2021 ANNUAL WATER QUALITY REPORT

APRIL 2022

Shingle Creek

West Mississippi Watershed Management Commission

The Monitoring Program

Staff conducts fish survey on Shingle Creek, Brooklyn Center MN.

The Shingle Creek and West Mississippi Watershed Management Commissions annually monitor water quality in the lakes, streams and outfalls of the watersheds. Data has been collected from Shingle Creek since 1996 and at West Mississippi River outfalls since 2010. In 2012 Shingle Creek expanded its volunteer-based lake monitoring program to start systematic detailed lake monitoring. The program has also expanded to incorporate fish, macroinvertebrate, and aquatic vegetation monitoring in the lakes and streams. Student and adult volunteers collect additional lake water quality and stream and wetland macroinvertebrate data. A Water Quality report summarizing current and historic conditions in the watersheds has been published annually since 1998.

Surface water quality in the watersheds is typical of urban lakes and streams in the Twin Cities metropolitan area. Agriculture followed by urban development have changed drainage patterns, increased pollutants to the waters, and reduced habitat for aquatic and terrestrial life. Both Shingle Creek and Bass Creek do not meet state water quality standards for chloride, bacteria, and dissolved oxygen, and have severely impacted fish and macroinvertebrate communities. Thirteen of the 16 lakes were listed as Impaired Waters of the State because of their high concentrations of phosphorus. Diagnostic and feasibility studies completed between 2007 and 2011 have identified actions that can be taken in the watersheds to help improve water quality.

In the more than ten years since the results have been heartening. Three of the impaired lakes **now meet state standards** and have been removed from the list of Impaired Waters and two others now meet the standards and will be assessed for removal. Long-term stream water quality monitoring shows a **clear improvement** in suspended sediment and nutrient concentrations in both Shingle Creek and Bass Creek, a result of ongoing efforts to stabilize streambanks, increase the frequency of street sweeping, enhance erosion control on construction sites, and install Best Management Practices to treat stormwater before it is discharged into the streams. However, chloride concentrations in the streams, mostly from road salt applied in the winter for snow and ice control, continue to be high.

Why Do We Monitor?

- To quantify the **current status** of streams and lakes throughout the watershed and compare to water quality standards.
- To quantify **changes over time**, or trends, in stream and lake water quality
- To **identify problem areas** for potential BMPs
- To quantify the **effectiveness** of implemented BMPs throughout the watershed

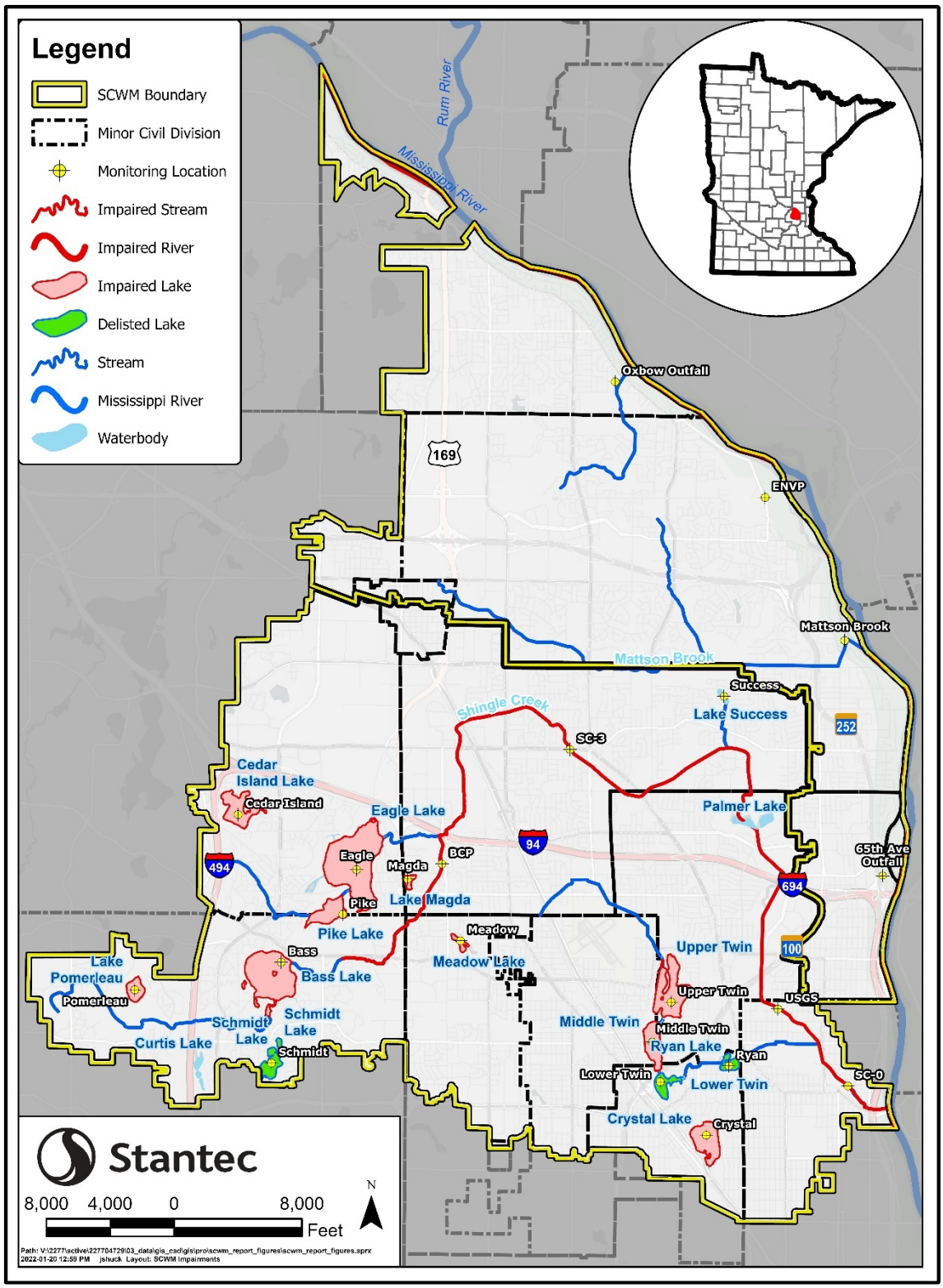


Figure 1. Impairments in the Shingle Creek and West Mississippi Watersheds.

What's in the watershed?

West Mississippi

- 25 square miles
- High impervious urban development (25%) and low-moderate impervious urban development (38%)
- 4 stream sites and 18.3 miles of streams
- No lakes, few wetlands

Middle Shingle Creek

- 15 square miles
- High impervious urban development (45%) and low-moderate impervious urban development (28%)
- 1 stream and 10.34 miles of streams
- 2 lakes: Success and Palmer

Upper Shingle Creek

- Headwaters of Shingle Creek
- 13 square miles
- High impervious urban development (28%) and low-moderate impervious urban development (26%)
- 3 streams and 16.2 miles of streams
- 8 lakes: Bass, Pomerleau, Schmidt, Cedar Island, Pike, Eagle, Magda, Meadow

Lower Shingle Creek

- Shingle Creek discharges to the Mississippi River
- 17 square miles
- High impervious urban development (71%) and low-moderate impervious urban development (8%)
- 2 streams and 18.9 miles of streams
- 5 lakes: Upper Twin, Middle Twin, Lower Twin, Crystal, and Ryan

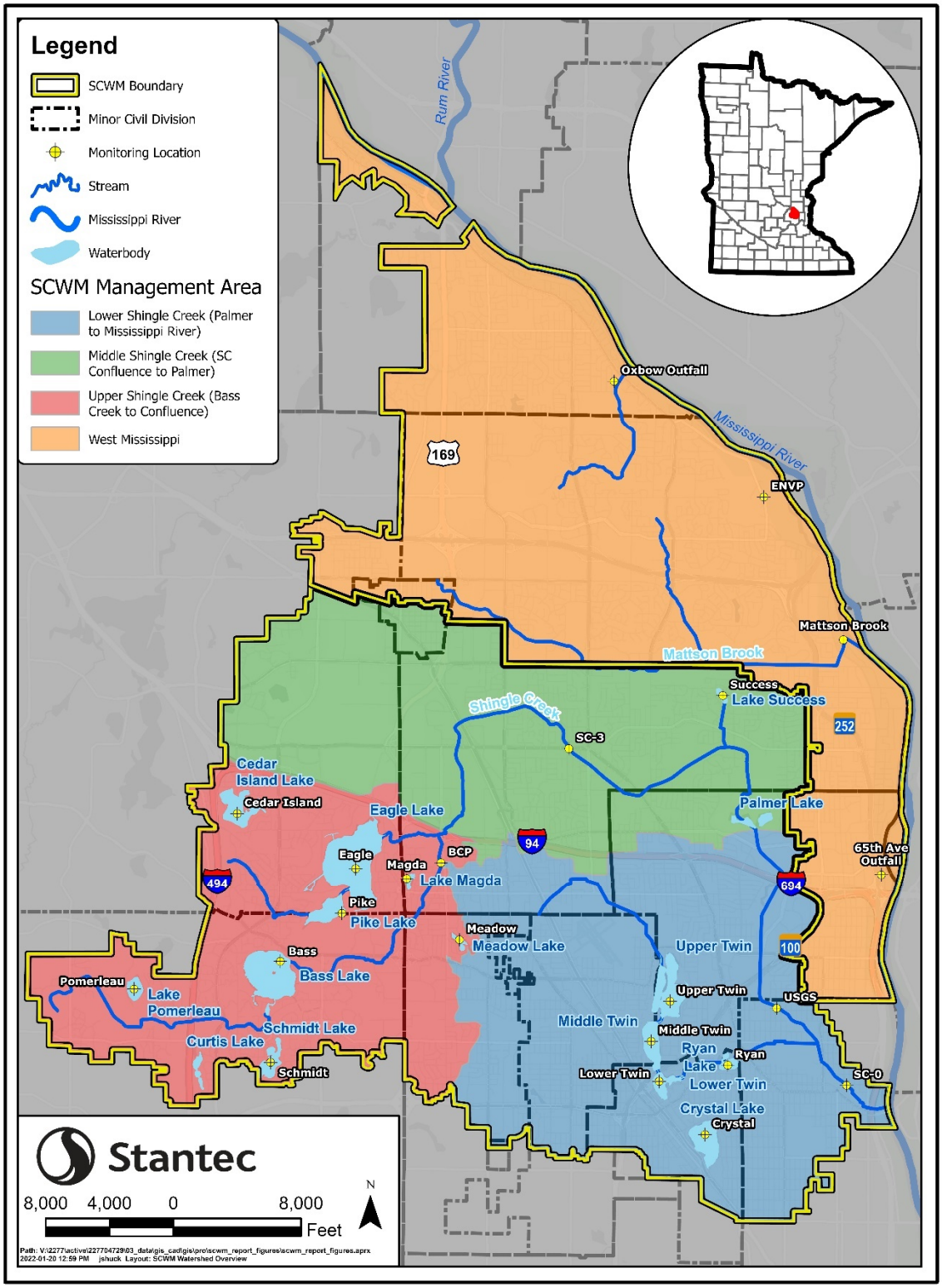


Figure 2. Overview and monitoring locations of the Shingle Creek and West Mississippi Watersheds.

Monitoring in 2021

Stream Monitoring

Routine Flow and Water Quality: Three sites along Bass and Shingle Creek were monitored biweekly from April through October: near the stream's outlet to the Mississippi River in Minneapolis (SC-0); mid-watershed in Brooklyn Park (SC-3); and in Bass Creek (BCP) in the upper watershed. Winter chloride was sampled monthly from November through March at the three locations mentioned and the USGS gage site (SC-1). In the West Mississippi Watershed, Mattson Brook (MB) was monitored monthly April through October and 65th Avenue was monitored year-round.

River Watch: Stream macroinvertebrates are typically monitored by high school students at two sites on Shingle Creek through the Hennepin County River Watch program, however the program has been affected by the COVID-19 pandemic. Shingle Creek at Park Center High School has been monitored for 24 years by science students from the school. Shingle Creek at Webber Park was monitored by students from Patrick Henry High School between 2001 and 2012, then in 2018, 2019, and 2021 by students from the Avail Academy.

Lake Monitoring

Routine Water Quality: Water quality in Cedar Island and Lake Success in Maple Grove was monitored biweekly from May through September as part of Shingle Creek's routing monitoring program. Aquatic vegetation was surveyed once in late spring and once in late summer. The carp and fish population of Cedar Island Lake were surveyed.

CAMP: Each year the Commission sponsors volunteer lake water quality monitoring through the Met Council's Citizen Assisted Monitoring Program (CAMP). Schmidt, Magda, Meadow, Eagle, and Pike Lakes were monitored in 2021.

Staff finds Northern (Pike) while conducting fish survey on Schmidt Lake, Plymouth MN.

Grant Projects: Crystal, Bass, and Pomerleau Lakes were monitored biweekly from June through September for water quality as part of grant projects. These lakes have all been listed as impaired for nutrients and are undergoing active management. Bass and Pomerleau Lakes received a second dose of alum in September 2020, following the first dose that occurred in May 2019. Crystal Lake underwent invasive carp removals in Summer 2021 and received its first dose of alum in September 2021. Water quality monitoring in the lakes has helped our understanding of changes in lake health following management activities.

Wetland Monitoring

The Shingle Creek and West Mississippi Watersheds typically sponsor wetland monitoring through the Wetland Health Evaluation Program (WHEP) administered by Hennepin County. There were no wetlands in either watershed monitored in 2021.

2021 in Review

This summary provides an overview of findings and conditions in the two watersheds in 2021. A more detailed assessment and data are available in the technical appendices, which can be found at shinglecreek.org/water-quality.html.

Rainfall

Water quality in lakes, streams and wetlands is heavily influenced by precipitation and storm water runoff. 2021 was a dry year. Precipitation in 2021 in the Shingle Creek and West Mississippi watersheds was below the historic average (1992-2021) each month except March, August and December. Total rainfall in 2021 was 26.0 inches, 7.5 inches below the historic average of 33.5 inches.

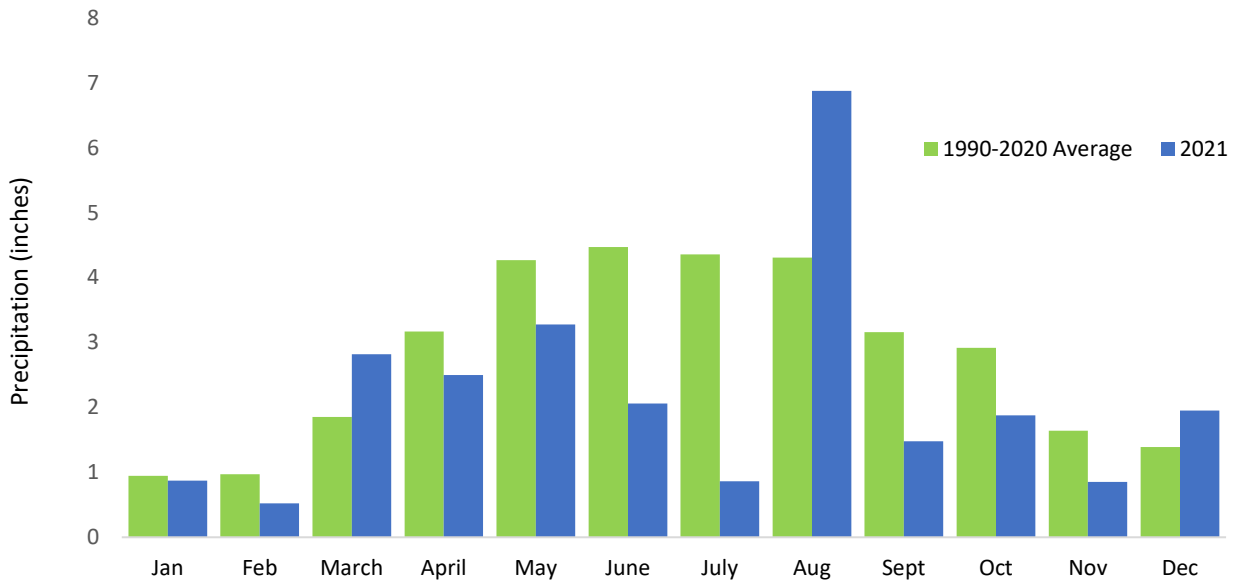


Figure 3. Monthly precipitation totals at the New Hope weather station for 1990-2021 and 2021.

Streams

Stream sites in Shingle Creek and West Mississippi Watersheds are monitored during normal, baseflow conditions (routine monitoring) and during rainfall events (storm monitoring) when flow is higher. Runoff during storms carries pollutants into the stream and can contribute to downstream water body impairments. Stream water quality during storms is often worse than during routine monitoring.

Shingle Creek

Flow at all the monitored Bass and Shingle Creek sites (BCP, SC-3, SC-0) and at the USGS gauge site were similar across sites and was largely driven by rainfall events in the watershed (Figure 4). The highest flows occur at the sites closest to the watershed outlet and the lowest flows occur near the headwaters (BCP). 2021 was a relatively dry year compared to historic precipitation averages (Figure 3), and total runoff from each monitoring site was the lowest it has been since 2003 (Appendix C). The small amount of runoff resulted in historically low TP and TSS loading to the watershed.

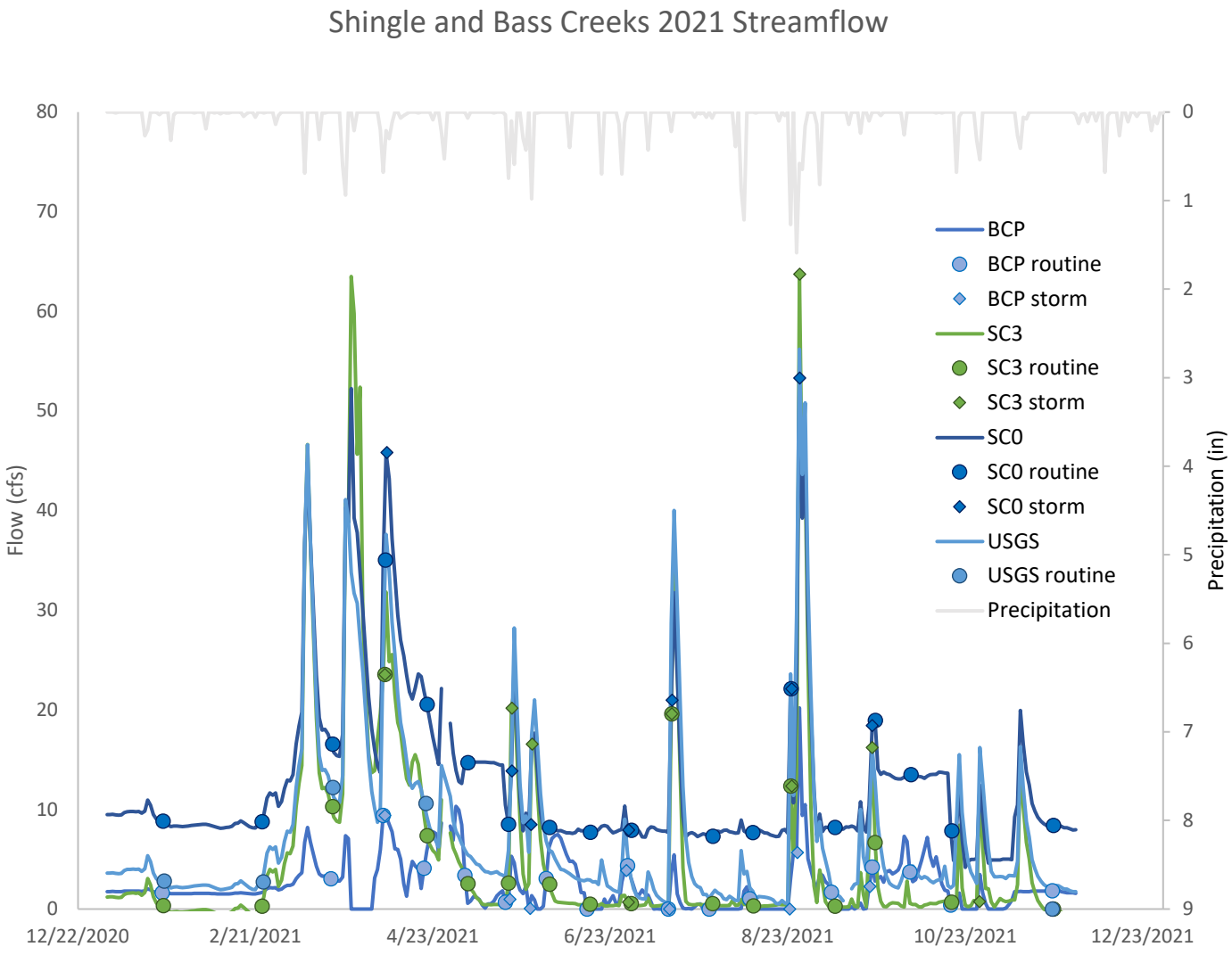


Figure 4. Flow, sample timing, and precipitation at monitored stream sites in the Shingle Creek Watershed during 2021.

Water quality at the Shingle Creek stream sites is generally worse during storm event monitoring (Figure 5). Average concentrations of chloride, *E. coli*, TP, and TSS during storm events were higher than during routine monitoring, with the exception of chloride. Chloride

samples were collected year-round but were highest during winter routine monitoring when road salt application occurs.

Annual pollutant loads of TP, TSS, and chloride were estimated for each monitoring site by multiplying the mean pollutant concentration by the annual volume of runoff at each site. Loads are highest near the Shingle Creek watershed outlet at site SC-0.

Table 1. Annual pollutant loads at each Shingle Creek routine monitoring site.

Site	TP Load (lbs/acre/year)	TSS Load (lbs/acre/year)	Chloride Load (lbs/acre/year)
BCP	0.09	11.2	112
SC-3	0.13	27.5	75
SC-0	0.10	19.13	97

Trends: Water quality data has been collected in Shingle Creek since 1996, and trend analysis shows significant changes to stream water quality. Soluble phosphorus concentrations are improving (decreasing) in both Shingle (SC-0 and SC-3) and Bass Creeks (BCP). TP and TSS has been significantly reduced at SC-0. Trends were not detected for dissolved oxygen, *E. coli*, or nitrogen.

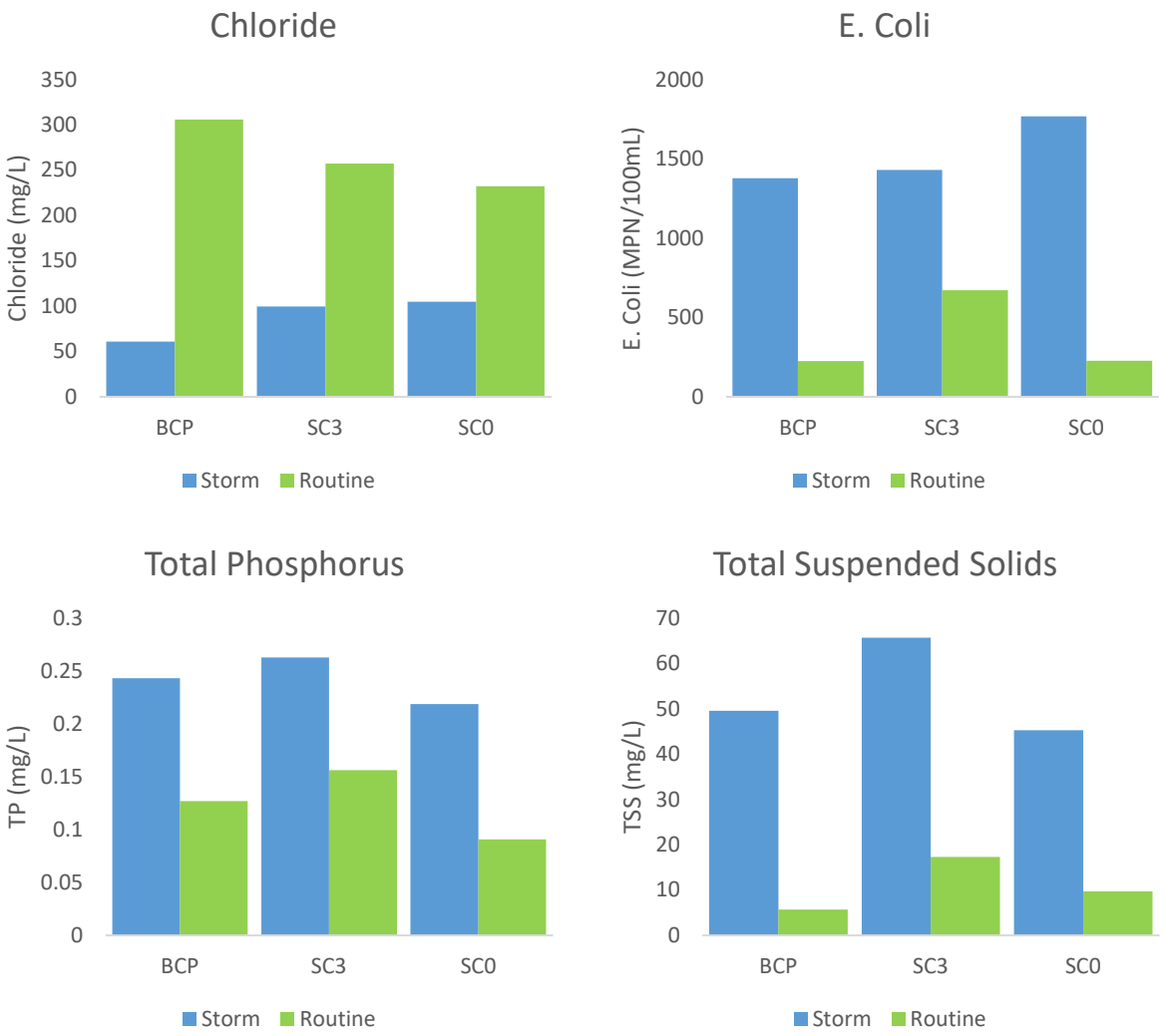


Figure 5. Average concentration of water quality parameters at Shingle Creek sites sampled during storm and routine monitoring in 2021.

West Mississippi

Flow at the Mattson Brook site was monitored starting end of March 2021, and the 65th Ave site was monitored for the entire year. Flow at the 65th Ave site in West Mississippi was much higher than at the Mattson Brook site (

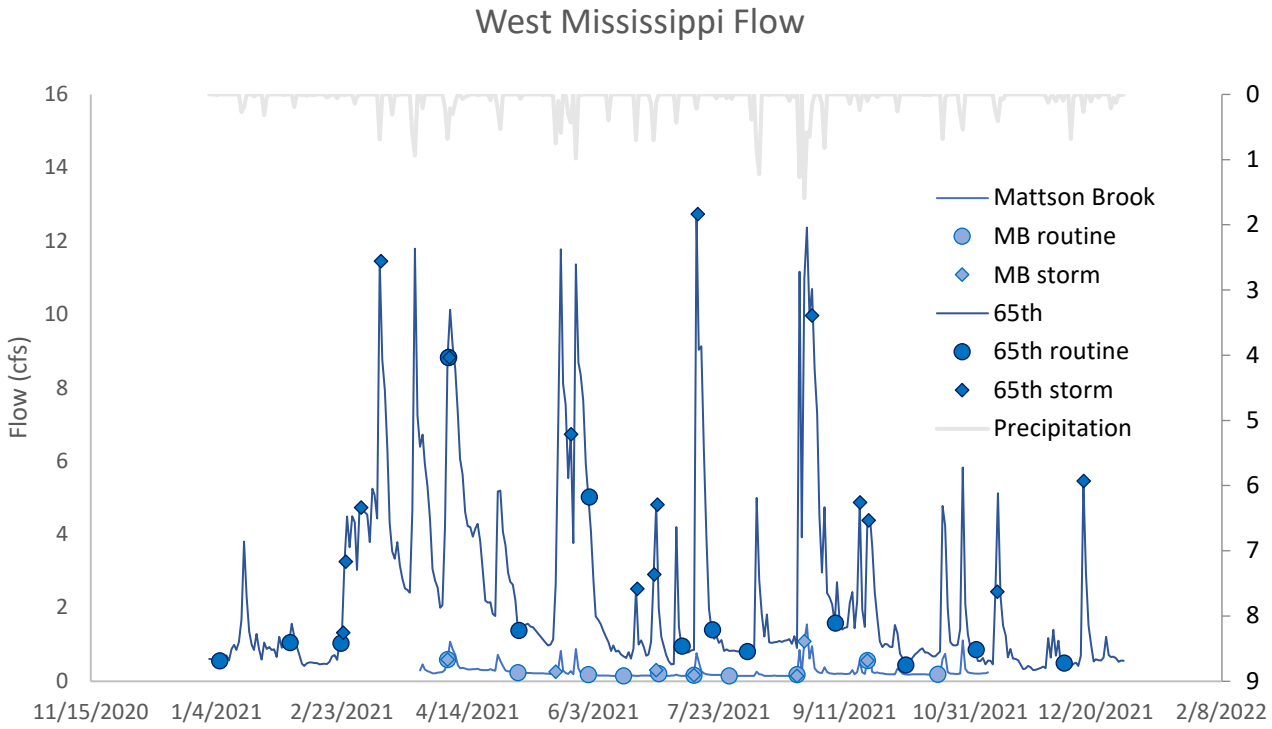


Figure *6*). Flow was highest following precipitation events.

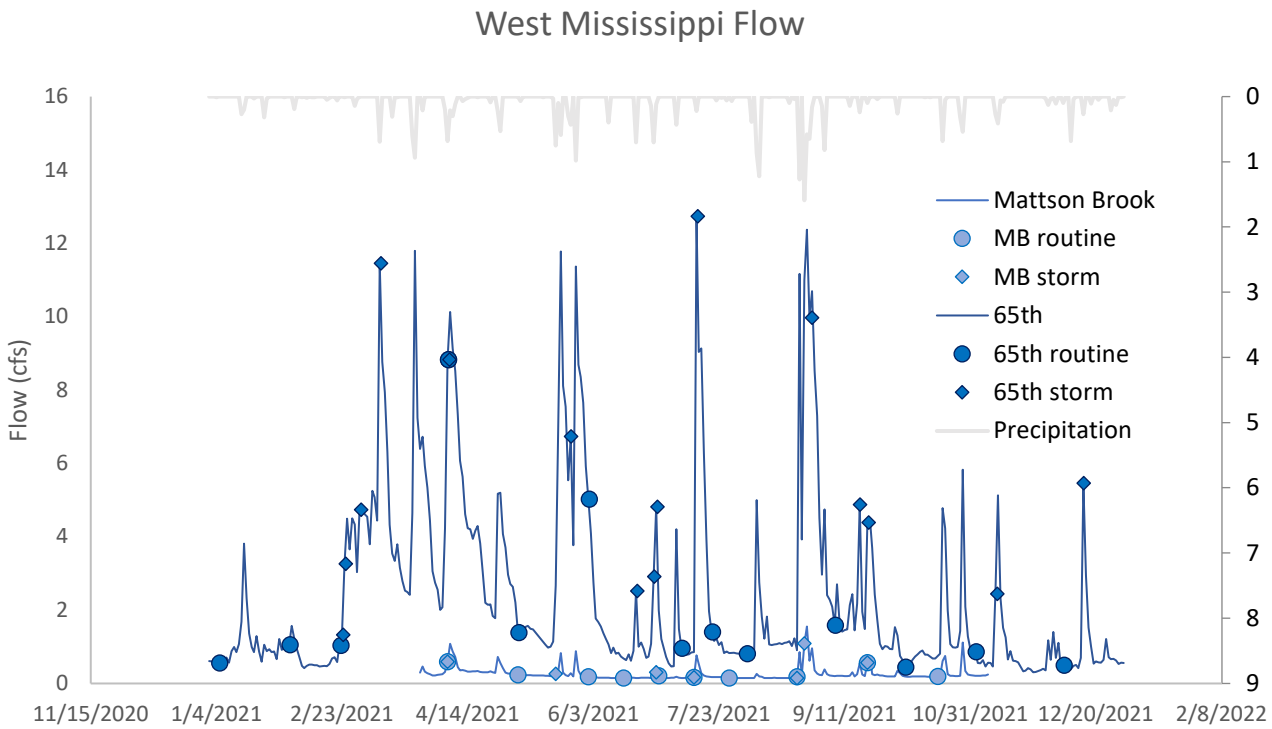


Figure 6. Flow, sample timing, and precipitation at monitored stream sites in the West Mississippi Watershed during 2021.

Similar to Shingle Creek stream sites, water quality (*E. coli*, TP, TSS) at West Mississippi sites was worse during storm events (Figure 7). Chloride is not monitored at these sites during winter months but is still higher in routine samples indicating a dilution effect of storm events on chloride concentrations.

Monitoring season pollutant loads of TP, TSS, and chloride were estimated for each monitoring site by multiplying the mean pollutant concentration by the volume of runoff during the monitoring season at each site. Year-round flow data for the Mattson Brook site were not available, preventing the calculation of an annual pollutant load. Pollutant loads at Mattson Brook are calculated for the monitoring season April 6 - September 20, 2021

Table 2. Monitoring season pollutant loads at West Mississippi routine monitoring sites.

Site	TP Load (lbs)	TSS Load (lbs)	Chloride Load (lbs)
Mattson Brook*	39	5,669	31,689
65th Ave**	766	127,607	1,191,165

* Mattson Brook load was calculated for the monitoring period April 6th – September 20th, 2021
** 65th Avenue load was calculated for the year 2021

Trends: Water quality data have been collected in the West Mississippi watershed since 2010. Trend analysis did not detect any trends in TP, ortho-P, TSS, *E. coli,* or chloride concentrations at Mattson Brook. Chloride concentrations have significantly increased at 65th Ave, likely due to the addition of winter monitoring at the site in 2020 and 2021 capturing snowmelt runoff. TP, ortho-P, and *E. coli* have significantly increased at 65th Ave.

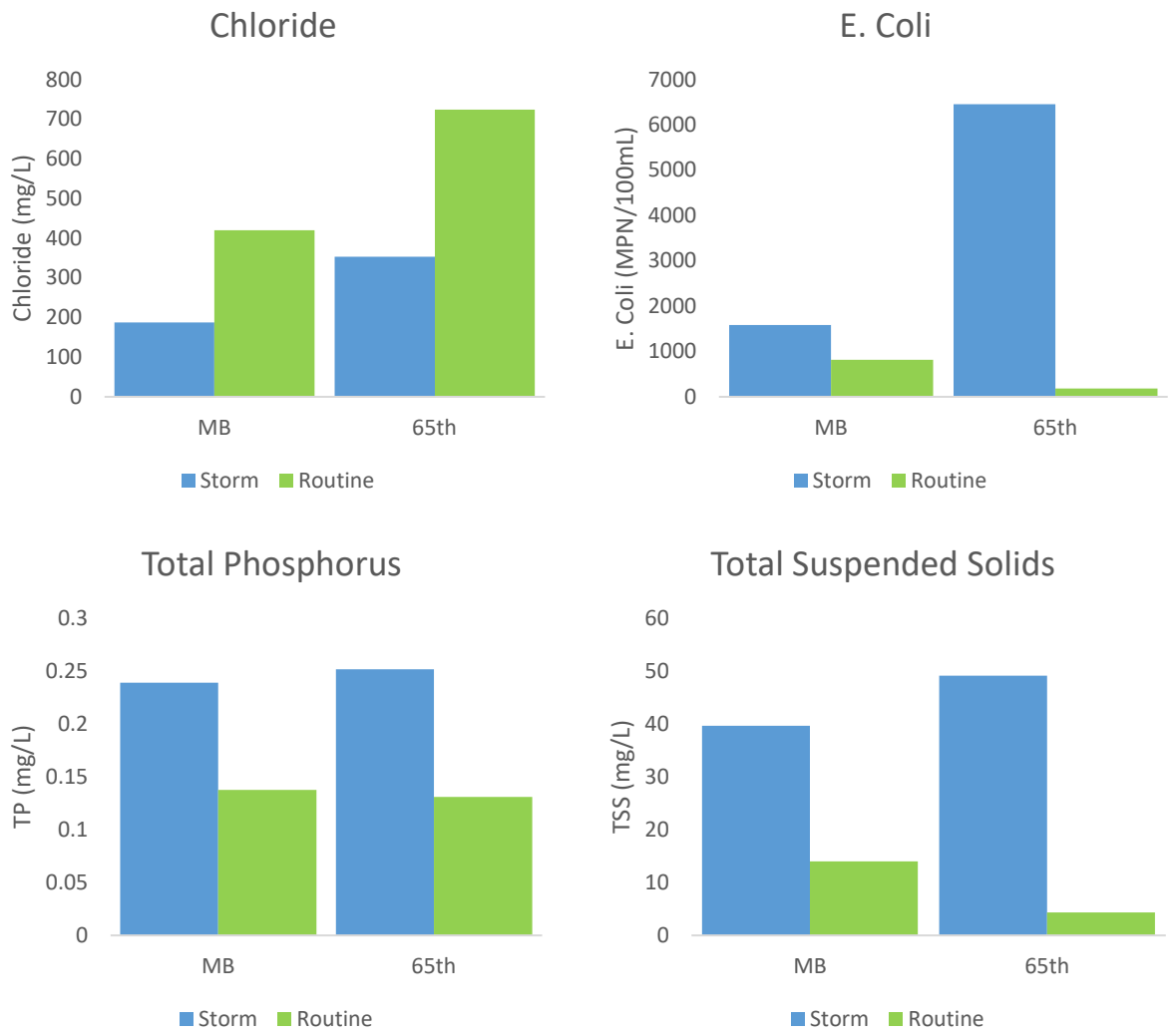


Figure 7. Average concentration of water quality parameters at West Mississippi sites sampled during storm and routine monitoring in 2021.

Chloride

Salt is entering our lakes and streams in the form of chloride from the use of road salt to deice, for water softening, and from fertilizer, manure, and dust suppressants. Once a water body is polluted with salt, it is virtually impossible to remove it. **All it takes is 1 teaspoon of salt to contaminate 5 gallons of water permanently!** Salt is of particular concern in the Shingle Creek watershed because Shingle and Bass Creeks are impaired due to chloride. The chloride impairment affects fish, plants, and invertebrates that live in and near the streams; high chloride concentrations disrupt organisms' ability to function and can result in a stream devoid of life.

In many water bodies, the relationship between chloride concentrations and specific conductivity is linear, meaning specific conductivity measurements can be used to estimate chloride concentrations. Specific conductivity and flow data are collected every 15 minutes at

the USGS gage station on Shingle Creek, providing a long-term, continuous dataset to evaluate changes over time and other patterns. Figure 8 shows estimated chloride concentrations and flow at the USGS site in 2021. The highest chloride concentrations occur in winter and early spring when snowmelt events carry recently applied road salt into the creek. In summer, rain events usually result in a dilution in chloride concentrations.

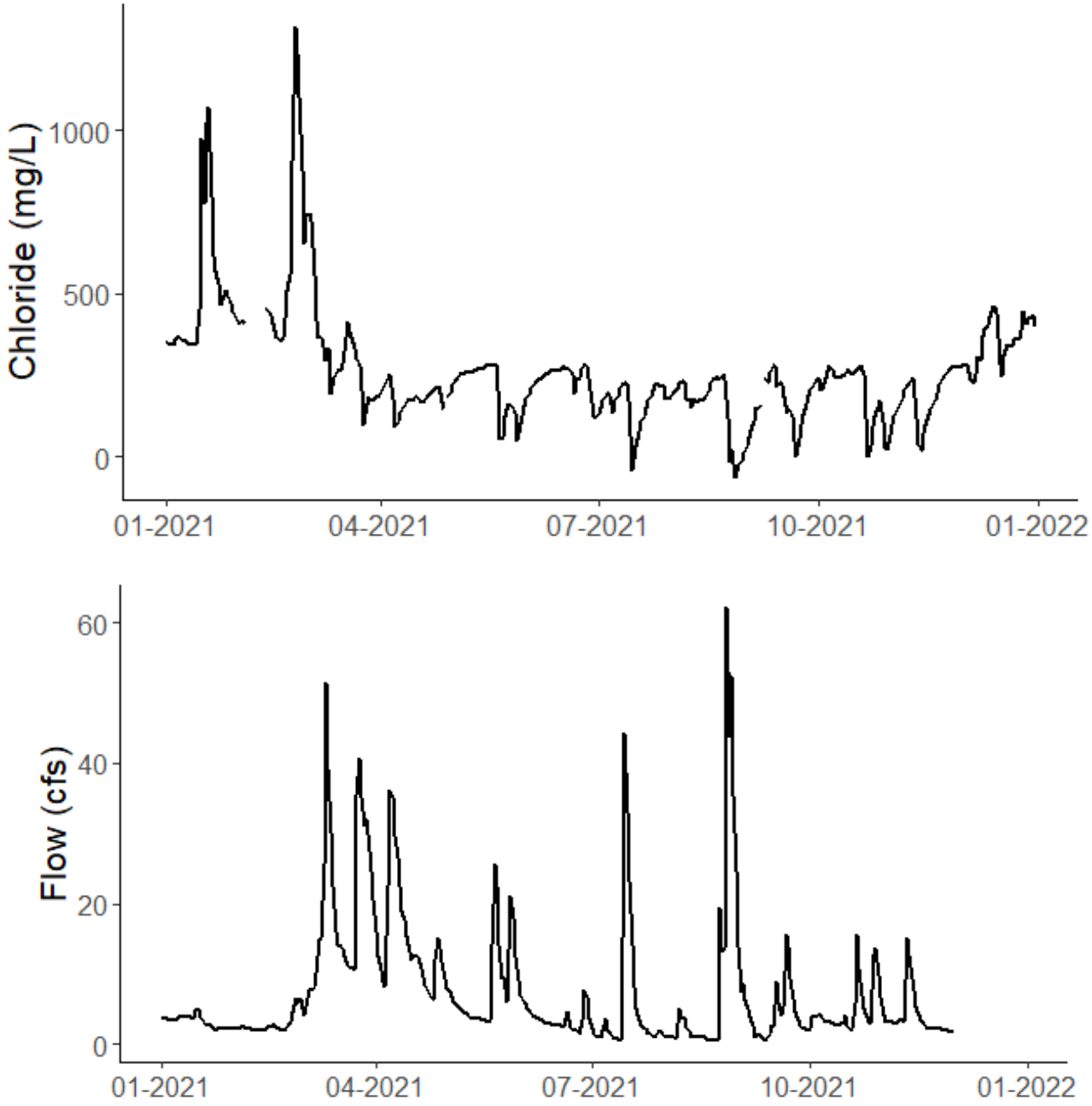
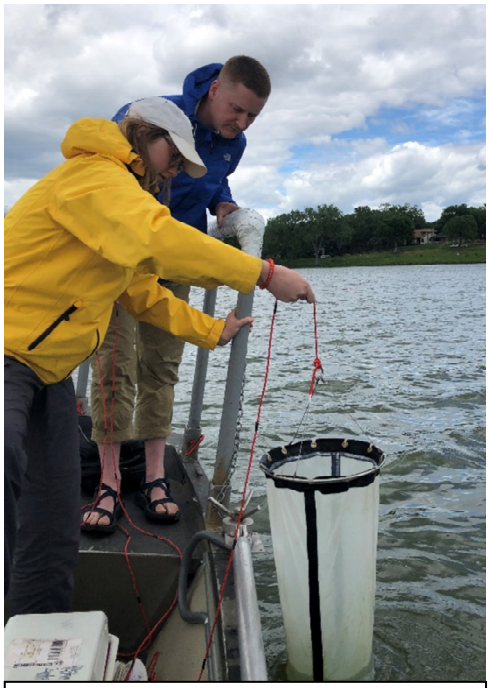


Figure 8. 2021 estimated chloride concentrations and flow at the USGS gage site on Shingle Creek at Queen Ave in Minneapolis.

Lakes

Five lakes were monitored by the Commission in 2021 as part of the routine monitoring program or grant projects. Lakes were visited 10 times from early June through the end of September. Water quality in the lakes was measured as Secchi depth, TP concentration, and chlorophyll-*a* concentration. Submersed aquatic vegetation (SAV) communities were surveyed in all five lakes. The health of the SAV community was measured using the Floristic Quality Index (FQI) and species richness. The second year of routine zooplankton and phytoplankton samples were taken in all five lakes in mid and late summer to assess the plankton community and how it changes over the monitoring season. Adding plankton samples to the routine monitoring program helps inform a holistic view of lake health at every trophic level.



Staff raise a plankton net out of the water to sample the zooplankton and phytoplankton communities of lakes in the watershed.

