation changes (5/22/15, 7/8/15, 8/24/15).

While neither Eurasian watermilfoil nor curly-leaf pondweed is especially abundant in Lake McCarrons the presence of these two species is still a management concern. In 2014, the June and August vegetation harvesting of the west end of the lake removed mostly coontail and Eurasian watermilfoil. While the removal of Eurasian watermilfoil is a positive step as it is an invasive species, the removal of too much coontail, a native plant species, needs to be taken into consideration before removal occurs. Native vegetation that is well established in a lake is the best preventative measure for invading invasive species (DNR, 2015d). Therefore, vegetation removal, especially on a lake with documented populations of non-native species, needs to occur with knowledge and forethought as to how the removal affects the remaining habitat for the potential increased growth of non-native species.

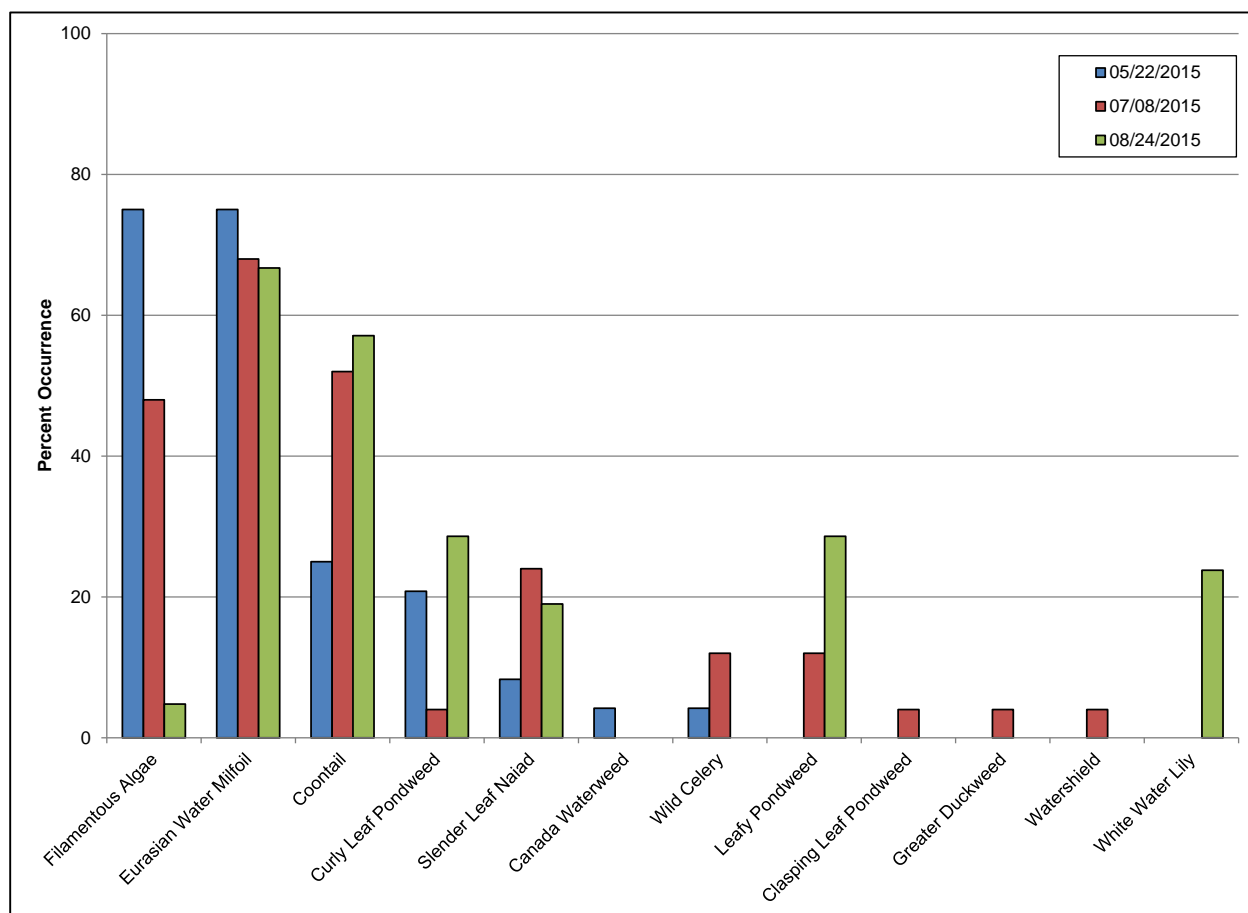


Figure 10-15: Lake McCarrons 2015 percent occurrence of vegetation present.

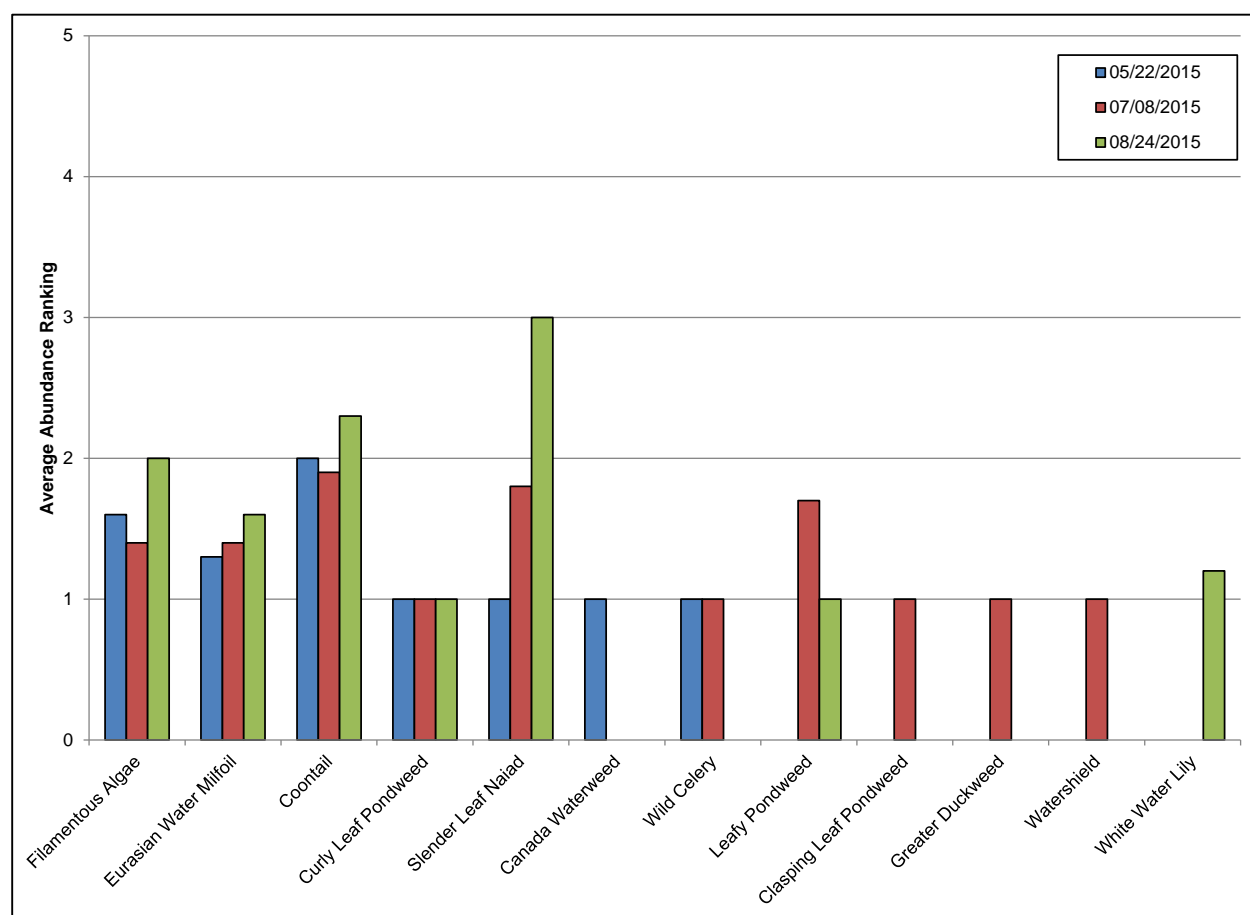


Figure 10-16: Lake McCarrons 2015 average abundance ranking of vegetation present.