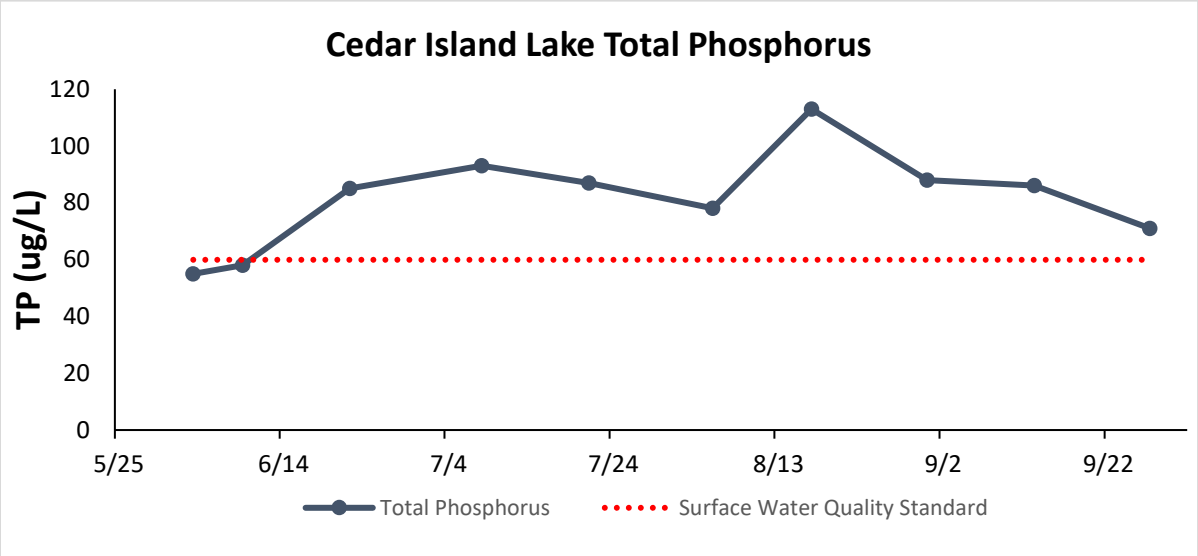
A brief overview of water quality, and SAV, phytoplankton, and zooplankton communities for all five monitored lakes is provided below. For more detailed data and analysis including fisheries assessments, methods, and long-term water quality data, see Appendix D.

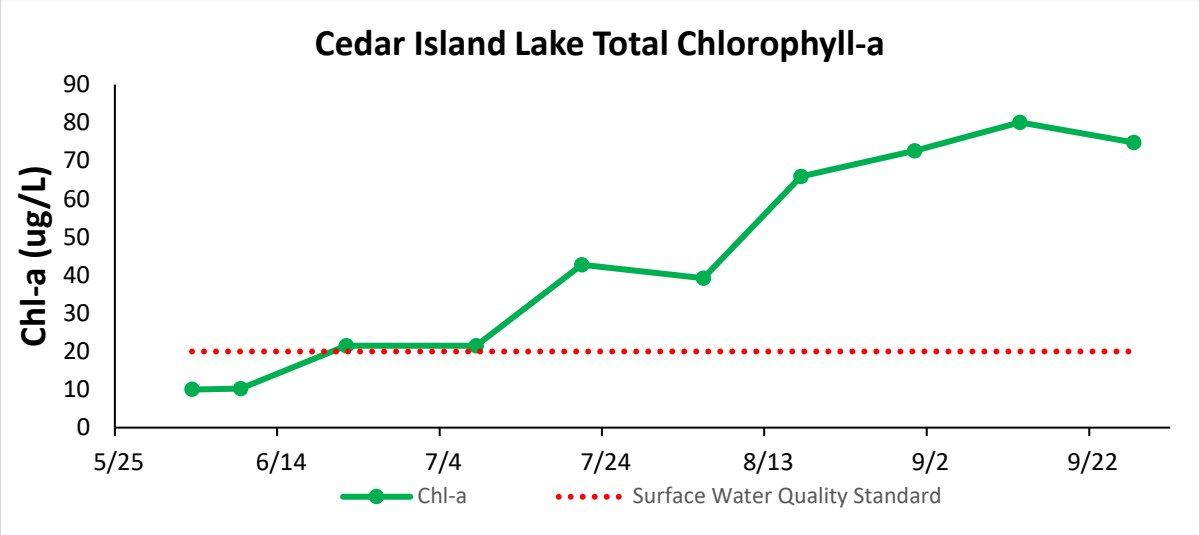
Cedar Island Lake

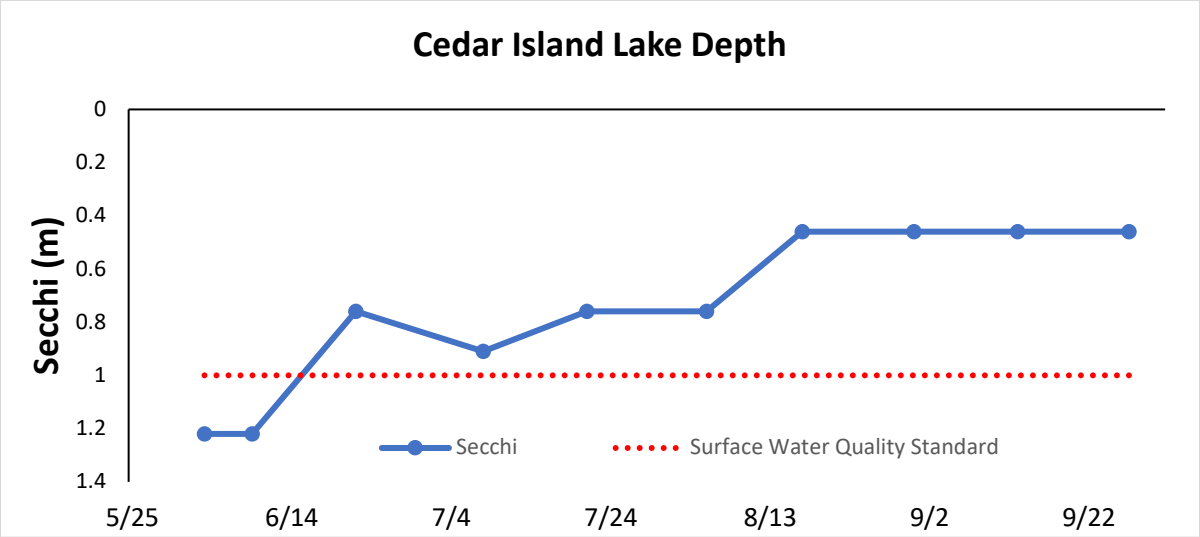
Cedar Island is a shallow lake in Maple Grove, MN. Water quality in the lake was sampled approximately biweekly from June through September 2021. Two SAV surveys were completed, one in early summer and one in late summer to document the vegetation community and how it changes over the growing season. The phytoplankton and zooplankton communities were sampled in mid-summer and late summer. The fish community and common carp population was surveyed in 2021.

Cedar Island Lake, Maple Grove MN

*Cedar Island Lake is impaired for nutrients. Water quality declined over the course of the growing season in 2021 and mostly did not meet the State's shallow lake standards (*Figure 9







). TP exceeded the standard of 60 ug/L for most of the monitoring period. Chlorophyll-a, a measure of algal abundance in lake water, increased over the monitoring period. Water clarity, measured as Secchi depth, was generally poor with as little as 1.5 feet in visibility.

The zooplankton and phytoplankton communities of Cedar Island Lake were sampled in June and September 2021. Figure 10 shows the phytoplankton community in Cedar Island Lake. The community shifted from chlorophyta (green algae) in summer to cyanobacteria (blue algae) in the fall, additionally experiencing an increase in dinoflagellates in the fall. Zooplankton shifted from *bosmina*-dominated in summer to *daphnia*-dominated (Figure 11). The shift in zooplankton was unexpected for a typical Minnesota Lake.

The aquatic vegetation surveys in Cedar Island Lake showed low species diversity (Figure 12). Only 8 species were observed in 2021 and coontail, a native but sometimes nuisance aquatic plant, was the dominant species during both surveys. Other species observed include muskgrass, curly-leaf pondweed, straight-leaved pondweed, waterlily, and duckweed. Curly-leaf pondweed was found in low abundance.

Eight fish species were sampled during the fish survey: black bullhead, black crappie, bluegill, central mudminnow, green sunfish, hybrid sunfish, largemouth bass, and pumpkinseed sunfish. No common carp were sampled during the survey.

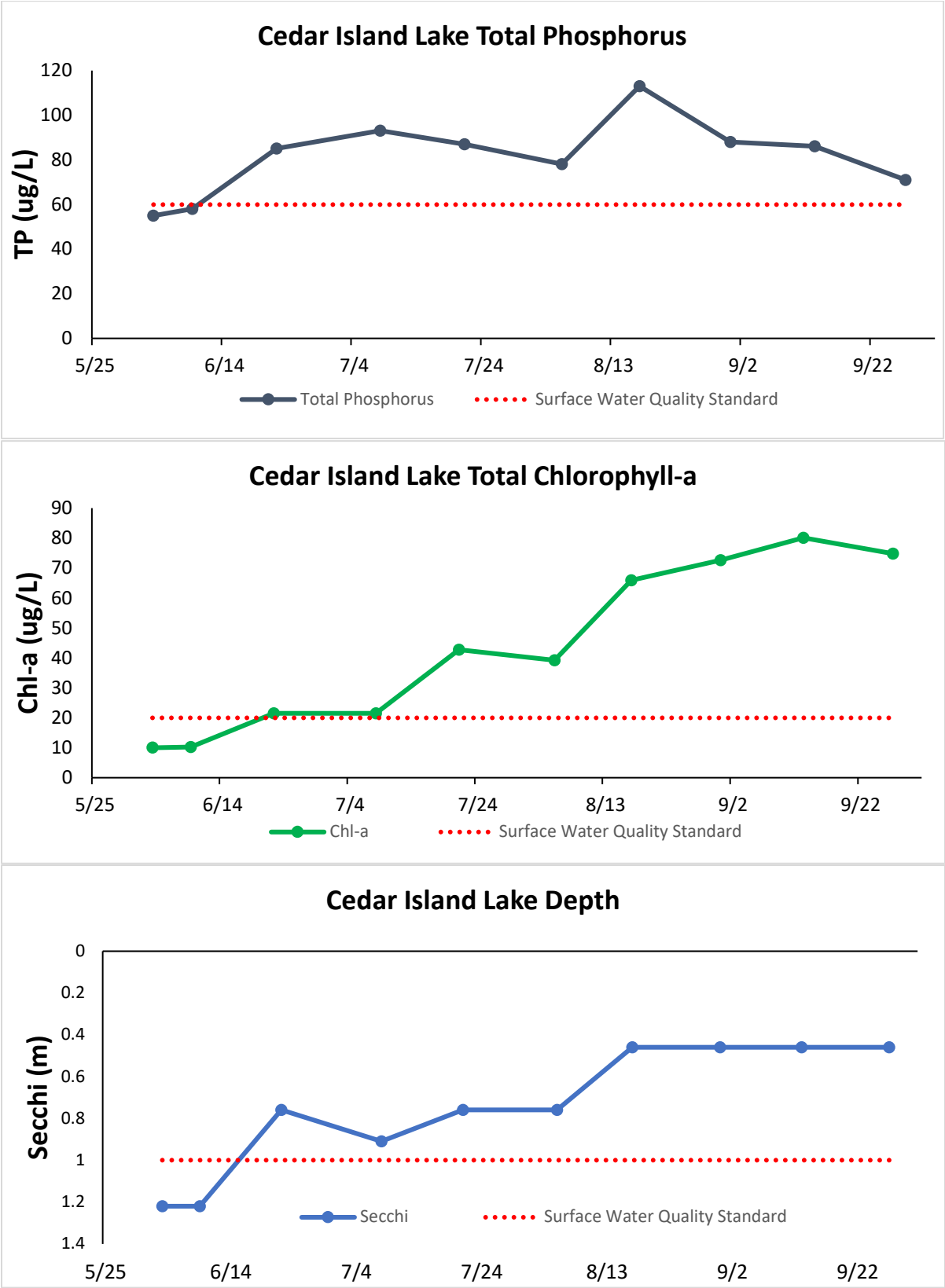


Figure 9. Water quality parameters in Cedar Island Lake during the 2021 monitoring season.

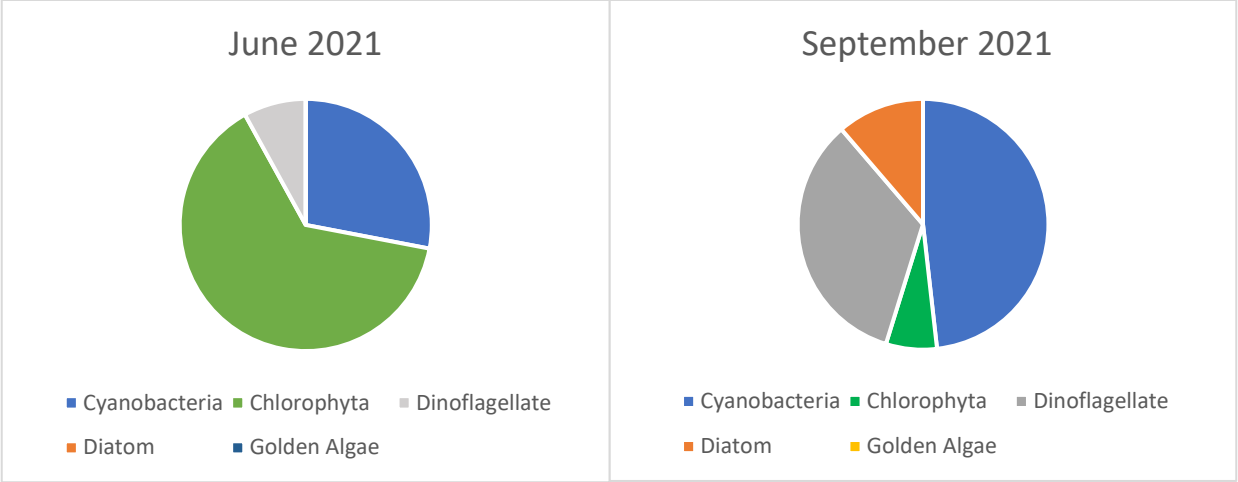


Figure 10. Phytoplankton community as relative percentage from June and September 2021 in Cedar Island Lake.

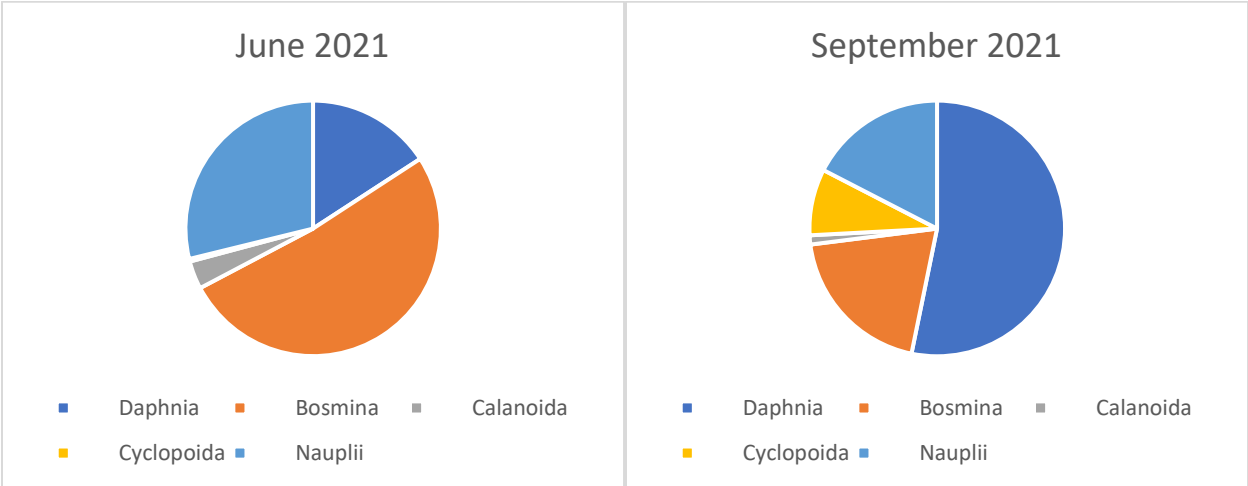


Figure 11. Zooplankton community as relative percentage from June and September 2021 in Cedar Island Lake.

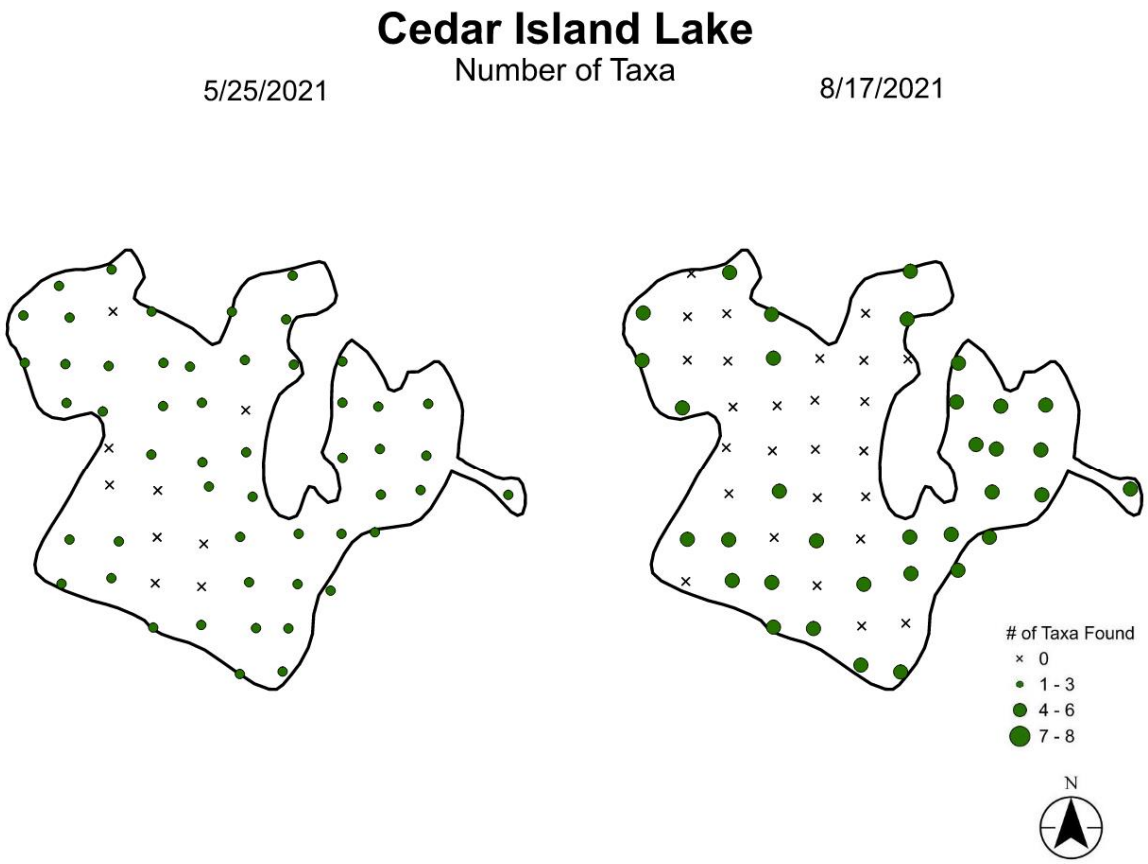


Figure 12. Submersed aquatic vegetation (SAV) showing number of taxa found at each location on Cedar Island Lake during the early and late summer surveys.

Lake Success

Staff toss a rake over the side of the boat to sample vegetation in Lake Success.

Lake Success is a small waterbody in Brooklyn Park. Water quality in the lake was sampled biweekly from June through September 2021. Two SAV surveys were completed, one in early summer and one in late summer, to document the vegetation community and how it changes over the growing season. The phytoplankton and zooplankton communities were sampled in mid-summer and late summer.

Lake Success is not listed as impaired because of lack of data, but water quality has been in decline in recent years. Figure 13 shows TP, chlorophyll-a, and Secchi depth over the course of the monitoring season. Data are shown against the shallow lake standard for reference. Total phosphorus exceeded the standard for most of the season. Chlorophyll-a peaked in late summer, indicating an algae bloom. The increase in chlorophyll-a occurred simultaneously with decreased water clarity.

Straight-leaved pondweed sampled in Lake Success in August 2022.

An analysis of the phytoplankton and zooplankton within the lake indicated a healthy, balanced community. The phytoplankton community was dominated by cyanobacteria during both sampling events, and in late summer was the only genera found in the lake causing a harmful algae bloom (HAB) (Figure 14). The sole genera was *Microcystis*, which is an aggressive, bloom-forming cyanobacteria that has the potential for toxin production. The zooplankton community reflected changes in algae (Figure 15). In late summer, the community shifted to being dominanted by *bosmina*, which are a group of zooplankton that can feed on low quality food sources like cyanobacteria and have an advantage in late summer.

Very little vegetation was found in Lake Success during the early and late summer SAV surveys (Figure 16). Only 4 species were observed: muskgrass, curly-leaf pondweed, straight-leaved pondweed, and duckweed.

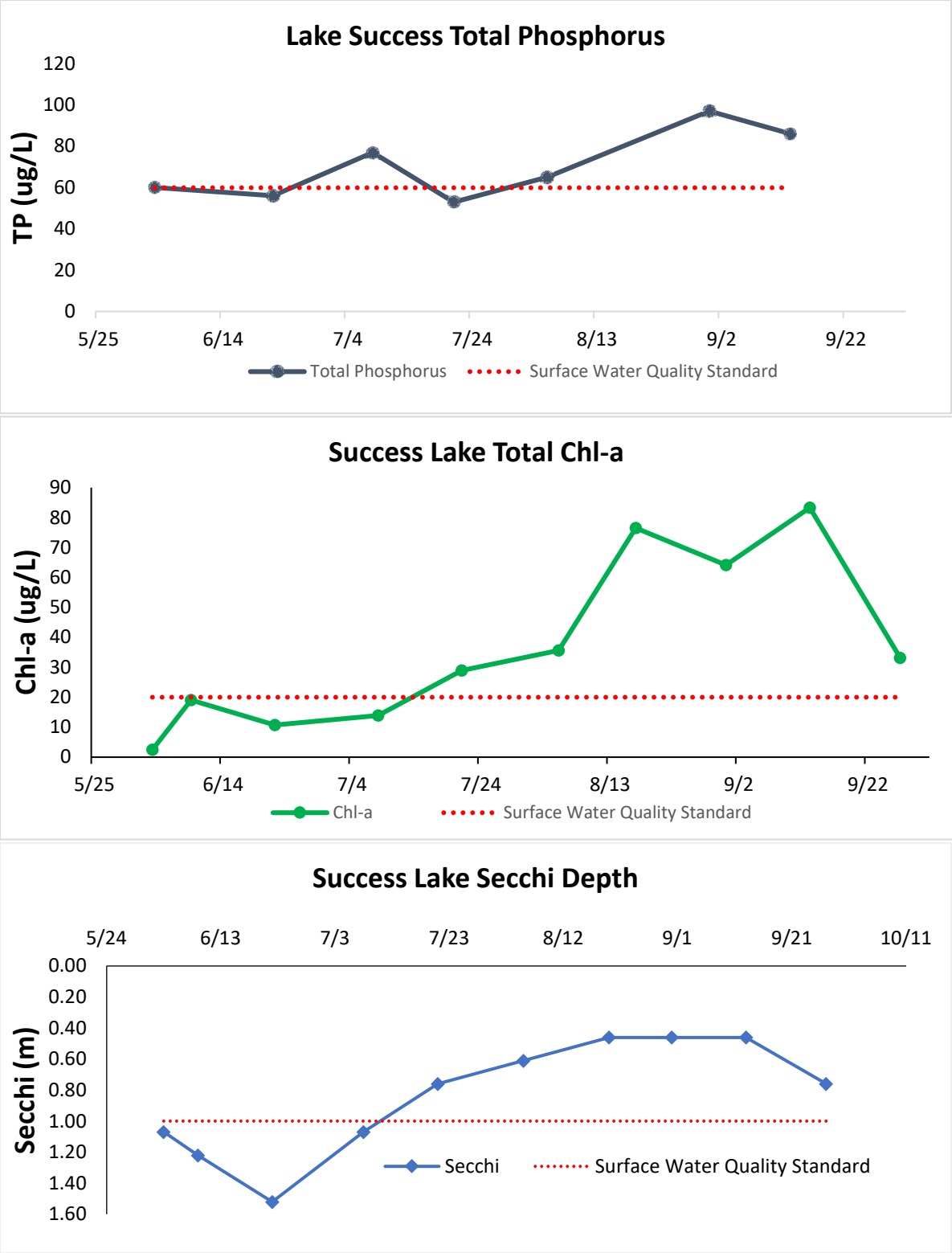


Figure 13. Water quality parameters in Lake Success during the 2021 monitoring season.

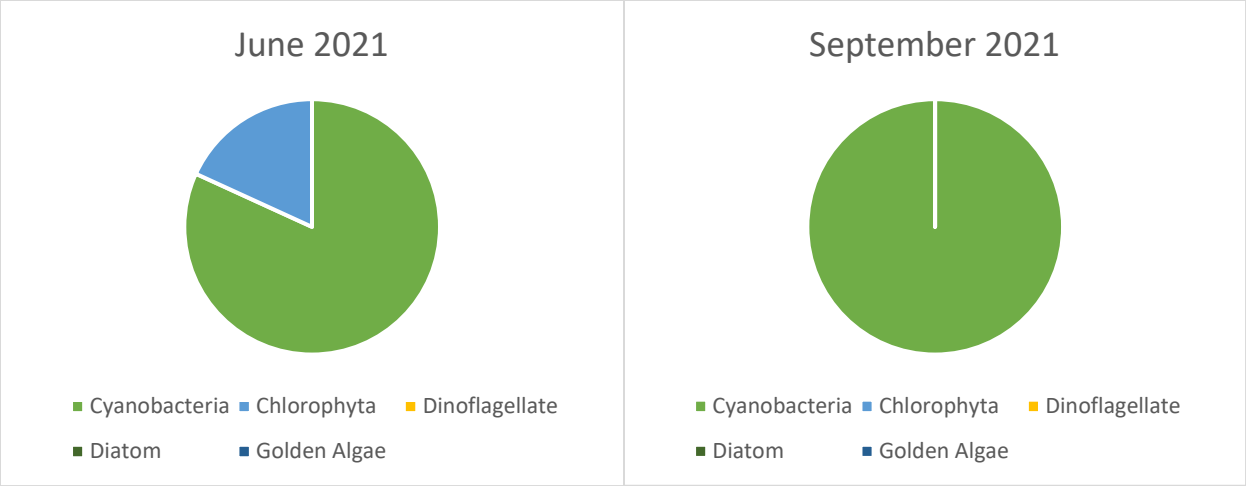


Figure 14. Phytoplankton community as relative percentage from June and September 2021 in Lake Success.

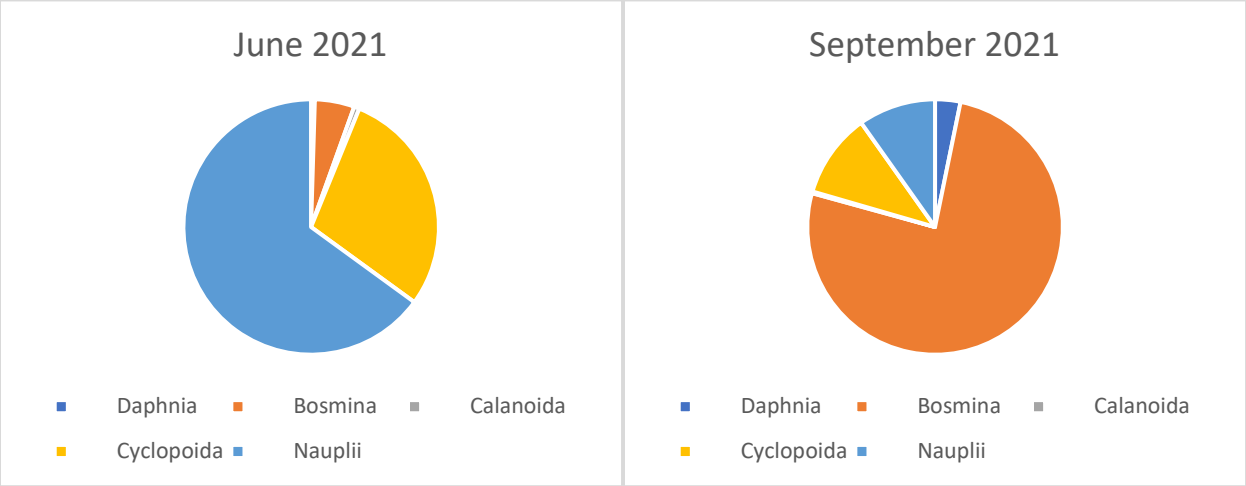


Figure 15. Zooplankton community as relative percentage from June and September 2021 in Lake Success.

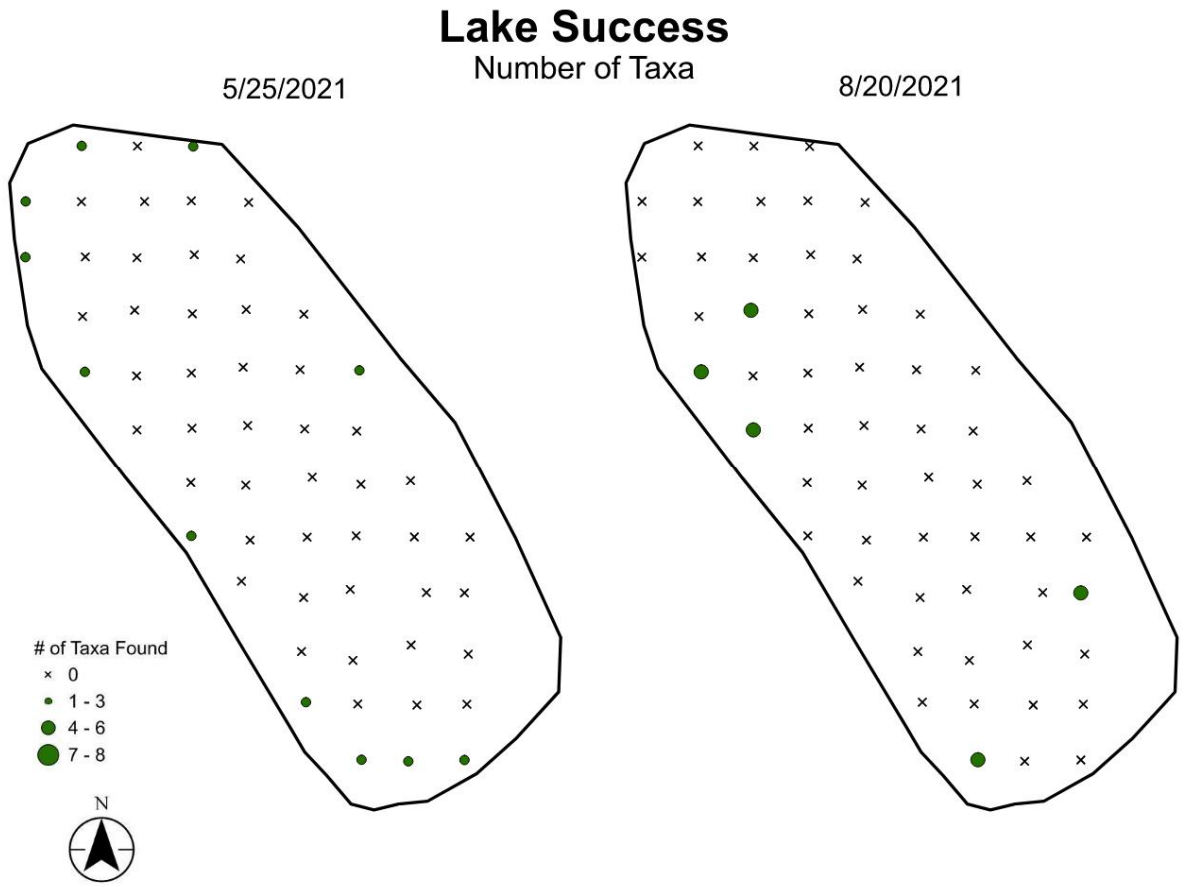


Figure 16. Submersed aquatic vegetation (SAV) showing number of taxa found at each location on Lake Success during the early and late summer surveys.

Bass Lake

Bass Lake, Plymouth MN.

Bass Lake is a shallow lake in Plymouth. Water quality in the lake was sampled biweekly from June through September 2021. Two SAV surveys were completed, one in early summer and one in late summer, to document the vegetation community and how it changes over the growing season. The phytoplankton and zooplankton communities were sampled in mid-summer and late summer. A delineation of curly-leaf pondweed was performed in April 2021. Delineated curly-leaf pondweed areas were treated with an herbicide in May 2021.

Bass Lake is impaired for nutrients and has undergone active management by the Commission in recent years. Bass Lake received its first alum treatment in May 2019. The second treatment was applied in September 2020 at the end of the monitoring season. In 2021, surface TP remained below the shallow lake standard during the entire monitoring season (Figure 17). Chlorophyll-a concentrations increased in mid-summer, exceeding eutrophication standards and indicating an algae bloom. Secchi depth decreased over the course of the summer. Despite declines in water quality in late summer, the lake experienced the best seasonal average water quality on record. TP samples taken from the hypolimnion remained low throughout the monitoring season, like in 2019 and 2020, indicating the efficacy of the 2019 alum treatment. See Appendix D for historical and hypolimnetic water quality data.

An analysis of the phytoplankton and zooplankton within the lake indicated a healthy community. The phytoplankton community was well-balanced in early summer, with diatoms, dinoflagellates, chlorophyta, and cyanobacteria (Figure 18). In late summer, the community shifted to cyanobacteria dominant. Cyanobacteria became slightly more dominant in late summer, a normal shift as water temperature is warmer. The zooplankton community shifted from nauplii-dominated to a more even distribution of groups in late summer (Figure 19). Nauplii are the early stage of many zooplankton species. Their abundance in early summer indicates a healthy zooplankton community with a plentiful food source.

SAV surveys in Bass Lake showed good vegetation growth in the lake and control of curly-leaf pondweed growth (Figure 20). Curly-leaf pondweed was found at 61 locations shortly before herbicide treatment in May, and by August was only observed at two locations. Sixteen species were observed in 2021.

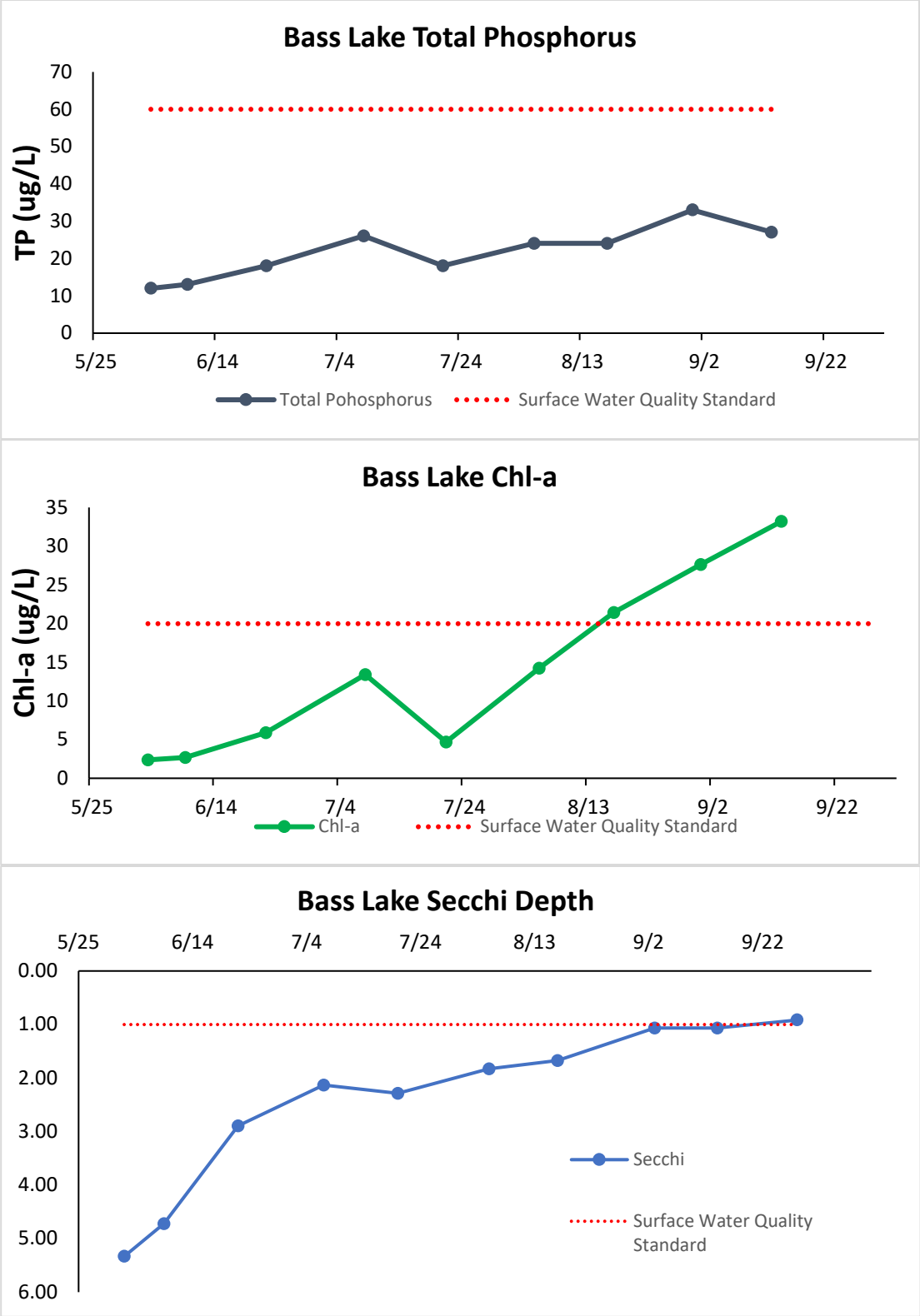


Figure 17. Water quality parameters in Bass Lake during the 2021 monitoring season.

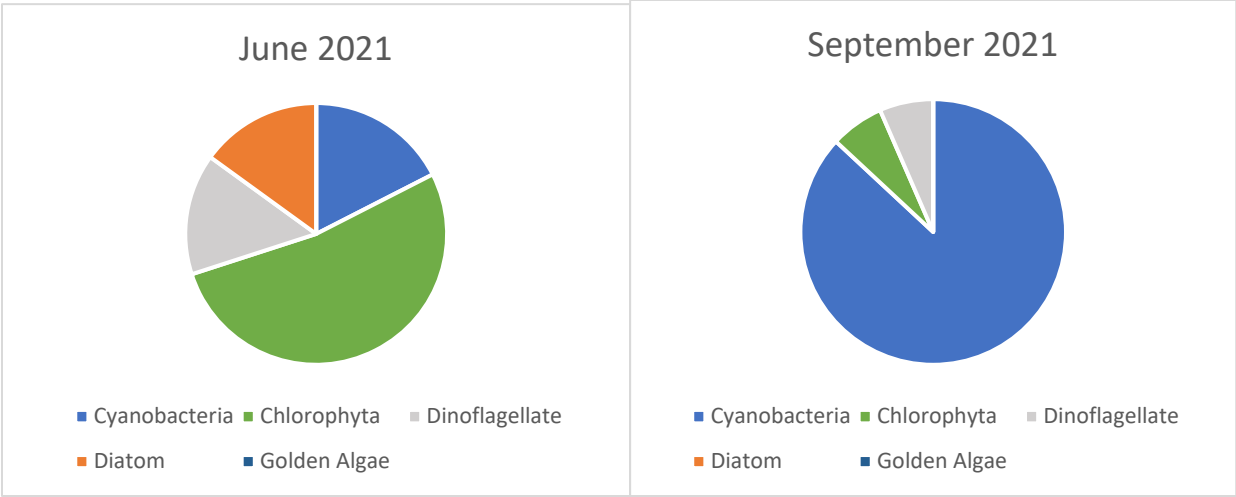


Figure 18. Phytoplankton community as relative percentage from June and September 2021 in Bass Lake.

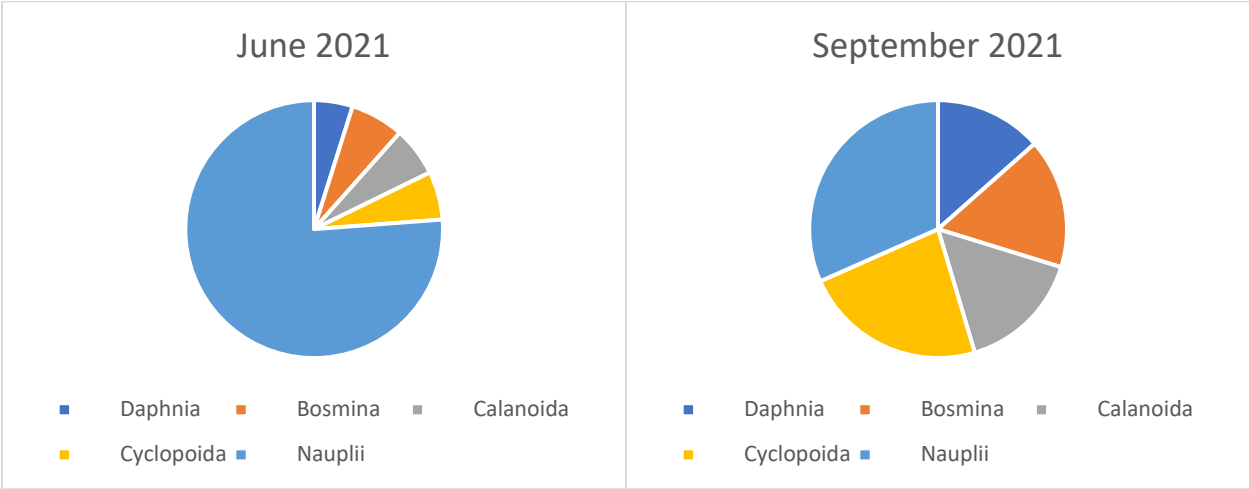


Figure 19. Zooplankton community as relative percentage from June and September 2021 in Bass Lake.

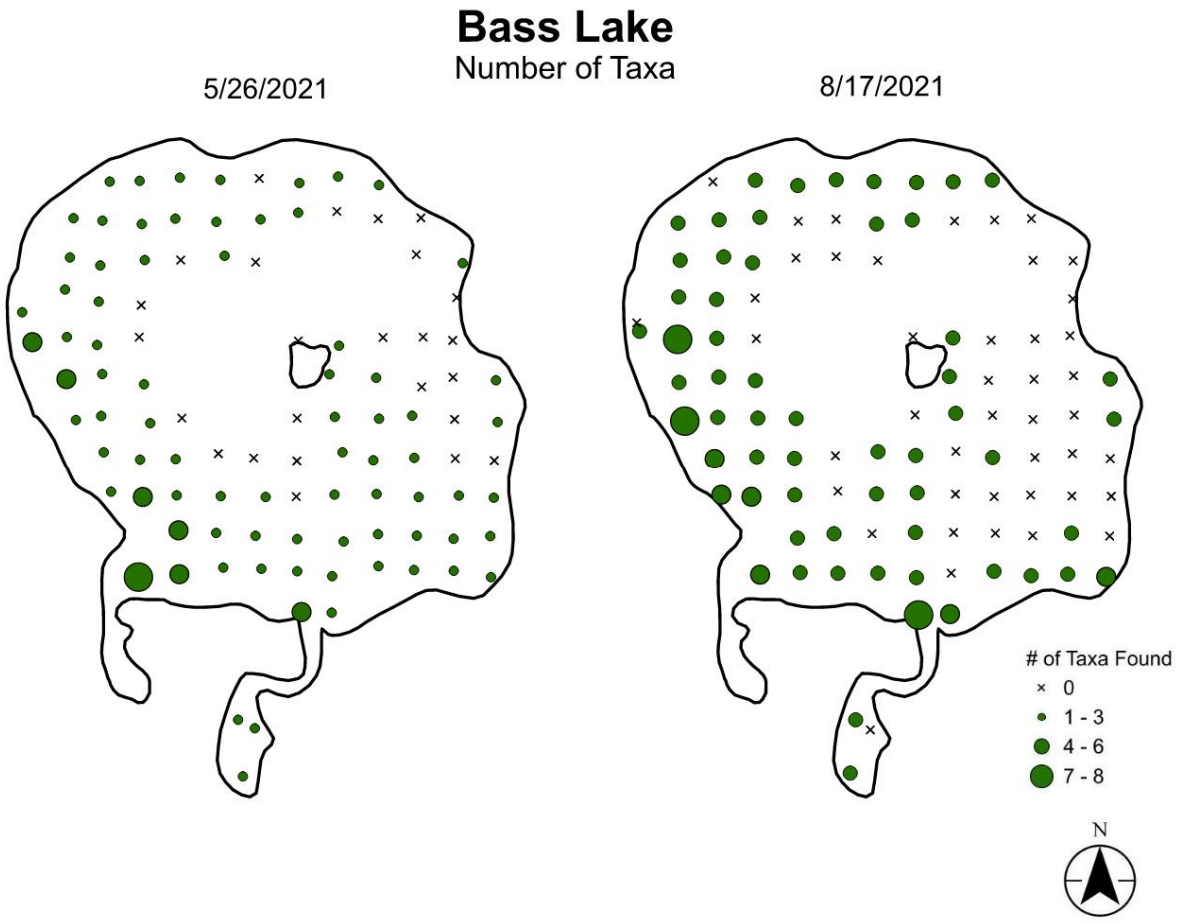


Figure 20. Submersed aquatic vegetation (SAV) showing number of taxa found at each location in Bass Lake during the early and late summer surveys.