10.6 FISH STOCKING AND SURVEYS

Previous stocking in Lake McCarrons has included black crappie, northern pike, and walleye, which has occurred intermittently in previous years (Table 10-5). Before being surveyed in 2014 by the Minnesota DNR, the previous survey of fish populations was in 2008. Both surveys showed a large variety of panfish, with a significant number of bluegills, as well as black crappie and perch (CRWD, 2015a). There was no fish survey conducted on McCarrons Lake in 2015. In general, the fish populations on the lake are stable and are affected mainly by stocking activity. Lake McCarrons is scheduled to be surveyed again by CRWD in 2016.

Table 10-5: Lake McCarrons historical record of fish stocking.

Year	Black crappie	Northern pike		Walleye
	Adult	Adult	Yearling	Fry
2009		80		
2007	630			
2005			124	
2004				75,000

10.7 OVERALL LAKE EVALUATION

Lake McCarrons has displayed significant improvements in water quality since the 2004 alum treatment to reduce TP levels in the lake. While 2014 exhibited decreased TP, Chl-a, and Secchi quality, 2015 values were back in line with previous years. This is reflected in the ‘A’ lake grade that the lake received in 2015, similar to the ‘A’ grades the lake was given in the years since the alum treatment (from 2005-2013). Hypolimnetic TP values also decreased in 2015 from 2014. While the lake exceeded the eutrophication parameter state standards multiple times in its monitored history, these exceedances occurred prior to the alum treatment.

Lake McCarrons supports a variety of vegetation at different points in the growing season, but the main vegetation in the lake throughout the year consists of Eurasian watermilfoil and coontail. In 2014 and 2015, the District worked with lakeshore owners to address vegetation concerns regarding these two plant species on the west end of the lake.

11 CONCLUSIONS & RECOMMENDATIONS

11.1 CONCLUSIONS

In 2015, the water quality of the five District lakes (Como, Crosby, Little Crosby, Loeb, and McCarrons) varied by water body and by time of year. In comparing 2015 water quality results to 2014 results, Como Lake degraded in water quality, while the other lakes (Crosby, Little Crosby, Loeb, and McCarrons) improved by varying degrees. This was the opposite trend observed in 2014.

Based on the MPCA eutrophication numeric water quality standards, Loeb Lake and Lake McCarrons met the MPCA standards for all parameters (TP, Chl-a, Secchi) during the 2015 growing season. Crosby Lake and Little Crosby Lake met the MPCA shallow lake standards for Chl-a concentration and Secchi disk depth, but failed for TP concentration in 2015. Como Lake did not meet the MPCA shallow lake standards for TP concentration or Chl-a concentration, but met the standards for Secchi disk depth during the 2015 growing season.

Total phosphorus was an important driver for water quality in all five District lakes in 2015. High phosphorus in lakes can cause overgrowth of algae (measured by Chl-a concentrations) and aquatic plants, which reduces water clarity. Phosphorus will continue to be a contaminant of concern in CRWD as inputs of fertilizers, leaves, grass clippings, and pet/wildlife waste in this urban watershed are very prevalent and difficult to control. Water quality improvement projects upstream of lakes that reduce the amount of phosphorus runoff will continue to be a priority in the District.

Invasive species (both plant and animal) continue to be a threat to District lakes, though they are not currently observed in significant amounts in any CRWD lake. In 2015, curly leaf pondweed was observed in all lakes. Eurasian watermilfoil was observed in Crosby Lake (the first recorded occurrence), Loeb Lake, and Lake McCarrons. Common carp were observed in Como Lake for the first time in many years. Invasive species can cause harm to lakes through displacement of native species and disruption of the food chain, both of which can affect overall lake health.

CRWD lakes are an important District resource, providing both economic (e.g. recreational resources) and environmental (e.g. flood attenuation) benefits. Understanding overall health of CRWD lakes in order to improve them for both kinds of benefits will be beneficial for the District and the region. Each District lake is an important community resource that is easily viewed and accessed by many people on a daily basis. Therefore, these lakes will continue to be a focal point for management by CRWD.

Como Lake has exhibited a cyclical pattern in water quality for the monitored eutrophication parameters in past years, which will continue to be studied and analyzed in order to understand

the lake's water quality. Loeb Lake and Lake McCarrons have had historically good water quality, but will continue to be monitored in the future to identify annual changes and trends. Crosby and Little Crosby Lakes will also continue being monitored in order to better understand the dynamic interaction between the lakes and the Mississippi River and how that influences lake water quality.

This report also contained additional information on biological data that was previously reported upon beginning in the *2013 Lakes Monitoring Report* (CRWD, 2014a), including phytoplankton and zooplankton populations, aquatic vegetation communities, and fish populations. All of these parameters affect lake water quality and are important components in analyzing overall lake health. The 2014 report (CRWD, 2015a) expanded upon additional biological data that was collected and had not previously been reported. In 2015, staff expanded the water quality data analysis to examine seasonal changes in historical TP/Chl-a/Secchi depth data, as well as the comparison between historical epilimnetic and hypolimnetic TP data.

Future reports will contain more analysis of biological data, in conjunction with the chemical and physical data monitored. In recent years, CRWD has developed a more robust dataset of biological parameters that had not previously been consistently collected from year to year. Having annual data for more years of monitoring will give a better starting point from which to evaluate trends and analyze all biotic and chemical drivers in lakes to holistically generate an improved picture of overall lake health.

11.2 RECOMMENDATIONS

11.2.1 ACCOMPLISHMENTS IN 2015

Many improvements have been made to the lake monitoring program in recent years in order to better understand the water quality in individual lakes as well as how the watershed as a whole could be affecting lake water quality. Data collection and analysis through the monitoring program helps to further CRWD's mission "to protect, manage and improve the water resources of the Capitol Region Watershed District."

In 2015, CRWD made progress towards the goals stated in the *2014 Lakes Monitoring Report* (CRWD, 2015a) for monitoring and reporting. From these goals, the following was accomplished in 2015:

1. Analyzed additional parameters:

CRWD expanded the analysis of chemical and physical data previously collected but not fully analyzed in prior reports. Previous CRWD analyses have focused mainly on three water quality parameters: TP, Chl-a, and Secchi disk depth. Analysis of other attributes will allow a better understanding of overall lake health. In 2015, analysis of lakes data was expanded to include:

- *Hypolimnetic water quality*: Reports have historically focused on the nutrient concentration of the epilimnion (mixed surface layer) of lakes, since MPCA

standards are based on this lake layer. The hypolimnion is the bottom-most stratified layer of a lake that is below the thermocline and made up of stagnant water that maintains a relatively uniform temperature. Characterizing the hypolimnetic water quality is important because this layer contains an accumulation of pollutants at the lake bottom. The hypolimnion also makes up the interface between lake water and bottom sediments, which may contain biologically available nutrients. In 2015, a comparison of epilimnetic TP and hypolimnetic TP was made for all lakes for all historical data. This demonstrated the more drastic fluctuations of TP in the hypolimnion as compared to the epilimnion. Future reporting will continue to examine hypolimnetic water quality data to determine possible internal phosphorus loading dynamics from in-lake sediments as other sources.