Pomerleau Lake

Pomerleau Lake is a deep lake in Plymouth. Water quality in the lake was sampled biweekly from June through September 2021. Two SAV surveys were completed, one in early summer and one in late summer, to document the vegetation community and how it changes over the growing season. A delineation of curly-leaf pondweed was performed in April 2021. Delineated curly-leaf pondweed areas were not treated. The phytoplankton and zooplankton communities were sampled in early summer and late summer.

Pomerleau Lake, Plymouth MN.

Pomerleau Lake is impaired for nutrients and has undergone active management by the Commission. Pomerleau Lake received its first alum treatment in May 2019. The second treatment was applied in September 2020 at the end of the monitoring season. Similar to 2020, water quality in 2021 was excellent. Surface TP, chlorophyll-a, and Secchi depth met deep lake eutrophication standards throughout the entire monitoring season (Figure 21). TP samples taken from the hypolimnion remained low throughout the monitoring season, similar to 2019 monitoring data, indicating the efficacy of the 2019 and 2020 alum treatments. See Appendix D for historic and hypolimnion data.

The phytoplankton community was largely made up of cyanobacteria in both mid and late summer (Figure 18). The only genera of cyanobacteria found in September was *Woronchinia*. *Woronchinia* are a toxin-producing cyanobacteria. The zooplankton community was dominated by nauplii in early summer and shifted to bosmina later in the summer (Figure 19). Bosmina commonly forage on low quality food sources like cyanobacteria.

SAV surveys in Pomerleau Lake showed good vegetation growth in the lake and relatively low abundance of curly-leaf pondweed (Figure 20). Coontail is the dominant species found in the lake. Coontail was found at 64 and 75 locations in early and late summer, respectively. White waterlily was next most common species found during both surveys. Fourteen species were observed in 2021, which shows good species diversity for a metro-area lake.

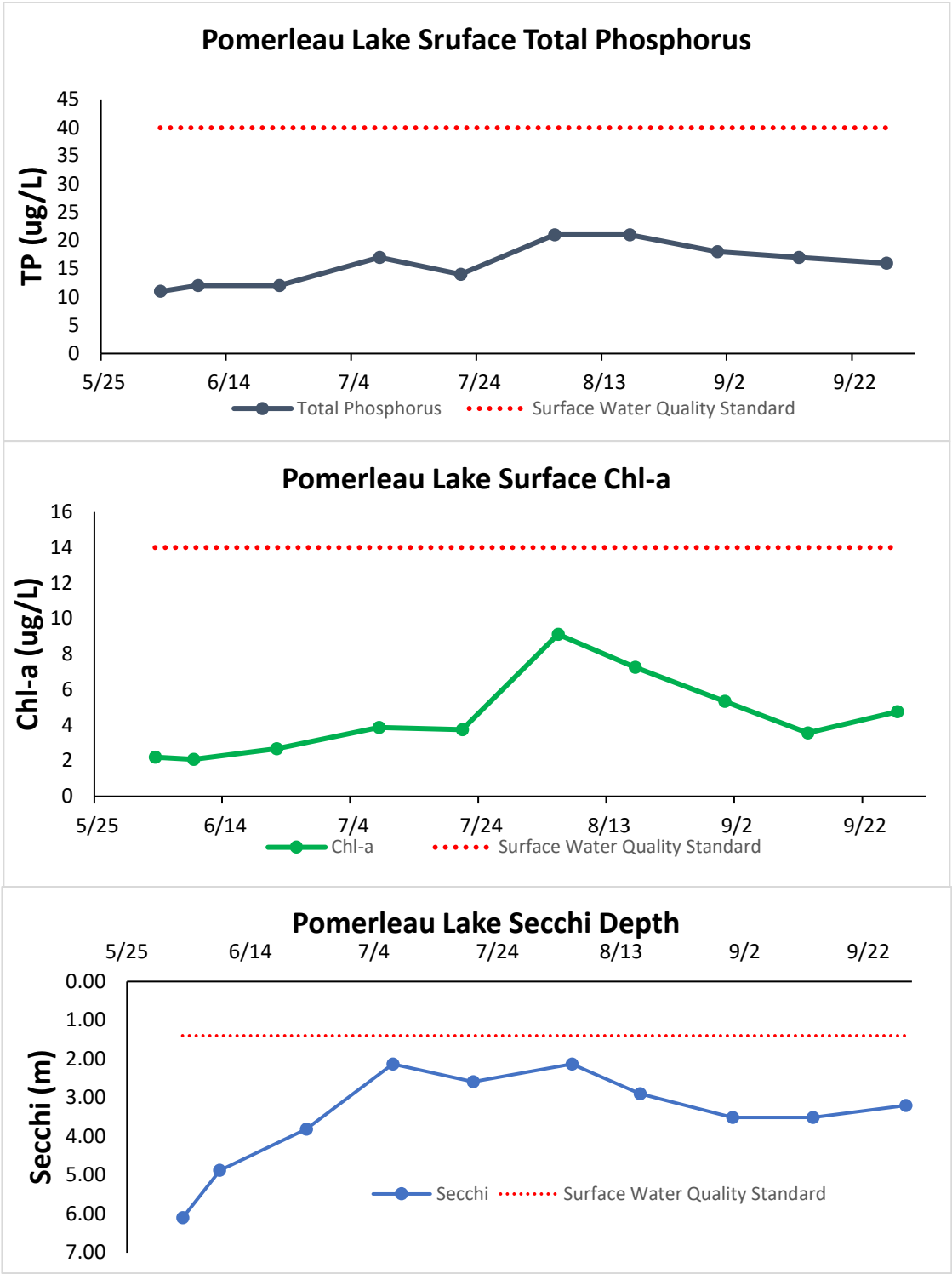


Figure 21. Water quality parameters in Pomerleau Lake during the 2021 monitoring season.

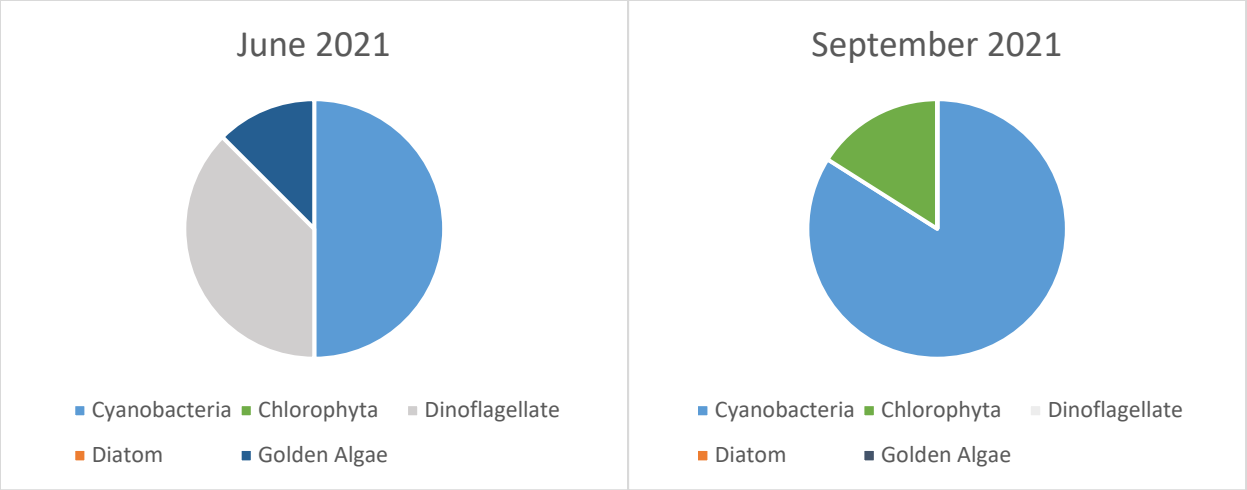


Figure 22. Phytoplankton community as relative percentage from June and August 2021 in Pomerleau Lake.

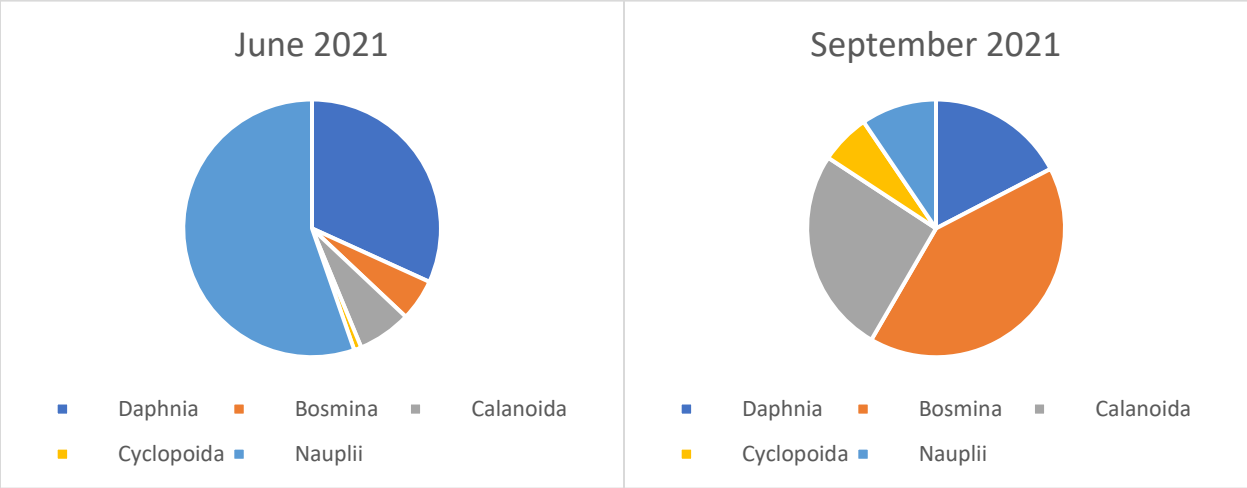


Figure 23. Zooplankton community as relative percentage from June and August 2021 in Pomerleau Lake.

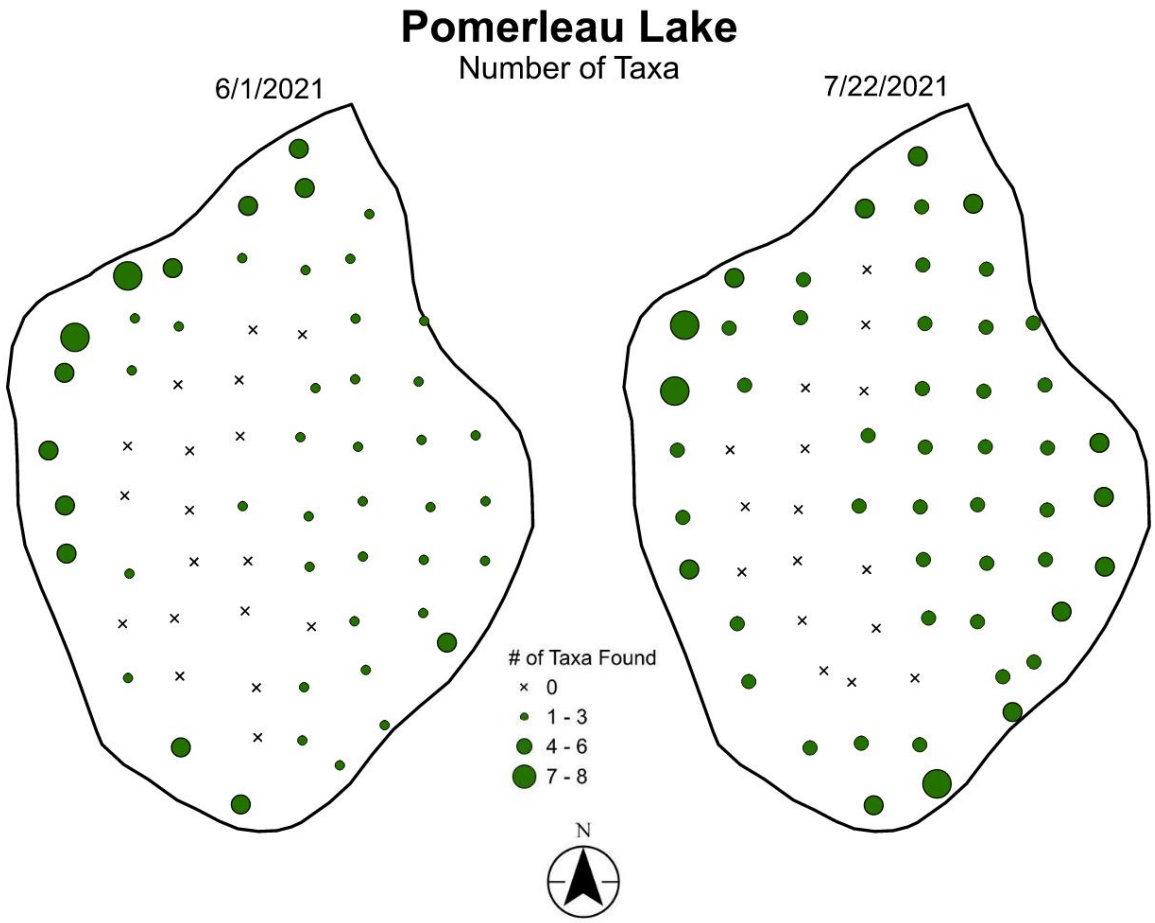


Figure 24. Submersed aquatic vegetation (SAV) showing number of taxa found at each location in Pomerleau Lake during the early and late summer surveys.

Crystal Lake

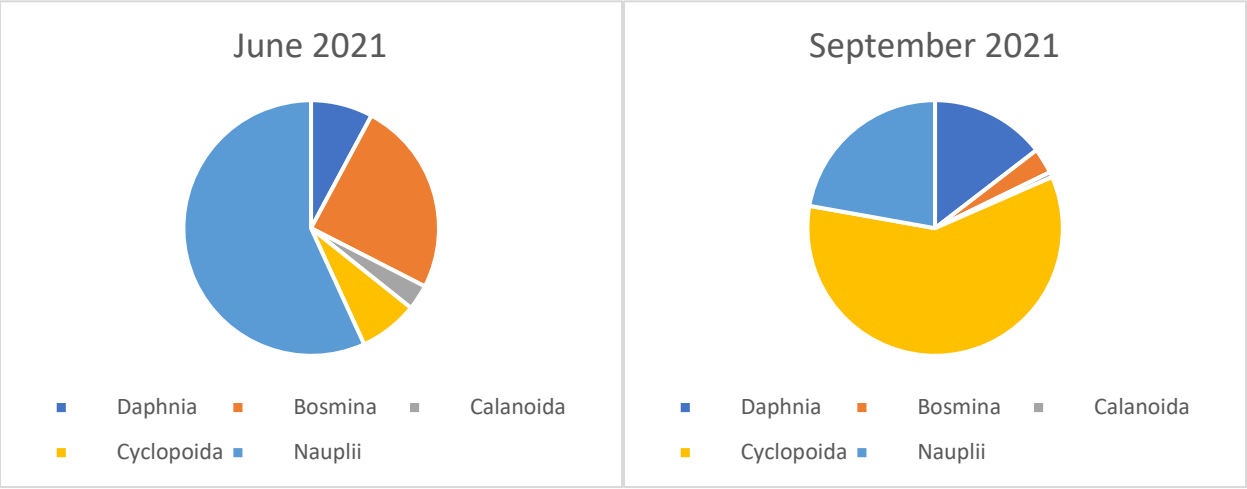
Crystal Lake, Crystal MN.

Crystal Lake is a deep lake in Robbinsdale. Water quality in the lake was sampled biweekly from June through September 2021. A mid-summer SAV survey was completed on the lake in 2021. The phytoplankton and zooplankton communities were sampled in early summer and late summer.

Crystal Lake is impaired for nutrients and is undergoing active management by the Commission. Over 3,000 common carp were removed from the lake in June and July 2021, and the lake received its first alum treatment in September 2021 to reduce internal phosphorus loading. The second alum treatment will be applied in late summer or fall 2022.

Surface TP exceeded the deep lake eutrophication standard for many of the sampling dates in 2021 and reached peak values in September (Figure 25). Chlorophyll-a concentrations exceeded the standard during all monitoring events. Secchi depth varied over the summer and did not meet the eutrophication standards for any monitoring event. TP samples taken from the hypolimnion show high concentrations, indicating internal loading from lake sediments during anoxic conditions. See Appendix D for historic and hypolimnion data.

*An analysis of the phytoplankton in Crystal Lake showed an early summer community dominated by cyanobacteria and a late summer community made up completely of cyanobacteria (*Figure 26*). Concentrations of cyanobacteria in late summer were very high and indicate the likelihood of a HAB. The zooplankton community shifted from nauplii-dominated in mid-summer to cyclopoida-dominated in late summer (*Figure 27



).

A mid-summer aquatic vegetation survey was performed on Crystal Lake in July 2021. As in 2020, only two species were observed during the survey: curly-leaf pondweed and white waterlily. Both species were found in very low abundance (Figure 28). The Crystal Lake vegetation community is in poor condition. Increased water clarity from the 2021 alum treatment and reduced foraging by common carp will support increased vegetation growth in the lake.

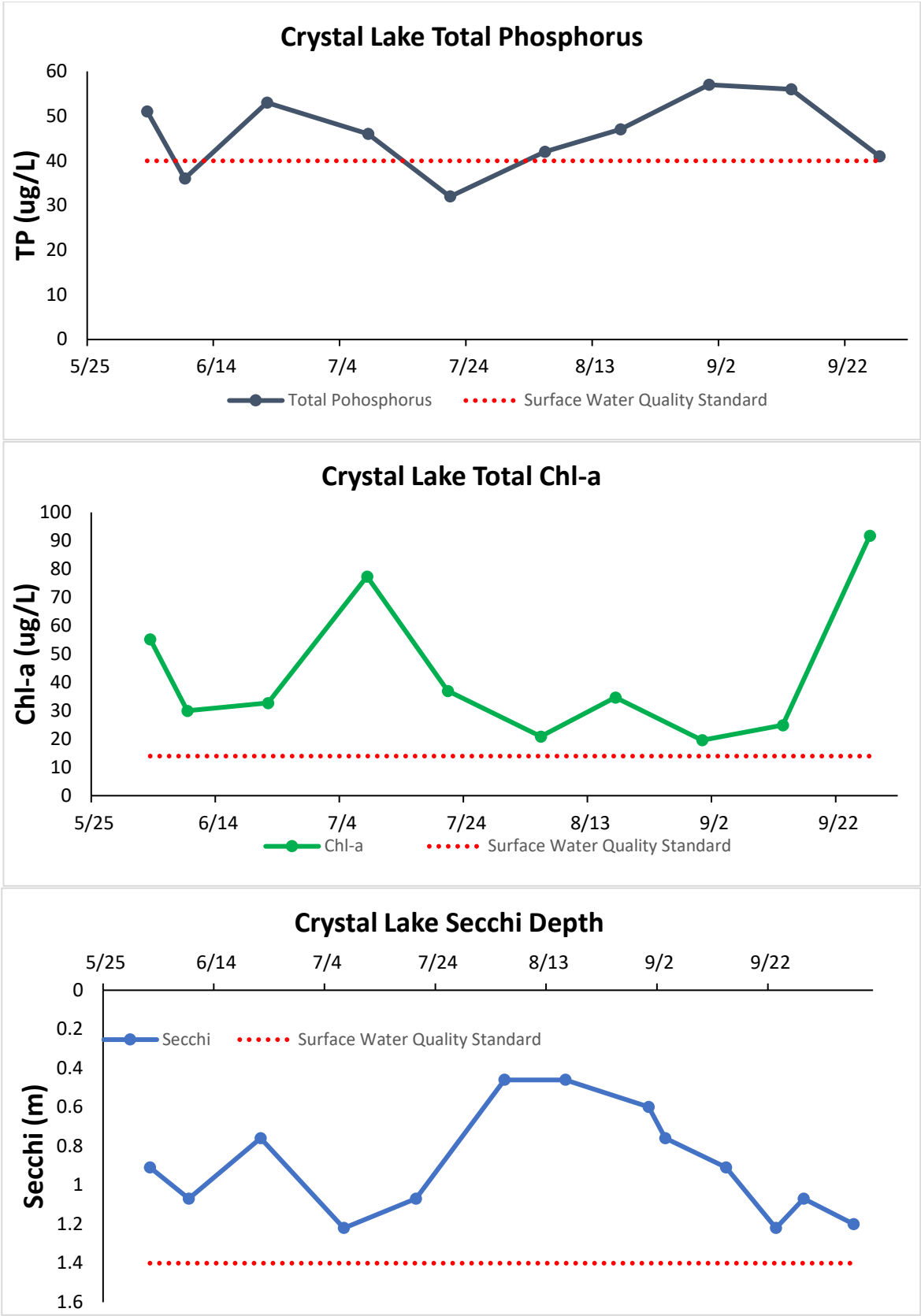


Figure 25. Water quality parameters in Crystal Lake during the 2021 monitoring season.

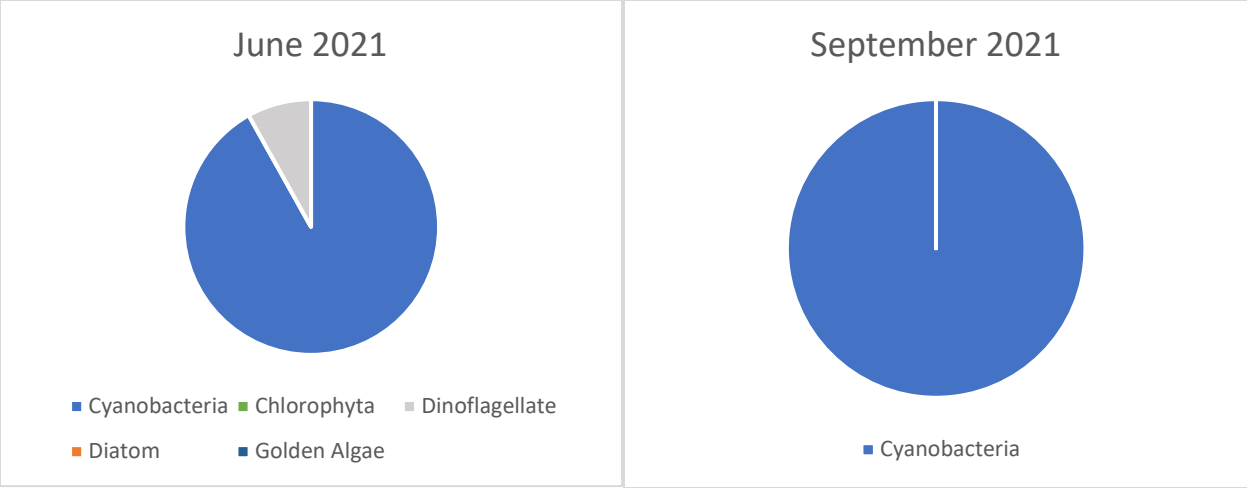


Figure 26. Phytoplankton community as relative percentage from June and September 2021 in Crystal Lake.

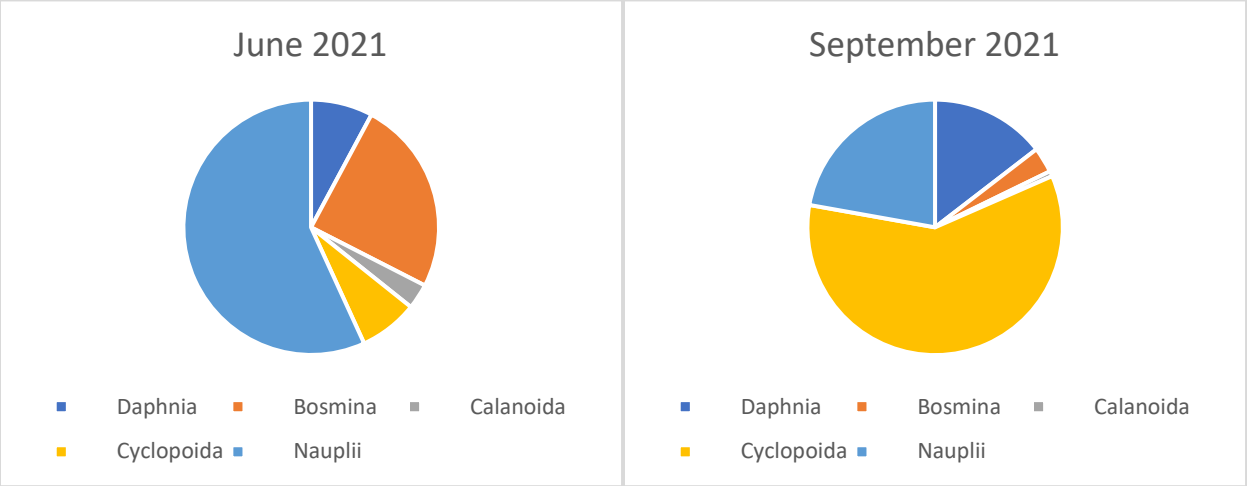


Figure 27. Zooplankton community as relative percentage from June and September 2021 in Crystal Lake.

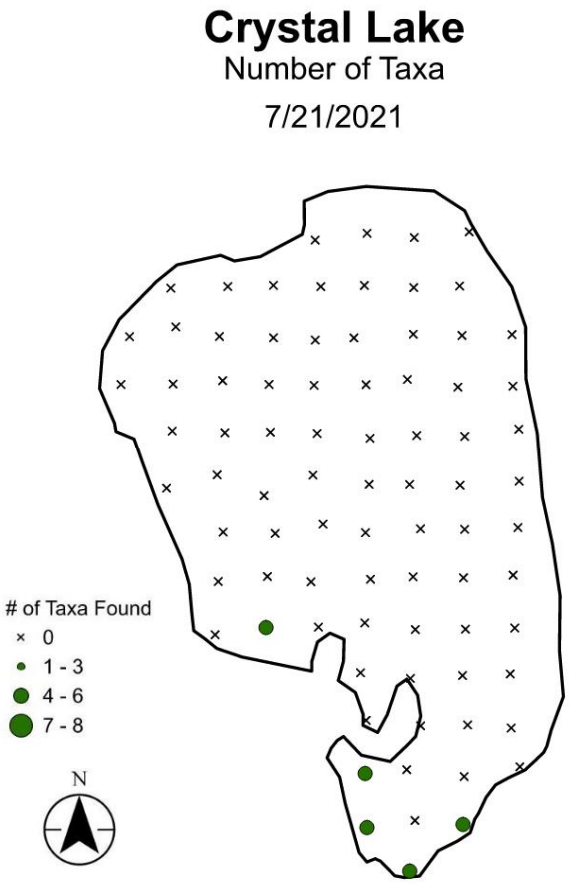


Figure 28. Submersed aquatic vegetation (SAV) showing number of taxa found at each location in Crystal Lake during the mid-summer survey.

Moving Forward

Routine and storm monitoring will continue on Bass and Shingle Creeks in 2022. The 65th Ave outfall and the Environmental Preserve discharge channel in West Mississippi will also be monitored by the Commission.

Lake Magda and Schmidt Lake will undergo routine lake monitoring in 2022. Early and late summer SAV surveys will be done on both lakes, and a fish survey is planned for Lake Magda. Phytoplankton and zooplankton community monitoring will continue. As part of ongoing active management projects, Crystal Lake will be monitored for water quality, SAV, and phytoplankton and zooplankton. Curly-leaf pondweed management is planned for Bass Lake. Crystal Lake will receive the second of two planned alum applications in September and active carp management will continue. Volunteer monitoring through the CAMP program will occur on Upper, Middle, and Lower Twin Lakes and Bass Lake.

Active management of Meadow Lake began in November 2021 with a water level drawdown to consolidate the sediments and significantly reduce or eliminate invasive vegetation and fathead minnows that degrade water quality and clarity. Meadow Lake will be monitored for water quality, SAV, phytoplankton and zooplankton, fish community, and sediment chemistry to assess the impacts of the drawdown.

APPENDIX A

2021 Precipitation

Appendix A: Precipitation Data

Table A1. Summary of 2021 and long-term precipitation data measured at the New Hope, MN station (Station ID: 215838).

Month	2021 Precipitation (inches)	1992-2021 Monthly Average Precipitation (inches)	Departure from Historical Average (inches)
January	0.87	0.95	-0.08
February	0.52	0.97	-0.45
March	2.82	1.85	0.97
April	2.5	3.17	-0.67
May	3.28	4.27	-0.99
June	2.06	4.47	-2.41
July	0.86	4.36	-3.50
August	6.88	4.31	2.57
September	1.48	3.16	-1.68
October	1.88	2.92	-1.04
November	0.85	1.64	-0.79
December	1.95	1.39	0.56
TOTAL	25.95	33.47	-7.52

APPENDIX B

2021 West Mississippi Stream Data

65th Avenue

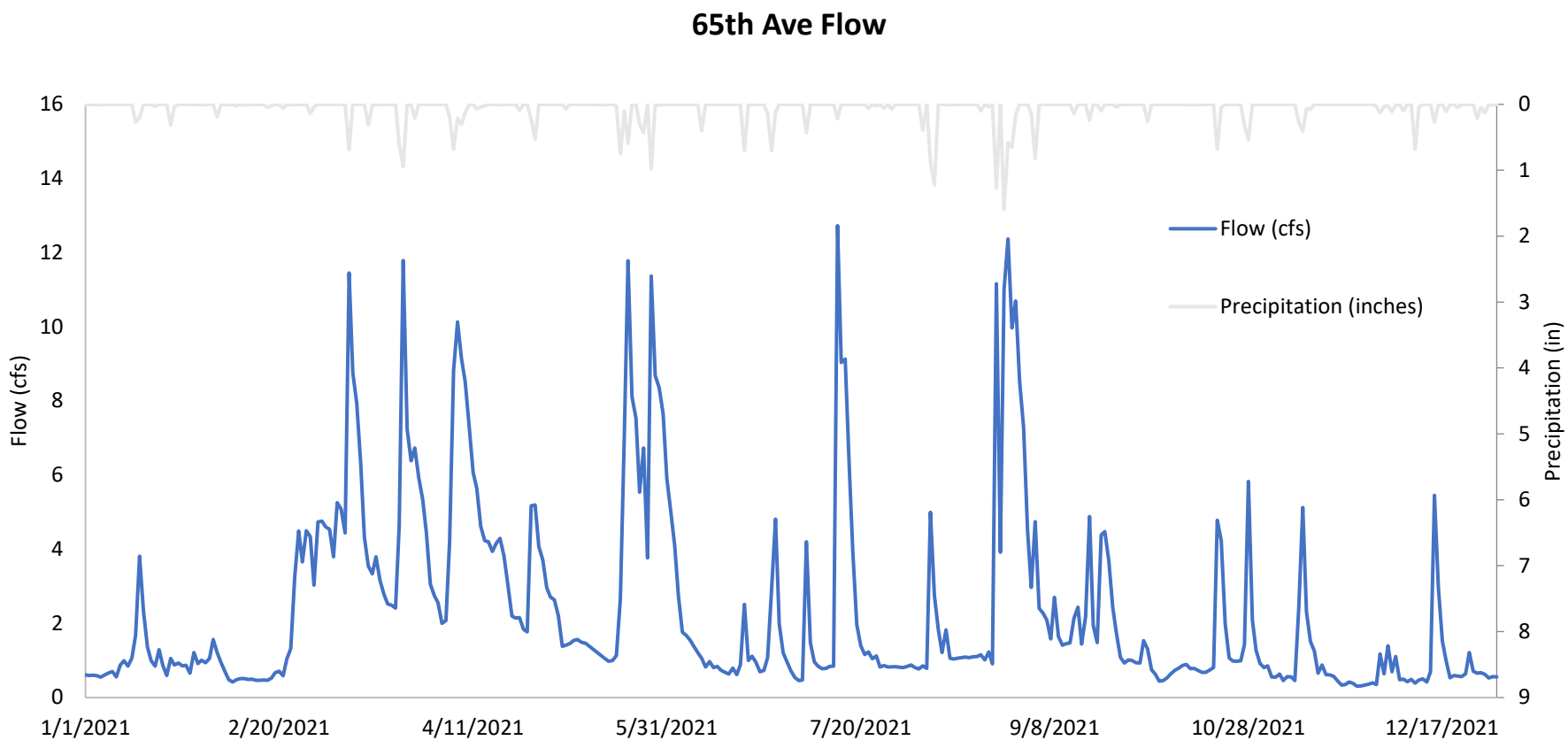


Figure B1. Flow at the 65th Ave sampling station in 2021. The blue line represents flow in cubic feet per second (cfs). Daily precipitation, measured at the New Hope, MN weather station, totals in inches are represented in gray on the secondary axis.

Table B1. Water quality data from the 65th Ave site measured in 2021. Parameters measured include temperature (temp.), dissolved oxygen (DO), percent saturated dissolved oxygen (DO_{sat}), pH, specific conductivity (sp. cond.), oxidation reduction potential (ORP), total phosphorus (TP), orthophosphate (orthoP), total suspended solids (TSS), chloride and Escherichia coli (E. coli).

Date	Time	Temp. [°C]	DO [mg/L]	pH	Sp. Cond. [µS/cm]	Salinity [ppt]	TP [mg/L]	OrthoP [mg/L]	TSS [mg/L]	Chloride [mg/L]	E. coli [MPN/100mL]	VSS [mg/L]	TKN [mg/L]
01/05/2021	09:15	3.1	12.13	7.9	2028	1.03	0.06	0.02	~2	441	93	~1	1.7
02/02/2021	09:15	3.9	12.43	8.4	1888	0.95	0.09	0.02	3	409	112	~1	1.5
02/22/2021	14:45	4.6	10.94	8	8154	4.49	0.5			6040			5.7
04/06/2021	09:00						0.07	0.01	6	258	299	3	1.4
04/06/2021	09:01						0.11	<0.01	6	260	435	4	1.5
05/04/2021	08:10	12.5	10.25	7.8	1560	0.79	0.07	0.18	5	317	43	~2	1.4
06/01/2021	08:50	18.2	8.74	7.2	1258	0.63	0.09	0.02	3	235		~2	1.7
07/08/2021	08:00	18.4	7.93	7.8	1564	0.79	0.14	0.05	~1	301	326	~2	0.8
07/20/2021	08:35	23.1	8.32	7.2	1551	0.78	0.1	0.05	3	329	140	~2	0.96
08/03/2021	08:00	18.5	8.38	7	1798	0.92	0.08	0.04	4	340	126	~2	0.9
09/07/2021	08:30	17.4	8.81	6.9	1451	0.73	0.13	0.08	~1	261	63	<1	0.71
10/05/2021	08:25	16.4	9.25	7.3	1563	0.79	~0.032	0.011	~2	311	172	~2	0.88
11/02/2021	08:30	7.7	11.32	6.7	1555	0.79		<0.01		292		~1	0.78
12/07/2021	09:40	5.9	11.57	7.4	1765	0.89		0.18		350		~1	0.96

Table B2. Other water quality data from the 65th Ave site measured on four different dates in 2021. Parameters measured include Alkalinity, Ammonia, CBOD5-day, Chemical Oxygen Demand, Dissolved Phosphorus, Hardness (CaCO3), Nitrate/Nitrate, Nitrate/Nitrite, Nitrite/Nitrite, Sulfate, TBOD5-day, Total Cadmium, Total Chromium, Total Copper, Total Dissolved Solids, Total Lead, Total Nickel, Total Organic Carbon, and Total Zinc.

Date/Time	6/1/2021 8:50	**6/20/2021 12:55	7/8/2021 8:00	**9/17/2021 2:30
Alkalinity [mg/l]	219	121		50
Ammonia [mg/l]	0.16	0.34		0.24
CBOD5-day [mg/l]	2.6	16		5.5
Chemical Oxygen Demand [mg/l]	28	134		29
Dissolved Phosphorous [mg/l]	<0.02	0.13		~0.044
Hardness (CaCO3) [mg/l]	291	212		81
Kjeldahl-N / TKN / --- [mg/l]	1.7	3.6	0.8	1.1
Nitrate / Nitrate [mg/l]	0.92	0.75		0.46
Nitrate-Nitrite [mg/l]	0.92	0.96		0.46
Nitrite / Nitrite [mg/l]	<0.06	0.21		<0.06
Sulfate [mg/l]	65.2	34.5		12.5
TBOD5-day [mg/l]	2.9	24		>8
Total Cadmium [mg/l]	<0.0001		<0.0001	
Total Chromium [mg/l]	<0.001		<0.001	
EColi / EColi / [1/100 ml]			326	
Total Copper [mg/l]	0.0011		0.0144	
Total Dissolved Solids [mg/l]	716	483		172
Total Lead [mg/l]	0.0017		<0.0005	
Total Nickel [mg/l]	0.0021		0.0015	
Total Organic Carbon [mg/l]	5.4	22.8		7
Total Zinc [mg/l]	<0.005		0.0058	

** Sample taken from a storm capture day

Table B3. Stormwater quality data from the 65th Ave site in 2021. Parameters measured include total phosphorus (TP), orthophosphate (orthoP), total suspended solids (TSS) and Escherichia coli (E. coli).

Start Date	Time	End Date	Time	TP [mg/L]	OrthoP [mg/L]	TSS [mg/L]	E. coli [MPN/100mL]	VSS [mg/L]	TKN [mg/L]
02/23/2021	11:15	02/23/2021	20:40	0.41					4
02/24/2021	11:55	02/24/2021	18:00	0.34	0.04	63	184	25	3.7
03/02/2021	13:40	03/02/2021	18:55	0.26	0.09	30	146	13	2.3
03/10/2021	12:20	03/10/2021	16:45	0.36	0.03	122	365	49	1.6
04/06/2021	16:50	04/07/2021	01:55	0.17	<0.01	50	411	16	1.6
05/25/2021	01:41	05/25/2021	06:06	0.38	0.03	38	6300	18	1.5
06/20/2021	12:55	06/20/2021	22:35	0.46	0.02	93		37	3.6
06/27/2021	06:25	06/27/2021	09:10	0.23					1.2
06/28/2021	13:15	06/29/2021	04:05	0.17	0.02		6300		1.3
07/14/2021	11:50	07/14/2021	14:35	0.19	0.07	29	31500	11	1.1
08/28/2021	23:50	08/29/2021	06:35	0.08	0.03	9		5	0.75
09/17/2021	02:30	09/17/2021	04:45	0.155	0.03	42		19	1.1
09/20/2021	12:20	09/20/2021	17:20	0.066	0.01	15		8	0.72
11/10/2021	18:25	11/11/2021	05:55					5	1.1
12/15/2021	03:55	12/16/2021	14:10		0.01			10	1.6

Mattson Brook

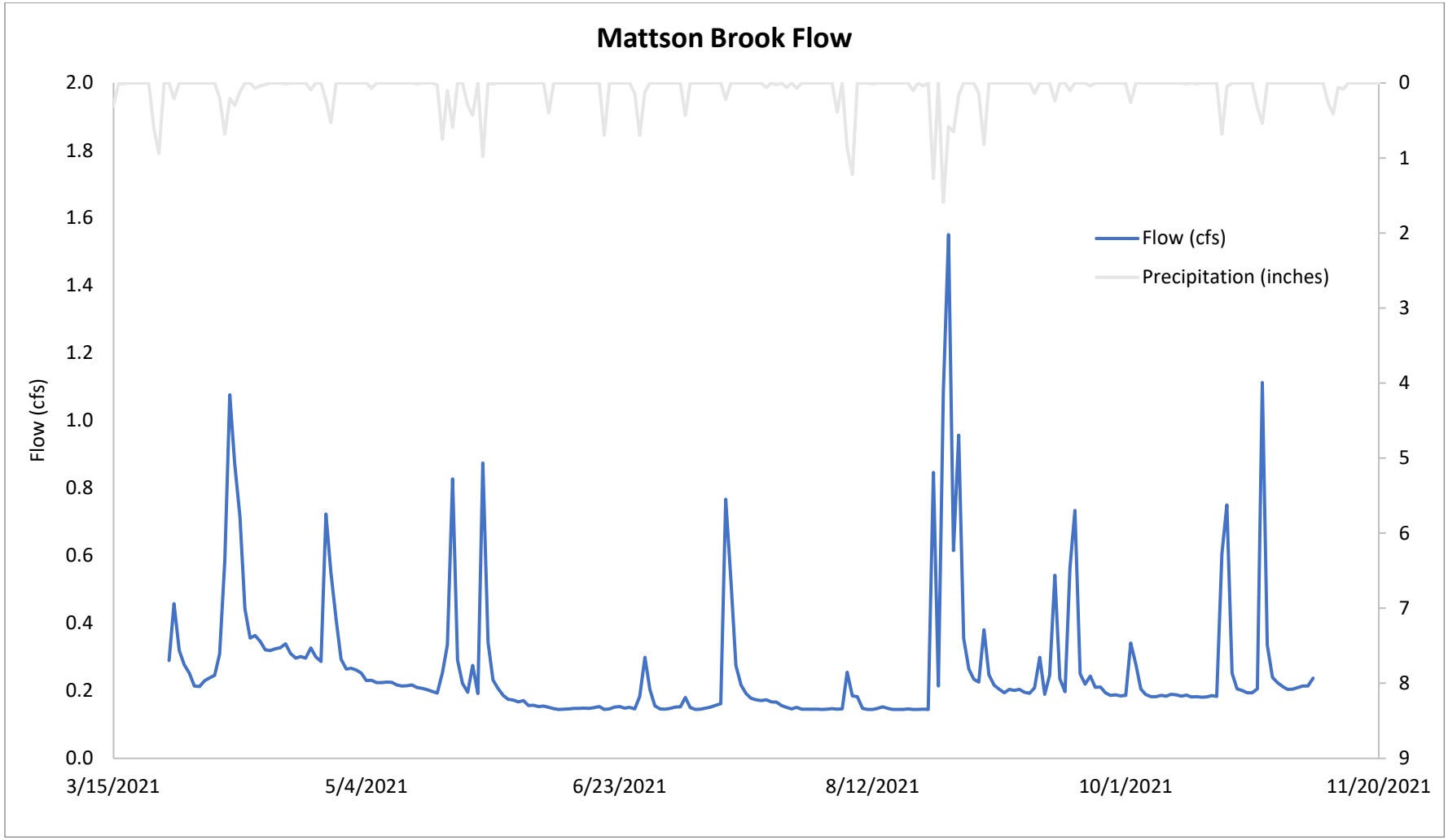


Figure B2. Flow at the Mattson Brook sampling station. The blue line represents flow in cubic feet per second (cfs). Daily precipitation totals in inches are represented in gray on the secondary axis.

Table B4. Water quality data from the Mattson Brook stream site measured in 2021. Parameters measured include temperature (temp.), dissolved oxygen (DO), percent saturated dissolved oxygen (DO_{sat}), pH, specific conductivity (sp. cond.), total phosphorus (TP), orthophosphate (orthoP), total suspended solids (TSS) chloride and Escherichia coli (E. coli).

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. Cond. [µS/cm]	ORP [mV]	TP [mg/L]	OrthoP [mg/L]	TSS [mg/L]	Chloride [mg/L]	E. coli [MPN/100mL]
4/6/2021	11:45	13.3	10.31	102.3	8.38	1725.6	460	0.063	0.01	2.3	352	101.9
5/4/2021	10:45	11.1	12.34	116.5	7.73	2008	124	0.058	0.026	1.9	380	32.7
6/1/2021	11:51	15.9	6.55	67.7	8.26	2011.7	328	0.132	0.117	2.1	428	58.3
6/15/2021	10:30	18.5	6.5	71.3	7.69	2440	345.3	0.228	0.204	24	521	81.6
6/29/2021	14:44	21.895	5.58	65.5	7.31	1386	162.8	0.156	0.088	9		1
7/27/2021	12:04	22.7	4.3	51.6	7.47	2227	144.1	0.278	0.161	51		1986.3
8/23/2021	10:15	19.3	4.8	54	7.38	1066	229	0.164	0.139	4.4		2419.6
9/21/2021	9:00	16.43	8.76	91.7		1101.3	434	0.032	0.07	26.8		2419.6
10/18/2021	8:55	9.71	6.78	61.6		1999.7	357	0.125	0.103	4.4		209.8

Table B5. Storm water quality data from the Mattson Brook stream site measured in 2021. Parameters measured include total phosphorus (TP), orthophosphate (orthoP), total suspended solids (TSS) and Escherichia coli (E. coli).

Start Date	Time	End Date	Time	TP [mg/L]	OrthoP [mg/L]	TSS [mg/L]	E. coli [MPN/100mL]
4/6/2021	11:44	4/7/2021	11:00	0.165	0.046	19.5	648.8
5/19/2021	13:20	5/20/2021	13:25	0.306	0.058	38	2419.6
6/28/2021	14:15	6/29/2021	14:31				
7/13/2021	12:01	7/15/2021	12:06	0.273	0.033	63.7	1
8/23/2021	16:45	8/24/2021	15:18	0.291	0.078	50	2419.6
8/26/2021	9:30	8/27/2021	11:05	0.159	0.051	26.8	2419.6
9/20/2021	7:47	9/21/2021	8:55				

Table B6. Nutrient and Chemical Loading for the 65th Ave and ENVP sites calculated for monitoring period.