- *Seasonality analysis of TP, Chl-a, and Secchi disk depth:* Monthly boxplots of historical daily average epilimnetic TP/Chl-a/Secchi depth were generated for the 2015 report to examine trends in seasonality for each lake. This data can describe how water quality changes in each lake on a monthly basis as well as water quality variability throughout the seasons.

2. Conducted sediment analyses of District lakes:

CRWD conducted sediment analyses on Como Lake and Lake McCarrons in February 2016 in order to better understand phosphorus stored in the lake sediments and its potential to be released. Phosphorus binds to sediment at the lake bottom and can become suspended in the water column, making inorganic phosphorus biologically available to algae. Therefore, the content of inorganic phosphorus contained in the bottom sediments can provide information on internal phosphorus loads within the lake as well as the potential for phosphorus within those sediments to become biologically available. Additionally, sediment cores can inform the effectiveness of an alum treatment or other in-lake management practices. For Como Lake and Lake McCarrons, a series of sediment cores were extracted from each lake and analyzed for sediment physical properties (organic matter, bulk density), total metal concentrations (iron, aluminum, manganese), and total phosphorus release rates.

Como Lake and Lake McCarrons were the only two CRWD lakes selected for sediment coring. Como Lake was selected because internal phosphorus loading is not well understood in the lake and the water body is currently impaired for nutrients. Lake McCarrons was selected in order to gain more information on the current and projected state of the 2004 alum treatment. Loeb Lake, Crosby Lake, and Little Crosby Lake were not sampled for sediment cores in 2016.

3. Conducted fish surveys:

CRWD surveyed fish populations at Como, Crosby, and Little Crosby Lakes in 2015. Fish surveys will continue annually during years in which DNR survey is not scheduled to survey CRWD lakes.

11.2.2 RECOMMENDATIONS FOR 2016

For 2016, CRWD has several goals and recommendations that are aimed at improving the lake monitoring program. Goals for 2016 include:

1. Analyze additional chemical and physical parameters:

CRWD intends to expand the analysis of chemical and physical data previously collected but not fully analyzed in prior reports. Analysis of other water chemistry and physical attributes will allow a better understanding of overall lake health, such as:

- *Chloride*: It is a contaminant of concern in metro area lakes. Como Lake is listed on the draft 2014 303(d) Impaired Waters List for chloride (MPCA, 2016), so this contaminant is becoming more of a management concern in CRWD lakes.
- *SRP*: Soluble Reactive Phosphorus, or Ortho-Phosphate. Evaluate separately from Total Phosphorus to better understand the role of this parameter in determining lake water quality.
- *Temperature profile*: Temperatures at different depths within the water column are currently measured by RCPW during their summer lake visits. Graphically creating temperature profiles of the lake throughout the monitoring season may also be helpful in explaining water quality trends.
- *Total Nitrogen*: This includes Ammonia-Nitrogen ($\text{NH}_3\text{-N}$), nitrate as nitrogen ($\text{NO}_3\text{-N}$), and Total Kjeldahl Nitrogen (TKN). While the limiting factor for algal growth in CRWD lakes is most often phosphorus, other nutrients such as nitrogen could also be playing a role in temporal blooms.

2. Continue to conduct fish surveys:

CRWD plans to survey fish populations at Como, Crosby, and Little Crosby Lakes annually during years the DNR is not scheduled to survey those lakes. Also, CRWD will survey Lake McCarrons and Loeb Lake bi-annually (except for years the DNR is scheduled to survey) since these lakes exhibit stable fish populations. In 2016, CRWD will survey Crosby Lake, Little Crosby Lake, Loeb Lake, and Lake McCarrons.

3. Complete an internal loading assessment of Lake McCarrons:

Internal loading (the release of phosphorus from lake sediments into the water column) can have a large effect on the amount of available phosphorus in a lake. Lake McCarrons received an alum treatment in 2004 in order to reduce internal phosphorus loading and improve lake water quality. Since the alum treatment, lake water quality has drastically improved in comparison to pre-alum treatment conditions. The expected efficacy of an alum treatment is 8-20 years. Since it has been 11 years since the treatment, a deterioration in its effectiveness is expected. Consequently, degradation in epilimnetic water quality was observed in 2014, along with an increase in hypolimnetic phosphorus that has been observed in recent years.

In 2016, CRWD will investigate the changes to internal loading that have occurred since the 2004 alum treatment using sediment cores from the bottom sediments that were extracted in February 2016. The results of these sediment cores will be used to complete a phosphorus budget that will evaluate all internal and external sources to the lake, which will assist in determining future management strategies for Lake McCarrons.

4. Complete an in-lake management analysis of Como Lake:

Como Lake has a long history of nutrient impairment due to excess phosphorus. The District has implemented several projects to address external phosphorus loading into the lake, including the Arlington-Pascal Stormwater Improvement Project. Despite efforts to control external sources, measurable water quality improvements have not been realized. Investigation into in-lake chemical and biological dynamics in Como Lake has been recommended.

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APPENDIX A: TECHNICAL MEMO — SUMMARY OF 2015 LAKE FISH SURVEYS

Technical Memo



Responsive partner.
Exceptional outcomes.

To: Britta Suppes, Monitoring Coordinator
Capitol Region Watershed District

From: Jeff Madejczyk, Wenck Associates, Inc.
Tom Langer, Wenck Associates, Inc.

Date: September 30, 2015

Subject: Summary of 2015 Lake Fish Surveys

Introduction

The Capitol Region Watershed District (CRWD or District) is located in Ramsey County, Minnesota. The District covers over 40 square miles in portions of five cities. CRWD conducts a variety of monitoring, implementation and educational efforts and projects aimed at improving the water and recreation resources within the watershed. In 2014, CRWD began conducting fish community surveys in lakes within the District to supplement routine fish monitoring efforts conducted by the Minnesota Department of Natural Resources (DNR). That same year, CRWD used Wenck Associates Inc., (Wenck) to assist with fish monitoring efforts. Wenck again teamed with CRWD in 2015 to complete lake fish surveys.

Lake fish community surveys were completed in three lakes in 2015 including Crosby Lake, Little Crosby Lake and Como Lake. Both Como Lake and Little Crosby Lake were also surveyed by Wenck in 2014. Wenck obtained the required fish survey permit from the DNR prior to conducting field efforts. Fish surveys in all three lakes included standard trap nets and gill nets following DNR methods. In Como Lake and Crosby Lake, nets were placed at established sampling points previously utilized by the DNR. For Little Crosby Lake there are no established DNR sampling points so the nets were placed at sampling locations established by Wenck in 2014. Fish community surveys in Crosby Lake and Little Crosby Lake were completed the week of August 3rd through August 6th, 2015. Fish community surveys in Como Lake were completed the week of August 10th through the 12th, 2015. All fish collected from all sampling gears were identified, sorted, counted, weighed and measured. Live fish were released back into the lake. Dead fish were disposed of within the lake.

Results

Como Lake

There were a total of 14 species and 508 fish collected from Como Lake in August 2015. Fish survey results from Como Lake in 2015 are presented in Table 1 and compared to survey results from 2014 (completed by Wenck) and 2011 (completed by the DNR). The total catch in 2015 was more than double the catch in 2014 but approximately 70 percent of the total catch in 2011. The main difference from the 2011 catch totals and the 2014 & 2015 catch totals is the large number of bluegills collected in 2011, compared to low numbers of bluegills collected the other two years. In 2015, the most numerous species collected were black crappie, which matches both the 2011 and 2014 surveys. The most numerous top predator species were northern pike in 2015 which matches the prior surveys. Walleyes were found in higher numbers in 2015 compared to prior surveys. One

item of note is the large total catch of black bullheads in 2015, comprising more than 37 percent of the total catch. It will be important to track bullhead numbers in future survey efforts and investigate if bullheads are possibly contributing to turbidity, nutrient or water clarity issues within Como Lake.