Site	TP load (lbs)	TSS load (lbs)	Chloride load (lbs)
65th Ave	766	127,607	1,191,165
Mattson Brook	39	5,669	31,689

* MB Load was calculated from April 6th – September 20th, 2021
** 65th Avenue Load was calculated for full 2021 year

APPENDIX C

2021 Shingle Creek Stream Data

Appendix C: 2021 Shingle Creek Stream Data

OVERVIEW

Shingle Creek (AUID 07010206-506) is impaired for chloride, aquatic life (macroinvertebrate IBI, fish IBI), and aquatic use (*E. coli*). Bass Creek (AUID 07010206-784), a headwater stream to Shingle Creek, is impaired for chloride and aquatic life (macroinvertebrate IBI, fish IBI). West Mississippi streams have not been assessed. The Shingle Creek and West Mississippi Third Generation Watershed Management Plan includes annual monitoring of four stream locations in the Shingle Creek Watershed, one on Basset Creek (BCP) and three on Shingle Creek (SC-3, SC-0, and USGS), and rotating monitoring of two sites in the West Mississippi Watershed (ENVP, Mattson Brook, Oxbow, and 65th Ave). The primary purpose of the stream monitoring program is to assess progress toward achieving the TMDLs and state water quality standards for the impaired streams and to track water quality of unimpaired streams. Activities included in the stream monitoring program include routine and storm water quality, flow, and conductivity monitoring. Three of the Shingle Creek sites (BCP, SC-3, and SC-0) and two rotating West Mississippi sites are monitored routinely during the growing season (April through October) for multiple water quality parameters. Shingle Creek sites are monitored once a month in the winter (November through March) for chloride concentrations. The USGS site is only monitored in the winter for chloride.

In Section 1.0, we provide an overview of the various stream sampling methodologies (Section 1.0) used to collect routine water quality (Section 1.1), storm water quality (Section 1.2), flow and load calculations (Section 1.3), and conductivity (Section 1.4) data at the stream sites. In Sections 2.0 and beyond we summarize activities and results from 2020 monitoring for each of the four sites monitored.

Results and discussions for each Shingle Creek stream can be found in the following order:

- Section 2.0 – BCP
- Section 3.0 – SC-3
- Section 4.0 – SC-0
- Section 5.0 – USGS
- Section 6.0 – Rainfall

See Appendix B for West Mississippi streams data.

1.0 Sampling Methods

1.1 ROUTINE WATER QUALITY

Shingle Creek and West Mississippi streams are within highly urban areas but serve as important water features to the cities they flow through. The streams flow through various parks and have multiple miles of adjacent walking paths. The streams are home to many animals including muskrats, fish, crayfish, and ducks. The Minnesota Pollution Control Agency (MPCA) monitors and assesses streams around the state to determine if they meet water quality standards. The agency relies on local partners, including soil and water conservation districts, watershed districts, tribal entities, nonprofit groups, and citizens to help monitor the thousands of streams in the state. Shingle Creek Watershed Management Commission (Commission) is an active participant in aiding the MPCA in sampling and collecting information on the state of water quality of its streams. The Commission is focused on sampling total suspended solids, total phosphorus, total dissolved phosphorus, soluble reactive phosphorus, chloride, and *E. coli*. In addition to these parameters for water quality standard comparison, the Commission collects certain chemical and physical parameters on its streams.

Routine stream monitoring samples are typically collected twice per month starting in April and ending in October. For three streams (BCP, SC-3, and SC-0), water samples are collected and assessed for total suspended solids (TSS), total phosphorus (TP), total dissolved phosphorus (TDP), soluble reactive phosphorus (ortho-P), chloride, and *E. coli*. In addition to these chemical parameters, *in-situ* readings of physical parameters are also taken. A YSI or similar multimeter water quality sonde is used to collect these measurements. Parameters measured include dissolved oxygen (DO) concentration, water temperature, pH, oxidation-reduction potential (ORP), and specific conductivity. During the late fall, winter, and early spring chloride samples and physical parameters are taken at the three previously mentioned stream sites and one additional site (USGS).

Stream stage height at BCP, SC-3, SC-0, and West Mississippi monitoring sites is measured using an automated water sampler (ISCO model 6712) which is deployed in early April until late October. The ISCO water sampler is connected to a pressure transducer deployed in the stream (ISCO 720 Submerged Probe Flow Module). Stage height is periodically adjusted throughout the monitoring season using stream tape-down measurements taken in the field. Tape-down measurement are the distance to water from a known, fixed elevation in or near the stream. Stream stage height is converted to flow (discharge) measurements during data processing. The process is described in Section 1.3. Flow data are collected year-round at the USGS gage site 05288705 on Shingle Creek.

Flow data, lab samples, and *in-situ* data are used to understand the cycling of chemicals and nutrients in the stream system, identify watershed pollutant loads, and indicate areas of excess chemicals and nutrients.

1.2 STORM WATER QUALITY

Storm water quality samples are typically collected from April through October when a storm event of 0.5 inches or greater occurs. Storm samples are taken each year at BCP, SC-3, and SC-0 sites, and

at West Mississippi sites chosen for routine monitoring that year. Storm event water samples are collected using the ISCO automated water sampler at 15-minute intervals. Discrete water samples are composited and sent to the lab for analysis of TSS, TP, TDP, OP, and *E. coli.* No physical parameters are measured during storm events.

1.3 FLOW AND LOAD CALCULATIONS

ISCO-measured state height is converted to flow measurements at the end of each field season. Field staff measure streamflow using a FlowTracker Handheld IDV (San Diego, CA) periodically throughout the monitoring season. Field staff developed a relationship between stream stage height and stream flow measured in the field. This relationship is fit with a polynomial equation that relates stage height to flow for the time that the ISCO is deployed (April through October). During winter months when the ISCO is not deployed at field sites, flow at SC-0, SC-3, and BCP is linearly interpolated using data from the USGS gage on Shingle Creek.

Flow and routine water quality samples are used together to generate load calculations for various water quality pollutants. Loads were estimated as the total streamflow volume at each site multiplied by the flow-weighted mean concentration (FWMC) of a given water quality parameter. Flow weighted mean concentrations are calculated as:

$$FWMC = \frac{\sum_{l}^{n} c_i * q_i}{\sum_{l}^{n} q_i}$$

Where c_i is the pollutant concentration of the ith sample and q_i is the streamflow of the ith sample.

1.4 CONTINUOUS SPECIFIC CONDUCTIVITY MONITORING

Specific conductivity and temperature probes (AquaTroll 500, In-Situ Inc., Fort Collins, CO) are deployed at BCP, SC-3, and SC-0 sites year-round. Specific conductivity and temperature are measured by the probe in 15-minute intervals and data are downloaded periodically. A linear relationship between continuously monitored specific conductivity and chloride concentrations measured from grab samples is modeled. The linear relationship between chloride and specific conductivity allows us to estimate chloride concentrations in the stream throughout the entire year.

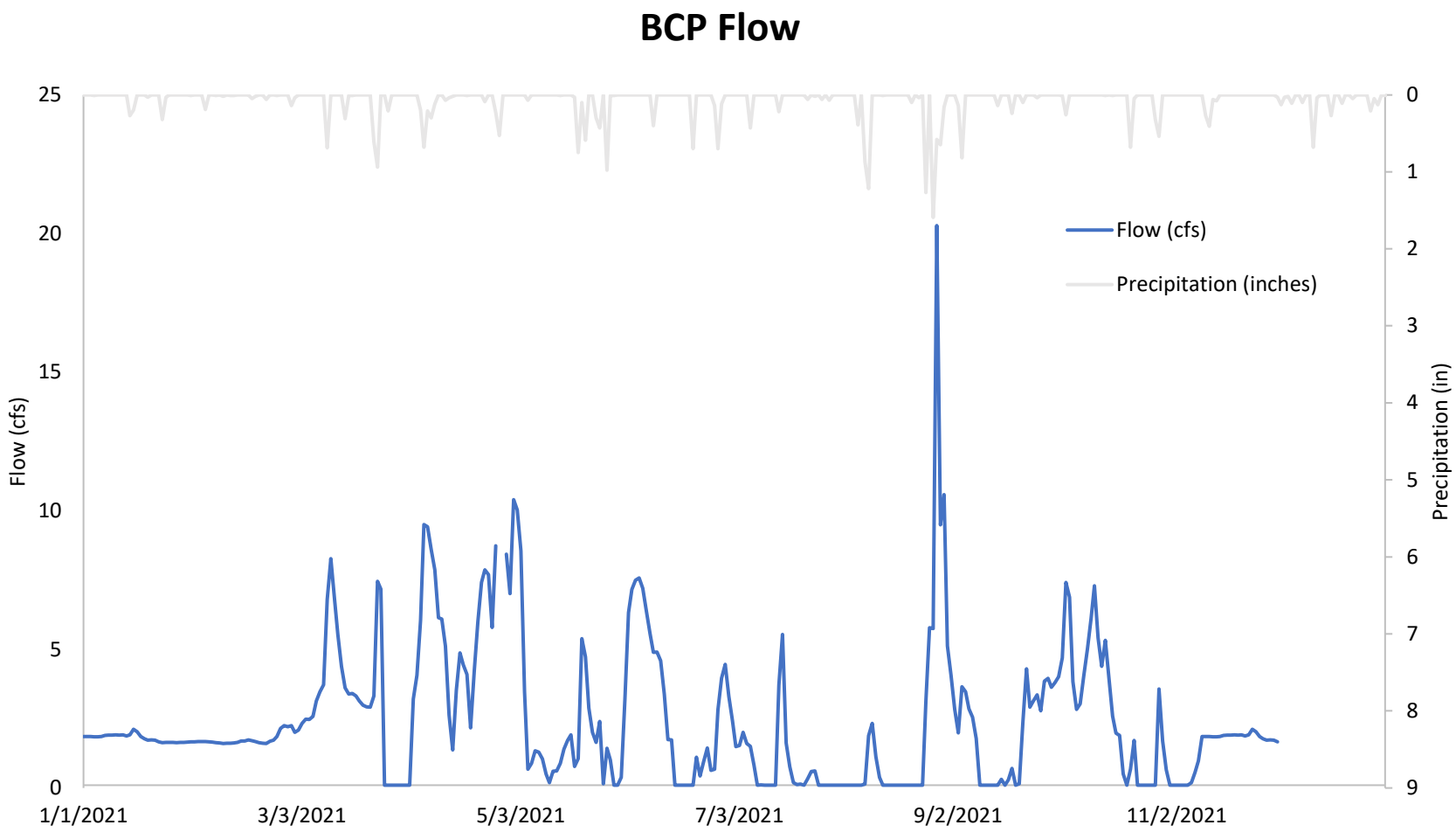


Figure C1. Flow at the BCP sampling station. The blue line represents flow in cubic feet per second (cfs). Daily precipitation totals in inches are represented in gray on the secondary axis.

Table C1. Water quality data from the Bass Creek Park (BCP) stream site measured in 2021. Parameters measured include temperature (temp.), dissolved oxygen (DO), percent saturated dissolved oxygen (DO_{sat}), pH, specific conductivity (sp. cond.), oxidation reduction potential (ORP), total phosphorus (TP), orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS), chloride and Escherichia coli (E. coli). Note that there is no data from February because water was frozen at this site during sampling events.

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. Cond. [µS/cm]	ORP [mV]	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	Chloride [mg/L]	E. coli [MPN/100mL]
1/20/2021	8:54	-0.19	7.37	52.7	6.97	3000	383					1062	
3/19/2021	7:53	6.52	12.22	102	7.84	1191	401					271	
4/6/2021	14:00	14.82	9.81	100.9	8.47	1137	401	0.089	0.026	0.036	11.5	262	135.4
4/20/2021	8:30	5.93	10.74	85.5	7.73	866	158.5	0.032	0.006	0.018	3.2	158	140.1
5/4/2021	9:09	10.35	6.37	58.7	7.26	1236	156.1	0.116	0.006	0.031	10.5	291	198.9
5/18/2021	8:16	17.3	7	75.2	7.58	1687	376	0.103	0.012	0.04	5.8	418	579.4
6/1/2021	9:22	14.85	6.57	66.7	8.33	837	358	0.088	0.023	0.052	4	187	410.6
6/15/2021	8:20	17.903	2.59	27.9	7.65	1516	335.2	0.16	0.073	0.079	6.5	369	110
6/29/2021	11:00	20.56	5.65	64.6	7.22	730	183.3						
7/13/2021	9:00	19.186	3.39	34.9	7.38	977	276.1	0.183	0.059	0.105	8.2	204	139.6
7/27/2021	9:10	23.15	4.17	50.4	7.31	1085	171.4	0.185	0.064	0.089	5.8	238	261.3
8/10/2021	11:25	23.51	3.58	43.6	7.65	794	604	0.186	0.07	0.127	3.3	143	325.5
9/7/2021	12:00	19.149	6.69	75.3	7.35	999	343.3	0.187	0.037	0.064	2.9	218	307.6
9/21/2021	7:30	15.9	5.08	52.5		637	426						
10/4/2021	8:15	14.28	5.4	54.3		14.28	332	0.127	0.064	0.104	3	174	150
10/18/2021	7:30	9.81	6.07	55.3		9.81	394	0.066	0.039	0.046	3.2	291	24.3
11/22/2021	7:30	3.12	5.36	41.8	7.83	693	407.8					130	

Table C2. Storm water quality data from the Bass Creek Park (BCP) stream site measured in 2021. Parameters measured include total phosphorus (TP), orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS) and Escherichia coli (E. coli).

Start Date	Time	End Date	End Time	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	E. coli [MPN/100mL]
4/6/2021	14:00	4/7/2021	8:00	0.112	0.018	0.003	17.6	272.3
5/19/2021	12:35	5/20/2021	12:08	0.427	0.011	0.057	62.1	2419.6
5/26/2021	12:02	5/28/2021	8:48	0.125	0.034	0.06	39.2	95.9
6/28/2021	13:40	6/29/2021	10:56	0.362	0.054	0.077	61.2	980.4
7/13/2021	9:49	7/15/2021	13:12	0.312	0.04	0.087	78.3	1
8/23/2021	16:10	8/24/2021	14:15	0.257	0.098	0.131	50.7	2419.6
8/26/2021	8:35	8/27/2021	8:46	0.156	0.062	0.09	16.3	2419.6
9/20/2021	7:15	9/21/2021	7:30	0.194	0.065	0.095	60.6	2419.6

Table C3. BCP historic load calculations including TP, TSS and Chloride load calculations for 2021.

Year	Flow	TP		Ortho-P		TSS		VSS		Nitrate		TKN		Chloride	
	Acre-ft	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)
2014	6,837	1,881	101	776	42	106,971	6			4,281	0.23	13,736	0.74		
2015	1,493	792	192	531	129	107,640	23.1			1,856	0.148	5,123	1.14		
2016	4,107	1,024	99	854	82	189,576	18.2					1,707	0.16		
2017	5,537	1,670	119												
2018	2,754	9,701	139												
2019	6,753	2,114	124												
2020	2,562	479	90			231,824	13.9							1,009,950	156
2021	1,566	454	107			58,231	13.7							581,796	137

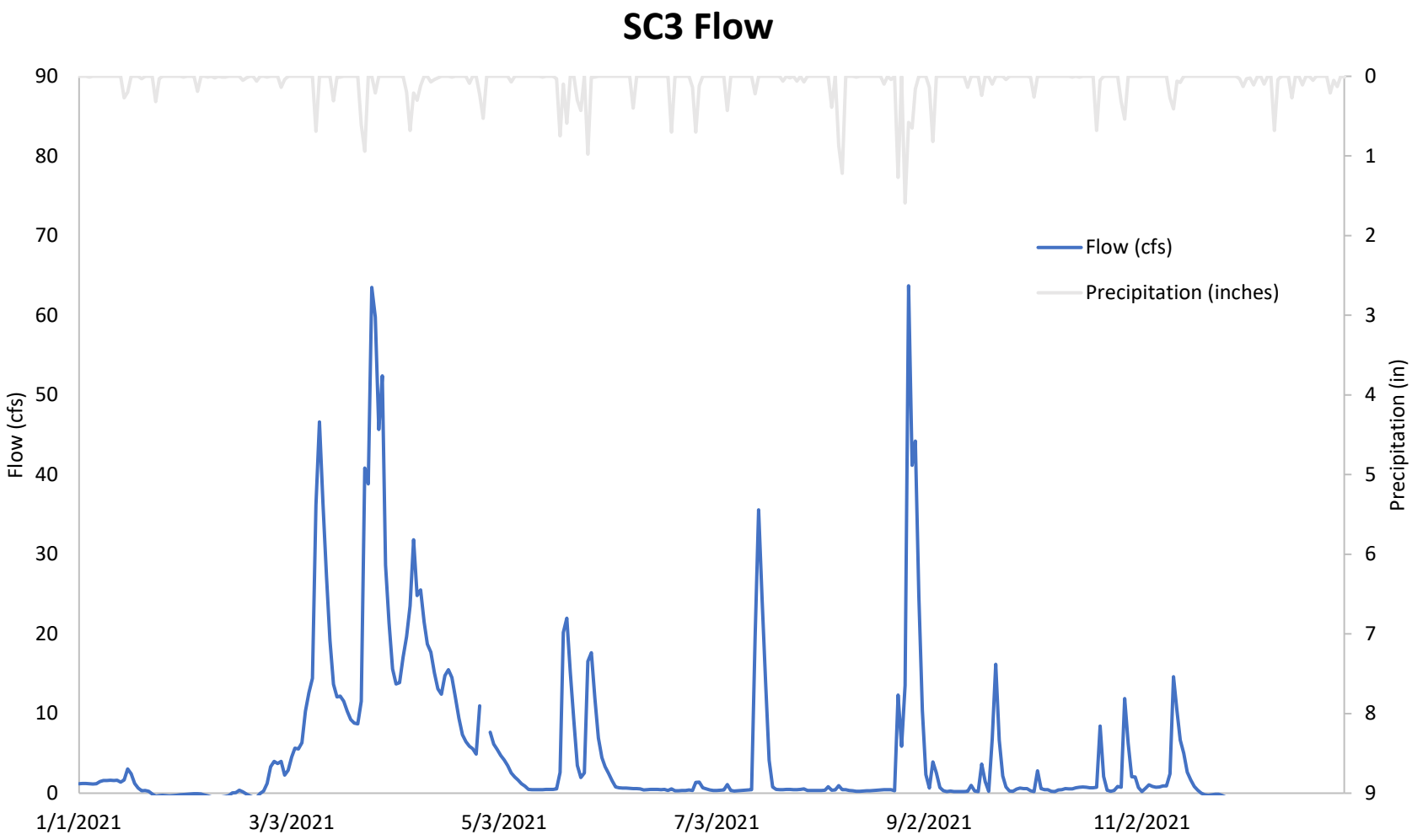


Figure C4. Flow at the SC-3 sampling station. The blue line represents flow in cubic feet per second (cfs). Daily precipitation totals in inches are represented in gray on the secondary axis.

Table C4. Water quality data from the Shingle Creek SC-3 stream site measured in 2021. Parameters measured include temperature (temp.), dissolved oxygen (DO), percent saturated dissolved oxygen (DO_{sat}), pH, specific conductivity (sp. cond.), oxidation reduction potential (ORP), total phosphorus (TP), orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS), chloride (mg/L) and Escherichia coli (E. coli). Note that there is no data from January and February because water was frozen at this site during sampling events.

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. cond. [µS/cm]	ORP [mV]	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	Chloride [mg/L]	E. coli [MPN/100mL]
1/20/2021	9:15	3.44	2.93	22.8	7.5	3000	266					405	
2/23/2021	8:30	2.86	5.81	45.3	7.29	3000	335					1165	
3/19/2021	14:45	5.67	11.54	93.9	8.13	1280	383					313	
4/6/2021	13:15	15.64	8.11	84.8	8.4	1326	416	0.077	0.011	0.023	5.8	357	209.8
4/20/2021	9:00	5.71	10.71	85.3	7.56	890	147.2	0.035	0.008	0.019	2.8	180	77.6
5/4/2021	9:49	11.56	7.51	71.3	7.36	1077	106.9	0.081	0.014	0.011	4.8	247	238.2
5/18/2021	8:47	13.89	6.82	67.5	7.47	1455	265	0.148	0.021	0.044	6.8	262	9.7
6/1/2021	10:39	15.74	5.41	56	8.2	1003	344	0.098	0.046	0.071		236	228.2
6/15/2021	9:41	16.474	4.58	48.2	7.5	1324	306.2	0.137	0.054	0.044	4.4	165	198.9
6/29/2021	12:40	21.103	2.8	31.9	7.27	607	87.2						
7/13/2021	10:15	17.613	2.25	24.6	7.44	1267	-22.9	0.264	0.094	0.098	4.8	140	30.9
7/27/2021	10:38	17.89	6.95	76.1	7.31	1296	84.9	0.132	0.011	0.023	7.1	159	141
8/10/2021	12:15	21.79	4.49	52.8	8.13	431	250	0.193	0.07	0.104	44.9	42.2	2419.6
8/23/2021	9:35	19.733	3.24	36.2	7.3	608	259.7	0.32	0.007	0.046	26.5	65.7	2419.6
9/7/2021	13:30	17.715	6.65	72.6	7.32	1125	260	0.143	0.033	0.026	6.2	151	84.2
9/21/2021	8:15	17.72	6.15	66.1		302	445						
10/4/2022	9:05	15.59	5.05	52.1		542.5	369	0.157	0.046	0.068	73.2	109	2419.6
10/18/2021	8:10	9.75	8.04	71.9		36.6	361	0.247	0.037	0.044	19.8	197	261.3
11/22/2021	7:50	0.91	11.27	82.5	7.2	11.4	112.1					180	

Table C5. Storm water quality data at the Shingle Creek SC-3 stream site measured in 2021. Parameters include TP (total phosphorus), orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS) and Escherichia coli (E. coli).

Start Date	Start Time	End Date	End Time	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	E. coli [MPN/100mL]
4/6/2021	13:15	4/7/2021	9:00	0.318	0.005	0.02	178	727
5/26/2021	12:16	5/28/2021	9:25	0.32	0.097	0.14	15	2419.6
6/28/2021	14:00	6/29/2021	12:34	0.195	0.099	0.13	21.4	648.8
7/13/2021	11:05	7/15/2021	12:42	0.196	0.015	0.05	58	1
8/23/2021	16:25	8/24/2021	14:45	0.562	0.052	0.07	163	2419.6
8/26/2021	9:05	8/27/2021	9:42	0.118	0.032	0.05	14.7	2419.6
9/20/2021	7:27	9/21/2021	8:15	0.183	0.026	0.04	51.6	2419.6
10/27/2021	22:53	10/27/2021	14:13	0.211	0.095	0.09	23.8	387.3

Table C6. SC-3 historic load calculations including estimated TP, TSS and chloride loads in 2021.

Year	Flow	TP		Ortho-P		TSS		VSS		Nitrate		TKN		Chloride	
	Acre-ft	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)
2004	7,355	4,189	209	1,543	77	599,657	30	255,736	13	6,173	0.31				
2005	10,616	5,500	191	2,640	92	464,200	16	215,600	7	8,800	0.30	35,200	1.22		
2006	3,843	2,200	211	880	84	451,000	43	138,600	13			20,240	1.94		
2007	6,270	2,200	129	880	52	391,600	23	105,600	6	3,960	0.23	24,200	1.42		
2008	2,962	880	109	220	27	85,800	11	92,400	11	1,540	0.19	8,580	1.07		
2009	961	220	84			33,000	13	15,400	6	440	0.17	1,320	0.51		
2010	4,799	1,980	152	660	51	391,600	30	147,400	11	4,180	0.32	17,820	1.37		
2011	10,099	3,192	116	719	26	591,218	22	211,470	8	3,326	0.12	25,419	0.93		
2012	5,147	2,024	145	615	44	287,380	21	108,114	8			12,572	0.90		
2013	7,033	4,110	215	1,012	53	633,717	33	395,899	21			43,336	2.27		
2014	11,736	5,042	158	1,594	54	983,344	31			8,865	0.28	34,023	1.07		
2015	5,159	2,334	166	1,289	75	293,355	20.9			2,101	0.15	15,950	1.14		
2016	17,247	4,301	149	3,588	108	796,091	54.7					7169	0.201		
2017	13,130	2,928	88												
2018	7,010	2,620	148												
2019	19,593	5,563	112												
2020	6,620	1,501	89			231,824	13.8							2,952,334	177
2021	3,613	1,739	176			373,214	37.9							1,018,485	104

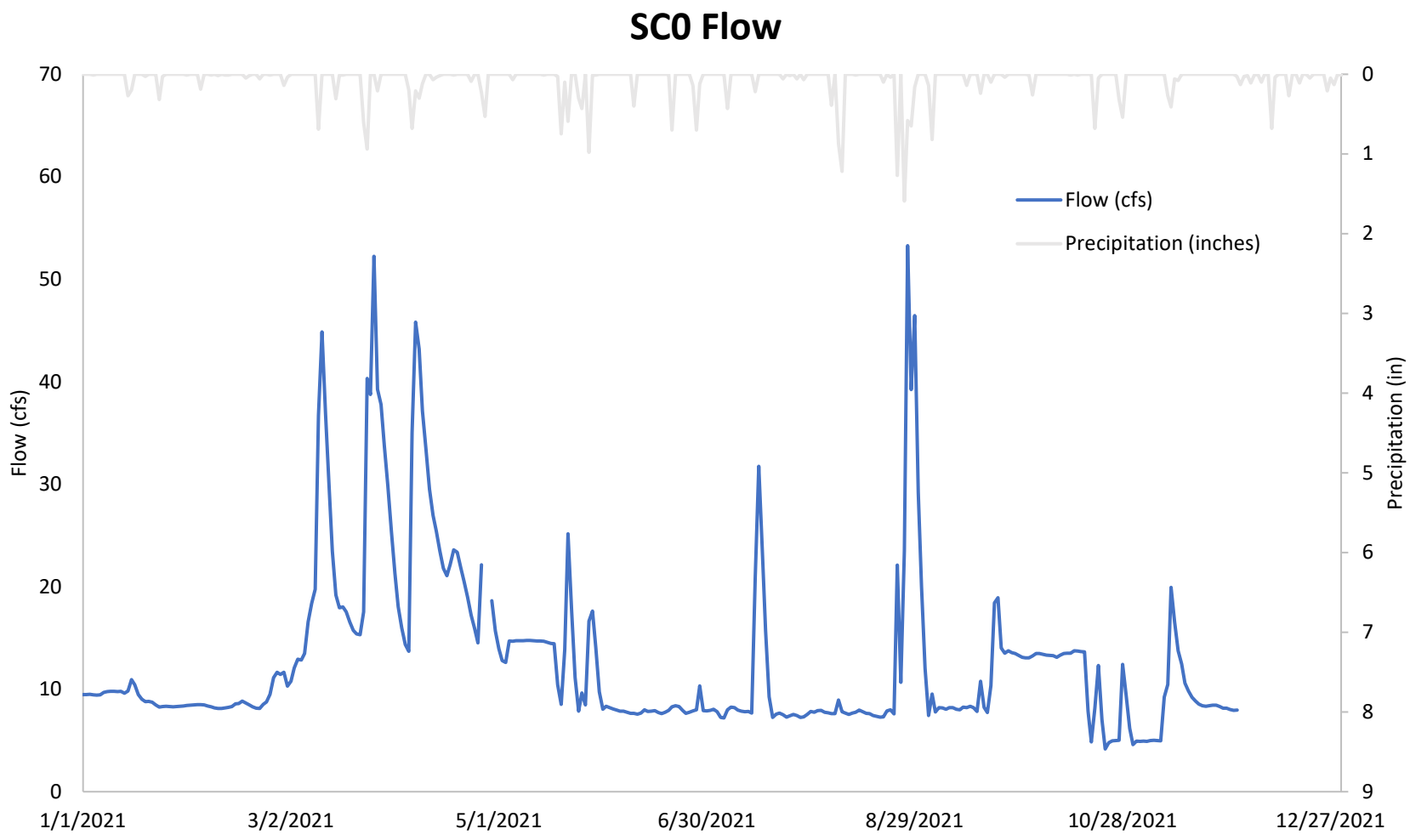


Figure C1. Flow at the SC-3 sampling station. The blue line represents flow in cubic feet per second (cfs). Daily precipitation totals in inches are represented in gray on the secondary axis.

Table C7. Water quality data from the Shingle Creek SC-0 stream site measured in 2021. Parameters measured include temperature (temp.), dissolved oxygen (DO), percent saturated dissolved oxygen (DOsat), pH, specific conductivity (sp. cond.), oxidation reduction potential (ORP), total phosphorus (TP), orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS), chloride and Escherichia coli (E. coli).

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. cond. [µS/cm]	ORP [mV]	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	Chloride [mg/L]	E. coli [MPN/100mL]
1/20/2021	9:47	-0.06	6.73	47.3	7.32	2691	279					699	
2/23/2021	8:54	0	5.24	37.4	7.5	2317	321					310	
3/19/2021	15:31	8.38	11.94	103.3	7.96	1574	380					399	
4/6/2021	0:45	16.04	8.67	91.4	8.64	877.5	416	0.089	0.026	0.036	11.5	262	
4/20/2021	10:00	6.917	12.96	106.9	7.9	981	135.9	0.057	0.003	0.016	3.7	178	17.3
5/4/2021	10:16	12.65	10.42	101.7	7.64	1243	127.3	0.093	0.01	0.021	5.6	236	57.3
5/18/2021	9:13	16.47	6.57	69	7.72	1304	3.14	0.061	0.013	0.029	7.6	223	85.7
6/1/2021	11:16	17.21	5.82	61.9	8.28	1001	331	0.076	0.028	0.043	3.2	188	79.4
6/15/2021	11:15	19.953	4.19	47.2	7.59	1270	339.3	0.1	0.057	0.049	5.6	210	313
6/29/2021	15:56	25.11	5.54	69	7.32	554	161.5	0.238	0.024	0.047	46.6	123	1
7/13/2021	12:45	21.169	5.02	58.2	7.38	1178	131.2						
7/27/2021	13:00	24.598	4.53	56.1	7.43	1171	138.3	0.096	0.046	0.052	16.7	168	307.6
8/10/2021	8:20	22.84	3.62	43.7	7.45	1018	602	0.088	0.044	0.052	4.2	150	410.6
8/23/2021	10:55	19.898	5.31	60.5	7.37	1180	195.6	0.071	0.037	0.043	2.6	185	579.4
9/7/2021	14:45	20.54	5.31	61.4	7.42	969	212.5	0.078	0.03	0.031	3.1	134	123.4
9/21/2021	9:52	17.43	4.63	49.3	7.21	607	439						
10/4/2021	9:35	15.79	4.92	51	7.34	1000.7	382	0.079	0.029	0.033	6	151	365.4
10/18/2021	9:25	10.54	5.75	53.1		1109.7	364	0.049	0.027	0.023	10.8	189	387.3
11/22/2021	8:15	0.34	10.66	75.1	7.21	1161	403.9					175	

Table C8. Storm water quality data from the Shingle Creek SC-0 stream site measured in 2021. Parameters include TP (total phosphorus , orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS) and Escherichia coli (E. coli).

Start Date	Start Time	End Date	End Time	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	E. coli [MPN/100mL]
4/6/2021	12:45	4/7/2021	9:00	0.25	0.006	0.017	99	461.1
5/19/2021	13:05	5/20/2021	13:51	0.207	0.011	0.042	34	2419.6
5/26/2021	1:11	5/28/2021	10:07	0.253	0.031	0.074	39.2	1413.6
6/28/2021	14:30	6/29/2021	15:41	0.362	0.077	0.077	61.2	980.4
7/13/2021	13:35	7/15/2021	11:29	0.125	0.035	0.039	5	178.9
8/23/2021	17:00	8/24/2021	15:47	0.246	0.111	0.117	36.8	2419.6
8/26/2021	9:50	8/27/2021	11:50	0.132	0.016	0.036	20	2419.6
9/20/2021	8:04	9/21/2021	9:58	0.201	0.025	0.043	49.8	2419.6
10/28/2021	23:30	10/28/2021	14:49	0.336	0.035	0.038	78.3	2419.6

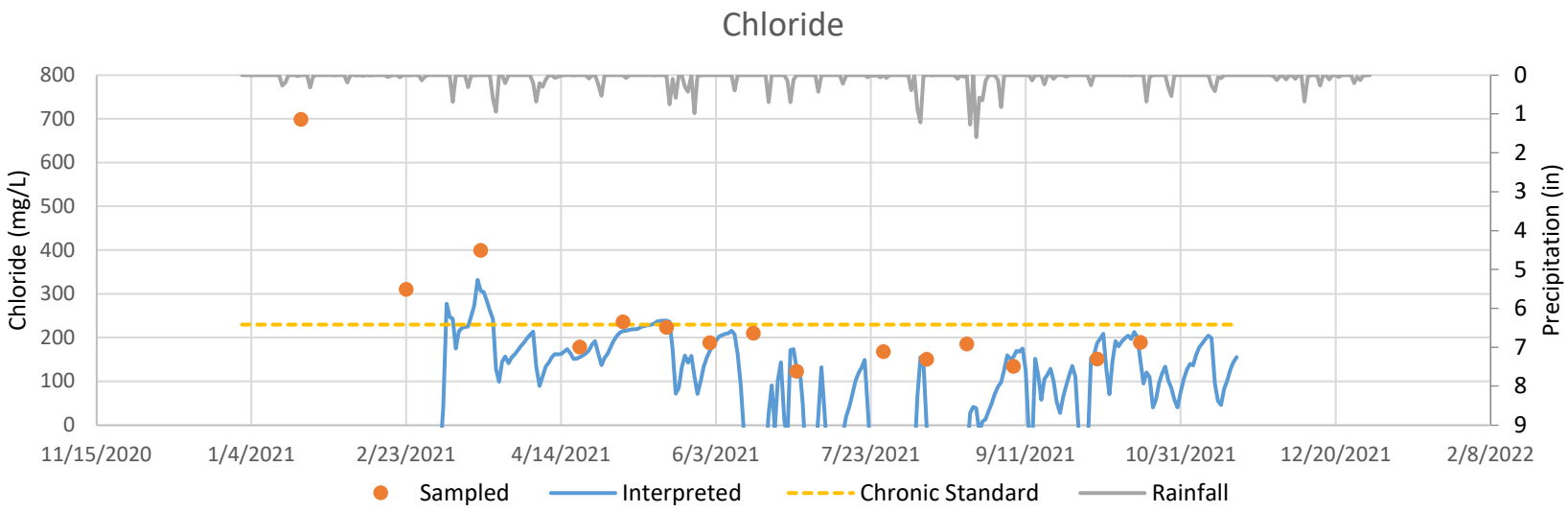


Figure C9. Interpreted and sampled Chloride data from the Shingle Creek SC-0 stream site measured in 2021. Chloride interpreted by the linear relationship generated between Conductivity data and Chloride at this site. The chronic standard for chloride is 230mg/L.

Table C9. SC-0 historic load calculations including TP, TSS and Chloride load calculations for 2021.

Year	Flow	TP		Ortho-P		TSS		VSS		Nitrate		TKN		Chloride	
	Acre-ft	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)
2004	8,612	3,748	160	882	38	749,572	32	308,647	13	4,409	0.19	--	--		
2005	15,367	6,820	163	1,320	32	1,577,400	38	1,031,800	25	13,420	0.32	52,800	1.26		
2006	13,255	5,060	140	1,540	43	1,095,600	30	459,800	13	--	--	39,600	1.10		
2007	11,239	3,960	130	880	29	811,800	27	431,200	14	9,240	0.30	38,720	1.27		
2008	7,950	3,080	142	660	31	367,400	17	248,600	12	6,380	0.30	25,080	1.16		
2009	3,917	880	83	220	21	231,000	22	92,400	9	1,320	0.12	5,720	0.54		
2010	7,634	3,300	159	660	32	561,000	27	233,200	11	3,740	0.18	22,000	1.06		
2011	18,023	5,814	119	1,255	26	1,098,478	22	465,297	9	14,807	0.30	54,294	1.11		
2012	7,943	3,384	157	579	27	648,520	30	286,019	13			21,219	0.98		
2013	9,916	4,382	163	511	19	660,628	24	583,448	22			36,177	1.34		
2014	17,483	5,945	125	1,131	24	1,239,189	26					55,102	1.16		
2015	8,630	2,187	113	1,679	71	683,057	29.1			4,680	0.073	23,688	1.01		
2016	17,007	4,241	148	3,538	72	785,013	58					7,069	0.309		
2017	16,149	3,601	88												
2018	9,886	2,850	114												
2019	24,763	7,001	112												
2020	14,340	3,047	84			438,045	12.1							4,726,436	131
2021	8,482	2,552	111			509,224	22.1							2,570,757	111

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

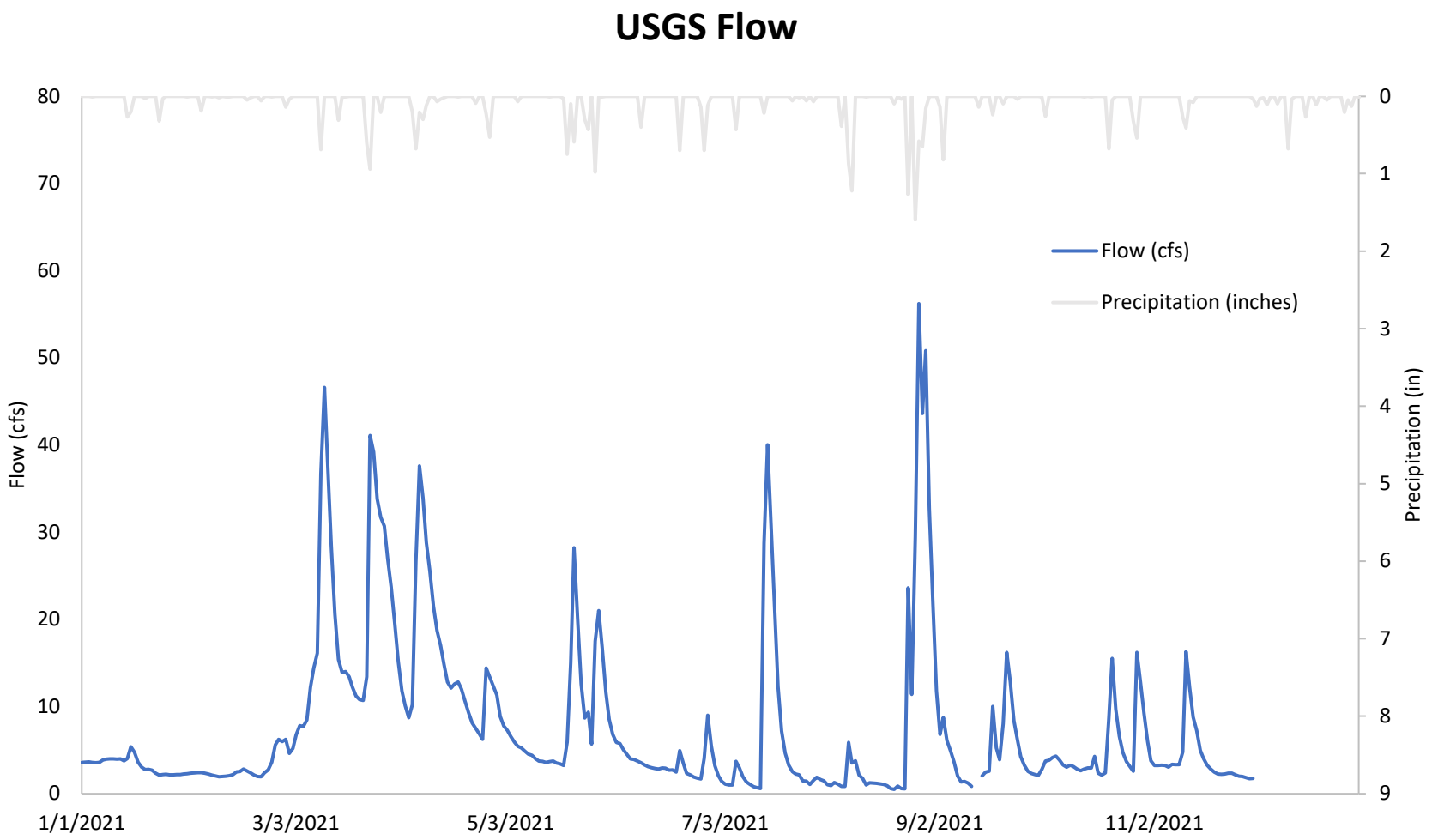
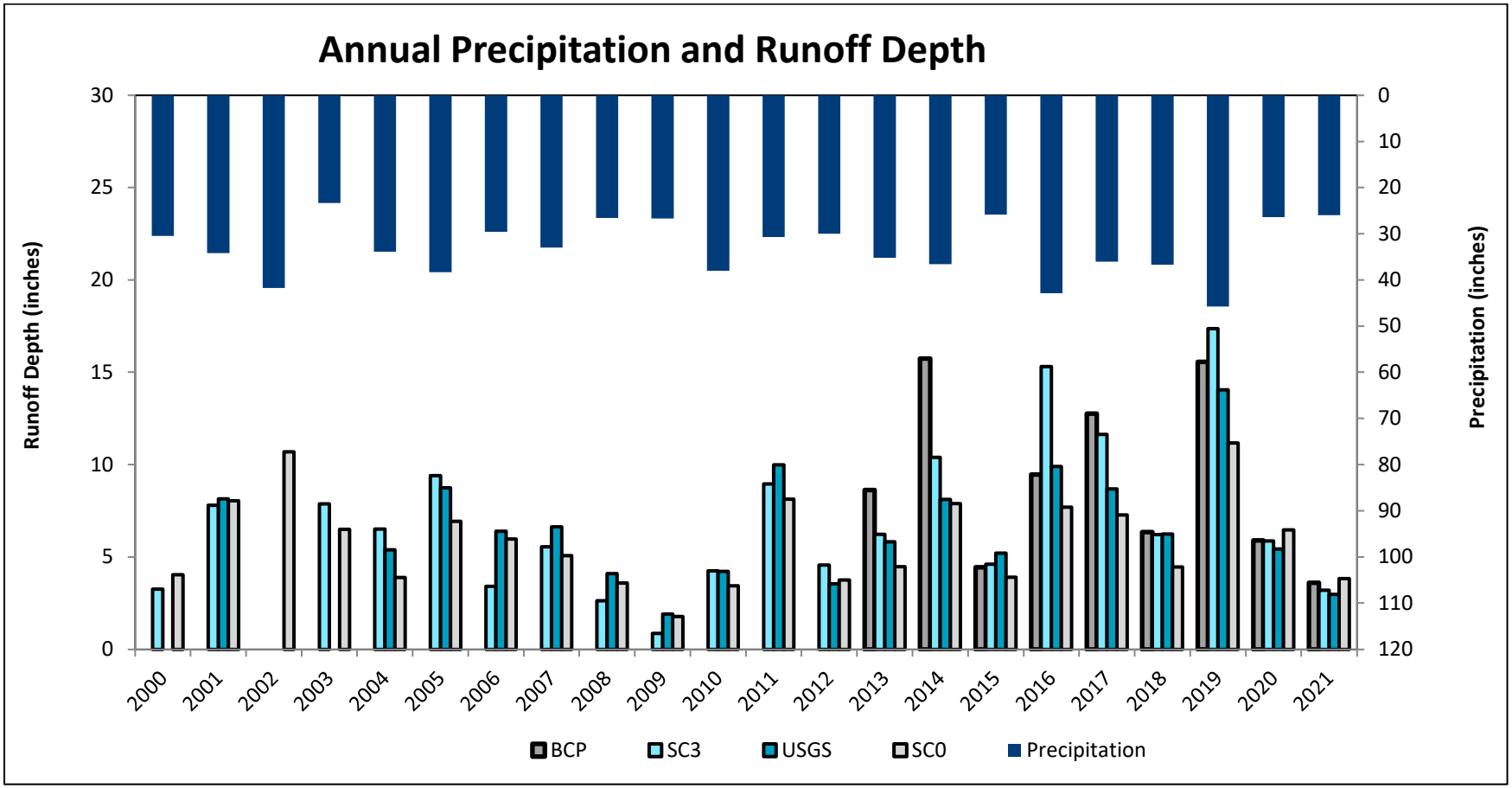


Figure C10. Flow at the USGS sampling station. The blue line represents flow in cubic feet per second (cfs). Daily precipitation totals in inches are represented in gray on the secondary axis.

Table C10. Water quality data from the United States Geological Survey (USGS) stream site measured in 2021. Parameters measured include temperature (temp.), dissolved oxygen (DO), percent saturated dissolved oxygen (DO_{sat}), pH, specific conductivity (sp. cond.), oxidation reduction potential (ORP) and chloride.

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. cond. [µS/cm]	ORP [mV]	Chloride [mg/L]
1/20/2021	9:33	0.96	5.3	39.0	7.55	2512	251	586
2/23/2021	8:41	2.91	3.6	27.6	7.4	2785	319	387
3/19/2021	15:15	7.45	11.0	96.0	8.17	1549	3.79	373
4/20/2021	10:30	7	12.0	102.9	7.66	1046	131.7	186
11/22/2021	8:30	1.56	5.4	63.6	7.21	624	153.1	196

Figure C10. Historic Annual Runoff Depth and Precipitation over the Subwatershed area for each stream site including: BCP, SC3, USGS and SC0 (2000 – 2021).



APPENDIX D

2021 Lake Monitoring

Appendix D: 2021 Lake Monitoring

OVERVIEW

The Shingle Creek Third Generation Watershed Management Plan includes a rotating schedule of intensive monitoring on all lakes in the Shingle Creek Watershed. The primary purpose of the intensive lake monitoring program is to evaluate protection efforts for lakes that are not impaired, and to assess progress toward achieving the TMDLs and state water quality standards for all impaired lakes throughout the watershed. Activities included in the intensive lake monitoring program include water quality monitoring, aquatic vegetation surveys, and fish sampling coordinated with the Minnesota Department of Natural Resources (DNR).

In Section 1.0, we provide an overview of the various sampling methodologies (Section 1.0) used to collect water quality (Section 1.1), phytoplankton and zooplankton sampling (Section 1.2), submersed aquatic vegetation (Section 1.3), and fisheries (Section 1.4) data on the lakes within Shingle Creek watershed. In Sections 2.0 and beyond we summarize activities and results from 2020 monitoring for each of the five lakes monitored.

Results and discussions for each lake can be found in the following order:

- Section 2.0 – Cedar Island Lake
- Section 3.0 – Lake Success
- Section 4.0 – Bass Lake
- Section 5.0 – Pomerleau Lake
- Section 6.0 – Crystal Lake

1.0 Sampling Methods

1.1 WATER QUALITY

Lakes are central to Minnesota's economy and our way of life, making it imperative that we protect our high-quality lakes and work to restore those with poor water quality. The Minnesota Pollution Control Agency (MPCA) monitors and assesses lakes around the state to determine if they meet water quality standards. The agency relies on local partners, including soil and water conservation districts, watershed districts, tribal entities, nonprofit groups, and citizens to help monitor the more than 10,000 lakes in the state. Shingle Creek Watershed Management Commission (Commission) is an active participant in aiding the MPCA in sampling and collecting information on the state of water quality of its lakes. The Commission is focused on sampling total phosphorus (nutrient), chlorophyll-*a* (a pigment in algae), and Secchi depth (a measure of water clarity). In addition to these parameters for water quality standard comparison, the Commission collects certain chemical and physical parameters on its lakes.

Routine lake sampling occurs on a rotating basis. For a lake that is selected for sampling in a given year, water samples are typically collected twice per month starting in May or June and ending in September. For all lakes, surface water samples are collected and assessed for total phosphorus (TP), soluble reactive phosphorus (ortho-P), total suspended solids (TSS), and chlorophyll-*a* (chlorophyll-a). In some of the deeper lakes, a hypolimnetic (deep) water sample is collected and tested for TP and ortho-P. In addition to these chemical parameters, a physical profile of the lake is assessed in the deepest part of the lake. A profile typically consists of measurements at the water's surface and at each meter below the surface throughout the entire water column. A YSI or similar multimeter probe is used to collect these measurements. Parameters measured include dissolved oxygen (DO), dissolved oxygen percent saturation, temperature, pH, oxidation reduction potential (ORP) and specific conductivity. Additionally, a Secchi depth reading is taken during every assessment to record the relative level of water transparency.

Lake profiles are used to better understand the chemical and nutrient cycling processes occurring within the lake, in addition to the stressors that may be contributing to biological impairments. The surface water chemical information is used for multiple reasons, one of which is to compare to the North Central Hardwood Forest (NCHF) ecoregions water quality standards established by the MPCA (Table 1.1).

Table 1.1. MPCA water quality standards for the NCHF ecoregion by lake type.

	Depth Class	TP (ug/L)	Chl-*a* (ug/L)	Secchi depth (m)
North Central Hardwood Forest	Deep	40	14	1.4
	Shallow	60	20	1.0

1.2 PHYTOPLANKTON AND ZOOPLANKTON SAMPLING

The phytoplankton and zooplankton communities are a key part of the lake ecosystem. They represent the base of the food chain and are often indicators of nutrient regimes and water quality. We began routine sampling for phytoplankton and zooplankton communities in 2020 by sampling each lake in early and late summer.

Both phytoplankton and zooplankton samples are taken by towing a plankton net with a known mesh size and net diameter vertically through the water column. The sample is transferred to a bottle and a known volume is subsampled for identification. Plankton were identified to the genera classification.

Five different phytoplankton families were identified in Shingle Creek lakes in 2021: Cyanobacteria, Chlorophyta, Dinoflagellate, Diatom, and Golden Algae. Cyanobacteria are commonly known as blue green algae and have the potential to form toxic blooms which are detrimental to human and ecosystem health. Cyanobacteria are indicative of nutrient rich, calm water. Cyanobacteria are not a preferred food source for zooplankton and they out compete other phytoplankton which are more important to the food chain. Chlorophyta are commonly known as green algae; they are prolific in mid-summer when harmful algae blooms (HABs) are not present. Green algae are a good sink for dissolved nutrients and are an important food source for zooplankton. Dinoflagellates are ubiquitous in freshwater lakes; they are an important part of the food chain and are indicative of low nutrients. Diatoms are most prevalent in the early growing season and they are a very important part of the food chain. Golden algae are similar to diatoms but are more uncommon in freshwater systems and can be found in the benthos (lake bottom).

Changes in phytoplankton composition are important for understanding:

- Pre and post management; indications of management impacts on water quality and all trophic cascades.
- Seasonal changes in nutrients and mixing regimes
- Food chain health throughout the growing season
- Risk of HAB formation

The most common composition change in a healthy lake ecosystem will shift from diatoms in the early spring to green algae in mid-summer to cyanobacteria in late summer. However, it is important to note that in healthy system that no one genera should be the only one represented. One hundred percent of one genera indicates an imbalance in the ecosystem in which one genera was able to completely out-compete the others.

1.3 SUBMERSED AQUATIC VEGETATION

In healthy lake ecosystems aquatic vegetation will grow throughout the littoral area (< or = 15 feet depth) and consist of a diverse native community (Figure 1.1). A well vegetated littoral area promotes and facilitates the health of a lake's ecosystem by providing critical spawning, foraging and nursery habitat for aquatic insects, amphibians, birds, and fishes. The littoral area is also important for human recreation and aesthetic enjoyment.

Figure 1.1. Biotic community health continuum portrayed using submersed aquatic vegetation.

1.3.1 Point Intercept Methods

To assess the presence, abundance, and health of the lake's aquatic vegetation community, two point-intercept surveys are typically conducted: an early season (May/June) and a late season survey (August). During each point-intercept survey, all submerged, floating leaf, and emergent species were identified at each survey point. Early season surveys are primarily conducted to understand the presence and distribution of Potamogeton crispus (curly-leaf pondweed, CLP), an aquatic invasive species (AIS) with high spring growth and early senescence. Late season surveys target the greatest assessment of SAV (submerged aquatic vegetation) community, abundance, and spatial distribution because the community is ideally at peak diversity.

Point-intercept survey point locations were replicated from previous surveys performed by Stantec and served as predetermined sampling locations for each lake. These points were originally developed by overlaying a grid across the entire lake according to the point-intercept methods presented in (Madsen 1999). To limit sampling of vegetation where it is not expected to grow, all deep lakes within Shingle Creek are capped to a maximum sampling depth of 20 feet or more (lake specific), therefore, all sampling points in depths beyond the designated cap are removed from the sampling grid. Thus, the sampling protocol and reporting of each lake is similar and allows comparisons to be made across systems and between years.

At each survey location a double-sided, weighted 14-tine rake was thrown from the boat, allowed to sink, and pulled across the lake bottom to represent approximately 1 square meter of lake area. We refer to this process as a rake toss. For each rake toss, vegetation is removed from the rake, identified to the species level, placed in a perforated bucket, weighed, and assigned a proportion of the total biomass based on visual approximation (i.e., 80% of total weight was CLP and 20% of total weight was coontail). All biomass values are reported in wet weights (kg). Emergent plant species, lily species, duckweed species, and filamentous algae are not included in any biomass measurements due to difficulty in collecting a representative sample with the sample rake, however, their presence (P) and location are still recorded.

Continuous sonar readings were also collected during each survey trip using a Lowrance Elite 7 Sonar/GPS unit. This data was processed using CiBioBase (BioBase) software (https://www.cibiobase.com/) that allows for mapping water depth, bottom hardness, and plant biovolume. Biovolume differs from biomass in that it provides context to vegetation water column saturation. The higher the biovolume the more saturated the water column is with vegetation. Sonar readings in depths <2 feet are subject to extreme 'sonar noise' and therefore are not always accurate. Sonar readings do not detect surface floating vegetation (i.e., pad of Lily species, duckweed). BioBase interpolates sonar readings between boat tracks to estimate biovolume.

Variation in boat tracks during surveys sometimes results in areas where biovolume cannot be estimated because boat tracks were not dense enough. There are a few cases of missing biovolume estimates in this report described in the results.

Point-intercept survey data can be used to calculate various survey metrics and indices to assess the health of the SAV community and easily compare across survey years and lakes. The metrics total point sampled during the survey, total littoral (<15 feet deep) points sampled, percent of littoral points with vegetation, maximum depth of plant growth, and species richness (i.e., the number of species observed) were calculated for each lake. In addition, the key indices used to assess the SAV survey results in this study and previous studies were Floristic Quality Index (FQI), biomass estimates, Simpson's Diversity Index (Simpson's D), and Aquatic Macrophyte Community Index (AMCI). Typha sp. (cattail), emergent wetland plants that often grow in shoreline and littoral areas in lakes and wetlands, are not included in SAV survey metrics in this report.

1.3.2 SAV Community Metrics

Floristic Quality Index (FQI). The FQI is an assessment tool used to determine the biological health of the SAV community. The FQI uses species richness and the habitat specificity (C-score) of each species identified to score community health (**Equation 1**). C-score is an index of how desirable a particular species is and how tolerant it is to stressors. Minnesota Department of Natural Resources (DNR) standard C-scores range from 1 to 10 with 1 being the least desirable and most tolerant to stressors, and 10 being the most desirable and least tolerant to stressors.

Equation 1. Definition of the DNR's Floristic Quality Index (FQI).

$$FQI = \overline{C_{Score}} * \sqrt{No.of\ Species}$$

Lakes with higher FQI scores and taxa richness are typically comprised of diverse, native communities with abundant plant growth across the entire littoral area. As stressors to the SAV community increase, we typically see reduced species diversity, introduction of invasive species, more monodominant stands of vegetation, and decreased late-season SAV abundance and density within the littoral area. Extremely degraded lakes become void of plant growth and become dominated by algae, which can sometimes be harmful during blooms.

The DNR developed thresholds for FQI and species richness to assess the health of lake vegetation communities and compare communities across lakes (Radomski and Perleberg 2012). Thresholds for deep and shallow lakes in the Central Hardwood Forest and Western Corn Belt Plains ecoregions are presented in Table 1-1. All surveyed lakes are in the Central Hardwood Forest ecoregion.

Table 1-1. FQI and species richness thresholds for deep and shallow lakes in the Central Hardwood Forest ecoregion.

	Depth Class	FQI threshold	Species Richness Threshold
North Central Hardwood Forest	Deep	18.6	12
	Shallow	17.8	11

Vegetation Biomass. We developed a model to estimate the total SAV biomass within each lake. Depth was stratified into four intervals (0-5, 5-10, 10-15, >15 feet) to more accurately account for spatial variation in vegetation growth and improve model accuracy. For each species we calculate a

depth interval specific FQI, an average rake toss biomass, and a depth interval lake area. Multiplying these three parameters results in a species-specific total biomass/depth interval. All species-specific depth interval biomasses are then summed within each depth interval to calculate depth-specific biomasses and all depth intervals are summed to calculate a total lake biomass (**Equation 2**). The total lake biomass estimation uses the individual surveyed data point information to extrapolate coverage estimates across the entire basin. This is not meant to serve as an exact biomass calculation, rather, this estimate is useful to 1) make relative comparisons to other observed species, 2) be used to compare to future sampling efforts, and 3) provide general information to assist aquatic vegetation management planning.

Equation 2. Definition of total in-lake submersed aquatic vegetation biomass.

$$Total\ Lake\ Biomass = \sum ([Depth\ Interval]\ (Species\ Biomass * Species\ \%\ Occurence * Basin\ Area))$$

Biomass data were collected for this study; however, the data are not presented in this report. Biomass data will be kept for use with future management efforts.

Simpson's Diversity Index. Data collected during the point-intercept surveys was used to calculate the Simpson's Diversity Index (Simpson's D) (Simpson 1949). Simpson's D is a measure of community diversity that accounts for the relative abundance of each species rather than just the community composition. This index is useful in assessing communities that have a high abundance of only a few species and low abundance of other species, giving more weight to more abundant species. The index ranges from 0–100 with 100 representing high diversity and even abundance across species and 0 representing low diversity and disproportionate abundance.

Equation 3. Simpson's Diversity index.

$$D = 1 - \left(\frac{\sum n\ (n-1)}{N\ (N-1)}\right) * 100$$

n = the total number of organisms of a particular species

N = the total number of organisms of all species

Aquatic Macrophyte Community Index (AMCI). The Aquatic Macrophyte Community Index (AMCI) is a metric used to assess the biological quality of lake aquatic plant communities (Nichols et al. 2000). The AMCI combines maximum depth of plant growth, percent of littoral zone vegetated, Simpson's D, the relative frequencies of submersed, sensitive, and exotic species, and taxa number. AMCI ranges from 0-70, with higher values representing higher quality plant communities. The AMCI was calculated for each point-intercept survey using the methods described by Nichols et al. (2000).

1.4 FISHERIES ASSESSMENT

Fish communities are sampled using various techniques and equipment to target specific aspects of the fish community or due to the type of system being sampled. Three survey techniques and assessment methods were used to assess the fisheries communities.

1.4.1 Trap and Gill Net Surveys

DNR survey game fish populations using standardized trap and gill net survey methods to assess gamefish populations within lakes. DNR standard trap and gill net surveys consist of setting trap and

gill nets at predetermined locations based on lake size (Schlagenhaft 1993). The trap and gill nets are meant to tangle or entrap fish over a 12 to 24-hour period. Trap nets contain a lead net perpendicular to shore with a series of hoops and funnels at the end of the net that direct and entrap fish. The gill nets catch fish via gill entanglement and consist of multi-sized mesh panels. The gill nets are typically set in deeper (~8-12 feet), open water habitats. Fish captured from trap and gill net assessments are identified, total length measured and weighed. Furthermore, a quantification of fish captured is calculated using catch per unit effort (CPUE). A CPUE is calculated by adding the total number of each fish species captured in each respective gear type (i.e., trap net and gill net) and dividing the number of captured fish by the number of each gear type placed in the lake.

The CPUE can be used to compare and assess fish communities by using the DNR developed Schupp lake class (Schupp 1992). The Schupp system creates a standard fisheries-based lake class system that allows fish community health to be evaluated to lakes with similar size, structure, and regionality.

1.4.2 Common Carp Population Evaluation

The common carp (*Cyprinus carpio*) is a widespread AIS that can have deleterious effects on lake ecosystems. Common carp uproot aquatic vegetation, resuspend lake bottom sediments, and increase available nutrients that can fuel algal growth. The presence of common carp can lead to ecosystem degradation. Significant water quality degradation has been shown to begin at common carp densities of 100 kg/hectare (89 lbs/ acre) (Bajer 2012). Efforts aimed at restoring water quality that do not reduce the presence of common carp have limited success in long term restoration, therefore, survey efforts are used to determine common carp densities and whether there is a need for carp management. Common carp population assessments implement boat electrofishing techniques that target the carp population within a lake. Carp are targeted along shoreline habitats with captured carp total length measured, weighed, and tallied. A regression model is then used to extrapolate the abundance and density of common carp with the lake. Inputs into the regression model include the amount of time fished (shocking time), the total number of fish captured, and total biomass captured.

2.0 Cedar Island

2.1 INTRODUCTION & SAMPLING OVERVIEW

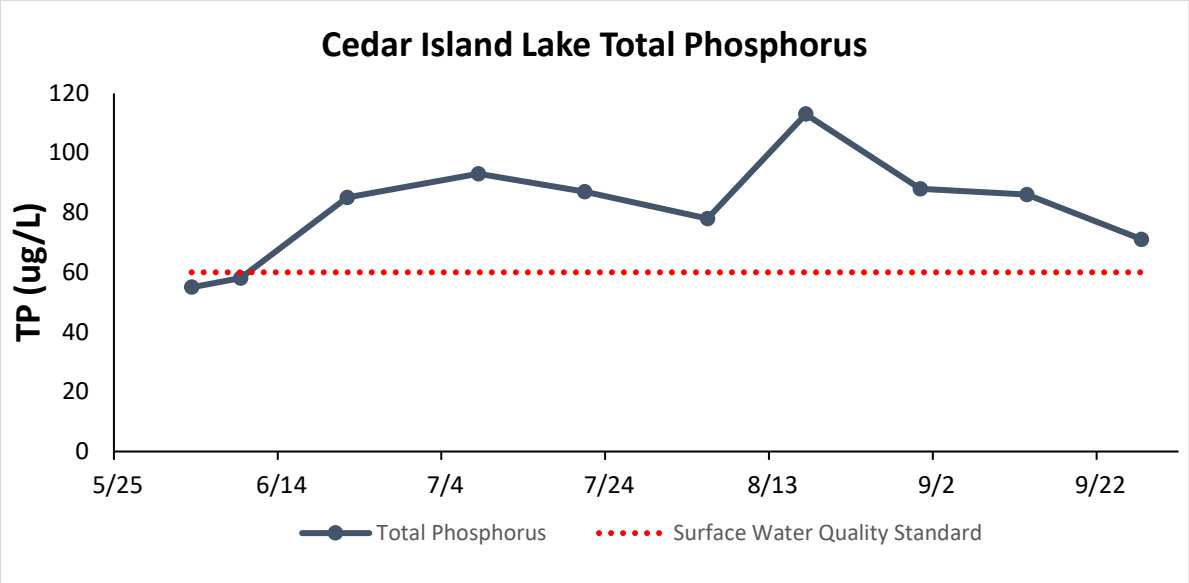
Cedar Island Lake (Public Water No. 27011900) is located in the city of Maple Grove within Hennepin County, MN. Cedar Island Lake is classified as a shallow lake and has an approximate surface area of 79 acres, all of which are in the littoral area (i.e., area less than 15 feet deep), 2.5 miles of shoreline, and a maximum depth of 7 feet. The list below summarizes the year in which each type of sampling was most recently performed on Cedar Island Lake:

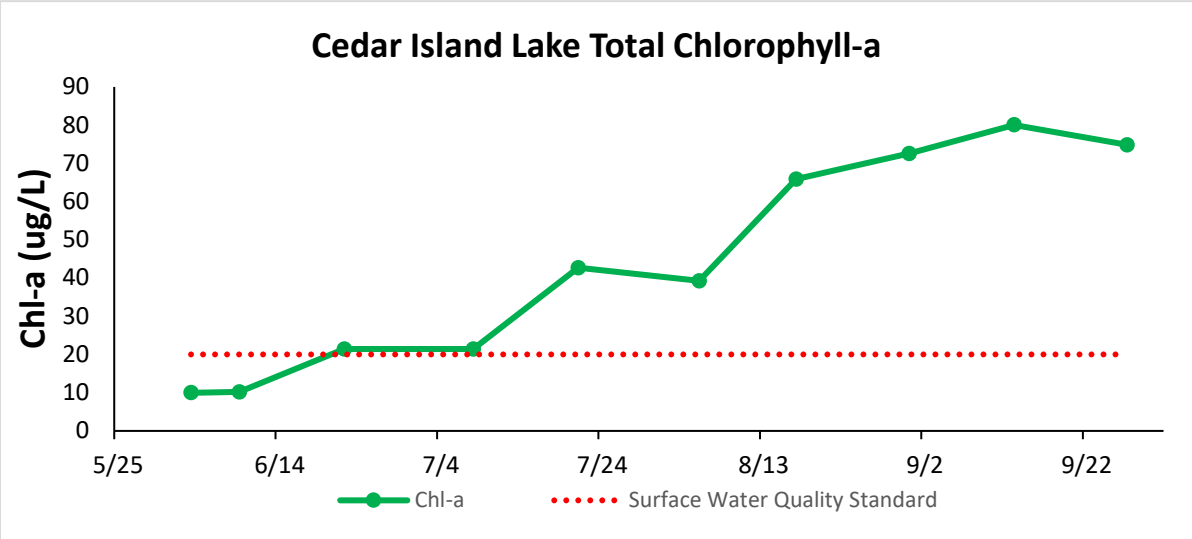
- Water Quality - 2021
- SAV – 2021
- Phytoplankton/Zooplankton - 2021
- Fisheries – 2021
- Carp – 2021

2.2 WATER QUALITY

Water was collected biweekly from early June through late September 2021 for a total of 10 samples (Figure 2.2.1). Total phosphorus, chlorophyll-a, and Secchi depth transparency all exceeded the surface water quality standard for most of the sample period.

Historic monitoring data shows improvements in both total phosphorus and chlorophyll-a concentrations (Figure 2.2.2). TP concentrations dropped considerably since the last available monitoring data from 2015, and is approaching the shallow lake standard of 60 ug/L. Chlorophyll-a also saw a slight decrease in concentration, however, average concentrations are still well above the shallow lake standard of 20 ug/L. Secchi depth transparency was historically improving from 2015-2020, but decreased in 2021, and is still below the shallow lake standard of 1 meter.





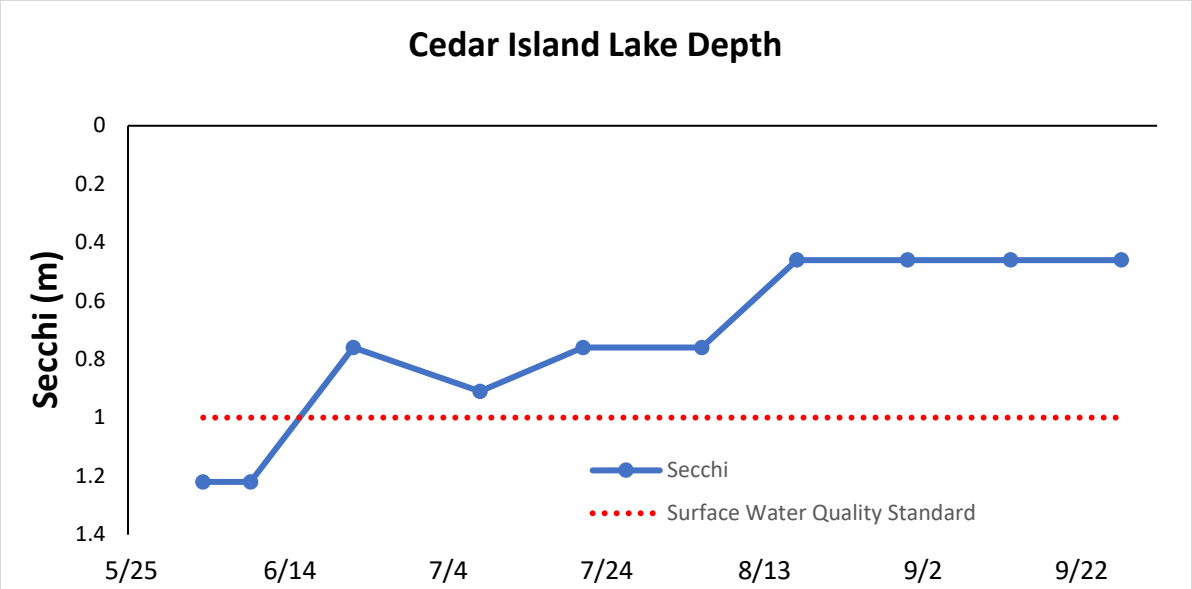


Figure 2.2.1. Seasonal TP, chlorophyll-a, and Secchi measurements and standards.

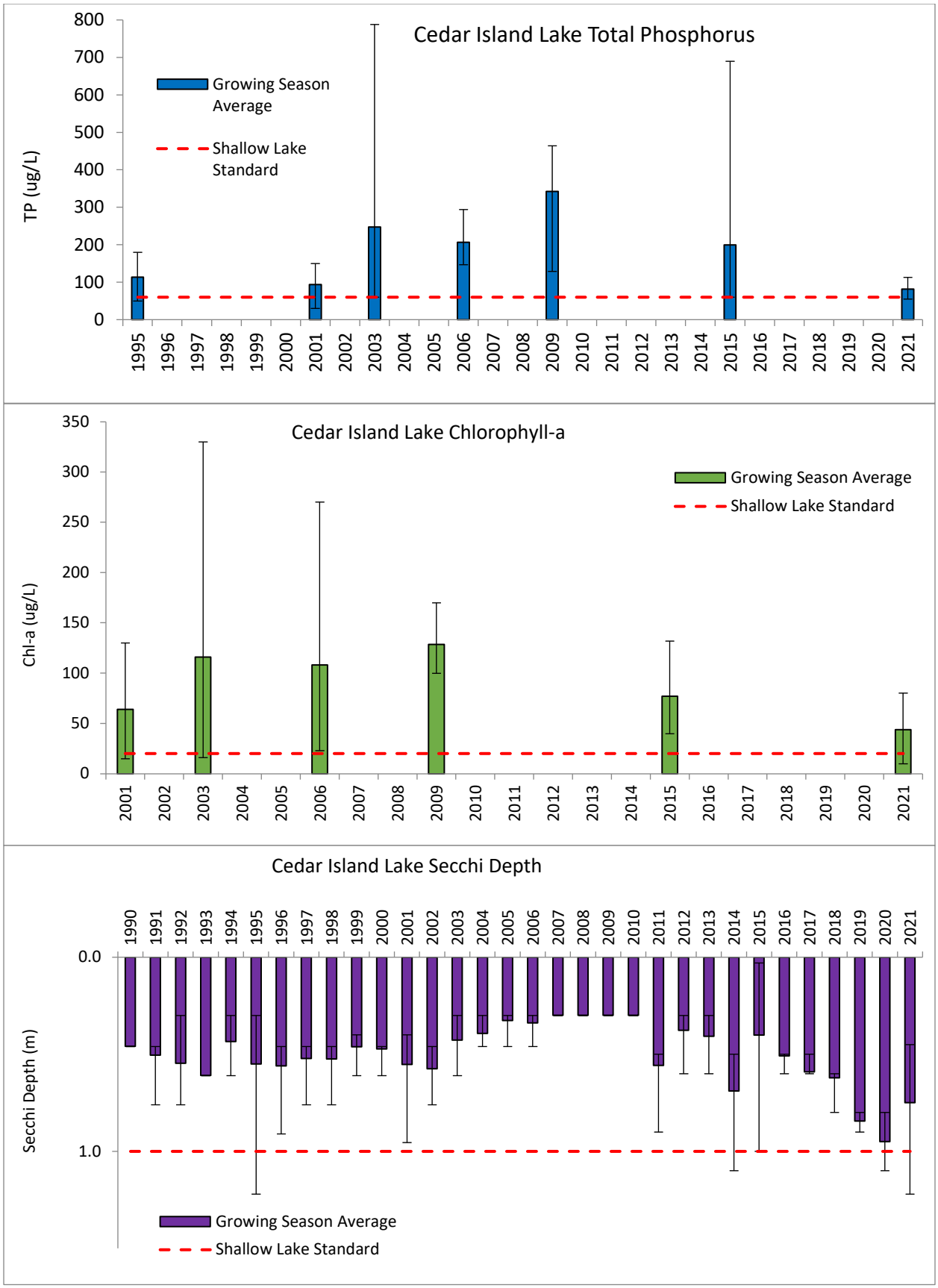


Figure 2.2.2. Annual growing season averages for total phosphorus, chlorophyll-*a*, and Secchi depth, with shallow lake standards in red for reference.

2.3 PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton and zooplankton composition were measured in June and September 2021 to compare the relative percentages of each family and changes throughout the season (Figures 2.3.1 & 2.3.2). Cedar Island Lake experienced a transition in phytoplankton dominance from chlorophyta to cyanobacteria, additionally experiencing an increase in dinoflagellates in the fall. In September cyanobacteria was 48%, which is typical as cyanobacteria are more competitive in warmer water. The cyanobacteria present in September were nitrogen fixing cyanobacteria which is an indicator of low nitrogen concentrations.

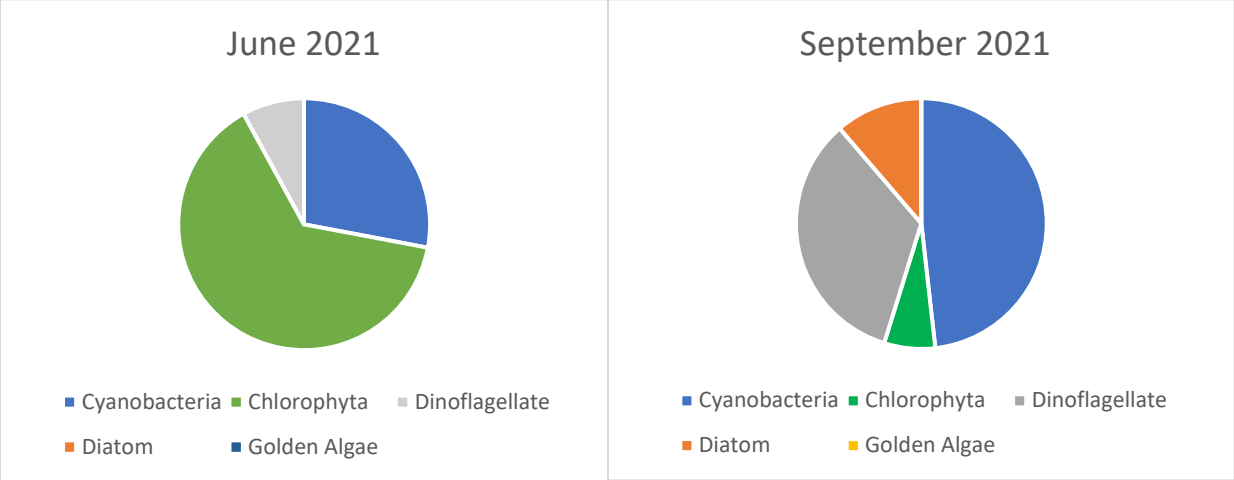


Figure 2.3.1: Phytoplankton relative percentage from June and September 2021 in Cedar Island Lake.

In June, *bosmina* dominated the zooplankton composition in Cedar Island Lake at 51% abundance. This is a less common trend as *bosmina* are typically lower in abundance in the early season and increase in numbers throughout the summer and into the fall (Heiskary 2016). Daphnia exhibited an opposite trend in abundance throughout the season, beginning at only 16% abundance in June, and dominating the abundance by September at 53%. Similar to the *bosmina*, this trend is the opposite of what is typically observed. Daphnia are passive grazers and tend to decline in population with the quality of food that is available.

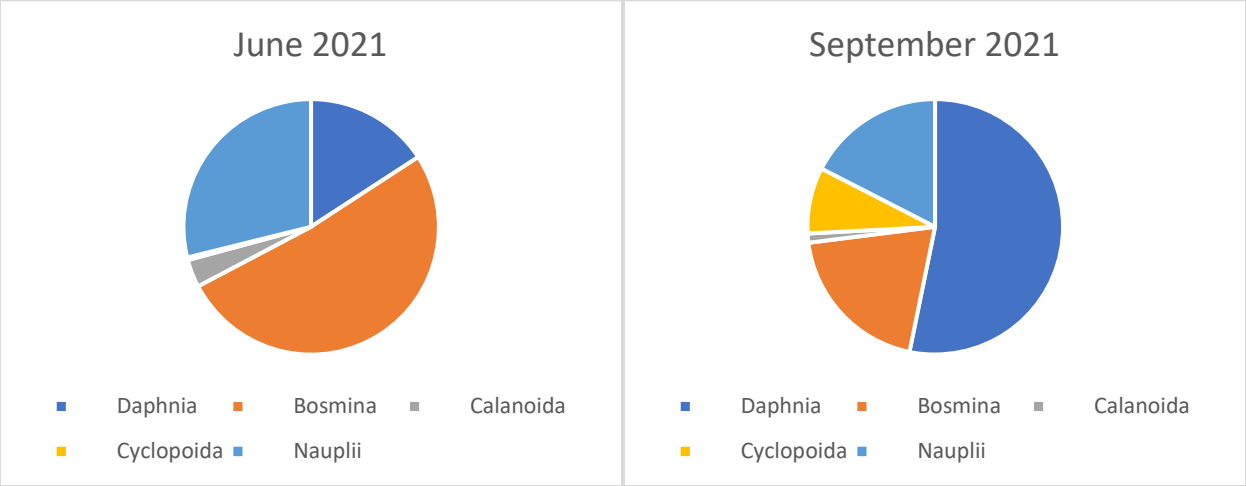


Figure 2.3.2: Zooplankton relative percentage from June and September 2021 in Cedar Island Lake.

2.4 SUBMERSED AQUATIC VEGETATION

Point intercept aquatic vegetation surveys were conducted on May 25, 2021 and August 17, 2021 to document the spring and summer submersed aquatic vegetation in Cedar Island Lake. (These surveys will be referred to as the spring and summer surveys.) A full lake point intercept SAV survey has never been conducted on the lake. Below are two tables outlining survey results and associated metrics and indices (**Table 2.4.1** and **Table 2.4.2**). Maps include early and late-season BioBase maps of vegetation biovolume (**Figure 2.4.1**), number of taxa at each sample point (**Figure 2.4.2**), CLP location and density (**Figure 2.4.3**), CLP was observed in low abundance during the spring survey and absent in the summer survey.

Table 2.4.1. Cedar Island Lake SAV metrics and indices.

	May 25, 2021	**August 17, 2021**
LAKEWIDE METRICS		
Total Points Sampled	60	60
Total Littoral Points Sampled	60	60
% Littoral with Vegetation	85	55
Max depth of plant growth (ft)	5.4	5.2
Shallow Lake Species Richness Threshold	*11*	
Species Richness	8	6
COMMUNITY INDICES		
Shallow Lake FQI Threshold	*17.8*	
Floristic Quality Index (FQI)	15.0	13.5
Simpson's Diversity Index	55.5	56.5
Aquatic Macrophyte Community Index (AMCI)	34	35

*Typha is not included in Taxa or Community Indices calculations as it does not have a C value.

Table 2.4.2. Cedar Island Lake plant taxa and littoral frequency of occurrence from 2021 surveys.

Taxa	Common Name	May 25, 2021	August 17, 2021
SUBMERSED TAXA			
Ceratophyllum demersum	Coontail	83	47
Chara sp.	Muskgrass	3	2
Potamogeton crispus	Curly-leaf pondweed	7	--
Potamogeton strictfolius	Straight-leaved pondweed	3	2
FLOATING TAXA			
Nymphaea odorata	White waterlily	28	23
Lemna minor	Small duckweed	2	
EMERGENT TAXA			
Typha sp.	Cattail	P	P
Eleocharis acicularis	Needle Spikerush	3	3
Schoenoplectus tabernaemontani	Soft-stem Bulrush	P	P

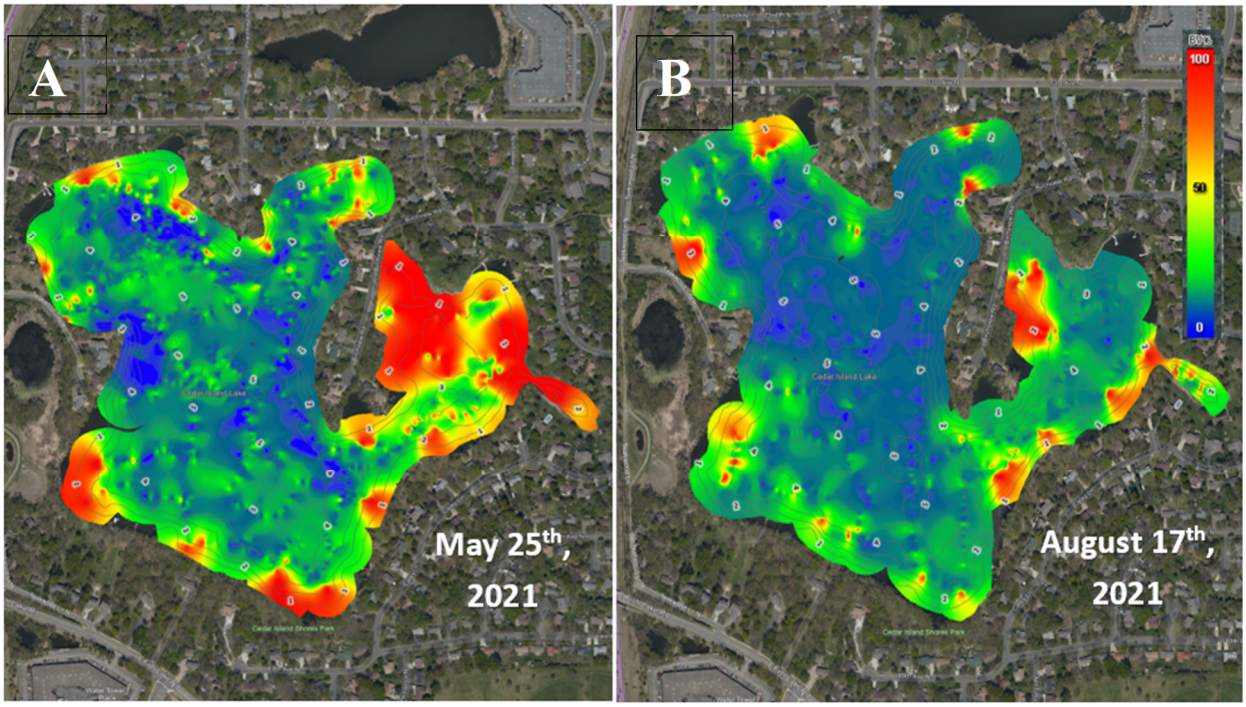


Figure 2.4.1. Biovolume heat maps for Cedar Island Lake during the June (A) and August (B) 2021 surveys. In the heatmaps, red indicates 100% biovolume and blue indicates 0% biovolume. Biovolume refers to the percentage of the water column taken up by vegetation.

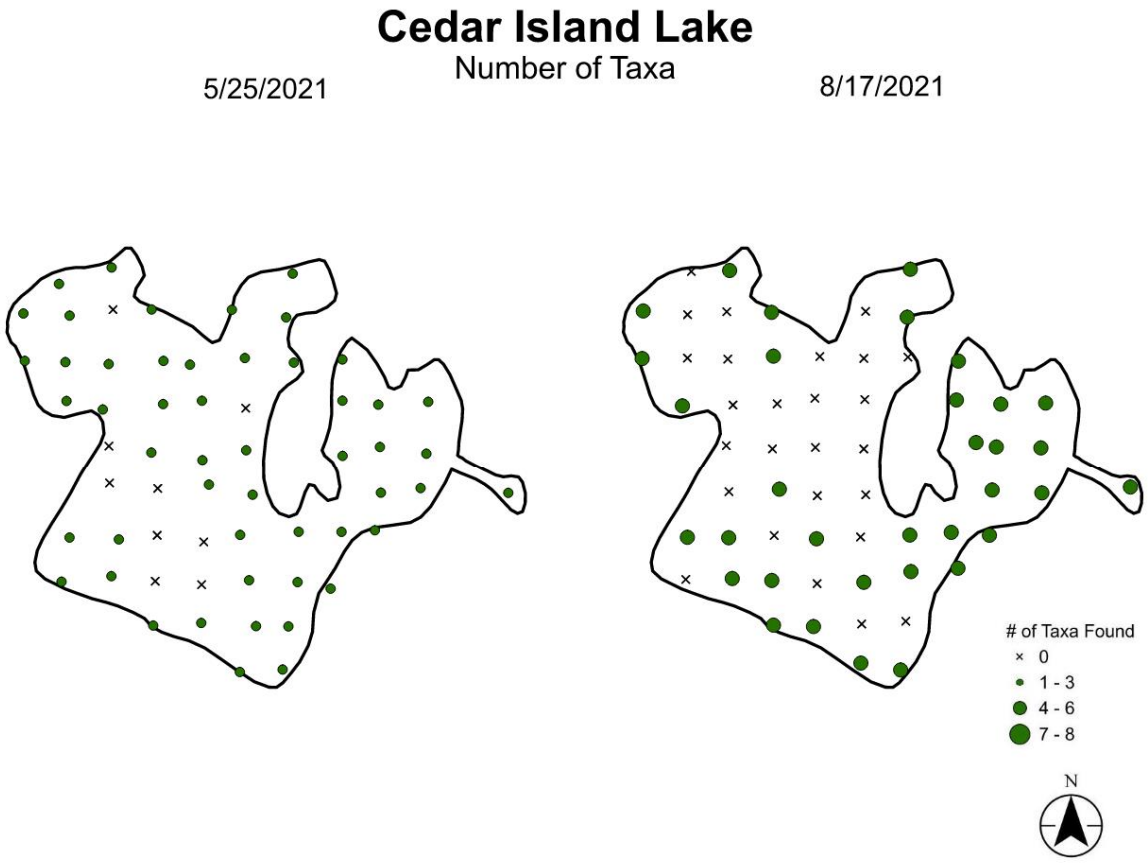


Figure 2.4.2. Map of the Number of taxa found at each point in Cedar Island Lake.

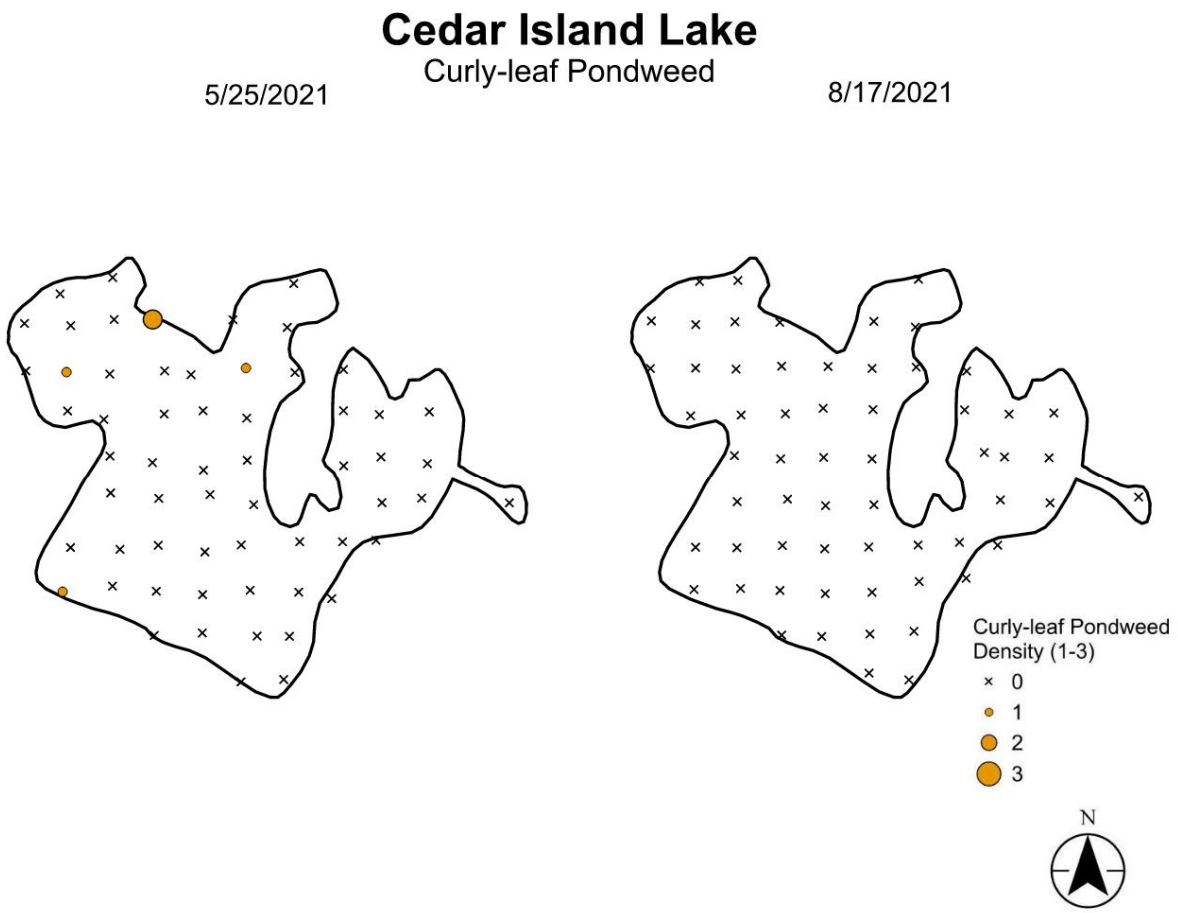


Figure 2.4.3. Map of the location and density of Curly-leaf Pondweed in Cedar Island Lake.

2.5 FISHERIES ASSESSMENTS

Three different gear types were deployed to assess the fish community during the 2021 season. Trap nets and gill nets were deployed on September 12, 2021 and left overnight and retrieved on September 13, 2021. A prior trap net fisheries assessment was conducted by Blue Water Science in 2008 and September 2016. In addition, Stantec conducted a common carp boat electrofishing catch per unit of effort (CPUE) survey using the methods outlined in Bajer & Sorenson 2012 on September 13, 2021. No prior carp surveys had been conducted on Cedar Island Lake.