Table 1: Summary Comparison of Como Lake Fish Community Surveys

Species	2015	% catch	2014	% catch	2011	% catch
Black Bullhead	190	37.4%	14	6.0%	71	9.6%
Black Crappie	239	47.0%	145	62.5%	272	37.0%
Bluegill	2	0.4%	7	3.0%	237	32.2%
Brown Bullhead	1	0.2%	0	0.0%	0	0.0%
Channel Catfish	10	2.0%	3	1.3%	19	2.6%
Common Carp	1	0.2%	0	0.0%	0	0.0%
Golden Shiner	7	1.4%	19	8.2%	2	0.3%
Green x Bluegill hybrid	2	0.4%	0	0.0%	0	0.0%
Northern Pike	21	4.1%	16	6.9%	49	6.7%
Pumpkinseed Sunfish	0	0.0%	7	3.0%	29	3.9%
Walleye	19	3.7%	6	2.6%	5	0.7%
White Sucker	3	0.6%	0	0.0%	3	0.4%
Yellow Bullhead	12	2.4%	1	0.4%	33	4.5%
Yellow Perch	1	0.2%	14	6.0%	16	2.2%
Total	508	100.0%	232	100.0%	736	100.0%

Crosby Lake

There were nine species and 75 total individual fish collected from Crosby Lake in 2015 (Table 2). Compared to the 2014 DNR surveys on Crosby Lake, there were less total species collected and half as many total fish collected in 2015. The main difference between the two survey years was the decrease in total catch of bluegills and black bullheads in 2015 compared to 2014. The most numerous fish in 2015 were bluegills and also pumpkinseed sunfish. Predator species observed included northern pike and bowfin, which were also observed in 2014. There were four species that were not collected in 2015 that were observed in the catch in 2014 including common carp, golden shiner, hybrid sunfish and white crappie.

Table 2: Summary Comparison of Crosby Lake Fish Community Surveys

Species	2015	% catch	2014	% catch
Black Bullhead	8	10.7%	57	37.7%
Black Crappie	4	5.3%	0	0.0%
Bluegill	32	42.7%	57	37.7%
Bowfin	4	5.3%	1	0.7%
Common Carp	0	0.0%	1	0.7%
Golden Shiner	0	0.0%	4	2.6%
Hybrid Sunfish	0	0.0%	11	7.3%

Species	2015	% catch	2014	% catch
Largemouth Bass	1	1.3%	1	0.7%
Northern Pike	3	4.0%	6	4.0%
Pumpkinseed Sunfish	16	21.3%	0	0.0%
White Crappie	0	0.0%	11	7.3%
Yellow Bullhead	2	2.7%	1	0.7%
Yellow Perch	5	6.7%	1	0.7%
Total	75	100.0%	151	100.0%

Little Crosby Lake

There were six species collected from Little Crosby Lake in 2015 and the total catch was low, at only 34 total fish (Table 3). The 2015 catch is just under half of the total fish collected from Little Crosby Lake in 2014. The most numerous fish collected in 2015 were pumpkinseed sunfish compared to black bullheads being the most numerous in 2014. There was only one black bullhead collected in 2015 compared to 2014 when there were 57 collected (which is more than the combined total catch from 2015). The only predator species observed from Little Crosby Lake in 2015 were northern pike.

Table 3: Summary Comparison of Little Crosby Lake Fish Community Surveys

Species	2015	% catch	2014	% catch
Black Bullhead	1	2.9%	57	80.3%
Bluegill	9	26.5%	2	2.8%
Golden Shiner	0	0.0%	1	1.4%
Green Sunfish	1	2.9%	0	0.0%
Green Sunfish x Bluegill Hybrid	0	0.0%	1	1.4%
Northern Pike	5	14.7%	2	2.8%
Pumpkinseed Sunfish	14	41.2%	2	2.8%
Yellow Bullhead	1	2.9%	0	0.0%
Yellow Perch	3	8.8%	6	8.5%
Total	34	100.0%	71	100.0%