2.5.1 Trap and Gill Net Surveys

Eight fish species were sampled during the September 12-13, 2021 survey: Black bullhead (Ameiurus melas), black crappie (Pomoxis nigromaculatus), bluegill (Lepomis macrochirus), central mudminnow (Umbra limi), green sunfish (Lepomis cyanellus), hybrid sunfish (Lepomis sp.), largemouth bass (Micropterus salmoides), and pumpkinseed sunfish (Lepomis gibbosus). Table 2.5.1 presents each fish species sampled, along with the number of fish sampled, CPUE, and average weights.

Presented in Table 2.5.1 are the Lake Class 40 CPUE and average weight median and normal ranges for each sampled species. As mentioned above, the DNR uses the Schupp Lake Class system (Schupp 1992) to classify every lake in the state into 44 ecological lake classes. Each lake class grouping varies based on physical and chemical characteristics such lake size, lake depth, and water

chemistry since these factors can influence fish species and community assemblages. Normal ranges are not available for many of the fish species and or gear types sampled in Cedar Island Lake as these species are not commonly sampled by the DNR in other Lake Class 40 lakes.

Table 2.5.1. Fish Species Sampled During September 12-13, 2021 Cedar Island Fisheries Survey.

Species	Gear	Total Sampled (Count)	CPUE	Lake Class 40 Normal Range CPUE	Avg Weight (lbs)	Lake Class 40 Normal Range Weight (lbs)
Black Bullhead	Fyke	2	0.7	2.5-70.2	0.08	0.1-0.5
Black Crappie	Fyke	21	7.0	1.3-27.7	0.16	0.1-0.4
Bluegill	Fyke	237	79.0	2.8-43.3	0.13	0.1-0.3
Central Mudminnow	Fyke	1	0.3	N/A	0.01	N/A
Green Sunfish	Fyke	5	1.7	0.4-3.8	0.02	0.1-0.2
Hybrid Sunfish	Fyke	3	1.0	N/A	0.07	N/A
Largemouth Bass	Fyke	2	0.7	0.2-1.1	1.79	0.3-1.0
Pumpkinseed	Fyke	29	9.7	0.8-9.3	0.13	0.1-0.2
Black Bullhead	Gill	202	202.0	8.0-90	0.65	0.1-0.4
Black Crappie	Gill	146	146.0	2.0-19.0	0.11	0.1-0.2
Bluegill	Gill	17	17.0	N/A	0.16	N/A
Hybrid Sunfish	Gill	1	1.0	N/A	0.20	N/A
Largemouth Bass	Gill	7	7.0	1.0-3.8	1.62	0.2-0.7
Pumpkinseed	Gill	5	5.0	N/A	0.09	N/A

CPUE = Catch per unit of effort
N/A = DNR Median and normal ranges (i.e. 25th – 75th percentile) not available for this species in this lake class.

2.5.2 Carp Population Assessment

A CPUE electrofishing assessment following the methods outlined in Bajer & Sorenson (2012) was conducted on Cedar Island Lake on to determine abundance and biomass density of common carp populations. All field work for these assessments was performed following all regulations regarding aquatic invasive species management under DNR special research permit #32020. One hour of electrofishing was conducted traversing the shorelines and littoral areas of the lake. Following the conclusion of the survey no common carp were captured or observed in Cedar Island Lake during the 2021 electrofishing surveys. We can confidently conclude due to the lack of common carp population present in Cedar Island Lake that the potential carp population is not impacting water quality at this time.

3.0 Lake Success

3.1 INTRODUCTION & SAMPLING OVERVIEW

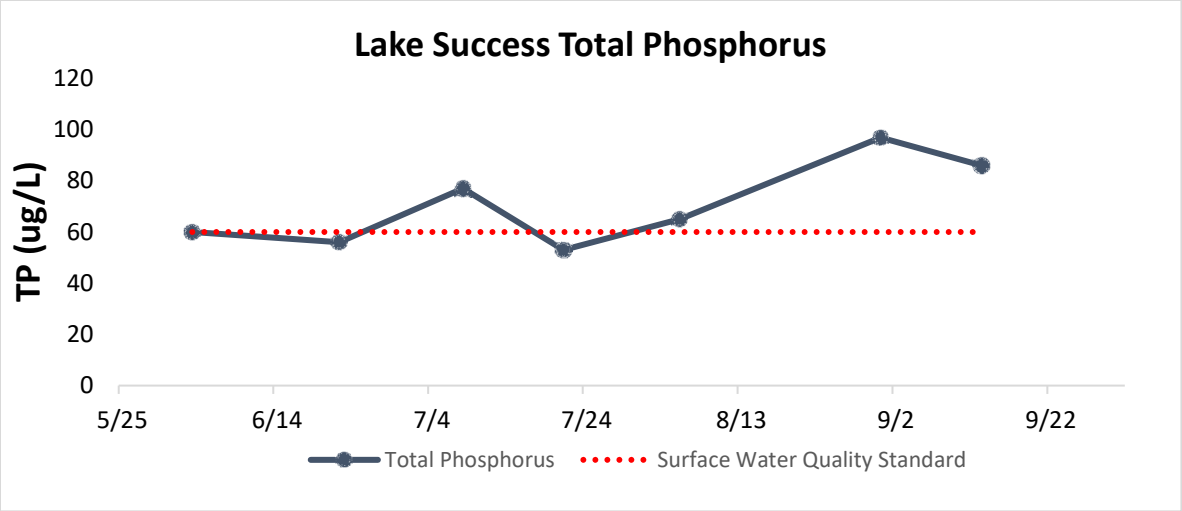
Lake Success (Public Water No. 27063400) is located in Brooklyn Park within Hennepin County, MN. Lake Success is classified as a wetland and has an approximate surface area of 8 acres. The list below summarizes the year in which each type of sampling was most recently performed on Lake Success:

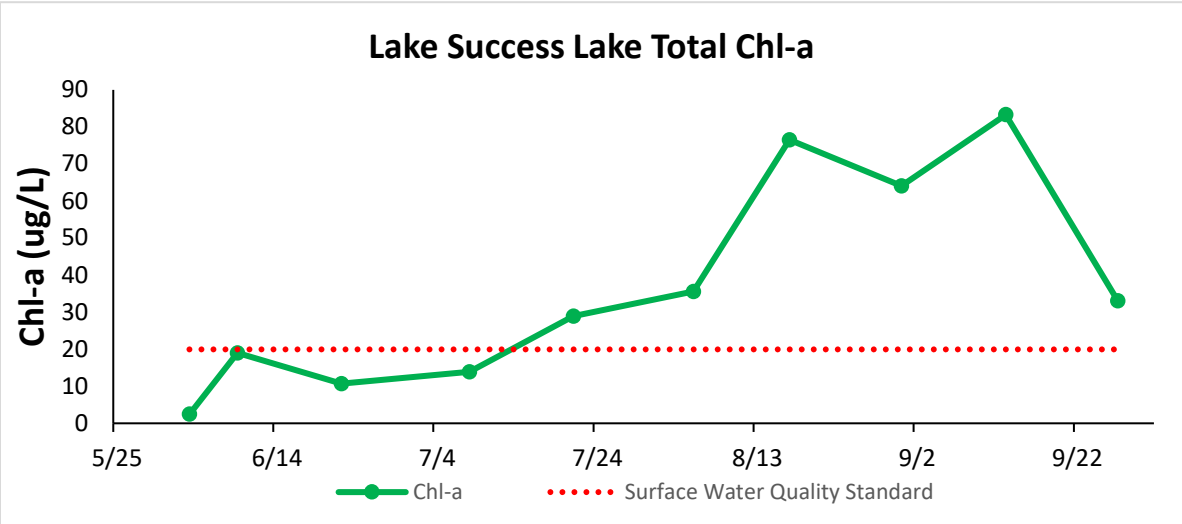
- Water Quality - 2021
- SAV – 2021
- Phytoplankton/Zooplankton - 2021
- Fisheries – Not assessed
- Carp – Not assessed

3.2 WATER QUALITY

Figure 3.2.1 shows TP, secchi, and chlorophyll-a concentrations from May through September 2021. All three variables exceeded the surface water quality standard from July- September, with TP having a slight dip in concentration in mid-July.

Figure 3.2.2 shows historic average concentrations collected during the growing season. Success Lake has decreased in overall water quality, with all three variables failing to meet shallow lake standards. Both TP and chlorophyll-a were in compliance with the water quality standard in 2016 and have surpassed the threshold in 2021. Secchi depth transparency trends have remained similar since 2014, remaining just below the shallow lake standard.





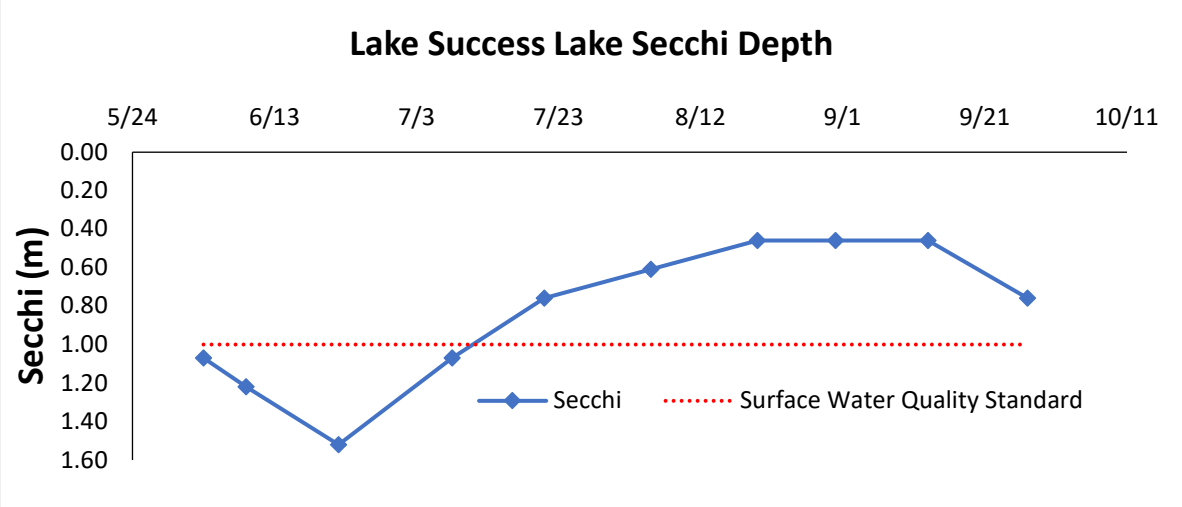


Figure 3.2.1. Seasonal TP, chlorophyll-a, and Secchi measurements and standards.

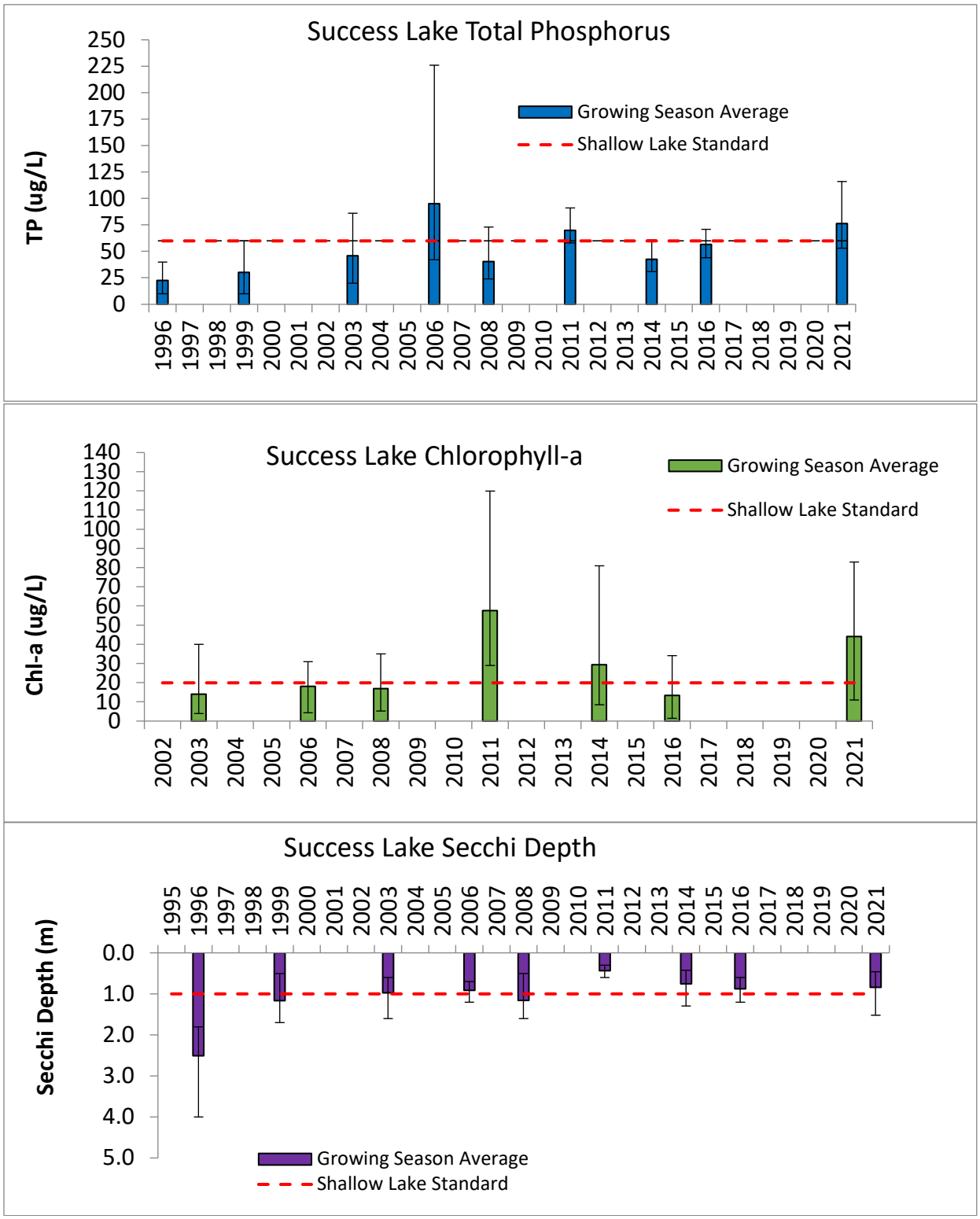


Figure 3.2.2. Annual growing season averages for total phosphorus, chlorophyll-*a*, and Secchi depth in Lake Success, with shallow lake standards in red for reference.

3.3 PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton composition was measured for two samples in June and September 2021 to compare the relative percentages of each family (Figures 5.3.1 & 5.3.2). In June, Lake Success was comprised of primarily chlorophyta. As waters warmed throughout summer and into September cyanobacteria was able to dominate the assemblage, eventually becoming the only phytoplankton present in the lake, causing a large HAB. The sole genera was Microcystis, which is an aggressive bloom forming cyanobacteria that has the potential for toxin production.

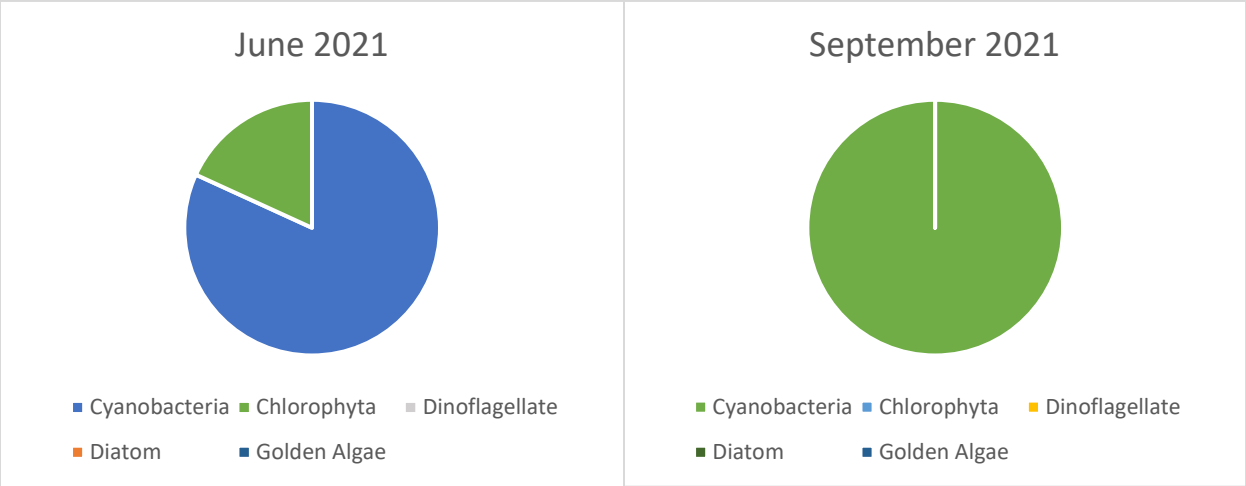


Figure 3.3.1: Phytoplankton relative percentage from June and September 2021 in Lake Success.

Lake Success was dominated by nauplii (65 %) in June, with cyclopoida (29%), bosmina (5%), and calanoida (1%) present. By September, the assemblage became largely dominated by bosmina (76%) when quality food sources diminished, and larger species are no longer present to outcompete them (Heiskary 2016).

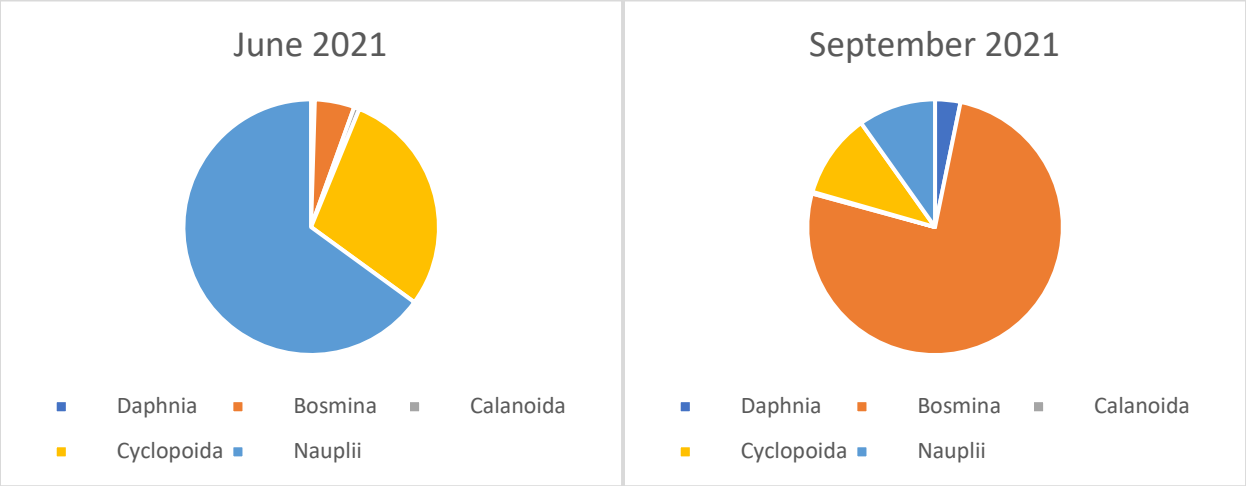


Figure 3.3.2: Zooplankton relative percentage from June and September 2021 in Lake Success.

3.4 SUBMERSED AQUATIC VEGETATION

Point intercept aquatic vegetation surveys were conducted on May 25, 2021 and August 20, 2021 to document the spring and summer submersed aquatic vegetation in Lake Success. The most recent full lake point intercept SAV surveys were conducted by Stantec in June and August 2016 where no

plants were observed. Lake Success is classified as a wetland that and most of the lake's area is (i.e., <15 feet deep). Below are two tables outlining survey results and associated metrics and indices (**Table 3.4.1** and **Table 3.4.2**). Maps include early and late-season BioBase maps of vegetation biovolume (**Figure 3.4.1**), number of taxa at each sample point (**Figure 3.4.2**), CLP location and density (**Figure 3.4.3**), CLP was present with low occurrence in the spring survey but absent in the summer survey.

Table 3.4.1. Lake Success SAV metrics and indices.

	May 25, 2021	August 20, 2021
LAKEWIDE METRICS		
Total Points Sampled	54	39
Total Littoral Points Sampled	51	38
% Littoral with Veg	39	13
Max depth of plant growth (ft)	8.4	5.0
Species Richness	3	2
COMMUNITY INDICES		
Floristic Quality Index (FQI)	10.4	9.2
Simpson's Diversity Index	48.4	40.0
Aquatic Macrophyte Community Index (AMCI)	33	35

Table 3.4.2. Lake Success plant taxa and littoral frequency of occurrence from 2021 surveys.

Taxa	Common Name	May 25, 2021	August 17, 2021
SUBMERSED TAXA			
Chara sp.	Muskgrass	15	--
Potamogeton crispus	Curly-leaf pondweed	2	--
Potamogeton strictfolius	Straight-leaved pondweed	33	10
FLOATING TAXA			
Spirodela polyrhiza	Greater duckweed	--	3

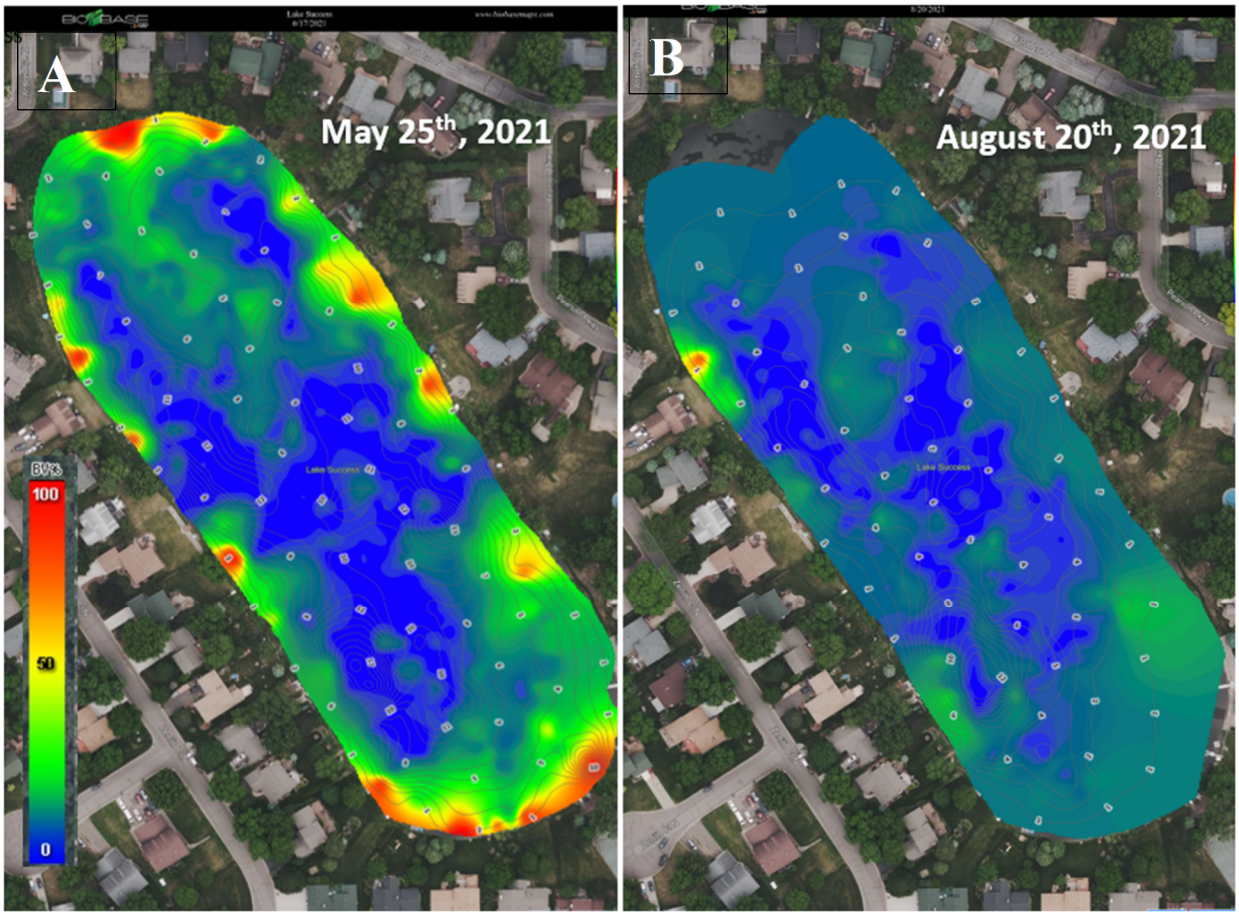


Figure 3.4.1. Biovolume heat maps for Lake Success during the June (A) and July (B) 2021 surveys. In the heatmaps, red indicates 100% biovolume and blue indicates 0% biovolume. Biovolume refers to the percentage of the water column taken up by vegetation.

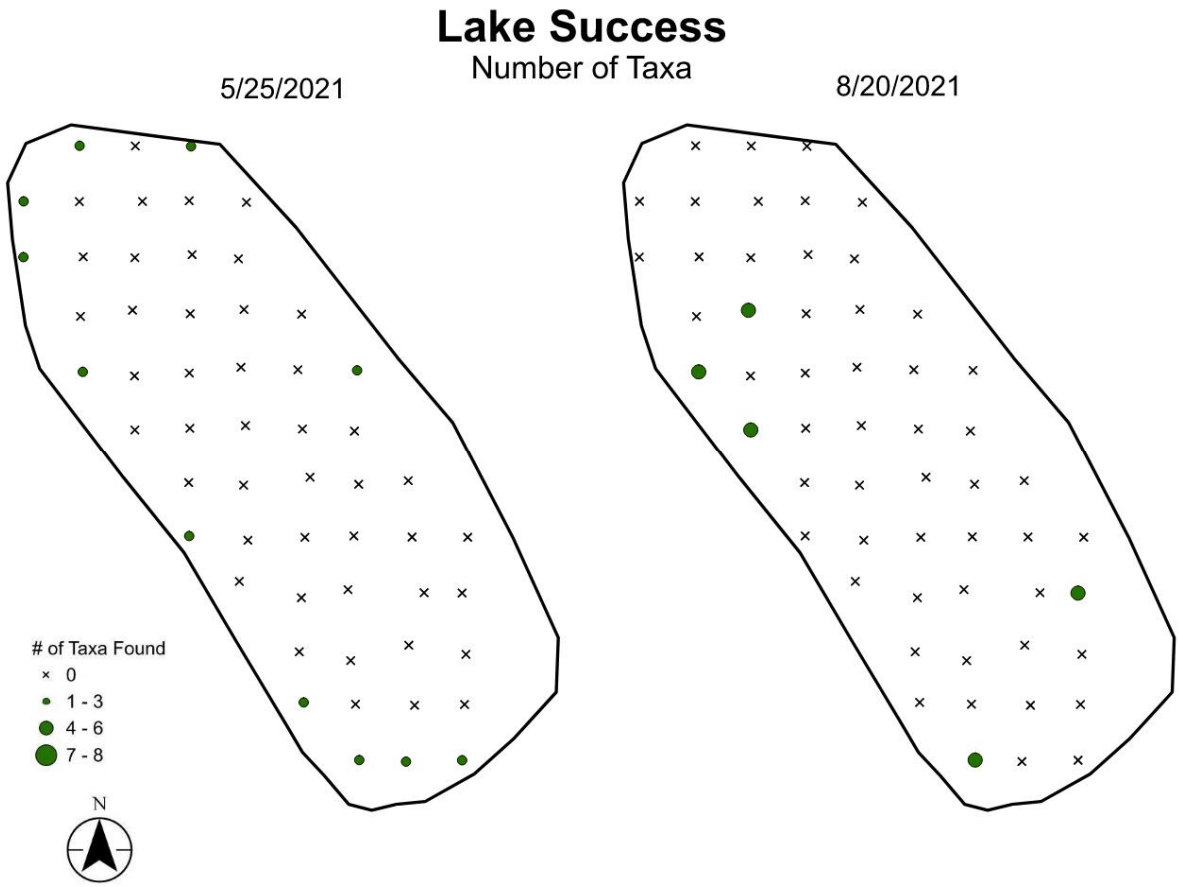


Figure 3.4.2. Map of the number of taxa found at each point in Lake Success.

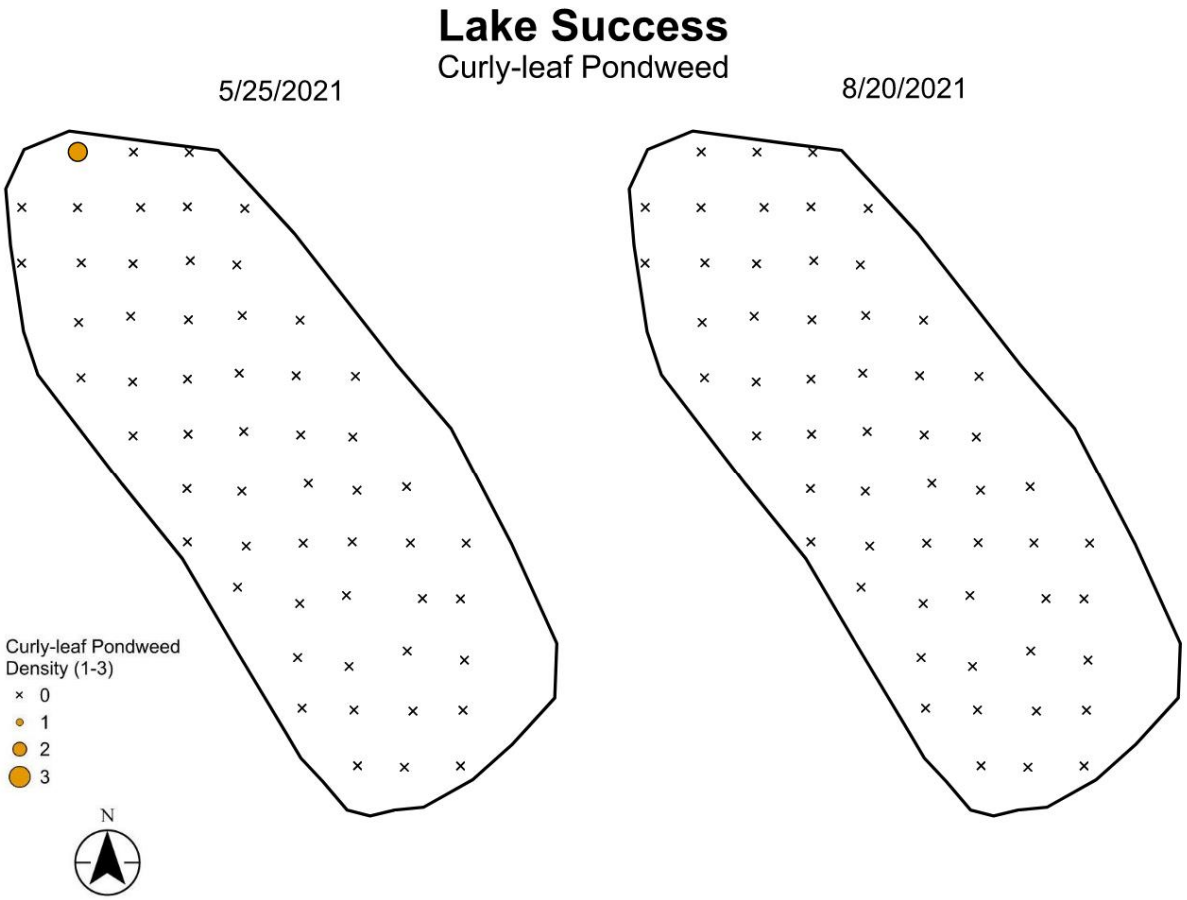


Figure 3.4.3. Map of the location and density of curly-leaf Pondweed in Lake Success.

4.0 Bass Lake

4.1 INTRODUCTION & SAMPLING OVERVIEW

Bass Lake (Public Water No. 27009800) is located in the city of Plymouth within Hennepin County, MN. Bass Lake is classified as a shallow lake and has an approximate surface area of 176 acres, 148 acres of littoral area (i.e., area less than 15 feet deep), 3.2 miles of shoreline, and a maximum depth of 31 feet. The list below summarizes the year in which each type of sampling was most recently performed on Bass Lake:

- Water Quality – 2021
- Phytoplankton/Zooplankton - 2021
- SAV – 2021
- Fisheries - 2017
- Carp – 2017

Bass Lake received an alum treatment on May 15, 2019 to mitigate internal phosphorus loading (Figures 4.1.1 and 4.1.2). Alum was applied to a 35-*a*cre area of the lake that consisted of all parts of the lake 14 feet and deeper. Alum was applied at 789 gallons/acre. The second alum treatment occurred in September 2020 following the monitoring season. Alum was applied at the same dose as in 2019.

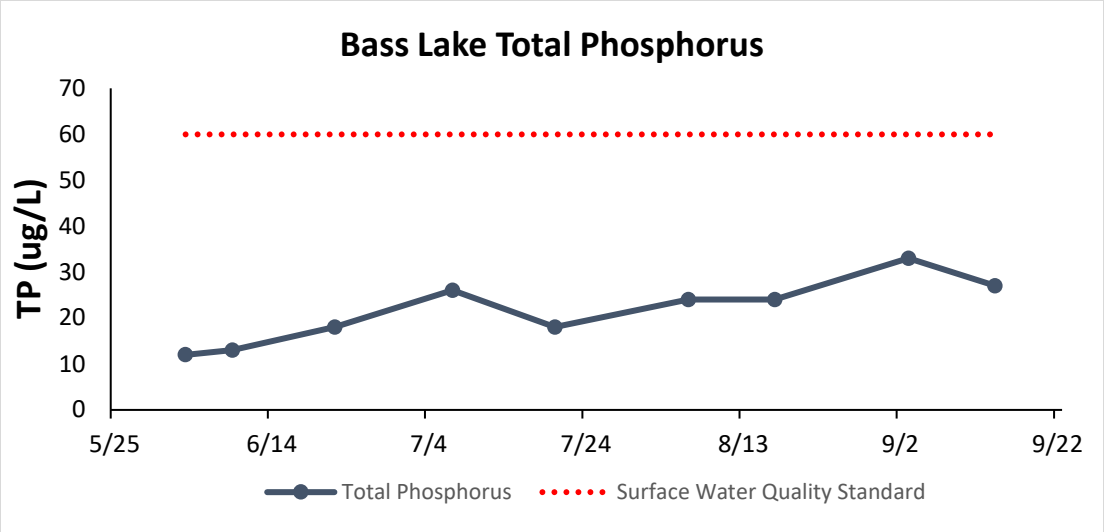
Figure 4.1.1. A barge applies alum to Bass Lake in 2019.

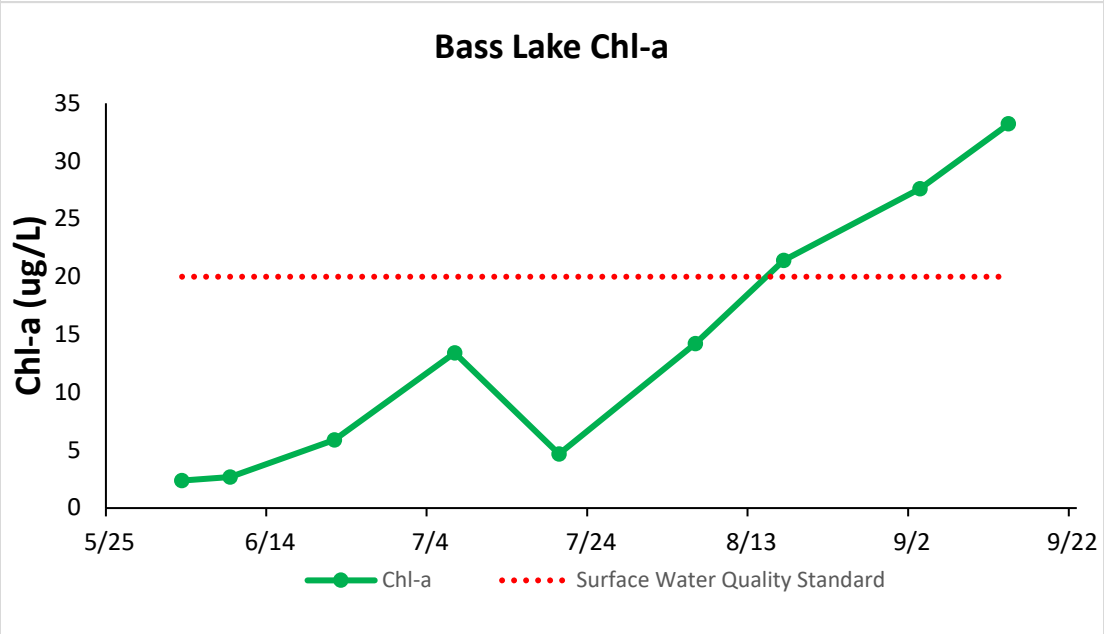
Figure 4.1.2. The alum application barge on Bass Lake in 2019.

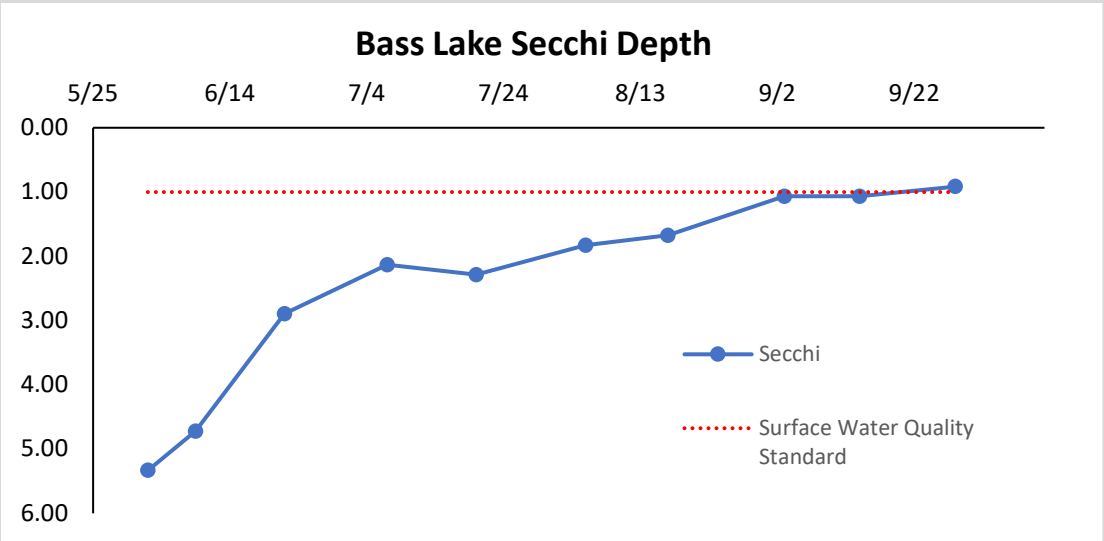
4.2 WATER QUALITY

Figure 4.2.1 shows TP, chlorophyll-a, and Secchi depth transparency from samples collected during the monitoring season in 2021. TP concentrations maintained well below the surface water quality standard for the entire monitoring season. *Chlorophyll-a* was able to meet the standard for most of the summer, only exceeding the limit in late August-September. Secchi depth readings began well below the surface water quality standard, slow declining throughout summer, eventually barely failing to meet the standard in late September.

Figure 4.2.2 shows historic averages. Water quality in Bass Lake has been improving since the alum treatment in 2019. Both *chlorophyll-a* and TP concentrations have reached an all-time low with average monitoring season concentrations well below the shallow lake standard. Secchi depth transparency observed a significant increase, averaging over double the required shallow lake standard.







4.2.1. Seasonal TP, *chlorophyll-a*, and Secchi measurements and standards.

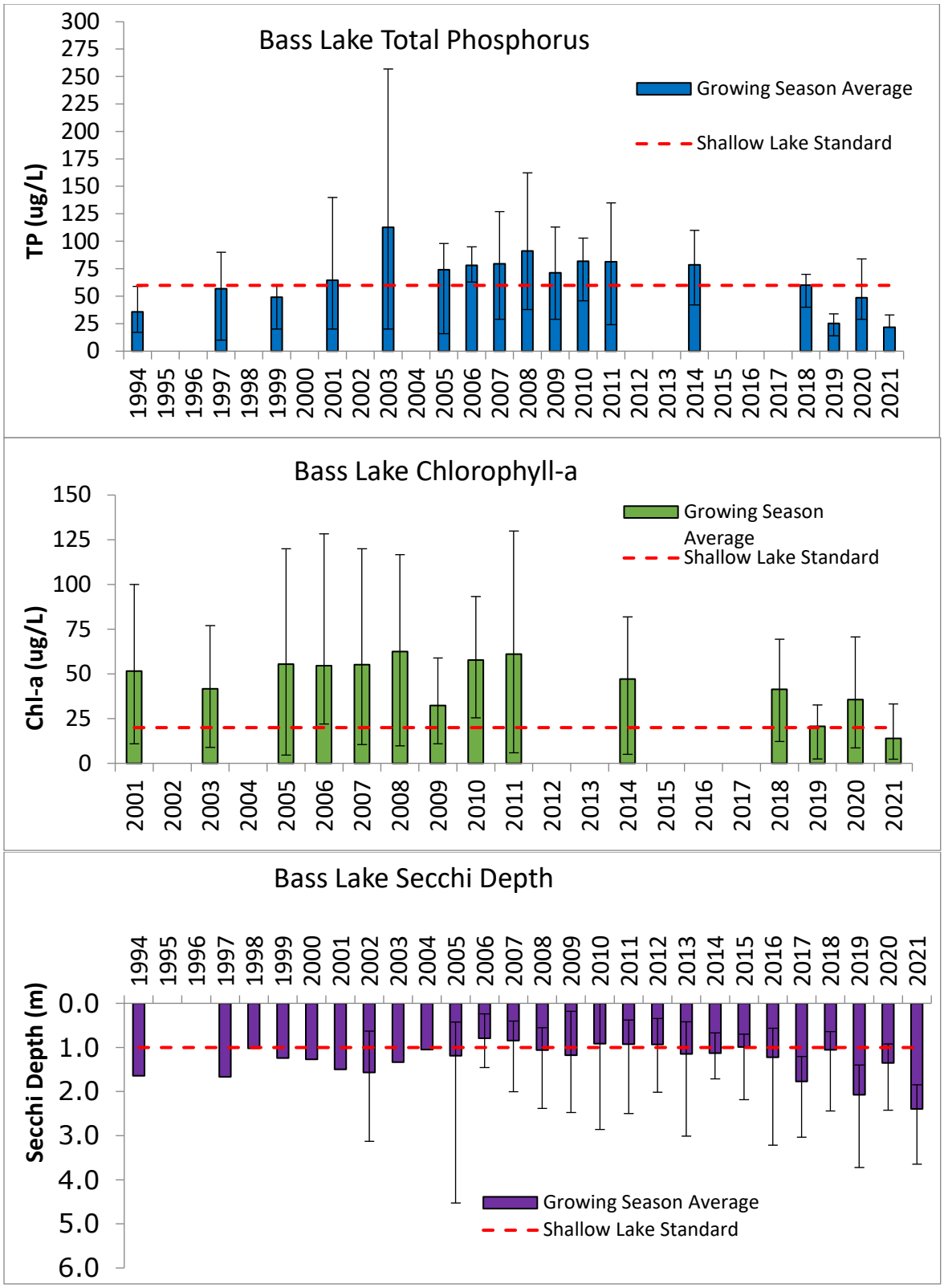


Figure 4.2.2. Annual growing season averages for total phosphorus, chlorophyll-*a*, and Secchi depth, with shallow lake standards in red for reference.

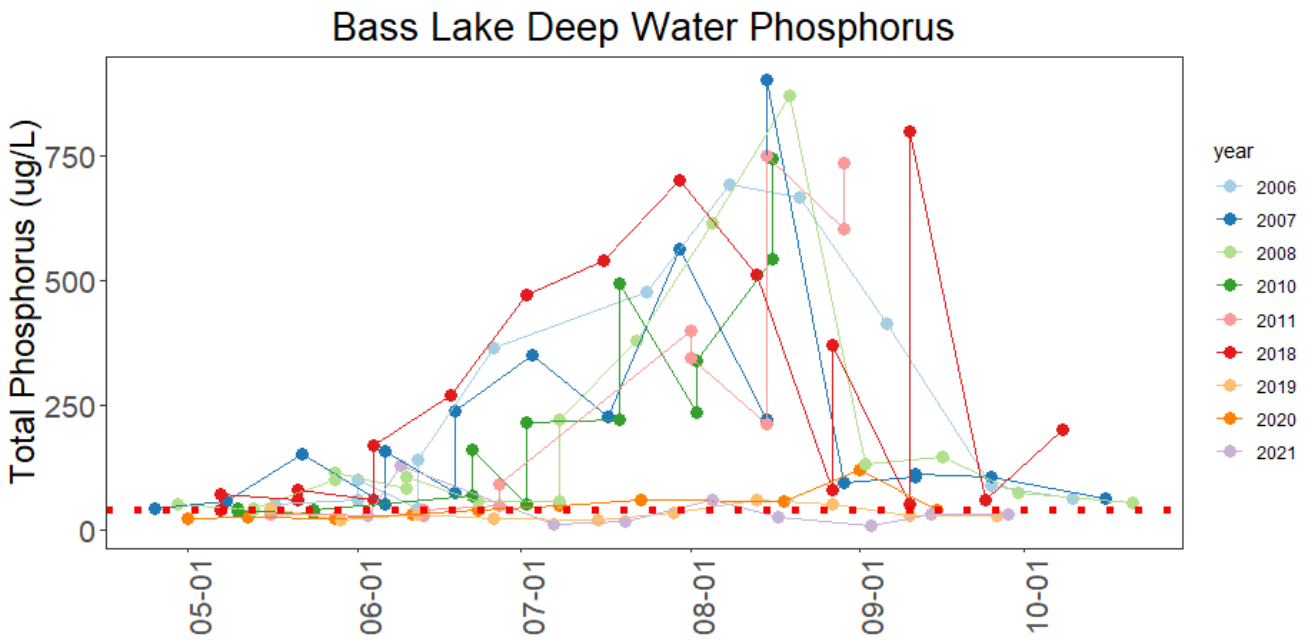


Figure 4.2.3. Hypolimnetic (deep) total phosphorus (TP) throughout the summer in several years from 2006 to 2021.

Due to alum inactivation of sediment phosphorus release in 2019 and 2020, phosphorus does not appear to accumulate in the hypolimnion over the recent summers.

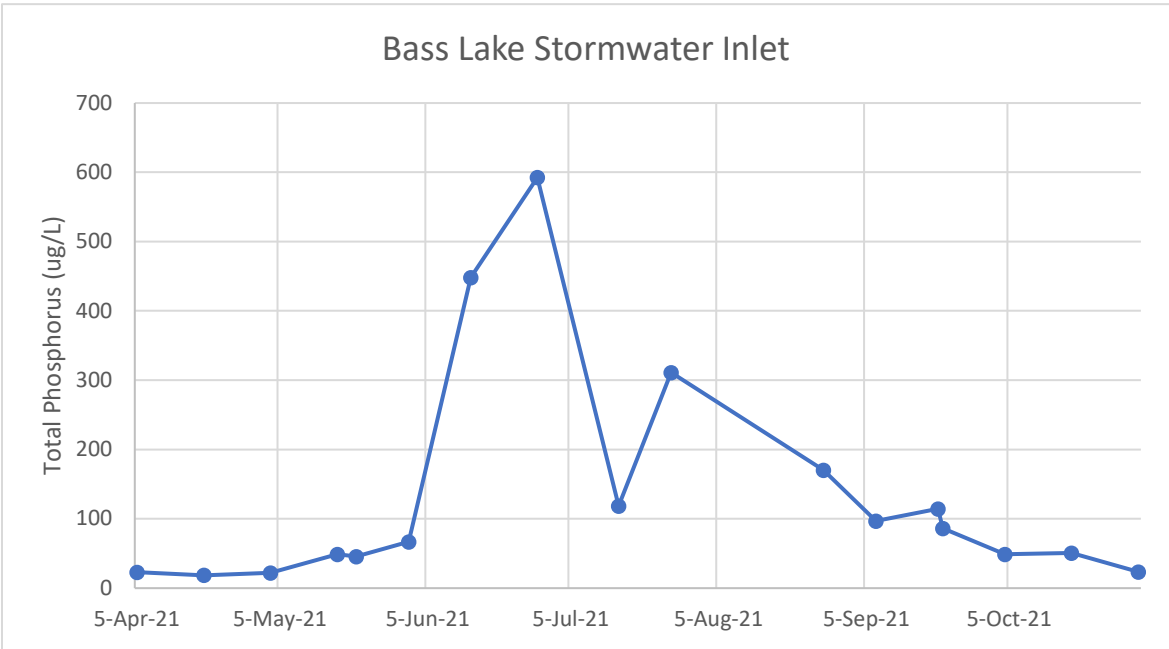


Figure 4.2.4. Total phosphorus (TP) throughout the summer at sampling station BL3-W, an inlet to Bass Lake (data collected by Three Rivers Park District).

4.3 PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton composition was measured for two samples in June and September 2021 to compare the relative percentages of each family (Figures 4.3.1 & 4.3.2). In June 2021, Chlorophyta was the largest community at 53% abundance with a mix of other families. There was a large shift in assemblage by September. With the presence of warmer water, cyanobacteria was able to dominate the assemblage, eventually making up 87% of the species composition. High levels experienced in September are indicative of a HAB. The type of cyanobacteria present are nitrogen fixers which take advantage of low nitrogen concentrations present in late summer.

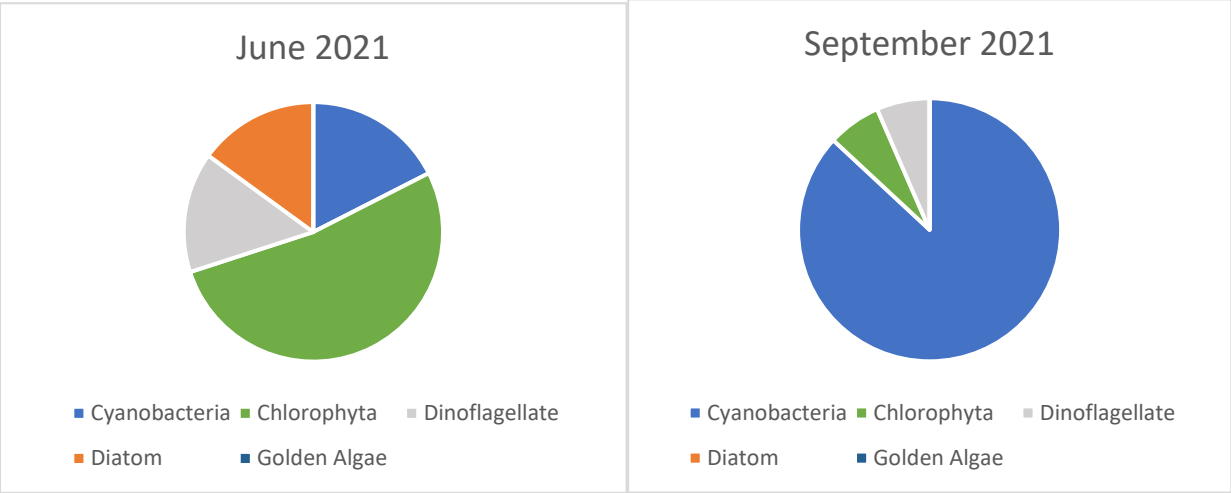


Figure 4.3.1: Phytoplankton relative percentage from June and September 2021 in Bass Lake.

In June 2021, Nauplii were the dominate species in Bass Lake at 76%. Nauplii are the egg stage of many species of zooplankton. The large percentage of the egg stage may indicate that the timing or location of sampling occurred after a fresh hatch. As summer progressed, species composition evened out. Nauplii were still the dominate species at 32%, however, cyclopodia, calanoida, bosmina, and daphnia all saw a significant increase in abundance.

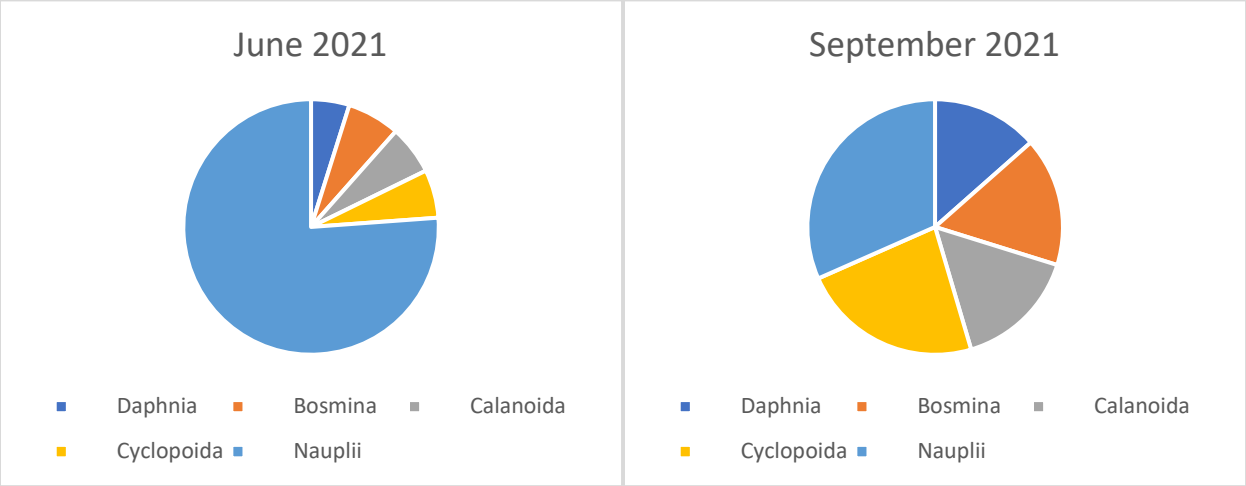


Figure 4.3.1: Zooplankton relative percentage from June and September 2021 in Bass Lake.

4.4 SUBMERSED AQUATIC VEGETATION

Point intercept aquatic vegetation surveys were conducted on May 26, 2021 and August 17, 2021 to document the spring and summer submersed aquatic vegetation in Bass Lake. Previous full lake

point intercept SAV surveys were conducted by Stantec in 2014, 2018, and 2019. Bass Lake is classified as a shallow lake with 148 of its 176 acres in the littoral zone (i.e., in water less than 15 feet deep). Below are two tables outlining the current and historic survey results and associated metrics and indices (**Table 4.4.1** and **Table 4.4.2**). Maps include early and late-season BioBase maps of vegetation biovolume in 2021 (**Figure 4.4.1**), number of taxa at each sample point in 2021 (**Figure 4.4.2**), CLP location and density in 2021 (**Figure 4.4.3**). CLP was present with high occurrence in the spring survey but minimal in the summer survey, which is common due to the early senescence of the plant.

Table 4.4.1. Bass Lake SAV metrics and indices.

	May 26, 2021	**August 17, 2021**
LAKEWIDE METRICS		
Total Points Sampled	104	103
Total Littoral Points Sampled	98	96
% Littoral with Veg	79	62
Max depth of plant growth (ft)	9.2	17.4
Shallow Lake Species Richness Threshold	*11*	
Species Richness	12	16
COMMUNITY INDICES		
Shallow Lake Floristic Quality Index (FQI) Threshold	*17.8*	
FQI	18.2	21.5
Simpson's Diversity Index	77.4	84.1
Aquatic Macrophyte Community Index (AMCI)	40	50

Table 4.4.2. Bass Lake plant taxa and frequency of occurrence from 2014, 2018, 2019, and 2021 surveys.

Taxa	**Common Name**	**June 24, 2014**	**August 21, 2014**	**May 21, 2018**	**August 16, 2018**	**May 28, 2019**	**May 28, 2021**	**August 18, 2021**
SUBMERSED TAXA								
Curly-leaf pondweed	*Potamogeton crispus*	21	--	46	--	--	61	2
Coontail	*Ceratophyllum demersum*	22	20	39	28	41	29	42
Muskgrass	*Chara sp.*	1	2	26	1	29	13	3
Waterweed (Canadian)	*Elodea canadensis*	--	--	10	5	15	6	7
Potamogeton pusillus	Small pondweed	--	--	5	2	--	9	24
Potamogeton epihydrus	Ribbon-leaved pondweed	--	--	--	1	--	--	--

Taxa	Common Name	June 24, 2014	August 21, 2014	May 21, 2018	August 16, 2018	May 28, 2019	May 28, 2021	August 18, 2021
Potamogeton foliosus	Leafy pondweed	--	1	--	--	--	--	--
Potamogeton zosteriformis	Flat-stem pondweed	2	2	--	--	--	4	P
Myriophyllum sibiricum	Northern watermilfoil	--	--	2	--	--	--	P
Vallisneria americana	Water celery	3	9	1	8	8	--	8
Utricularia vulgaris	Greater bladderwort	--	--	--	--	--	--	2
FLOATING TAXA								
Lemna minor	Small duckweed	--	--	1	9	4	2	1
Lemna trisulca	Duckweed (star)	--	--	1	--	6	8	15
Wolffia sp.	Watermeal	--	--	--	--	--	1	6
Spirodela polyrhiza	Large duckweed	--	--	--	--	--	2	2
Nuphar variegata	Yellow waterlily	8	8	7	7	12	7	8
Nymphaea odorata	White waterlily	2	8	6	8	9	7	11
	Filamentous algae	N/A	N/A	N/A	N/A	N/A	P	P
EMERGENT TAXA								
Typha sp.	Cattail	N/A	N/A	N/A	N/A	P	P	P
Sagittaria latifolia	Broad Leaved Arrowhead	--	--	--	--	--	--	P

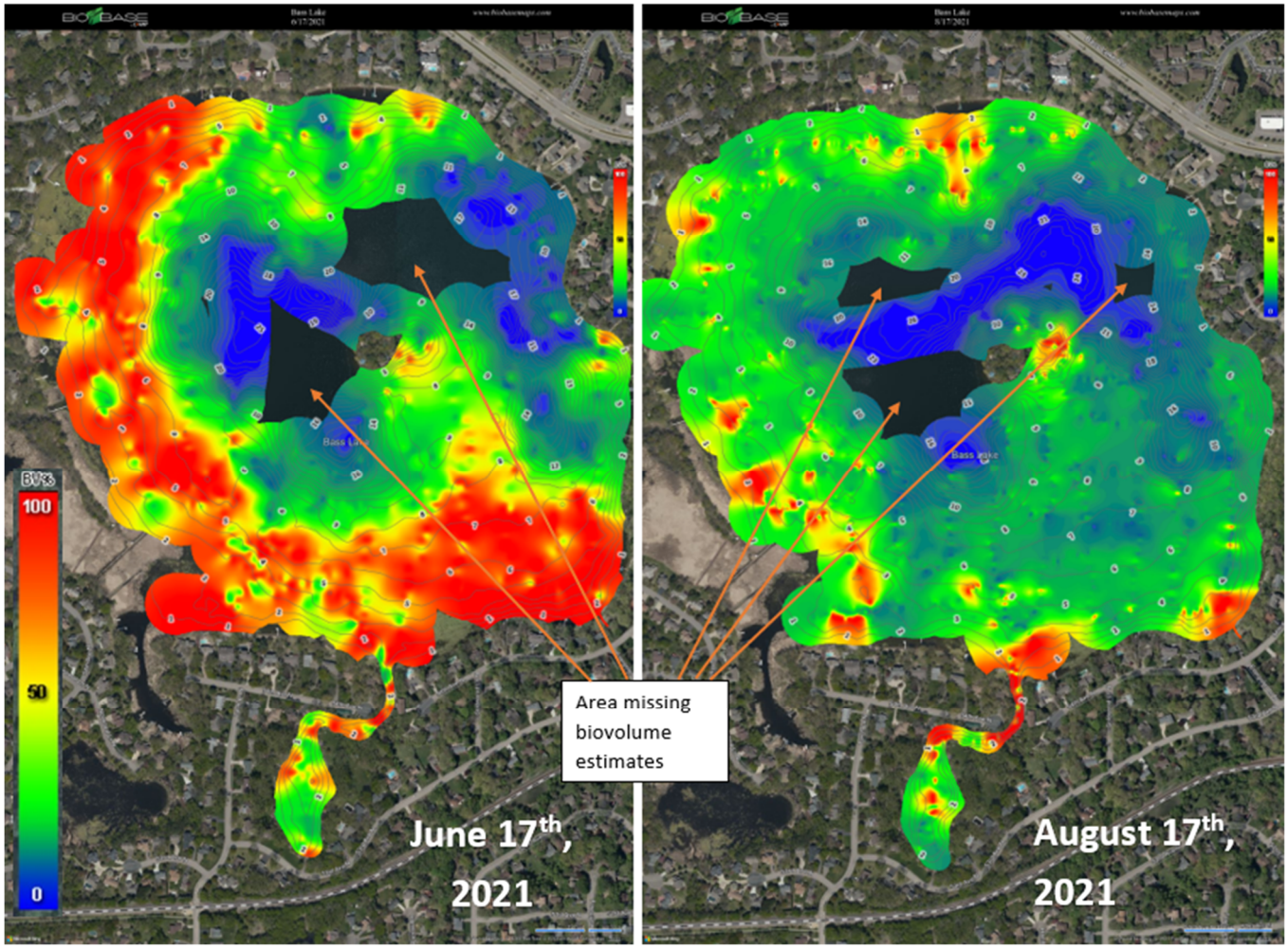


Figure 4.4.1: Biovolume heat maps for Bass Lake during the June and August 2021 surveys.

In the heatmaps, red indicates 100% biovolume and blue indicates 0% biovolume. Biovolume refers to the percentage of the water column taken up by vegetation.

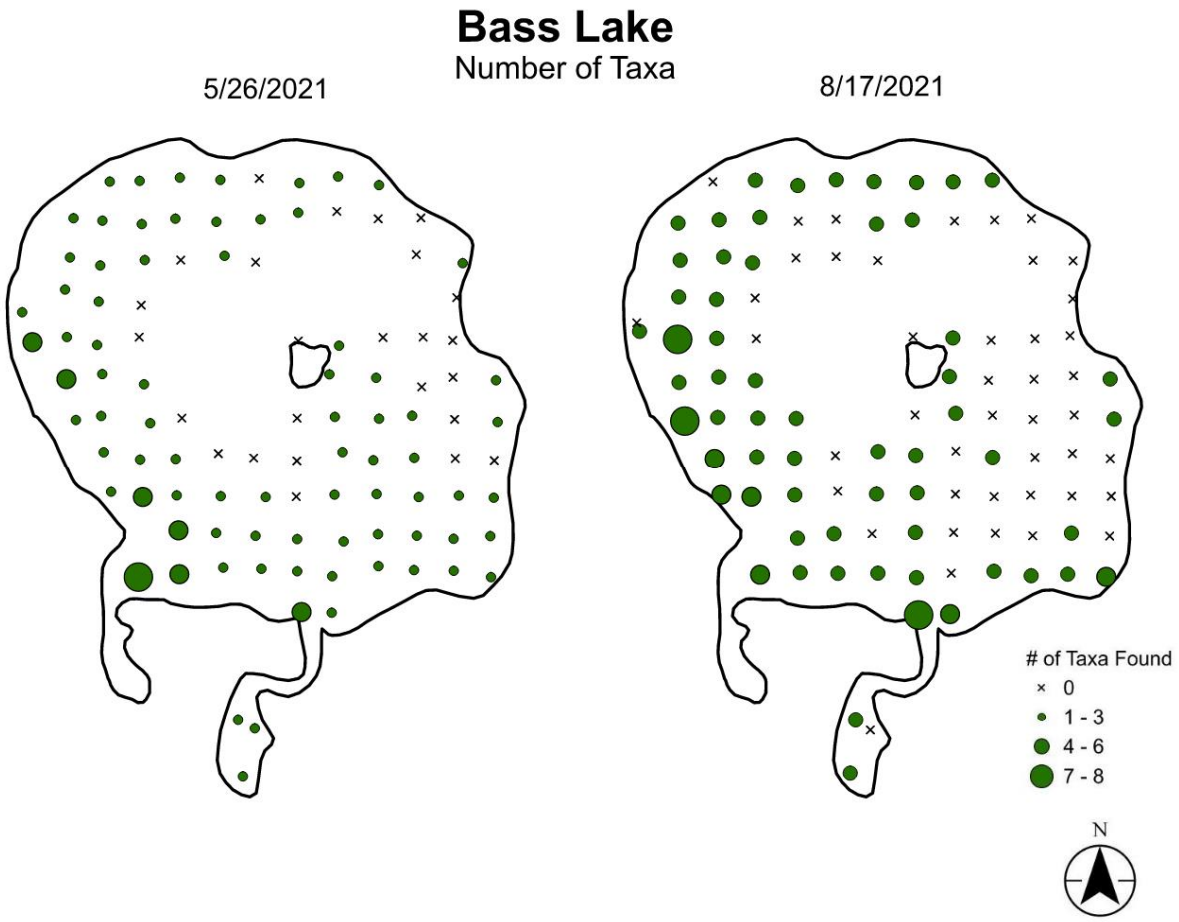


Figure 4.4.2: Map of the number of taxa found at each point-intercept survey location on Bass Lake.

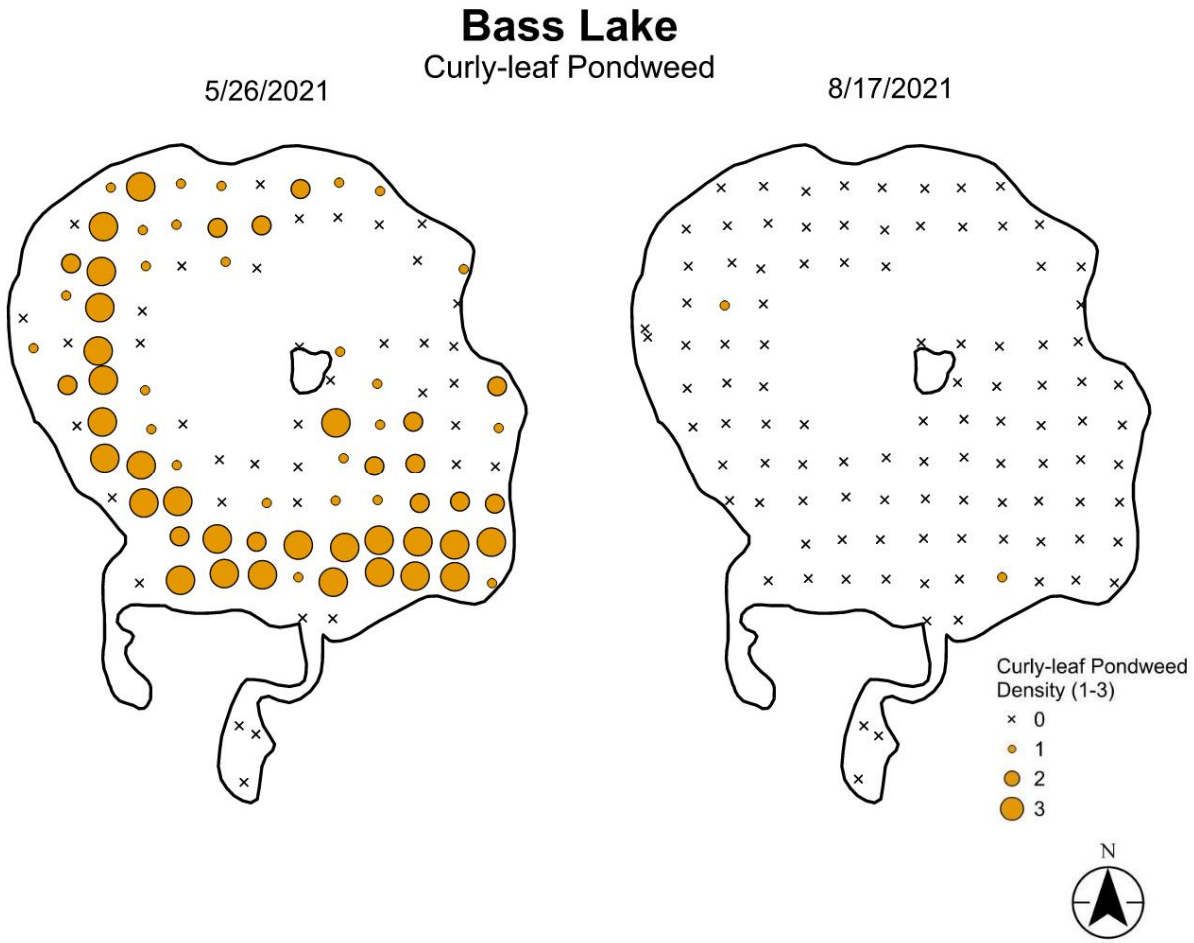


Figure 4.4.3. Map of the location and density of curly-leaf pondweed in Bass Lake during point-intercept surveys.

A CLP delineation was performed to target CLP herbicide treatments preceding the early season point-intercept survey. Stantec and staff from the DNR conducted the delineation on April 13th, 2021. Following the delineation three targeted areas were identified and treated by LimnoPro using diquat dibromide on June 1, 2021 (Figure 4.4.4).

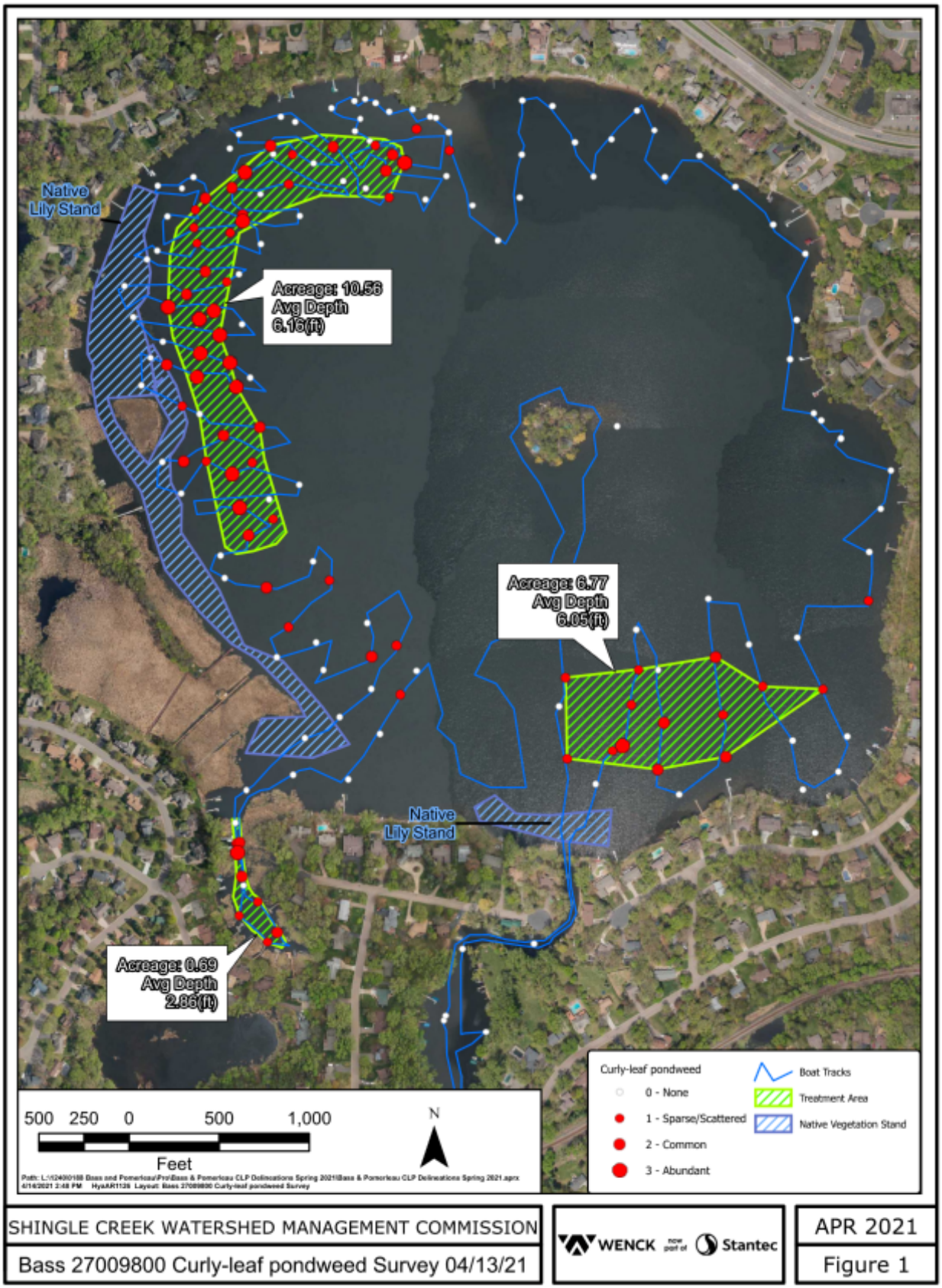


Figure 4.4.4. 2021 Bass Lake CLP delineation and treatment areas.

5.0 Pomerleau Lake

5.1 INTRODUCTION & SAMPLING OVERVIEW

Pomerleau Lake (Public Water No. 27010000) is located in the city of Plymouth. It is classified as a deep lake and has an approximate surface area of 30.5 acres, 21 acres of littoral area (i.e., area less than 15 feet deep), 0.78 miles of shoreline, and a maximum depth of 26 feet. The list below summarizes the year in which each type of sampling was most recently performed on Pomerleau Lake:

- Water Quality – 2021
- Phytoplankton/zooplankton – 2021
- SAV – 2021
- Fisheries – 2017
- Carp – 2018

Pomerleau Lake also received an alum treatment on May 13, 2019 to mitigate internal loading (Figure 5.1.1). Alum was applied to a 14-*a*cre area of the lake seven feet and deeper. Alum was applied at 1,374 gallons/acre. Pomerleau Lake received a second dose of alum in September 2020 following the monitoring season. Alum was applied to the same area and at the same dose as in 2019.

Figure 5.1.1. Photos from the alum treatment on Pomerleau Lake in May 2019.

5.2 WATER QUALITY

Figure 5.2.1 shows TP, chlorophyll-a, and Secchi depth from 2021 over the course of the monitoring season. Likely as a result of the May 2019 alum treatment, water quality was still substantially improved from past summers. All three eutrophication standards (total phosphorus, chlorophyll-*a*, and Secchi depth) were met throughout the growing season; not a single data point exceeded standards (Figure 5.2.1).

Historic data shows that Pomerleau Lake frequently failed to meet deep lake water quality standards. However, water quality has improved significantly in recent years. Since the alum treatment in 2019, TP, chlorophyll-a, and Secchi depth have met the eutrophication standards for

deep lakes. Additionally, hypolimnetic (deep) total phosphorus concentration have declined substantially in the past 3 years. Previously, bottom water concentrations would increase throughout the summer and become available for algal uptake during periods of turnover causing large algae blooms. With the introduction of alum, the available phosphorus has remained bound within the sediment, and therefore no longer available for algal uptake.

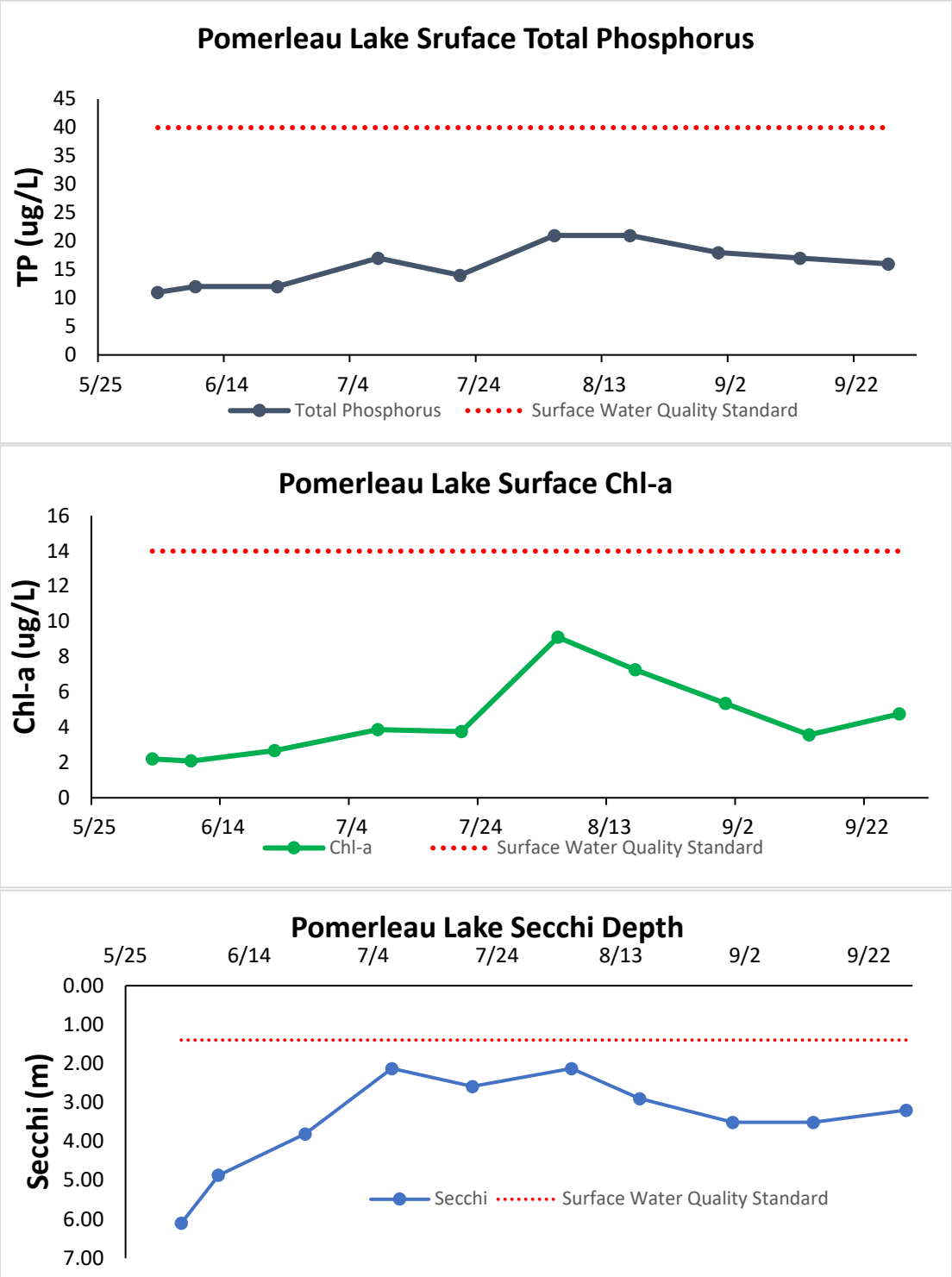


Figure 5.2.1. Seasonal TP, chlorophyll-a, and Secchi measurements and standards.

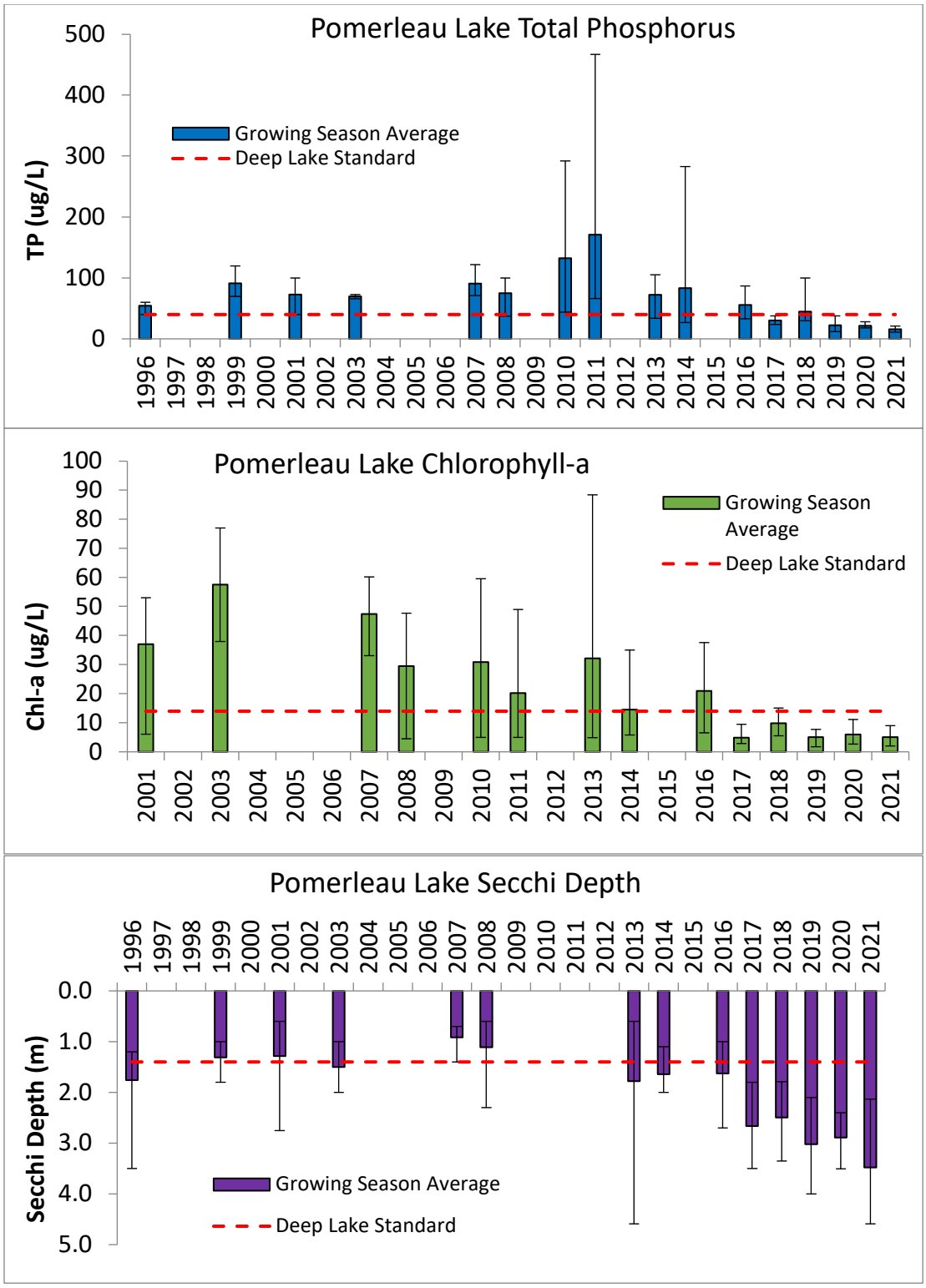


Figure 5.2.2. Annual growing season averages for total phosphorus, chlorophyll-*a*, and Secchi depth, with deep lake standards in red for reference.

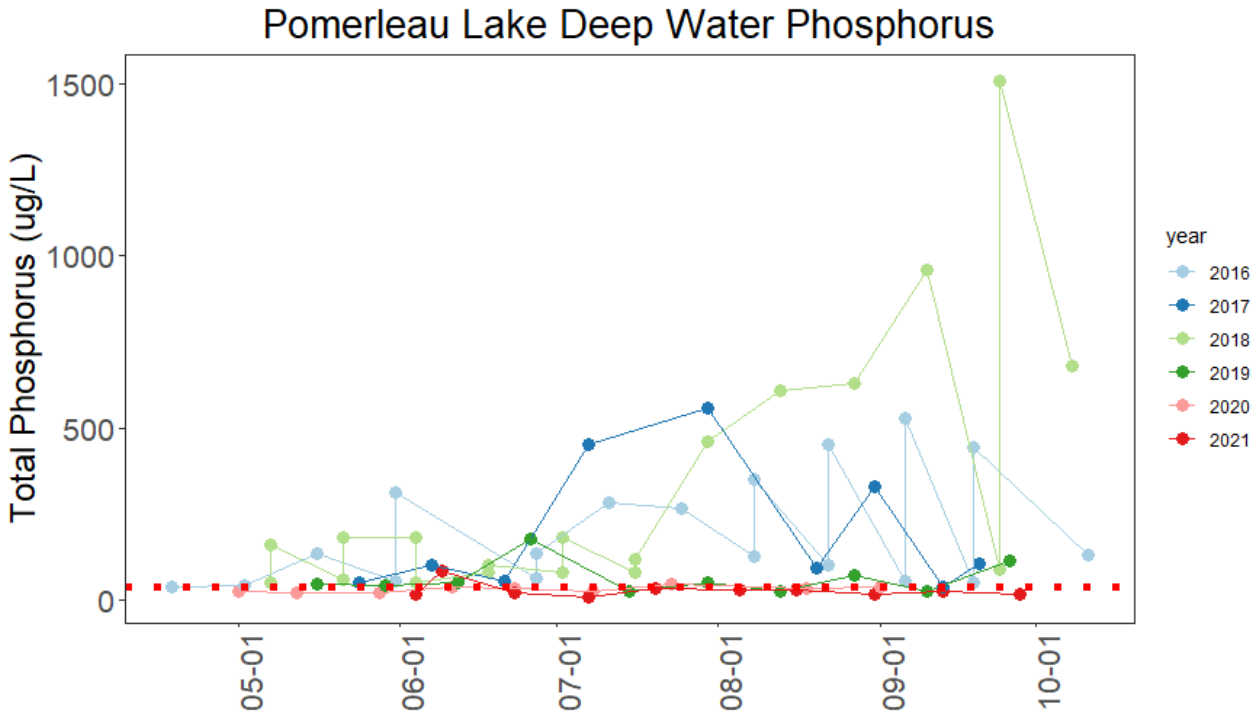


Figure 5.2.3. Hypolimnetic (deep) total phosphorus (TP) throughout the summers in Pomerleau Lake for available years.

5.3 PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton and zooplankton composition was measured for two samples in June and September 2021 to compare the relative percentages of each family (Figures 5.3.1 & 5.3.2). Pomerleau Lake experienced a shift in phytoplankton composition in the summer of 2021. Cyanobacteria dominated the phytoplankton community in both samples but increased significantly by September. The sole genera of cyanobacteria in September was *Woronchinia*. *Woronchinia* are a toxin-producing cyanobacteria.

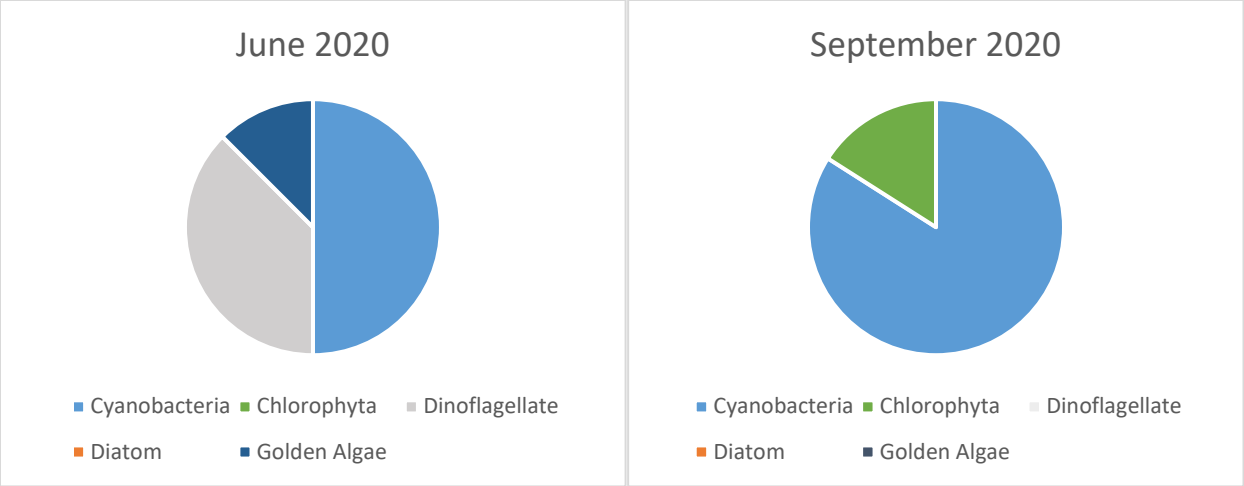


Figure 5.3.1. Phytoplankton relative percentage from June and September 2021 in Pomerleau Lake.

In June Nauplii were the dominate species at 55%, followed by daphnia at 32%. As summer progressed species composition became more evenly distributed. By September, bosmina grew to be the dominate species reaching 41% relative abundance, which is a common observation due to their ability to forage lower quality food sources.

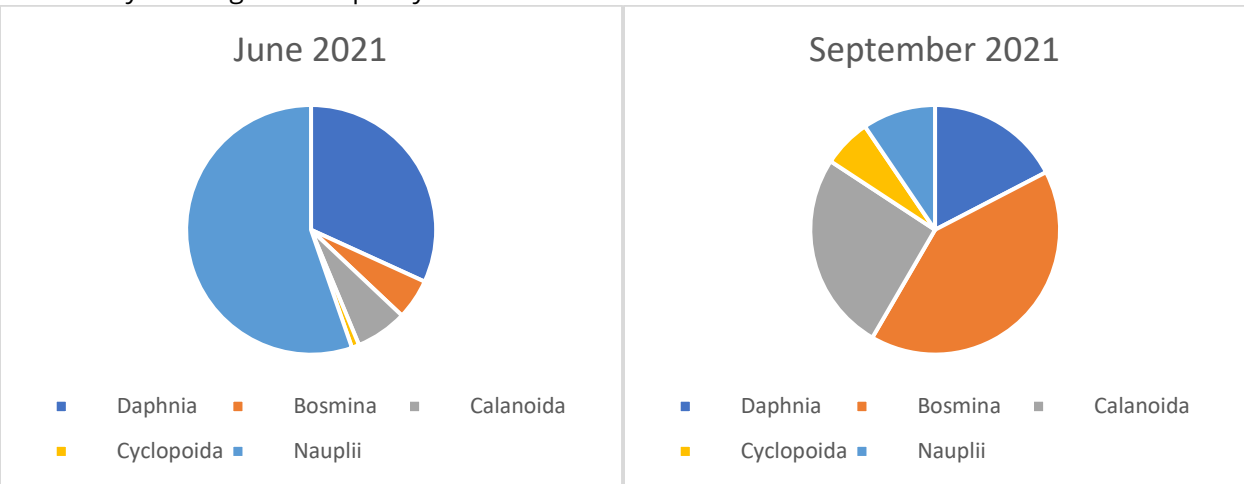


Figure 5.3.2: Zooplankton relative percentage from June and September 2021 in Pomerleau Lake.

5.4 SUBMERSED AQUATIC VEGETATION

Point intercept aquatic vegetation surveys were conducted on June 11, 2021 and July 22, 2021 to document the spring and summer submersed aquatic vegetation. Previous full lake point intercept SAV surveys were conducted in 2017 and 2019. Pomerleau Lake is classified as a deep lake. Below are two tables outlining survey results and associated metrics and indices (**Table 5.4.1** and **Table 5.4.2**). Maps include early and late-season BioBase maps of vegetation biovolume (**Figure 5.4.1**), number of taxa at each sample point (**Figure 5.4.2**), CLP location and density (**Figure 5.4.3**), CLP was observed in low occurrence during the spring survey and absent in the summer survey.

Table 5.4.1. Pomerleau Lake SAV metrics and indices.

	June 11, 2021	July 22, 2021
LAKEWIDE METRICS		
Total Points Sampled	64	65
Total Littoral Points Sampled	46	46
% Littoral with Veg	94	100
Max depth of plant growth (ft)	16.6	20.5
Shallow Lake Species Richness Threshold	*11*	
Species Richness	12	14
COMMUNITY INDICES		
Shallow Lake FQI Threshold	*17.8*	
Floristic Quality Index (FQI)	18.8	19.3
Simpson's Diversity Index	81.9	80.3
Aquatic Macrophyte Community Index (AMCI)	47	45

*Typha is not included in Taxa or Community Indices calculations as it does not have a C value.

Table 5.4.2. Pomerleau Lake plant taxa and littoral frequency of occurrence from 2021 surveys.

Taxa	Common Name	June 11, 2021	July 22, 2021
SUBMERSED TAXA			
Ceratophyllum demersum	Coontail	64	75
Chara sp.	Muskgrass	2	2
Elodea canadensis	Canada waterweed	19	15
Potamogeton crispus	Curly-leaf pondweed	45	2
Potamogeton strictfolius	Straight-leaved pondweed	8	2
Potamogeton zosteriformis	Flat-stem pondweed	--	3
Stuckena pectinata	Sago pondweed	--	6
Utricularia vulgaris	Greater bladderwort	2	2
FLOATING TAXA			
Nymphaea odorata	White waterlily	30	31
Nuphar variegata	Yellow waterlily	6	3
Lemna minor	Small duckweed	13	19
Lemna trisulca	Star duckweed	3	5
Spirodela polyrhiza	Greater duckweed	8	25
Wolffia sp.	Watermeal	5	11
EMERGENT TAXA			
Typha sp.	Cattail	P	P

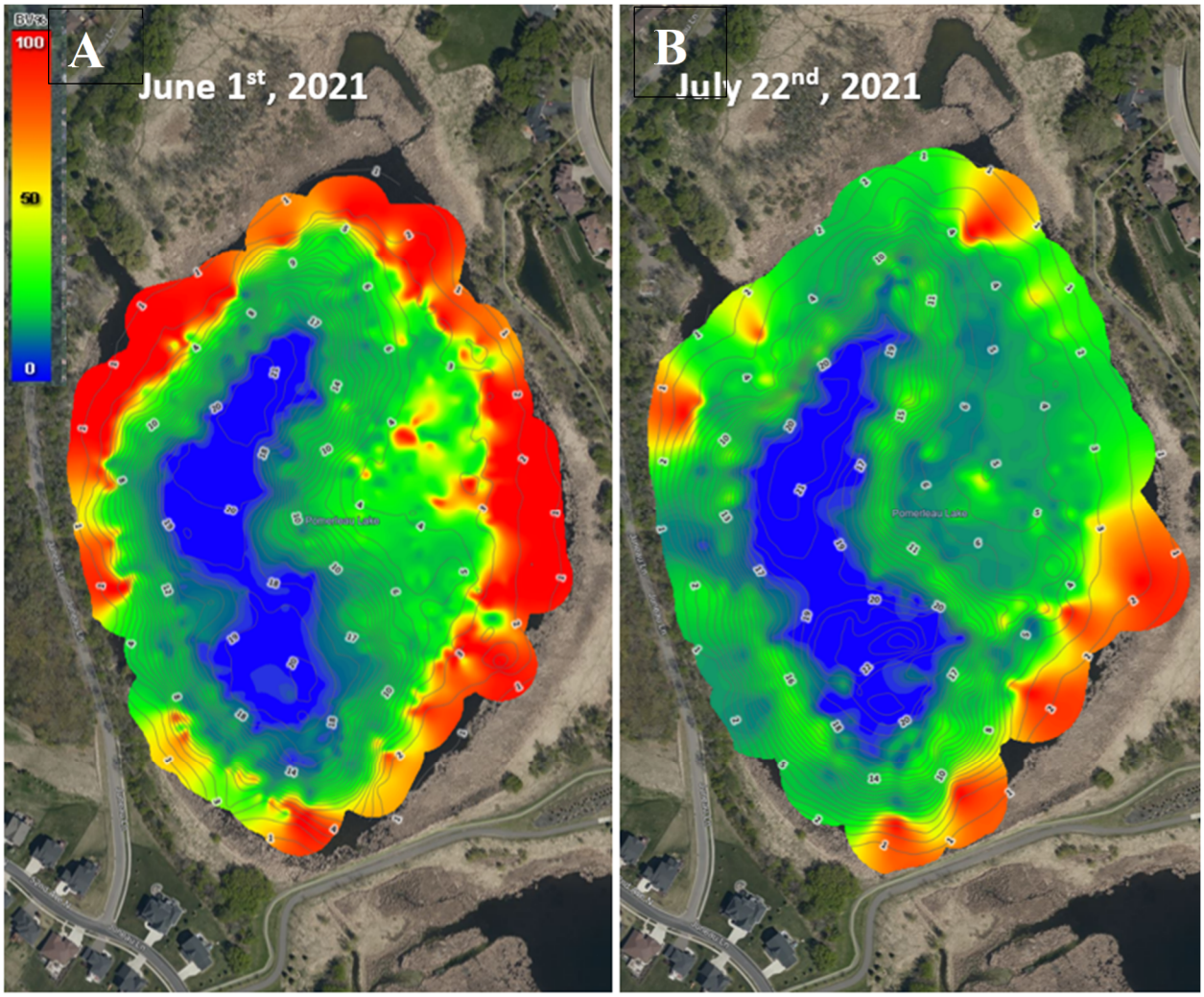


Figure 5.4.1. Biovolume heat maps for Pomerleau Lake during the June (A) and July (B) 2021 surveys.

In the heatmaps, red indicates 100% biovolume and blue indicates 0% biovolume. Biovolume refers to the percentage of the water column taken up by vegetation.

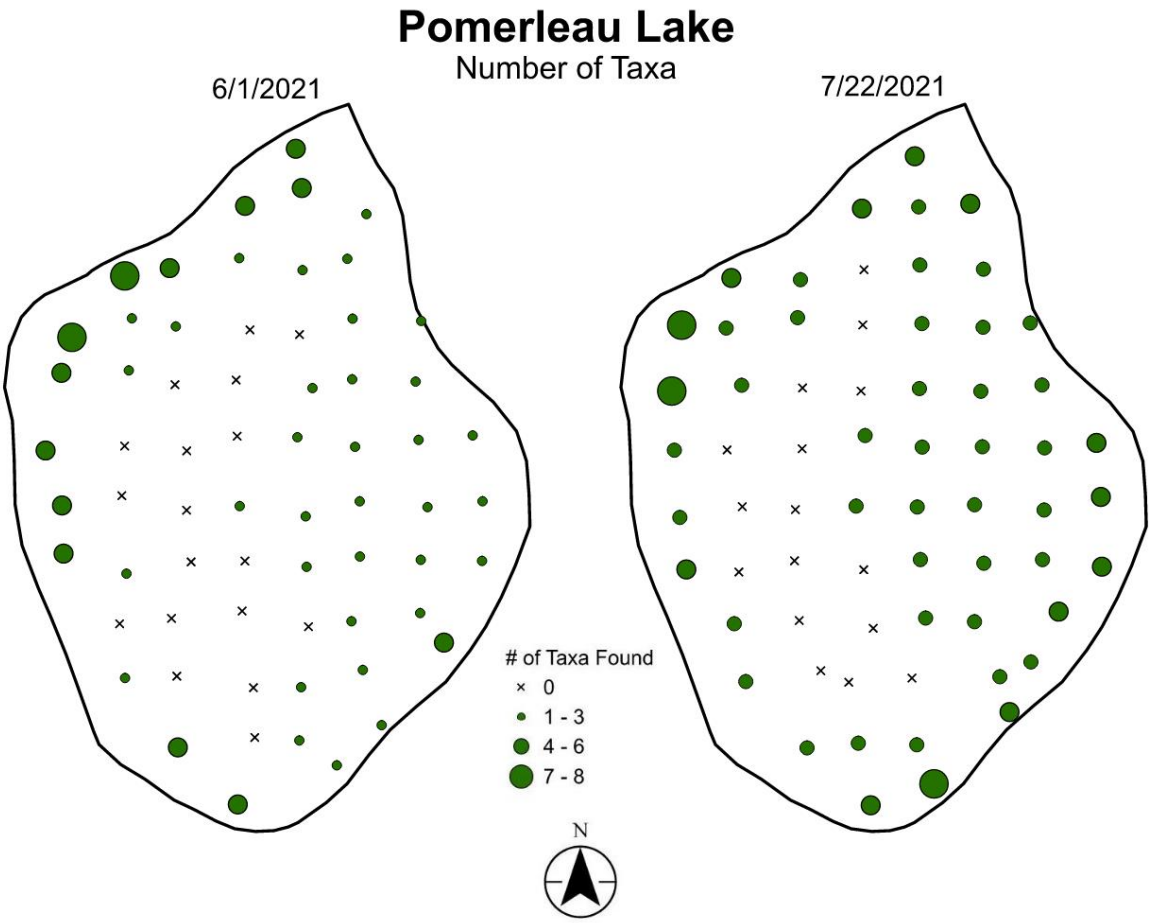


Figure 5.4.2. Map of the number of taxa found at each point in Pomerleau Lake.

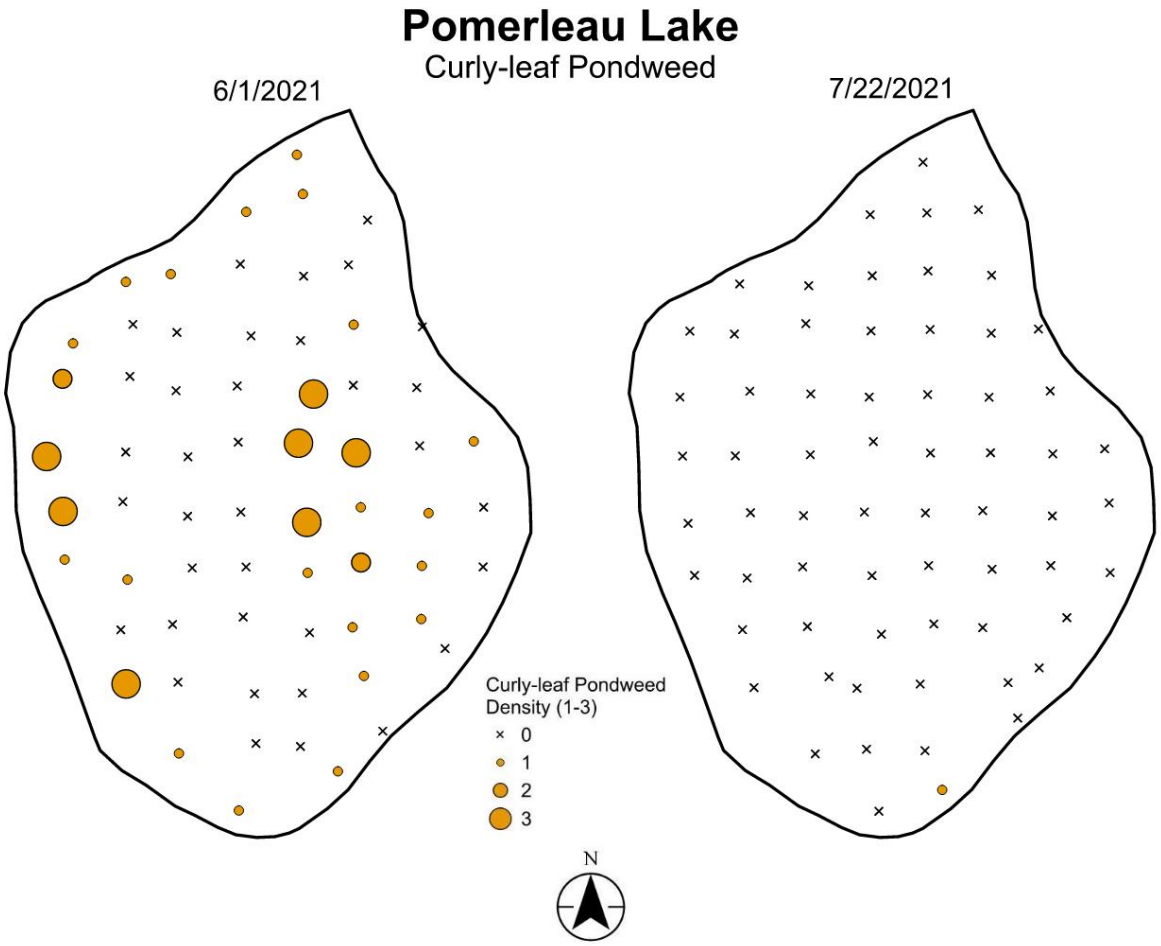


Figure 5.4.3. Map of the location and density of curly-leaf pondweed in Pomerleau Lake during point-intercept surveys.

In an ongoing effort to continually monitor the abundance of CLP and in addition to the full lake spring and summer point intercept surveys a CLP delineation outlining areas of high CLP occurrence was conducted by Stantec April 13, 2021 to document and determine the extent of CLP in Pomerleau lake and provide data to guide future management options (Figure 5.4.4). The lake was not treated with herbicide in 2021.

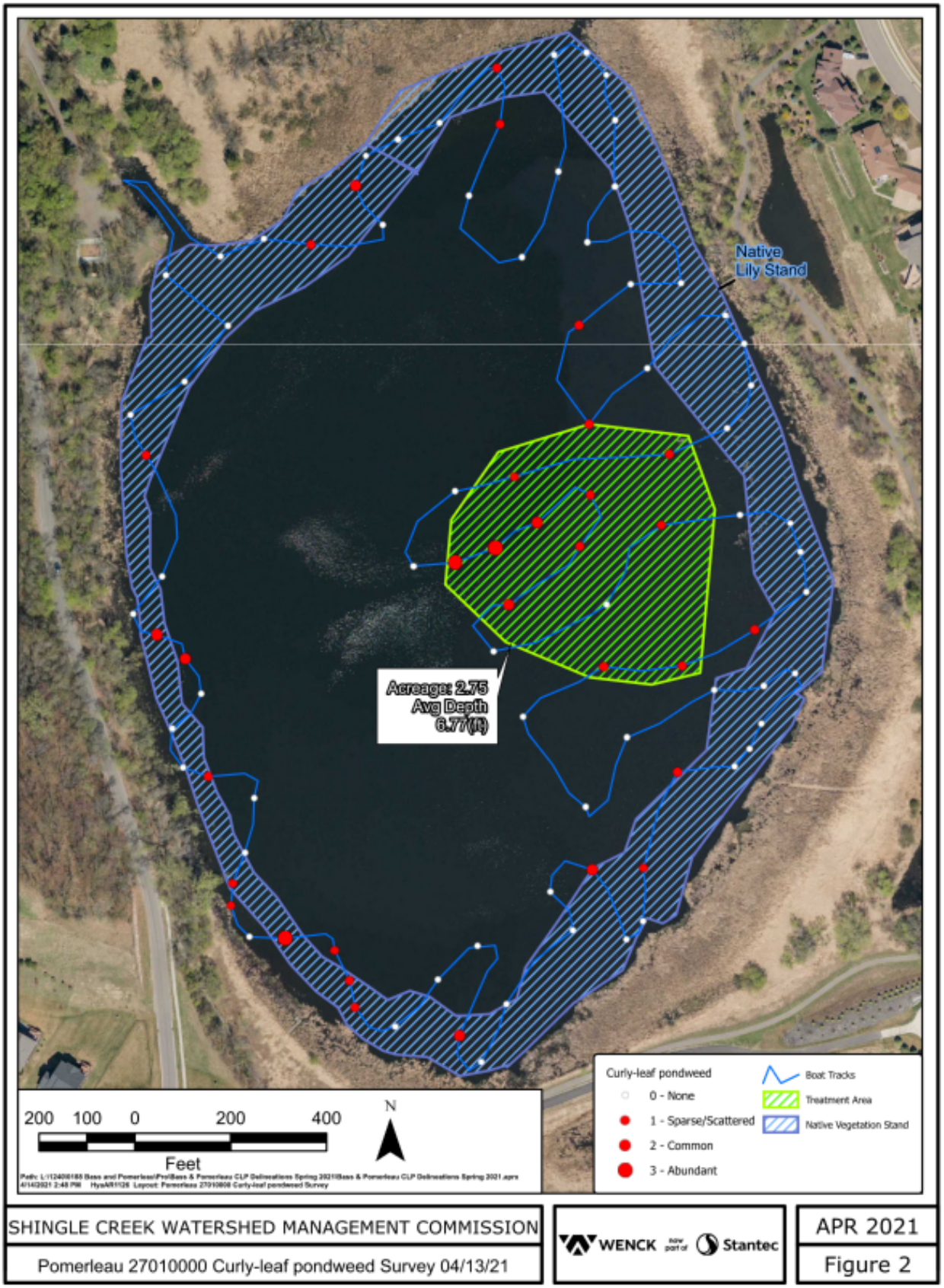


Figure 5.4.4: Pomerleau Lake CLP delineation.

6.0 Crystal Lake

6.1 INTRODUCTION & SAMPLING OVERVIEW

Crystal Lake (Public Water No. 27003400) is in Robbinsdale, MN within Hennepin County. Middle Twin Lake is classified as a deep lake and has an approximate surface area of 79 acres, 53 acres of littoral area (i.e., area less than 15 feet deep), an average depth of 9.8 feet, and a maximum depth of 39 feet. The list below summarizes the year in which each type of sampling was most recently performed on Crystal Lake:

- Water Quality - 2021
- SAV – 2021
- Phytoplankton/Zooplankton - 2021
- Fisheries – not assessed
- Carp – 2020

6.2 WATER QUALITY

Figure 6.2.1 show TP, Secchi depth, and chlorophyll-a from 2021 over the course of the monitoring season. All three variables demonstrated poor water quality, and all but TP failed to meet the surface water quality standard for the entire duration of monitoring. TP had two small dips in concentration, in June and July, but remained above the standard in all other instances.

Historic water quality data from Crystal Lake show the lake generally does not meet the deep lake standards (Figure 6.2.2). Average monitoring season TP concentrations have previously been below the impairment threshold; however, it has exceeded the eutrophication standard for the last two monitoring seasons. Both chlorophyll-a and Secchi depth, currently and historically, fail to meet the deep lake eutrophication standards. In 2021, deep water TP concentrations failed to meet eutrophication standards, following the lakes historic trend. A peak TP concentration in August-September indicates the release and accumulation of phosphorus from lake sediment under low oxygen conditions.

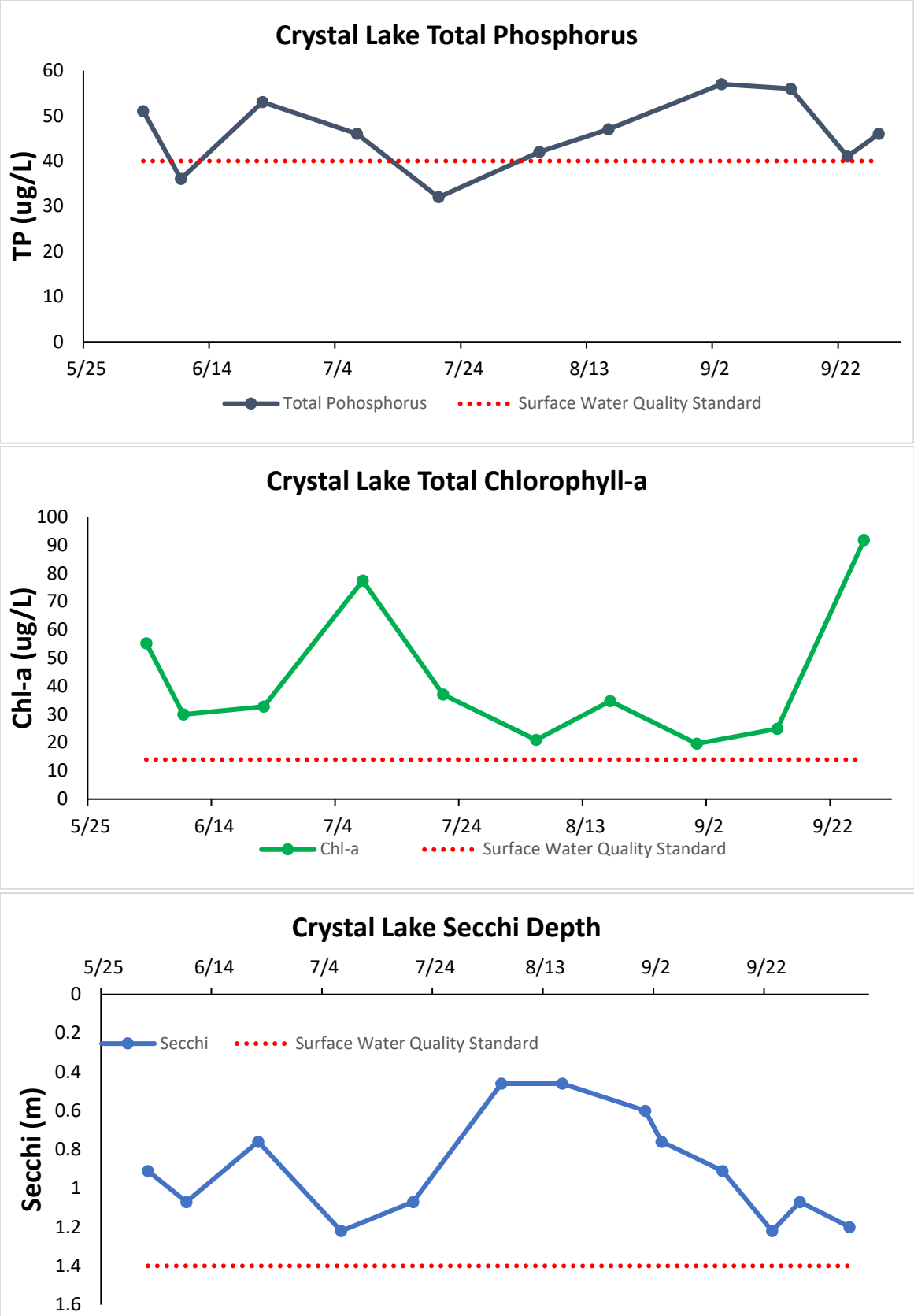


Figure 6.2.1. Seasonal TP, chlorophyll-*a*, and Secchi measurements and standards.

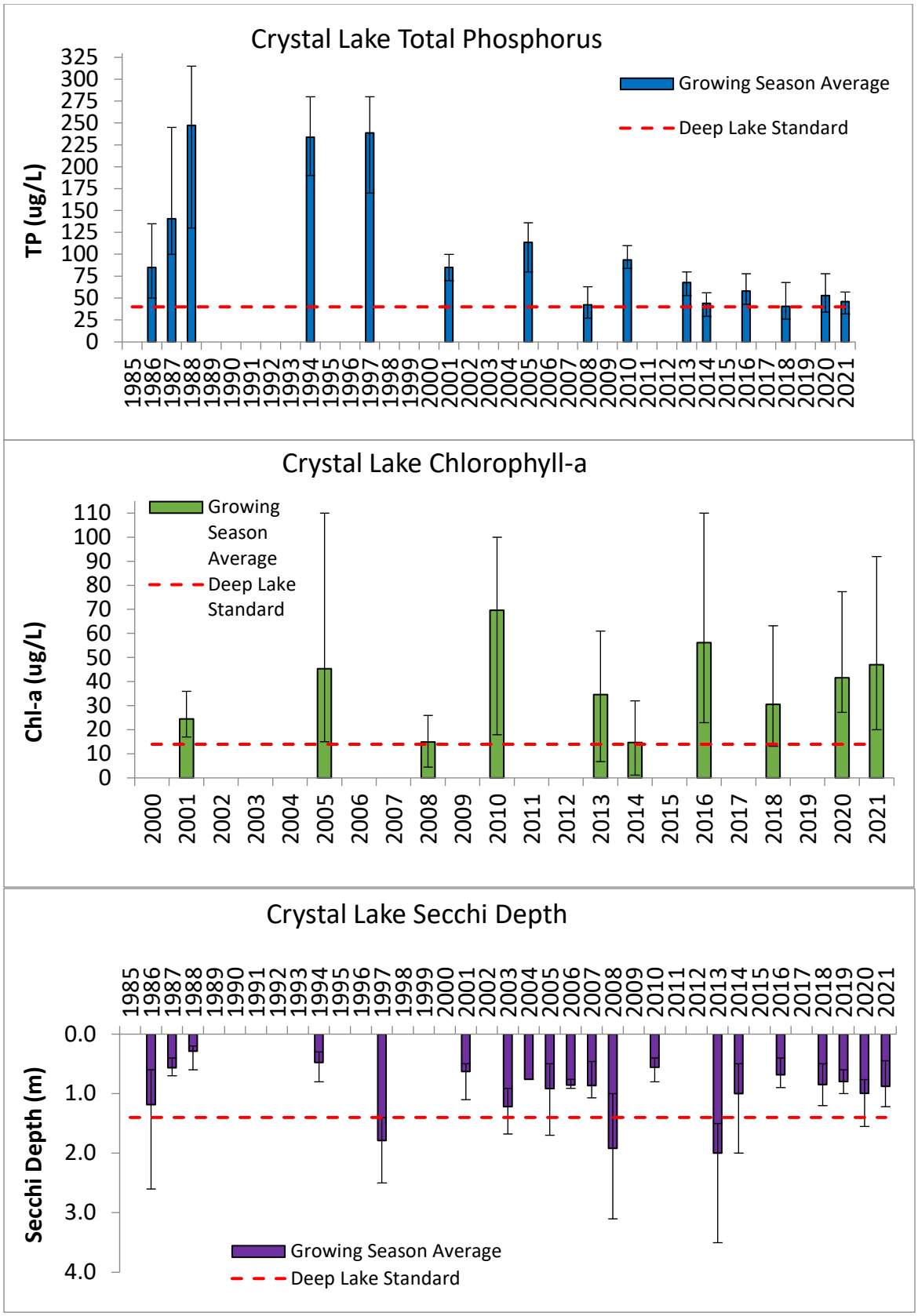


Figure 6.2.2. Annual growing season averages for total phosphorus, chlorophyll-*a*, and Secchi depth, with shallow lake standards in red for reference.

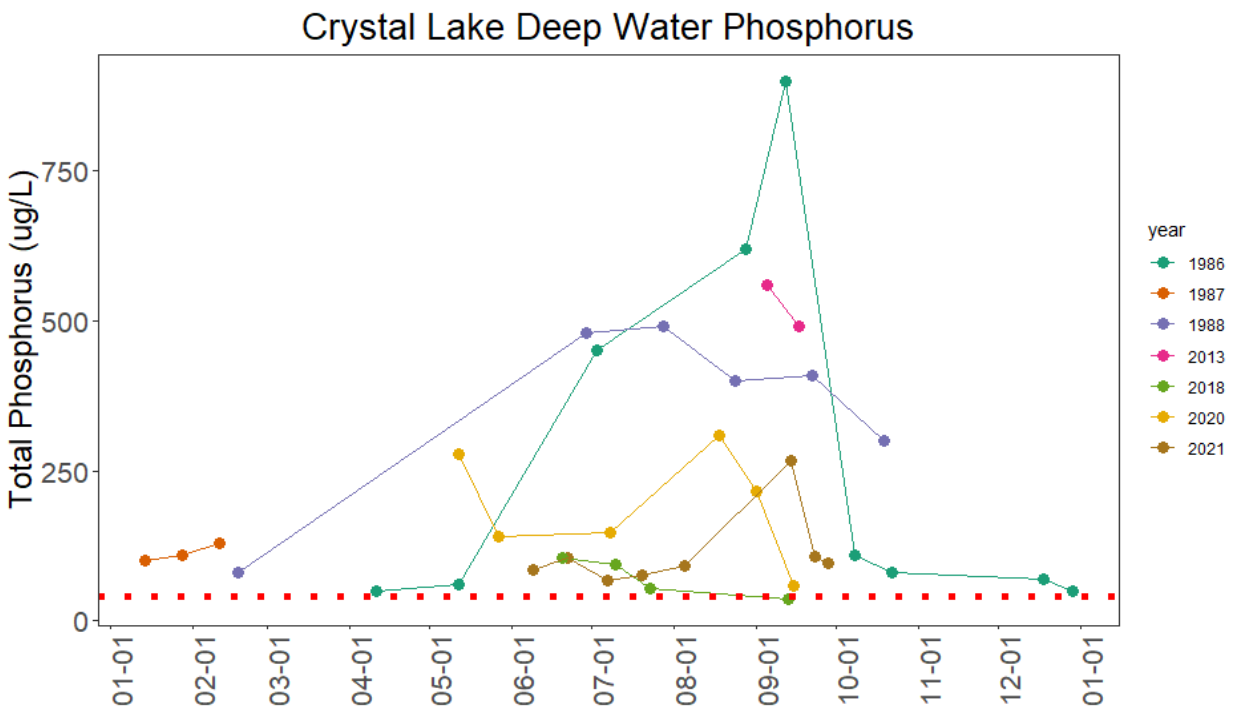


Figure 6.2.3. Hypolimnetic (deep) total phosphorus (TP) throughout the summers in Crystal Lake for available years.

6.3 PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton and zooplankton composition were measured for two samples in June and August 2021 to compare the relative percentages of each family (Figures 6.3.1 & 6.3.2). Crystal lake experienced a large *Microcystis* bloom in the summer of 2021. Cyanobacteria was already dominate in June and that dominance increased to 100% in September. In September 2021, the only species of phytoplankton identified was *Microcystis* in very high concentrations. *Microcystis* is a common bloom forming cyanobacteria that is capable of producing toxins.

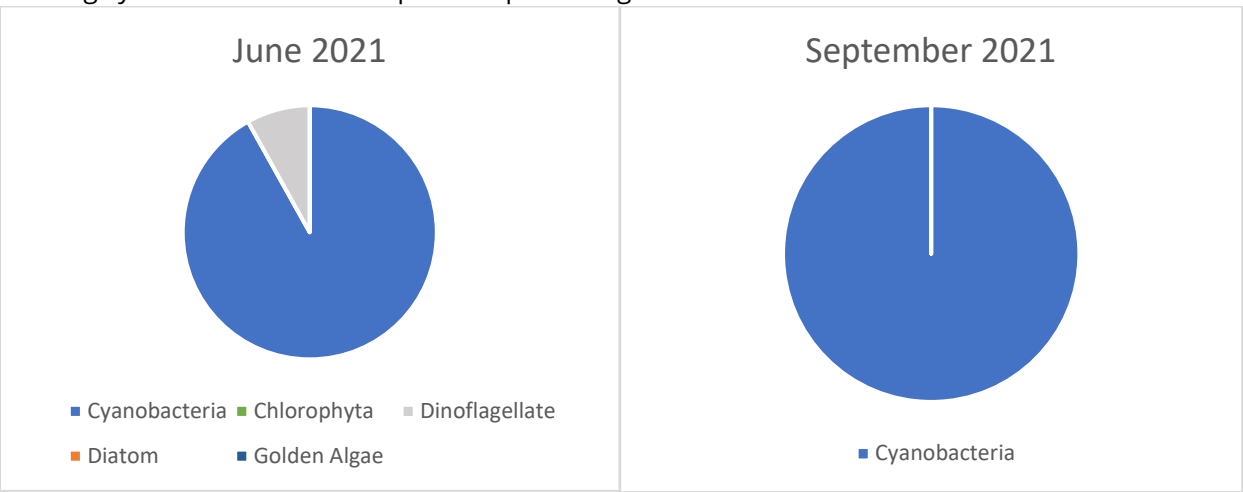


Figure 6.3.1. Phytoplankton relative percentage from June and September 2021 in Crystal Lake.

In June, a high percentage of Nauplii are preasent as well as Bosmina. As the season progresses a higher percent of Cyclopoida are found present. By september, cyclopoida are dominate at 59%.

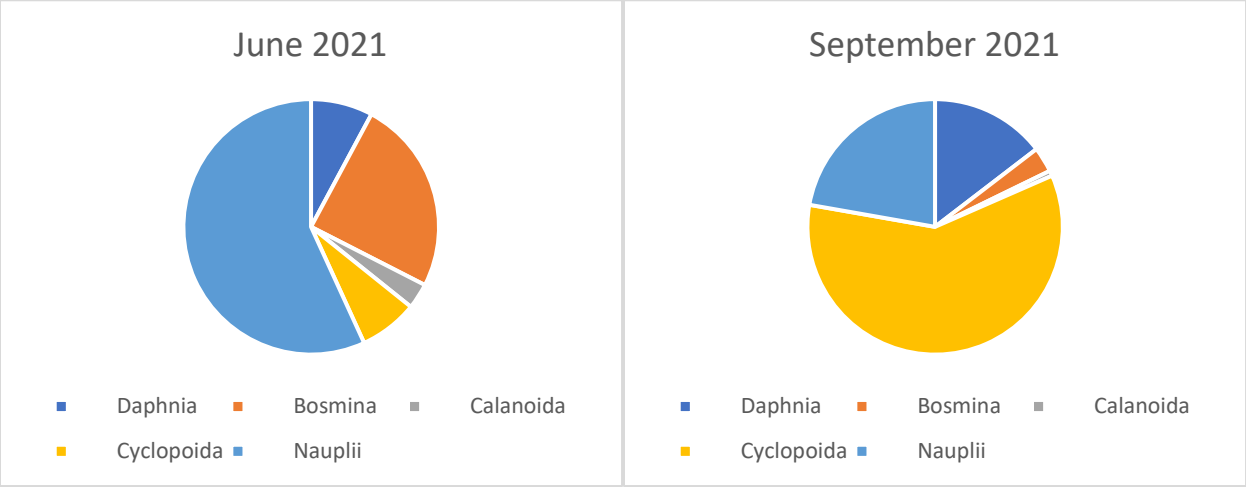


Figure 6.3.2: Zooplankton relative percentage from June and September 2021 in Crystal Lake.

6.4 SUBMERSED AQUATIC VEGETATION

A point intercept aquatic vegetation survey was conducted on July 22, 2021 to document the summer submersed aquatic vegetation in Crystal Lake. Previous full lake point intercept SAV surveys were conducted in 2019 and 2020. Crystal Lake is classified as a deep lake, with 53 of its 79 acres in the littoral zone (i.e., in water less than 15 feet deep). Below are two tables outlining survey results and associated metrics and indices (**Table 6.4.1** and **Table 6.4.2**). Maps include early and late-season BioBase maps of vegetation biovolume (**Figure 6.4.1**), number of taxa at each sample point (**Figure 6.4.2**). CLP was not captured during the point-intercept survey; however, it was observed in low abundance and is noted as present in the lake.

Table 6.4.1. Crystal Lake SAV metrics and indices.

	July 22, 2021
LAKEWIDE METRICS	
Total Points Sampled	82
Total Littoral Points Sampled	57
% Littoral with Veg	7
Max depth of plant growth (ft)	4.6
Species Richness	3
Deep Lake Species Richness Threshold	*12*
COMMUNITY INDICES	
Deep Lake FQI Threshold	*18.6*
Floristic Quality Index (FQI)	7.5
Simpson's Diversity Index	0.0
Aquatic Macrophyte Community Index (AMCI)	18

Table 6.4.2. Crystal Lake plant taxa and littoral frequency of occurrence from 2021 surveys.

Taxa	Common Name	July 22, 2021
SUBMERSED TAXA		
Potamogeton crispus	Curly-leaf pondweed	P
FLOATING TAXA		
Nymphaea odorata	White waterlily	5
EMERGENT TAXA		
Schoenoplectus tabernaemontani	Soft-stem bullrush	P

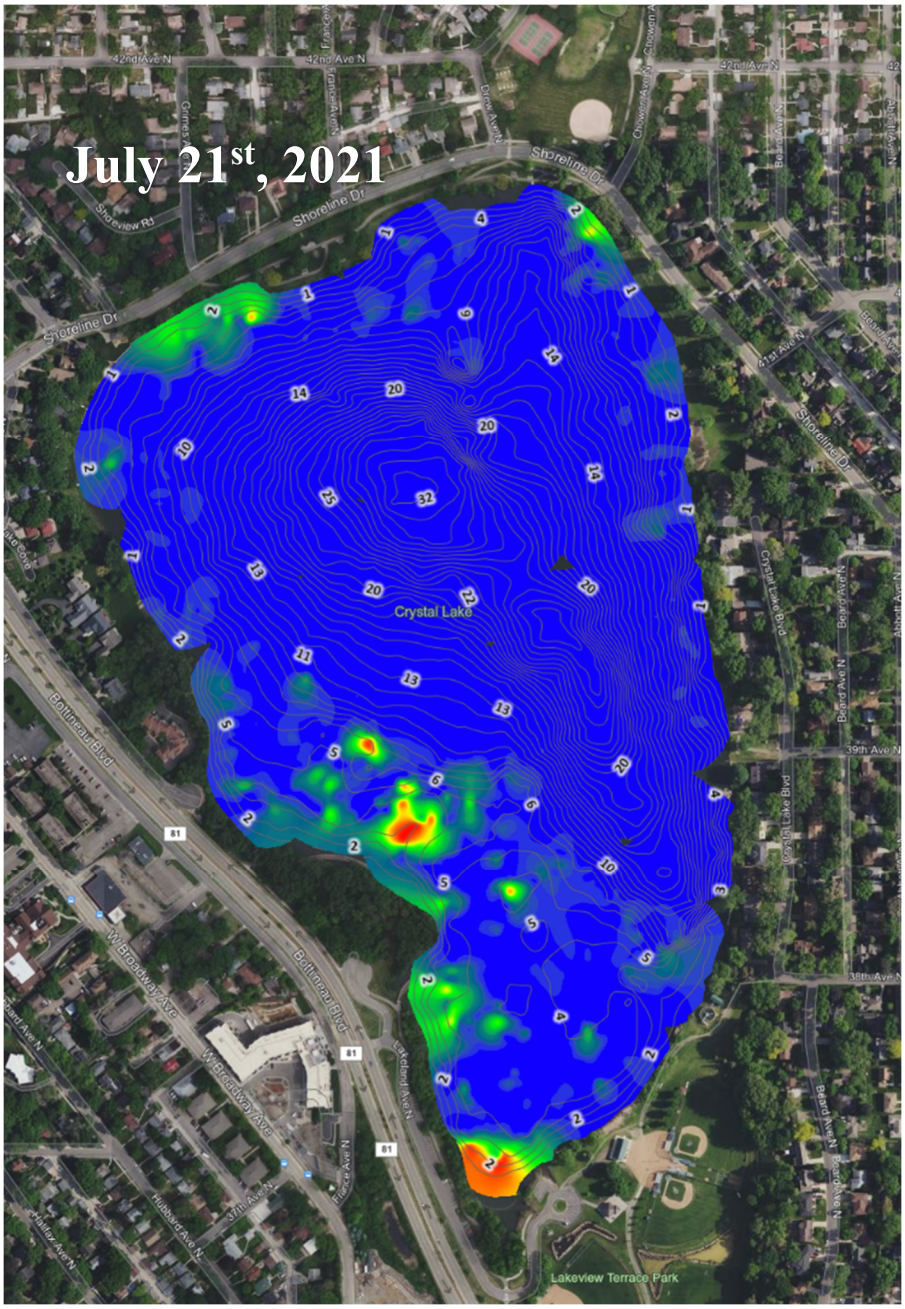


Figure 6.4.1. Biovolume heat map of Crystal Lake.

In the heatmap, red indicates 100% biovolume and blue indicates 0% biovolume. Biovolume refers to the percentage of the water column taken up by vegetation.

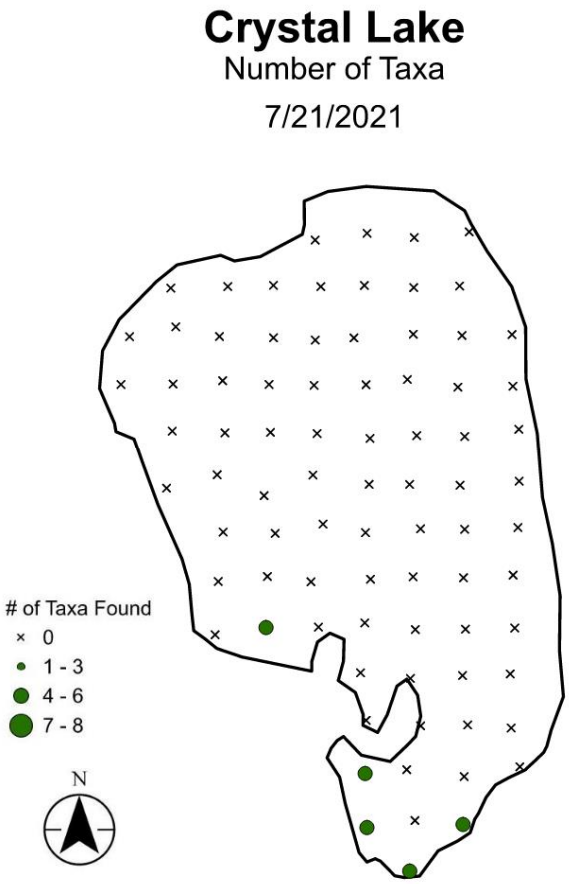


Figure 6.4.2. Map of the Number of taxa found at each point in Crystal Lake.

Crystal Lake did not have native rooted or unrooted submerged aquatic vegetation during the 2021 survey. The only rooted submerged aquatic species was CLP. CLP, an aquatic invasive species, has the potential to negatively impact water quality and recreation when present in great abundance. CLP grows under ice, which means populations can reach maximum growth in May and June, when growth of most native vegetation is still hindered by short day length. This attribute gives CLP an extreme competitive advantage, causing it to form dense stands that shade out other native species and prevent them from sprouting. CLP's early season grown leads to senescence in early summer. This means that as the plant senesces and is decomposed by bacteria, the nutrients stored in its stems and leaves are released into the water column and may promote algae blooms. It will be important to continually monitor the SAV community on Crystal lake to ensure a nuisance level of CLP does not establish.

6.5 CARP POPULATION ASSESSMENT

Stantec conducted a baseline common carp electrofishing CPUE assessment in 2020 to assess the abundance and biomass density of common carp present in Crystal Lake. See the 2020 Annual Report for results of the assessment.

In 2021, the Commission took on carp removal efforts in Crystal Lake. Three nets and two distinct methods were deployed during removal efforts in 2021. The makeup of the nets consisted of two baited box nets and one experimental baited float net, all located on the south shoreline of Crystal Lake where high carp catch rates were previously observed, and the water depth, bottom consistency, and lack of aquatic vegetation allowed for the greatest success in capture rates.

Four removal events occurred between June 18 and July 16, 2021. In total, 3,923 carp were captured and removed from the lake (**Table 6.5.2**). Each box net averaged between 311 and 355 carp per removal event, and the experimental float net averaged 184 carp per event.

Table 6.5.2. Crystal Lake common carp captures by removal event in 2021.

Date	Trap	Carp Caught	Total
18-Jun	Box net 1	845	2,361
	Box net 2	771	
	Float net	745	
30-Jun	Box net 1	48	233
	Box net 2	74	
	Float net	111	
9-Jul	Box net 1	337	1,001
	Box net 2	608	
	Float net	56	
16-Jul	Box net 1	163	328
	Box net 2	161	
	Float net	4	
			3,923

Approximately 33% of the estimated common carp population was removed during netting efforts in 2021 that resulted in a decrease in biomass of 142.3 lbs/acre (**Table 6.5.3**). A further decrease of 79.9 lbs/acre in carp biomass is still needed to reach the water quality impairment threshold of 89 lbs/acre.

Table 6.5.3. Crystal Lake common carp removal statistics 2021.

Metric	Result
Average length	459 mm (17.8 inches)
Average weight	1.31 kg (2.87 lbs)
Population Metrics	
2020 CPUE population estimate	12,011 carp
Total carp removed in 2021	3,923 carp
Percent of population removed	33%
Post removal population estimate	8,088 carp
Biomass Metrics	
2020 CPUE biomass estimate	311 lbs/acre
Lbs/acre removed in 2021	142.3 lbs/acre
Post removal effort biomass estimate	168.7 lbs/acre
Future Management Goals	
Water quality impairment threshold	89 lbs/acre
Carp removal goal to reach water quality impairment threshold	3,000-4,000 carp
Biomass removal goal to reach water quality impairment threshold	79.7 lbs/acre

7.0 References

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